Finnish case study – to increase or not to increase harvesting level. Do the biophysics matter?

Tuomo Kalliokoski

University of Helsinki

Manage for maximum wood production or leave the forest as a carbon sink?

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Luke
NATURAL RESOURCES
INSTITUTE FINLAND

SYKE
Suomen ympäristökeskus

LIFE09 ENV/FI/000571
Climate change induced drought
effects on forest growth and vulnerability (Climforisk)

Content

- Objective: The impact of different harvesting scenarios on the Radiative Forcing (RF)
- Methods & Models – analysis of different climate agents in terms of RF
- Stand level results – RF of different species
- Scaling up - regional results
- Conclusions

Climatic impact of increased forest use?

- Change over time in Radiative Forcing (RF) due to changes in forest structure (due to forest management)?

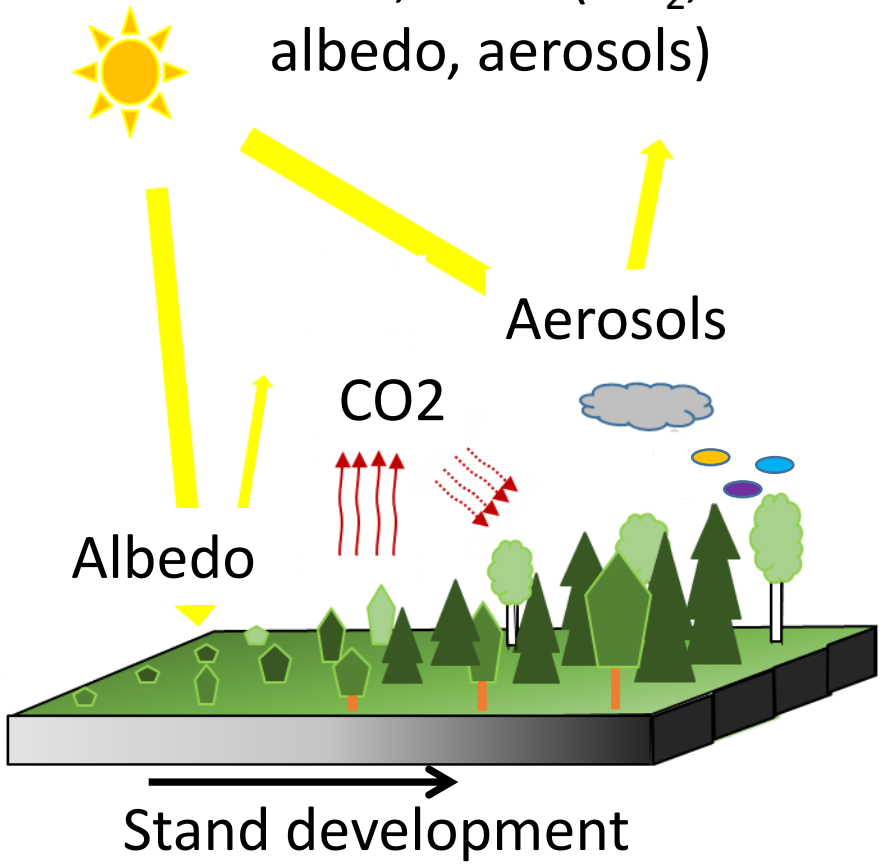
COOLING?

Wood products

Erkki Oksanen/Luke

Substituted carbon

- Here, RF = f(CO_2, albedo, aerosols)



Stand level set-up

- Only three species; Norway spruce, Scots pine, silver birch
- Only three forest types; Fertile (OMT) – Medium fertile (MT) – Infertile (VT)
- Description of stand development with MOTTI simulator
- Forest management according to Finnish recommendations (Tapio 2006)
  - Thinnings (basal area limit), timing of final harvest (diameter)
  - Harvested wood assortment (no energywood)

Methods & Models CO_2

CO2 life time in atmosphere

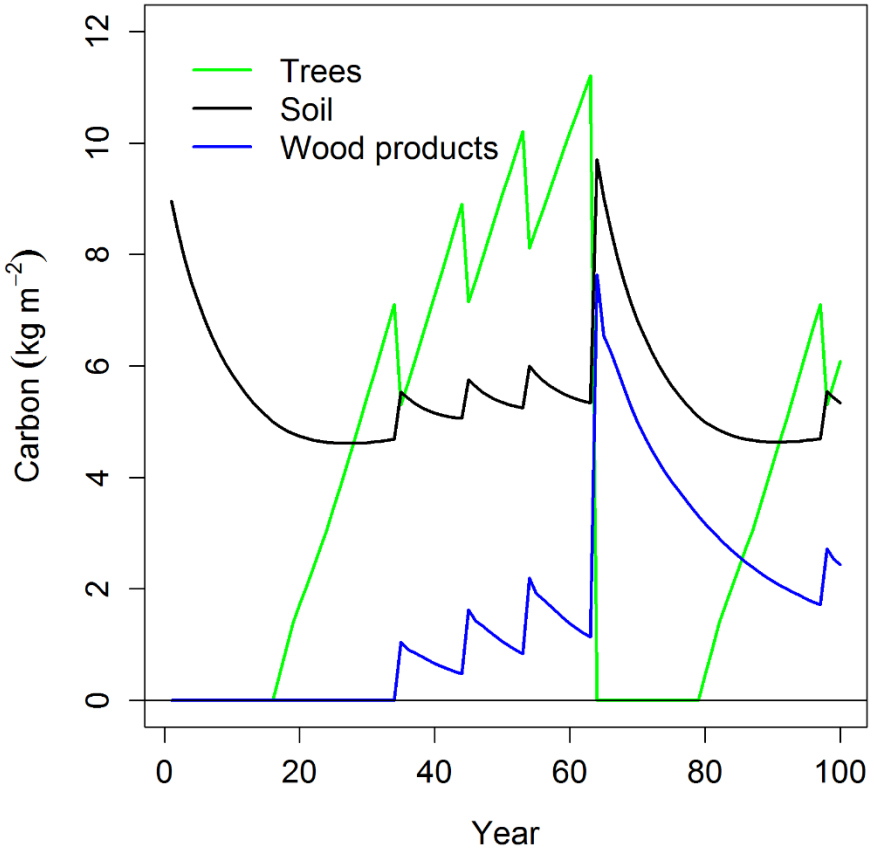
$$f(t) = a_0 + \sum_{j=1}^{3} a_j e^{-t/\tau_j}$$

21,7%

- Stand dynamics – MOTTI (Hynynen et al. 2005)
- Soil carbon – YASSO07 (Tuomi et al. 2013)
- Decay curves of wood products (Karjalainen et al. 1994)
- Substituted carbon with static coefficients (< 1, Sathre & O'Connor 2010 + other refs)

