Forest ecosystems in changing climate

Bjarni D. Sigurdsson

Prof. of forest science, Agric. Univ. Iceland

bjarni@lbhi.is

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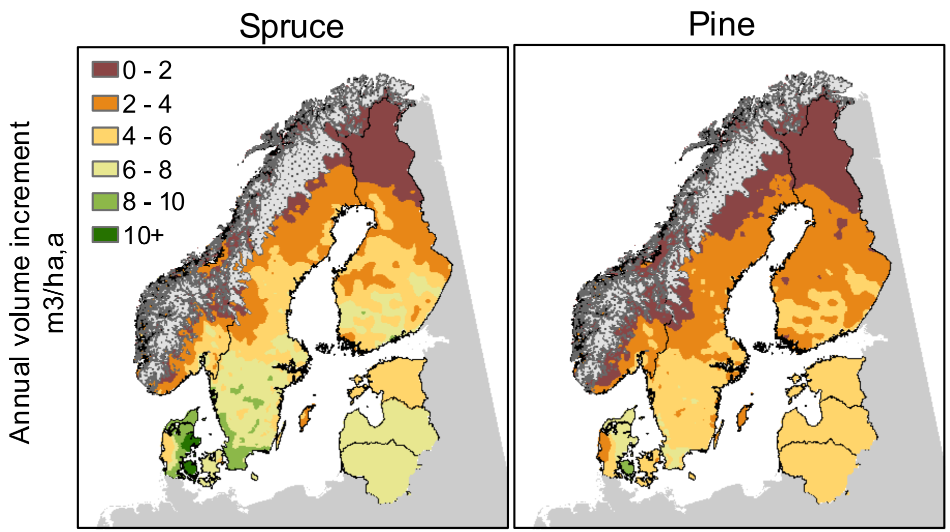
What is „climate change“?

NOT only increase in MAT

=> CO_2, T, P, N-dep., seasonality, disturbance, etc.!

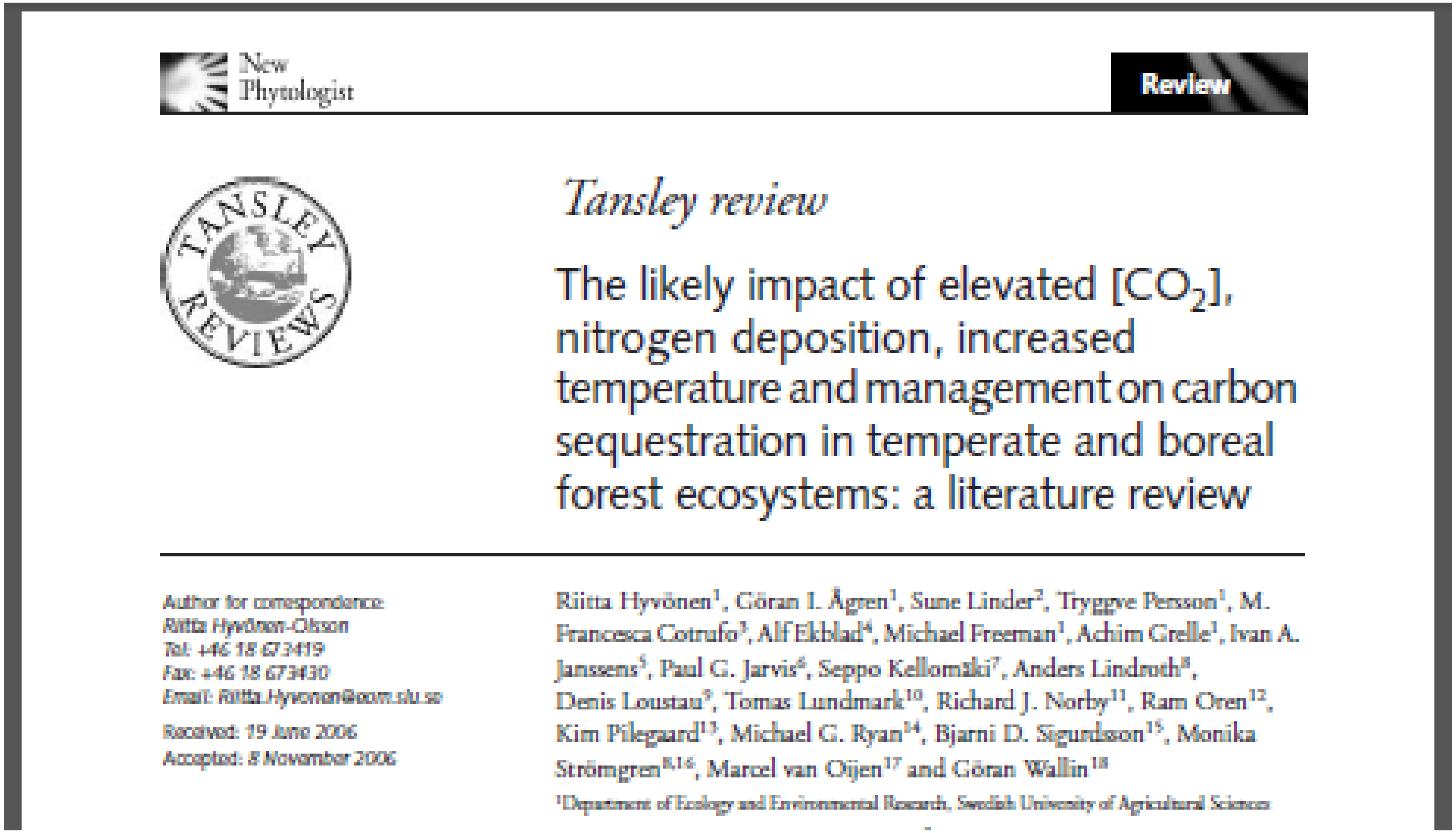


Created by Ola Langvall 2006

What are the strongest CC drivers in the boreal forest dynamics?

- MAT?
  - Max air temperature?
  - Winter frosts?
  - Growing season length and timing?
- Annual rainfall?
  - Summer water balance?
- Nutrient cycle feedbacks
  - Soil temperature and nutrient turnover?
  - Soil humidity and nutrient turnover?
- Other CC-Biotic interactions?

Recent review for boral forests



New Phytologist

Review

Tansley review

TANSLEY REVIEWS

The likely impact of elevated $[CO_2]$, nitrogen deposition, increased temperature and management on carbon sequestration in temperate and boreal forest ecosystems: a literature review

Author for correspondence:
Riitta Hyvönen-Olsson
Tel: +46 18 673419
Fax: +46 18 673430
Email: Riitta.Hyvonen@eom.slu.se

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Riitta Hyvönen[1], Göran I. Ågren[1], Sune Linder[2], Tryggve Persson[1], M. Francesca Cotrufo[3], Alf Ekblad[4], Michael Freeman[1], Achim Grelle[1], Ivan A. Janssens[5], Paul G. Jarvis[6], Seppo Kellomäki[7], Anders Lindroth[8], Denis Loustau[9], Tomas Lundmark[10], Richard J. Norby[11], Ram Oren[12], Kim Pilegaard[13], Michael G. Ryan[14], Bjarni D. Sigurdsson[15], Monika Strömgren[8,16], Marcel van Oijen[17] and Göran Wallin[18]

[1]Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences

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Main message: you can <u>not</u> predict changes in future forest growth with changes in single environmental factor!