=> RF impact of CO2 change

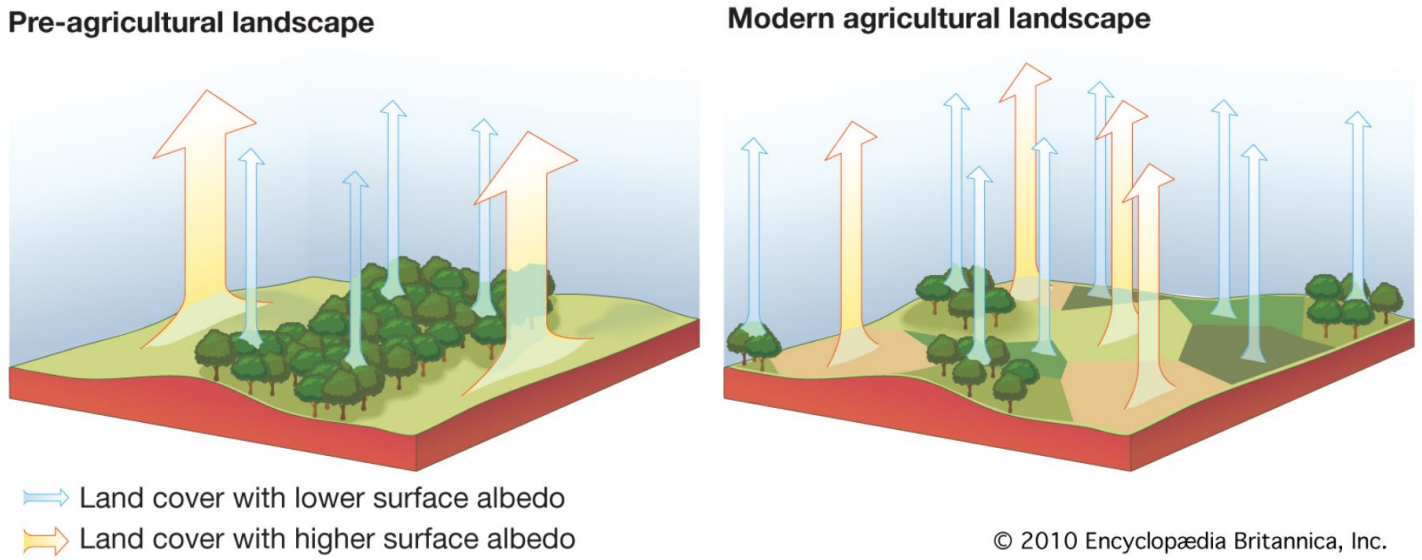
Carbon compartments (kg m^{-2})



Albedo and forests

- Albedo = ratio of reflected radiation from the surface to incident radiation upon it.
- Mirror reflects all light back => albedo is 1

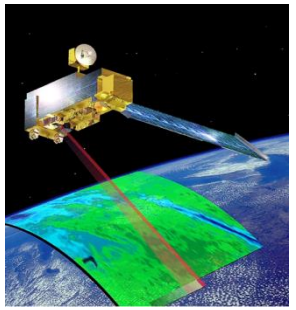
- Forest albedo is influenced by
  - Spatial arrangement and abundance of (green) biomass
  - Optical properties of all surfaces
  - Presence of snow
  - Sun angle



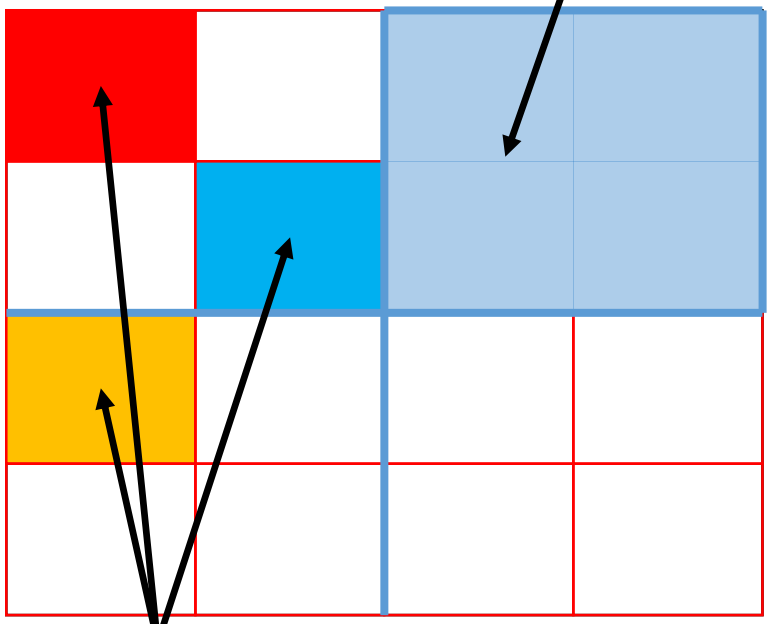
Methods & Models
ALBEDO from MODIS

- Albedo change over stand development (= stand volume)
- Albedo values were translated into net shortwave radiation at the top of atmosphere using ECHAM5 radiative transfer model