Table 1 Important cause–effect chains for carbon cycling

No.	Rate*	Perturbation	Cause–effect chain	Strength†	Knowledge‡
1	Fast	$[CO_2]$↑	NPP ↑ ⇒ N demand ↑ ⇒ Soil N availability ↓ ⇒ NPP ↓	Strong	High
2	Fast	N↑	NPP ↑	Strong	High
3	Fast	T↑	NPP ↑ ⇒ N demand ↑ ⇒ Soil N availability ↓ ⇒ NPP ↓	Strong	High
4	Fast	T↑	Soil respiration ↑ ⇒ Soil carbon ↓ ⇒ Soil respiration ↓	Strong	High
5	Fast	$[CO_2]$↑	Allocation to roots and mycorrhiza ↑ ⇒ Soil respiration ↑	Medium	High
6	Fast	T↑	Turnover of fine roots ↓ ⇒?	Medium	Medium
7	Intermediate	T↑	N mineralization ↑ ⇒ NPP ↑ ⇒ See mechanisms above	Strong	High
8	Intermediate	N↑	Root allocation ↓ ⇒ Root litter ↓ ⇒ Soil C store ↓	Medium	Medium
9	Intermediate	N↑	Mycorrhizal turnover ↑ ⇒ Litter input in soil ↑ ⇒ Soil C store ↑	Weak	Weak
10	Intermediate	N↑	Litter N concentration ↑ ⇒ Litter decomposition rate ↑? ⇒ Soil C store ↓	Weak	Unclear
11	Intermediate	$[CO_2]$↑	Litter N concentration ↓ ⇒ Litter decomposition rate ↓?⇒ Soil C store ↑	Weak	Unclear
12	Intermediate	N↑, $[CO_2]$↑	NPP ↑ ⇒ Litter production ↑ ⇒ SOM ↑	Weak	High
13	Intermediate	N↑	NPP ↑ and root allocation ↓ ⇒ N uptake ↓ ⇒ NPP ↓	Medium	Medium
14	Intermediate	$[CO_2]$↑	NPP ↑ and root allocation ↑ ⇒ N uptake ↑ ⇒ NPP ↑	Medium	Medium
15	Intermediate	N↑	Soil respiration ↓ ⇒ N mineralization ↓? ⇒ NPP ↓	Medium	Weak
16	Intermediate	N↑	Litter decomposition rate ↑↓ ⇒ Soil C store ↓↑	Medium	Weak
17	Slow	N↑	SOM decomposition rate ↓ ⇒ Soil C store ↑	Medium	Weak

*Rate at which cause–effect chains respond: fast, within-year; intermediate, a few years; slow, decades; very slow, centuries.
†Strength of the effects.
‡Knowledge of the links in the chain.
NPP, net primary production; SOM, soil organic matter.

Forest trees are long-living – Initial responses for seedlings may be very misleading for the net-effect!

Nutrient-feedbacks are VERY important in the Boral forest!

Nordic research project(s) 1994–1997–2005

Prof. Sune Linder, SLU; Prof. Seppo Kellomäki, Joensuu, et al.

Effects of CO_2, T and N on tree growth

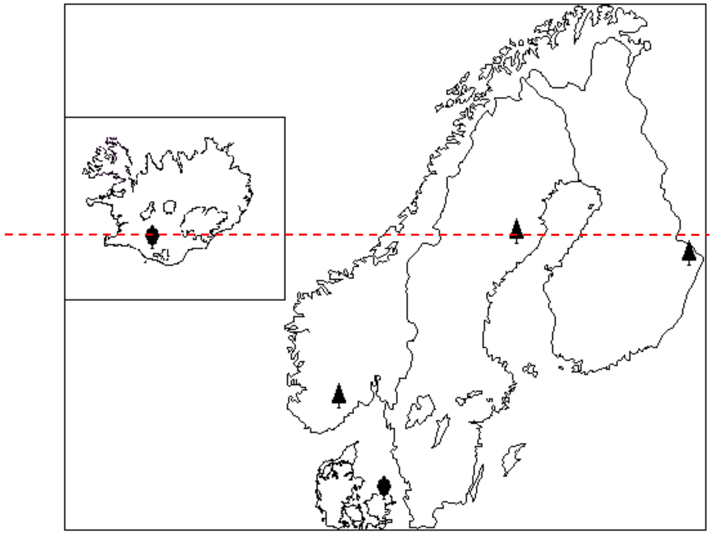
Denmark: beech

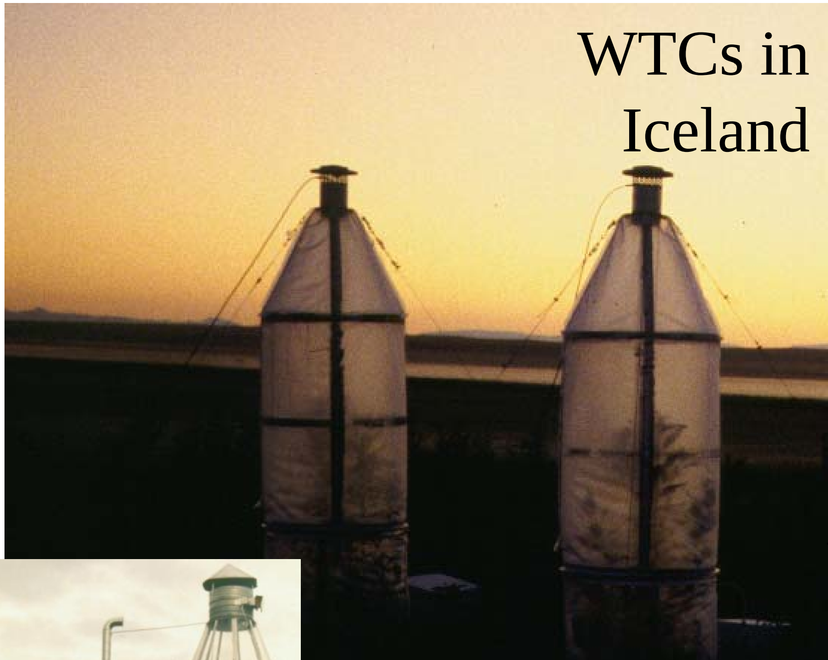
Finland: **Scots pine**

Norway: **Scots pine**

Sweden: Norway spruce

Iceland: **black cottonwood**





WTCs in
Sweden

WTCs in
Finland

Main findings of the Nordic project(s)

The main limiting factors for tree growth in Iceland were:

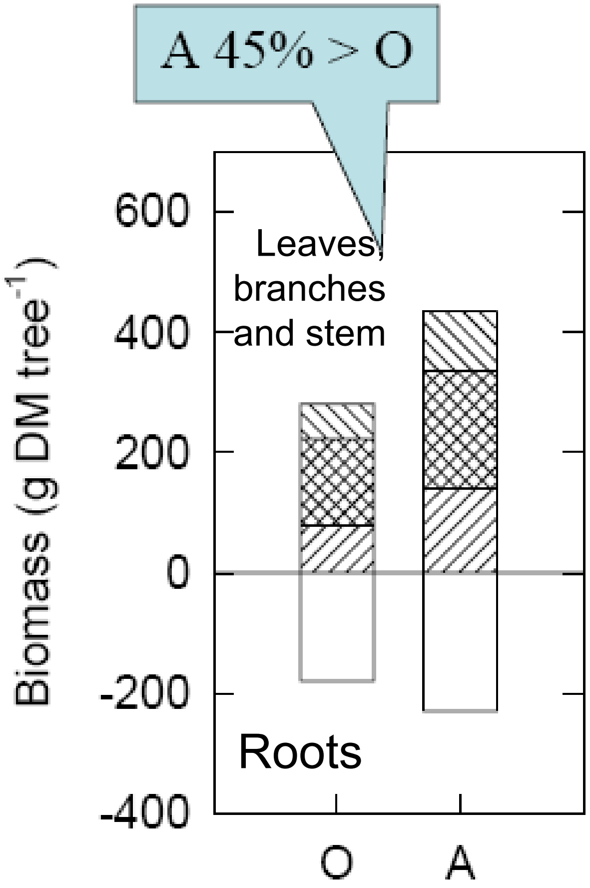
1. **Nutrient availablity (N)**
2. **Growing season's length**
3. **Air temperature**
4. **Higher CO_2**

Interactions between those factors are complex!