  => RF impact of albedo change



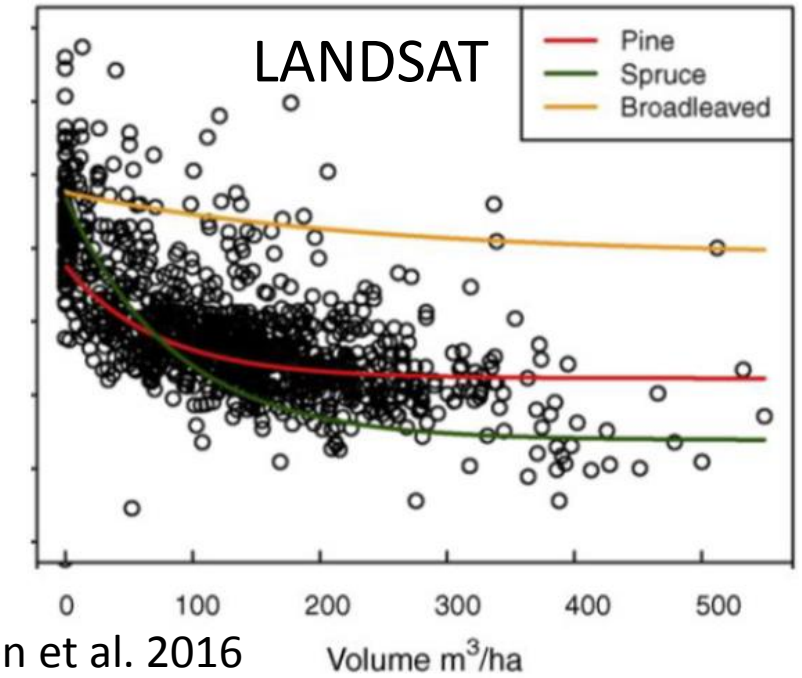
MODIS pixel,
A_i = albedo value



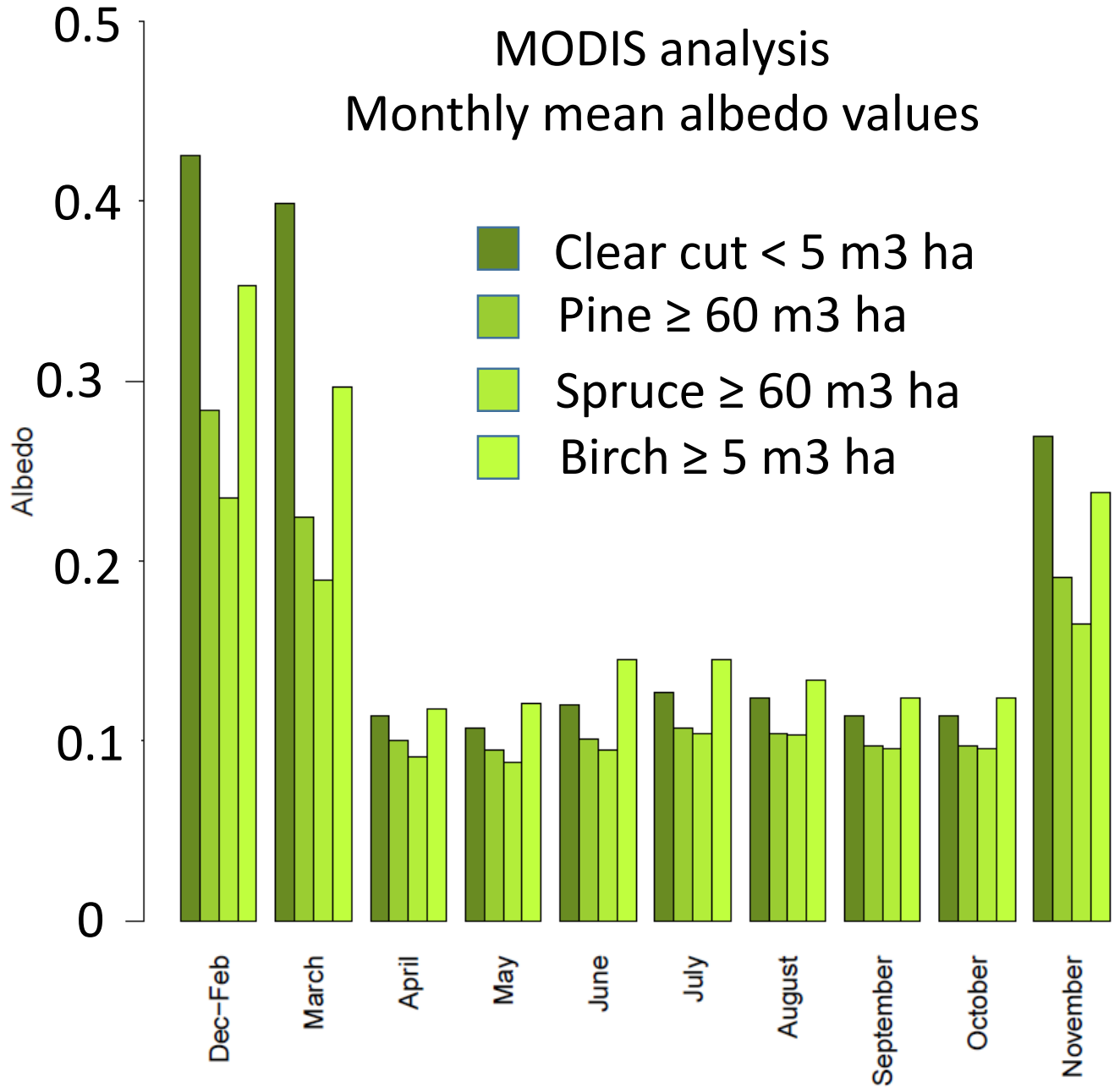
Multi-Source National Forest Inventory (MS-NFI) data pixel,
a_{ij} = ($Volume_{ij}$, $Species_{ij}$)

Methods & Models
ALBEDO

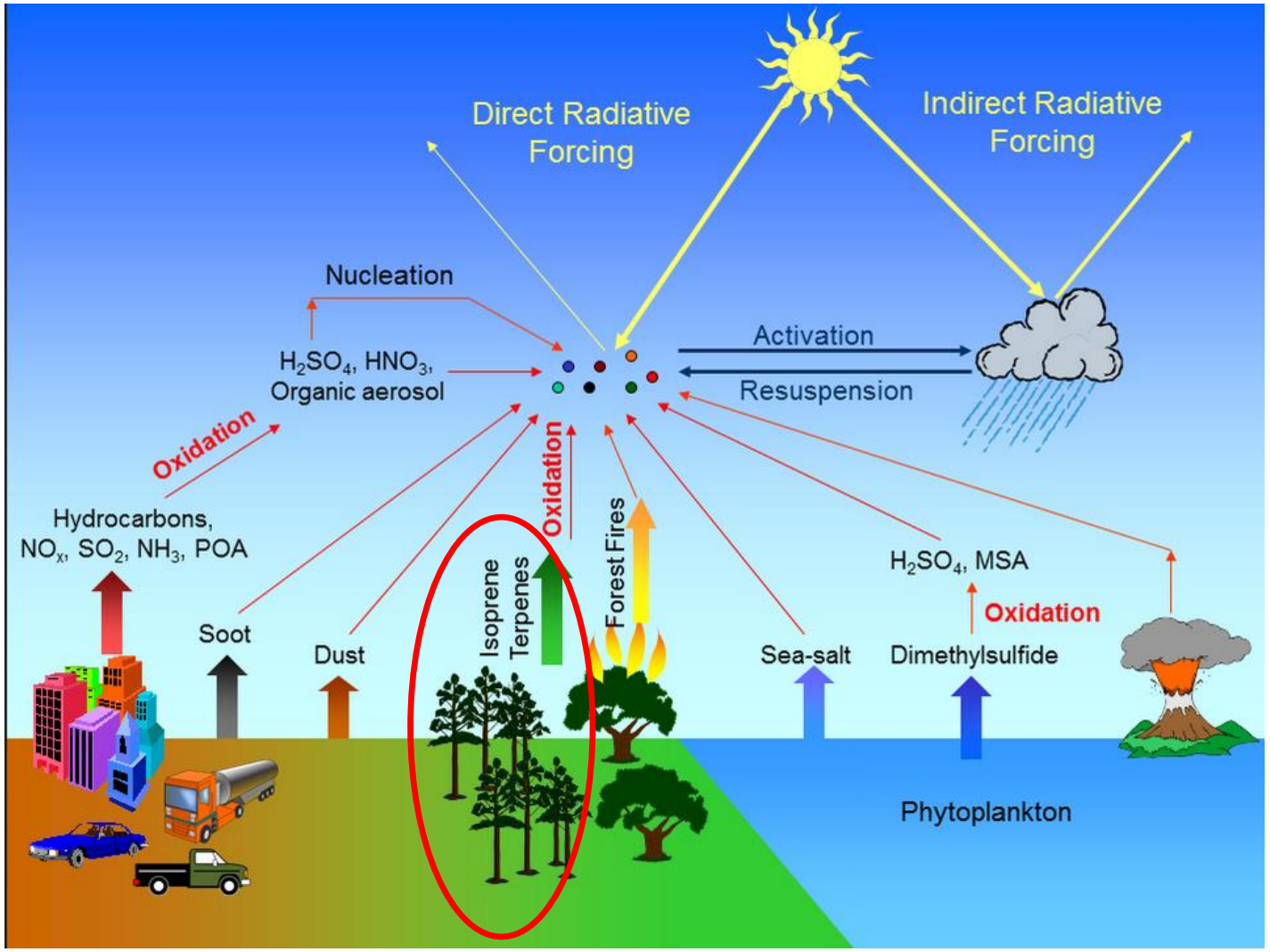
- In conifers, constant albedo stand volume ≥ 60 m^3 ha^{-1}
- In birch, constant albedo stand volume ≥ 5 m^3 ha^{-1}



Kuusinen et al. 2016



Aerosols and forests



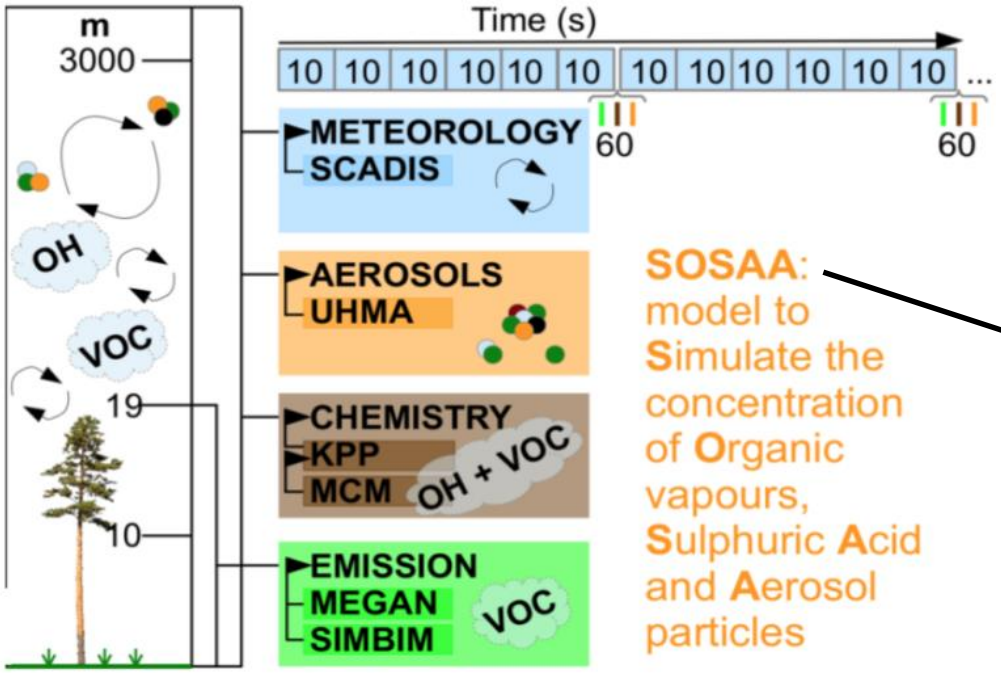
- **IPCC 2013:** Clouds and aerosols continue to contribute the largest uncertainty to estimates and interpretations of the Earth's changing energy budget.
- **Unger 2014:** The sign of the global radiation interaction between secondary organic aerols (SOA) and cloud in the present-day atmosphere is not robust across models.
- **Arneth et al. 2016:** How future changes in monoterpenes (group of BVOCs) emissions affect SOA growth and climate is very uncertain.

Input for aerosol modelling

Species	Age (yrs)	Canopy height (m)	Canopy depth (m)	Biomass (g/cm^2)	Curved LAI***
Scots pine	50	18.53	8.76	0.05043	4.160
Scots pine	20	6.74	5.2	0.05161	4.26
Scots pine	15	3.56	3.56	0.01939	1.600
Norway spruce	50	17.20	10.40	0.12225	7.335
Norway spruce	30	10.3	5.86	0.13344	8.0
Norway spruce	15	4.02	4.02	0.06798	4.079
Silver birch	50	27.74	11.10	0.01957	2.74
Silver birch	20	14.4	7.2	0.02865	4.01
Silver birch	10	6.75	6.08	0.00616	0.863