Increased growing season T in Iceland by 1.1 °C increased tree growth by 45%.

- T + miniralization effects
- The length of the growing season was not affected.

(Sigurdsson 2001. PhD thesis)



Changes in air temperature and [CO_2] are not enough!

New paper (July 2013)

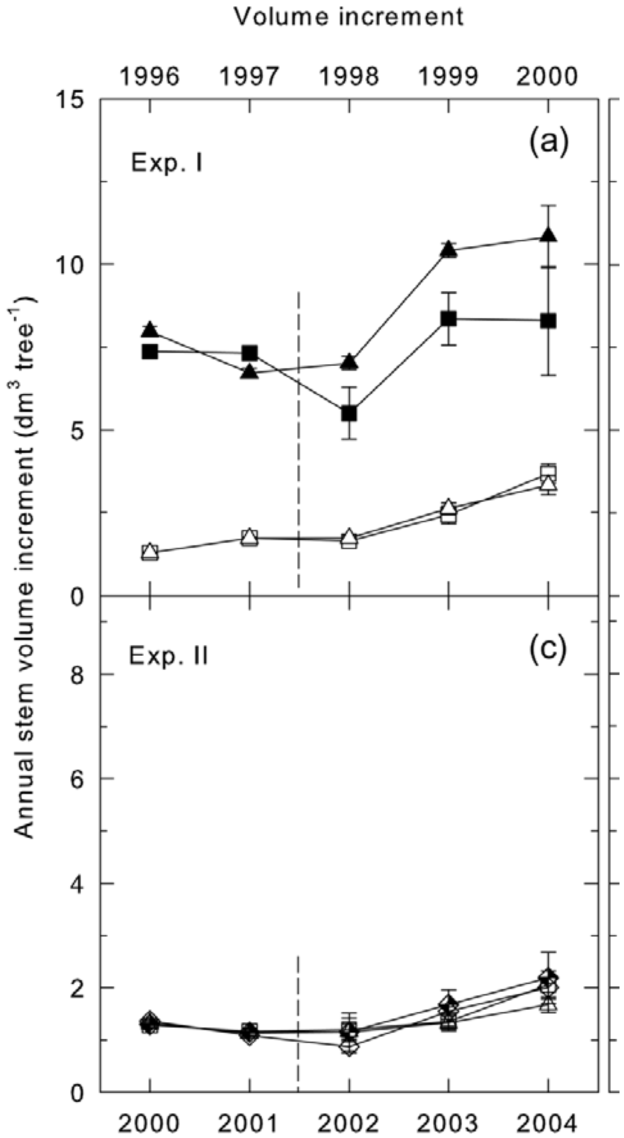
Tree Physiology Advance Access published July 21, 2013