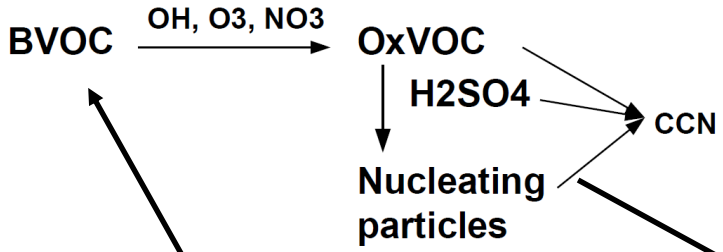
Methods & Models
AEROSOLS

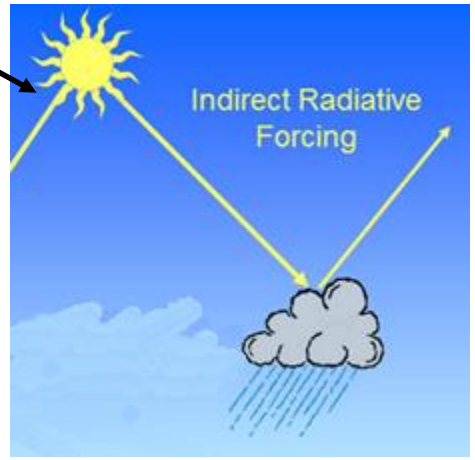
Direct effect with SOSAA model



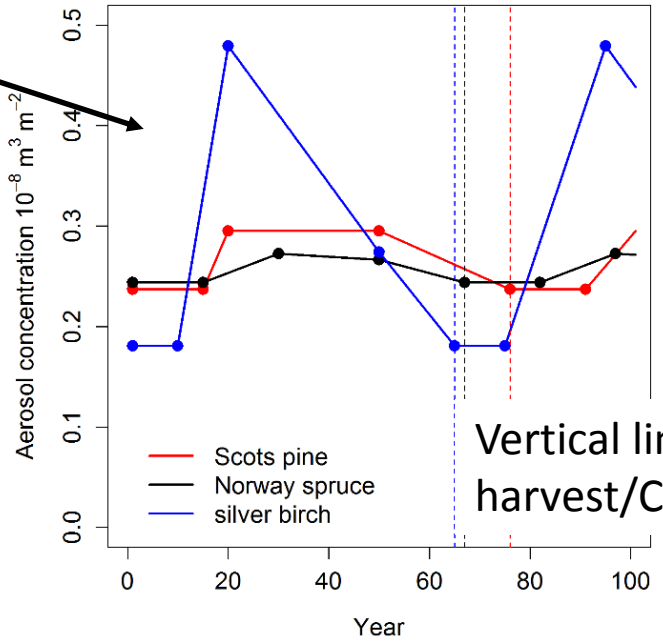
SOSAA: model to **S**imulate the concentration of **O**rganic vapours, **S**ulphuric **A**cid and **A**erosol particles

Indirect cloud effect (Kurtén et al. 2003)





Aerosol boundary layer concentration



Vertical lines = Final harvest/Clear cut

=> RF impact of aerosol change

Change in aerosol precursors in pine stand

Δbiomass

Current climate	Age 15 to Age 20	Age 20 to Age 50
Monoterpens	+424%	+6%
[OH]	+2%	0%
[H2SO4]	+3%	0%

From current climate to 2050 (SRES A2)	
Monoterpens	+37%
[OH]	-11
[H2SO4]	-68

ΔTemperature

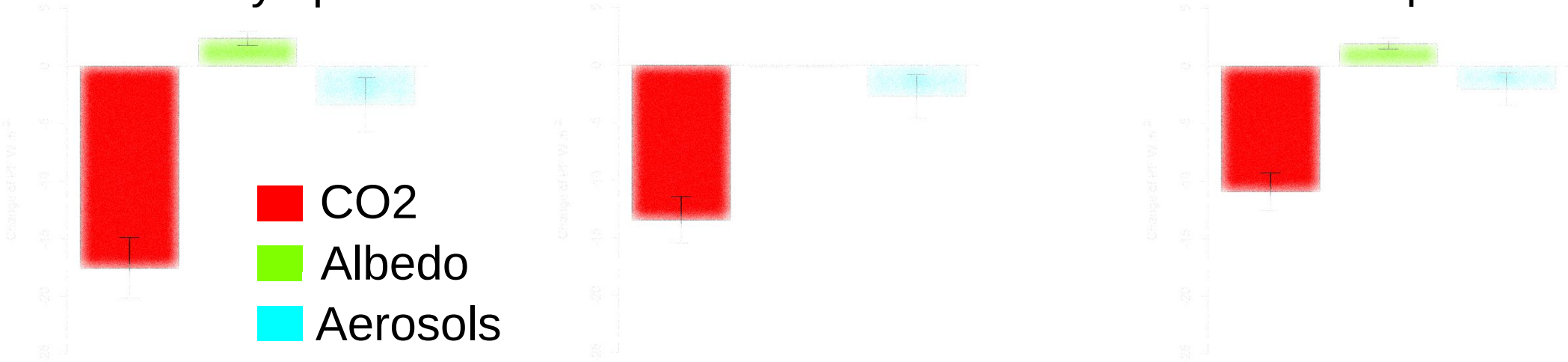
ΔSulfur oxide

Stand level direct climate impact - differences between species

Norway spruce

silver birch

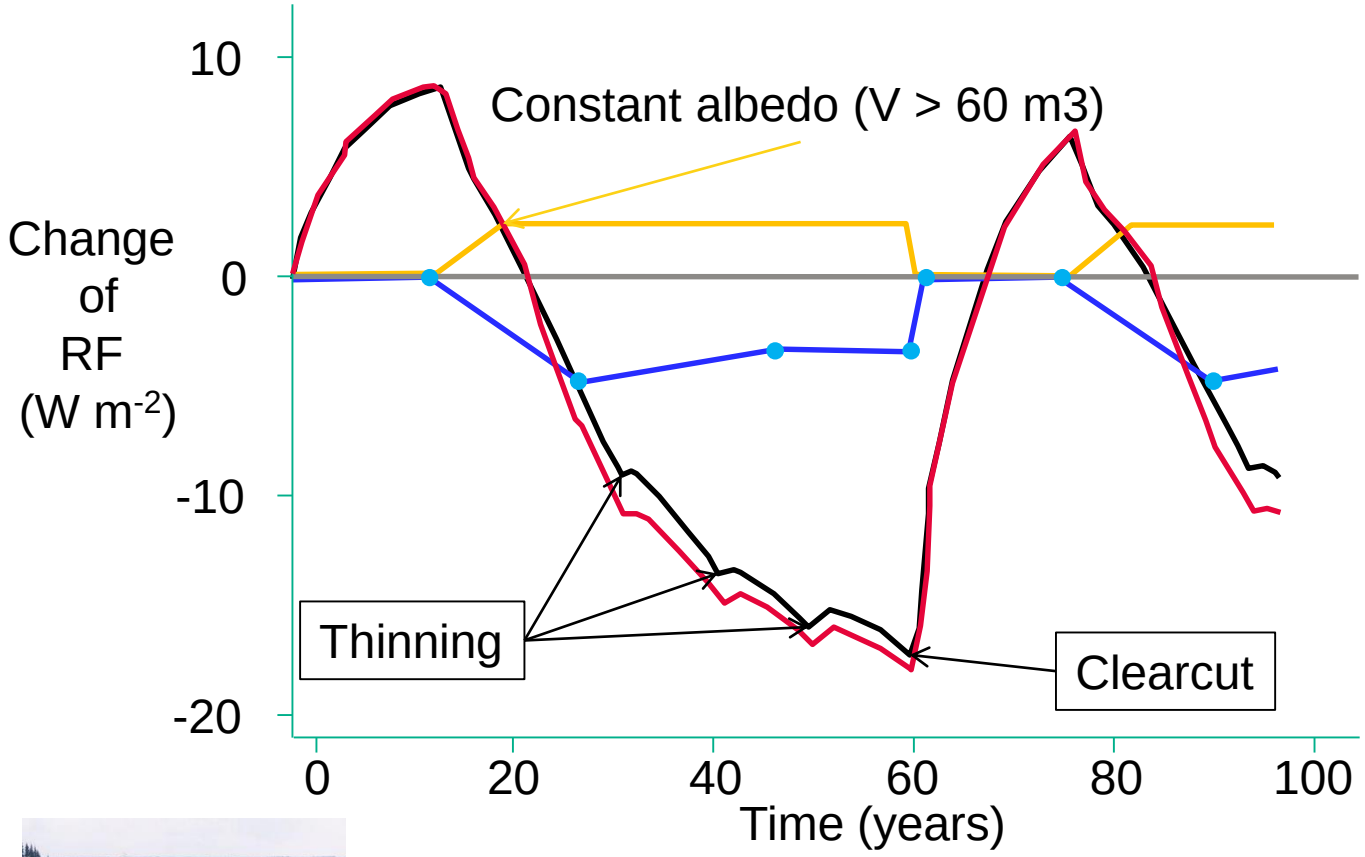
Scots pine



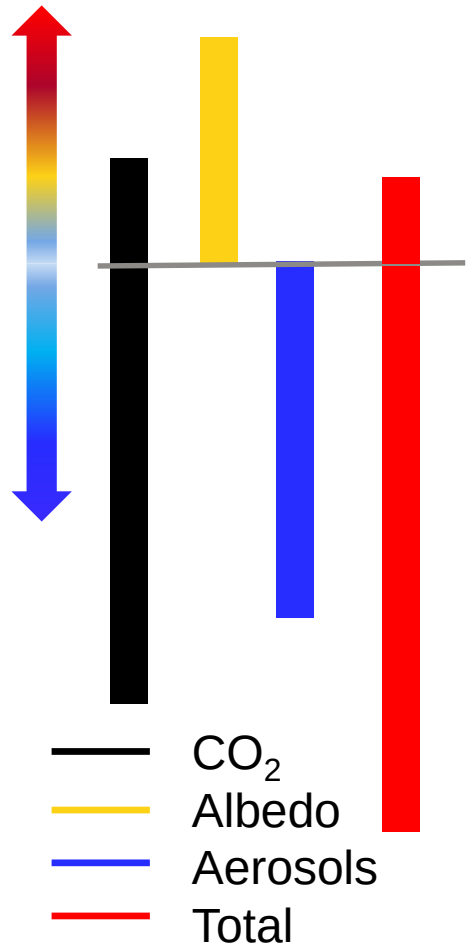
- In current climate, albedo and aerosol effects almost canceled out each other in Scots pine and Norway spruce.
- In silver birch, net effect of albedo and aerosols had cooling effect.

Stand level direct climate impact = CO2 in trees, soil and harvested wood + albedo + aerosols

Change in radiative forcing (RF) at stand scale



Cumulative RF



Substitution is the property of TECHNOSPHERE!

Another layer in analysis, Substituted carbon = Avoided emissions

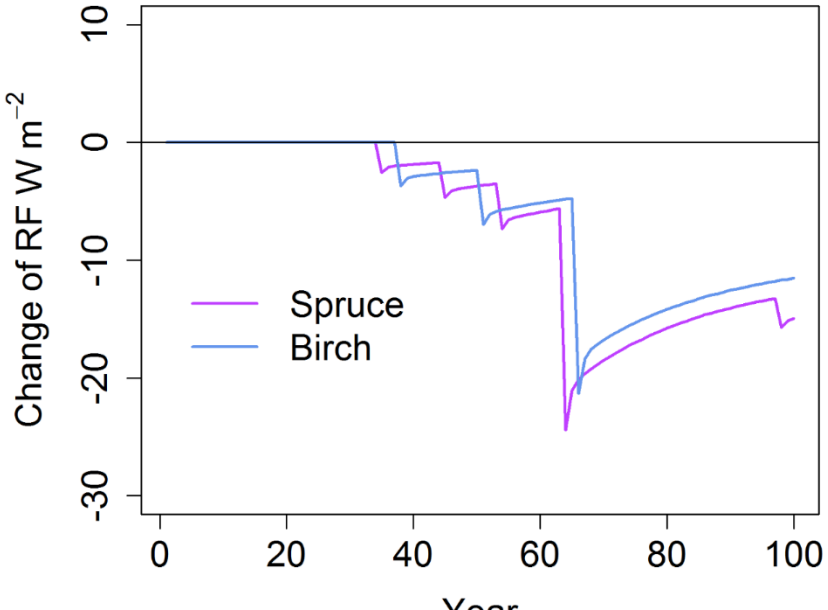
- Replacing fossil fuel based production and products (e.g. bioenergy, concrete, steel) with wood based materials

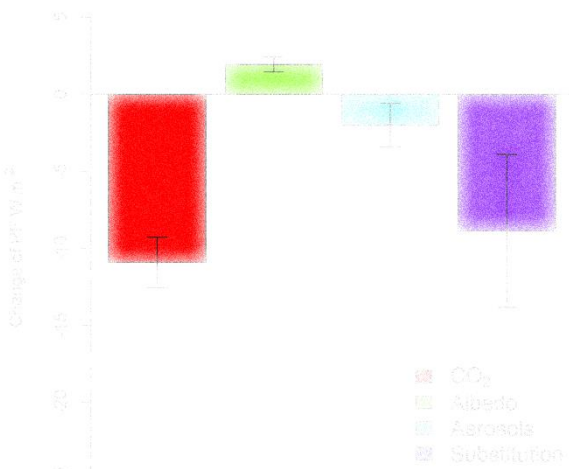
Substitution factors here:

- Pine logs 0.91 ± 0.57
- Spruce logs 0.91 ± 0.56
- Birch logs 0.82 ± 0.51

1000 kg pine logs
substitutes here 910 kg
fossil fuels and materials

Change in radiative forcing at stand scale



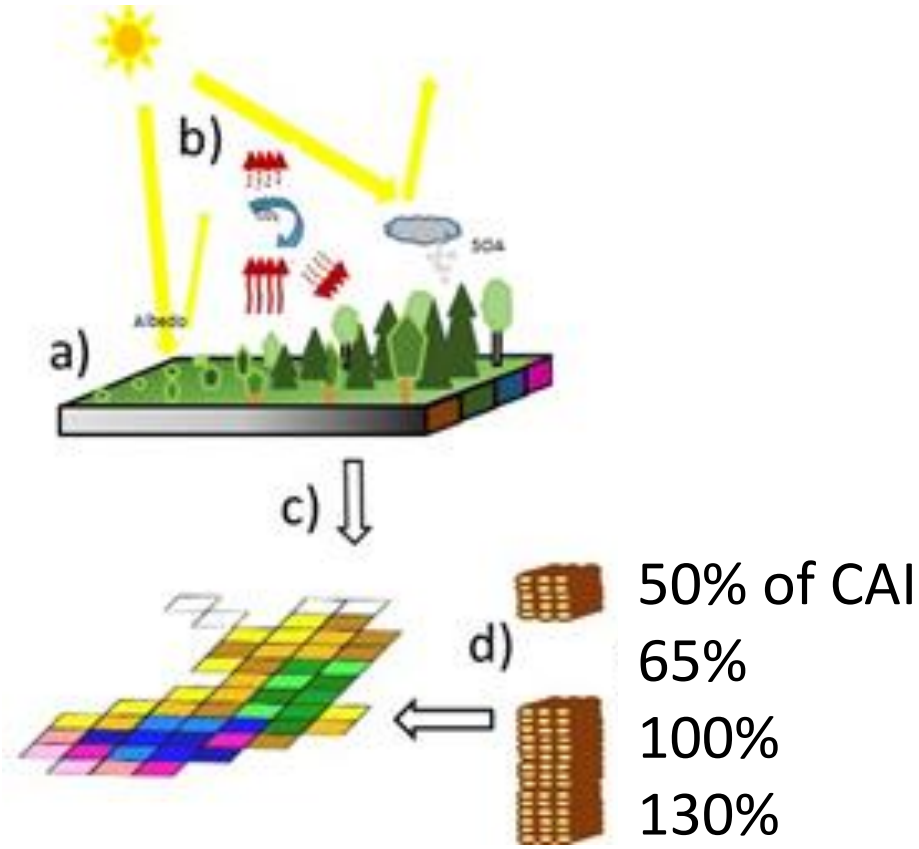


CO2 life time in atmosphere

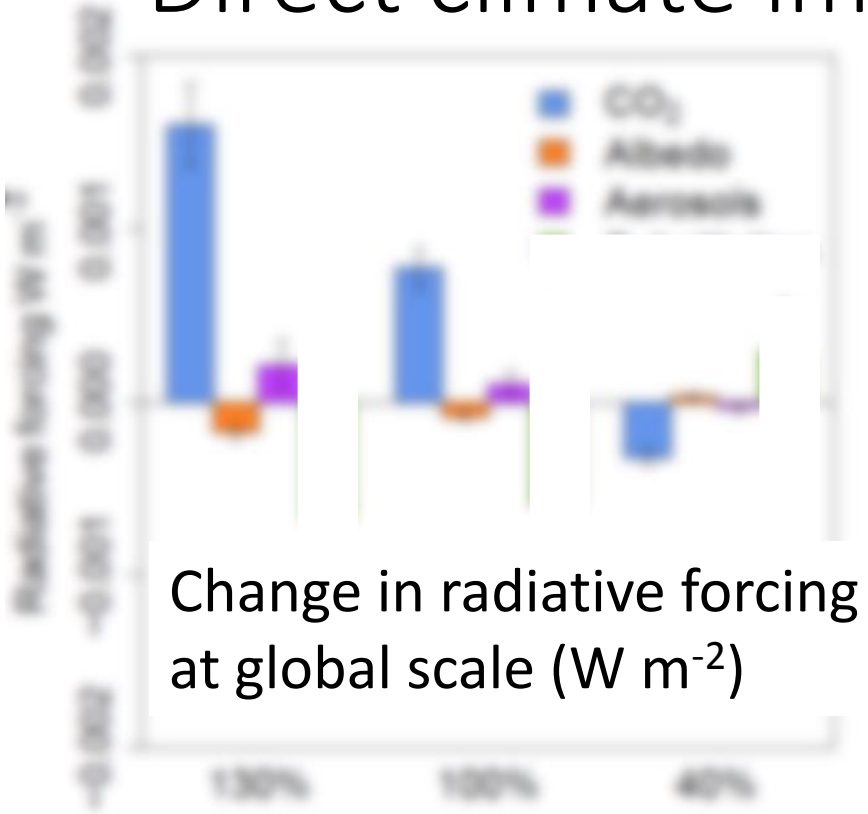
$$f(t) = a_0 + \sum_{j=1}^{3} a_j \, e^{-t/\tau_j}$$

Regional analysis - case Finland

- Current forest structure as starting point (no peatlands)
- Spruce, pine, and birch
- Fertile, medium fertile and infertile forest types
- Different harvest levels
  - 130%, 100%, 65% and 50% of current annual increment (CAI)



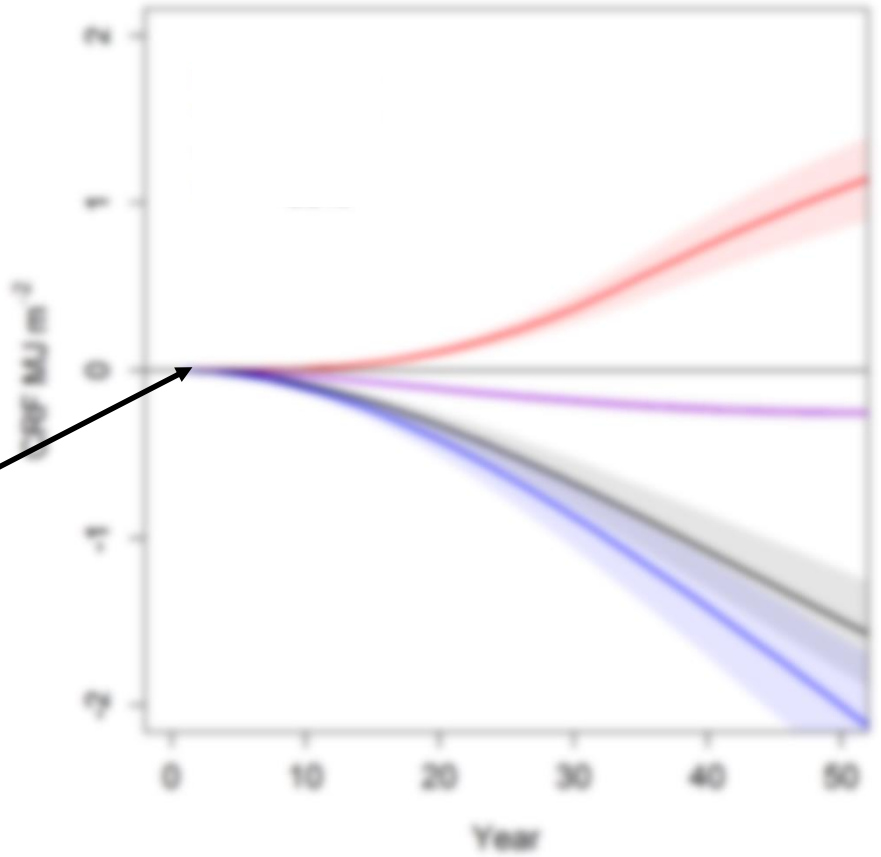
Case Finland
- Direct climate impacts



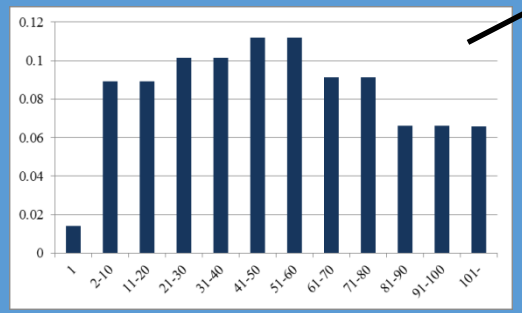
Change in radiative forcing at global scale (W m^{-2})

130%
100%
65% Current harvest level
50%

Cumulative Radiative Forcing (MJ m^{-2})

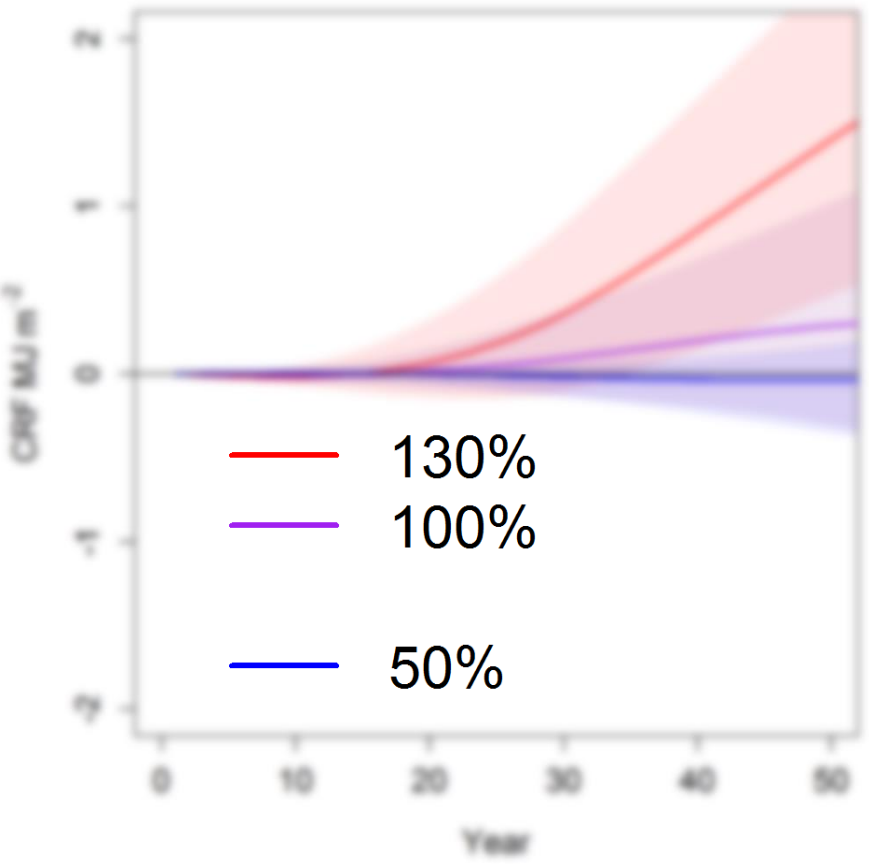


Current Age structure of Finnish forests

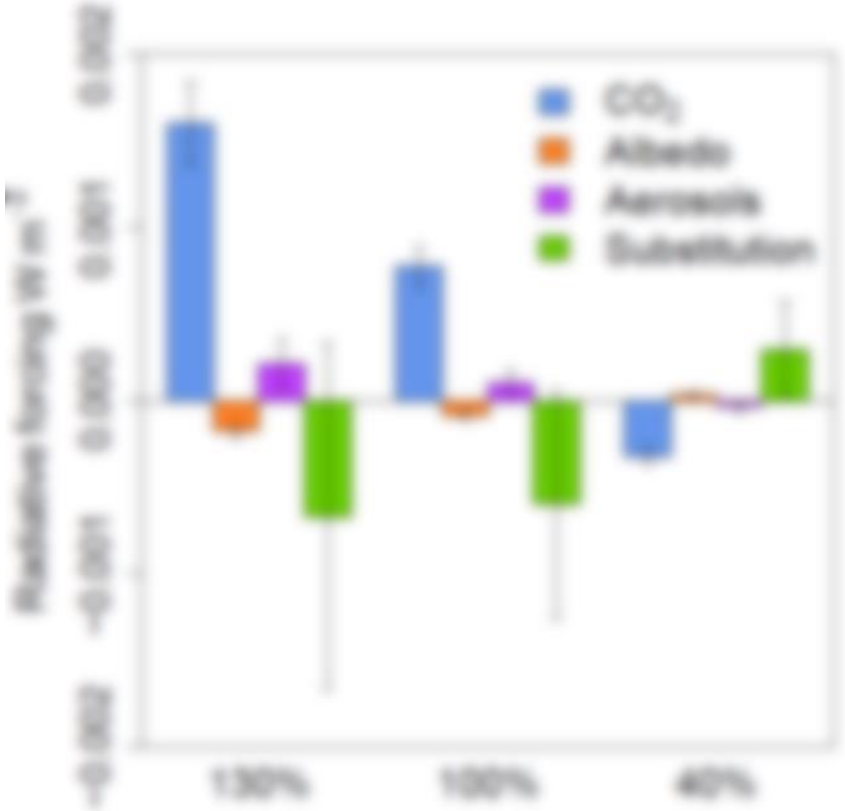


Case Finland
- Substitution included

Relative to 65% harvests



- Including the avoided emissions enhanced the negative net RF of forests
- The differences between harvest intensities (50%-100%) were greatly reduced
- Increasing forest harvesting from the current level didn't result in climate benefits within 50 yrs



- The outcome depends heavily on wood use and its role in replacing fossil fuel-based products and energy.

Conclusions

- The cooling effect of aerosols counterbalanced the warming impact of the surface albedo. BUT HUGE UNCERTAINTIES…
- The combined aerosol and albedo effect turned the radiative forcing from silver birch stands more negative than conifer stands.
- In this analysis, more intensive harvests and a shift in the wood use to products with low substitution factors, such as bioenergy, were not beneficial from a climate change mitigation viewpoint within 50 years.
- Substitution is the property of technosphere. Can/will change without any change in forest ecosystem or in whole forest sector.

Thank you!

tuomo.kalliokoski@helsinki.fi