Tree Physiology 00, 1–14
doi:10.1093/treephys/tpt043

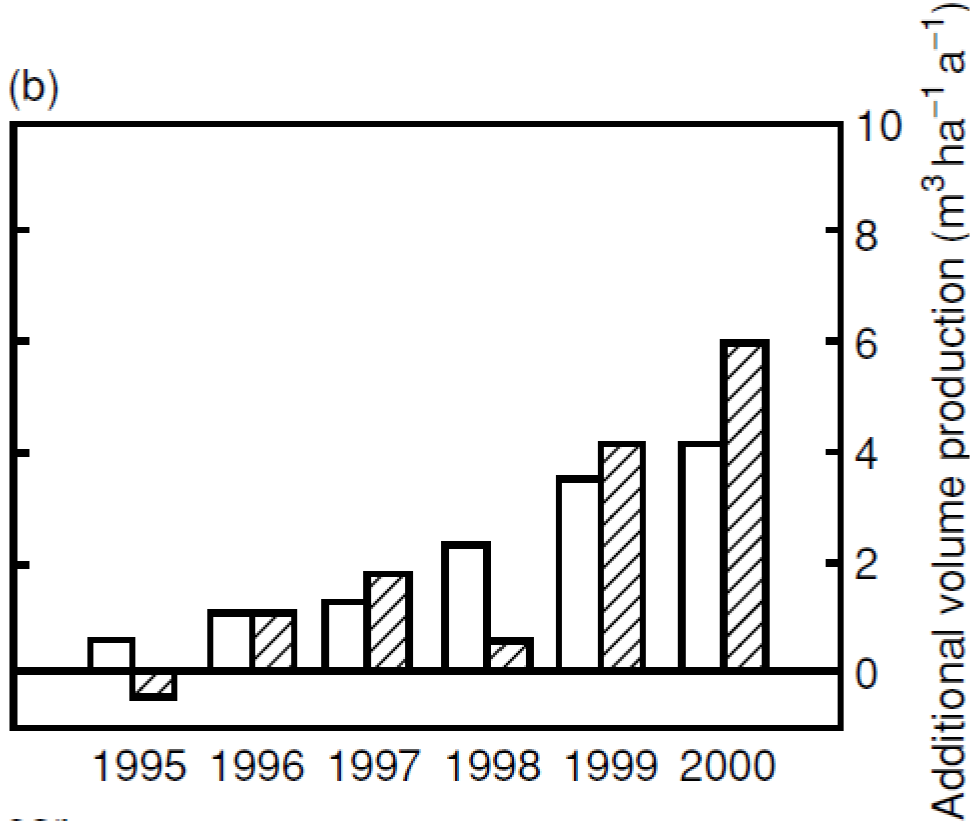
Research paper

Growth of mature boreal Norway spruce was not affected by elevated [CO_2] and/or air temperature unless nutrient availability was improved

Bjarni D. Sigurdsson[1,6], Jane L. Medhurst[2], Göran Wallin[3], Olafur Eggertsson[4] and Sune Linder[5]



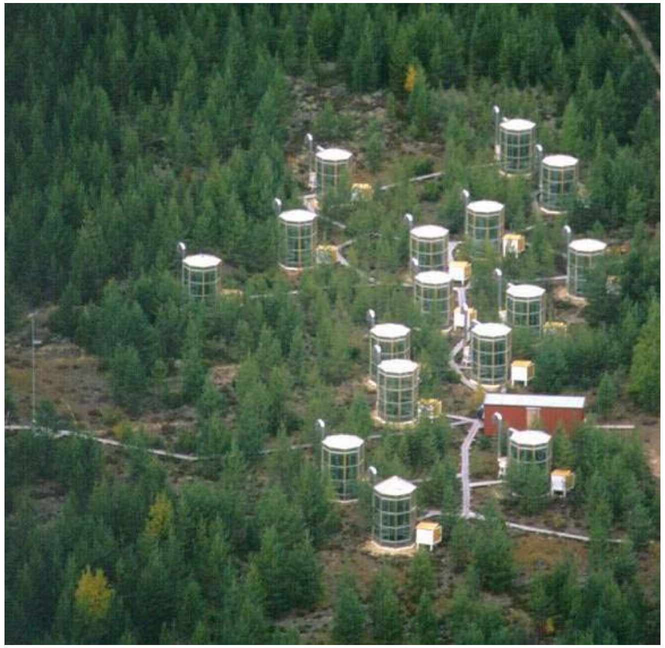
Elevating air temperature ~4 ° C – without increasing soil temperature **did not increase** aboveground growth of Norway spruce at (natural) low N-availability



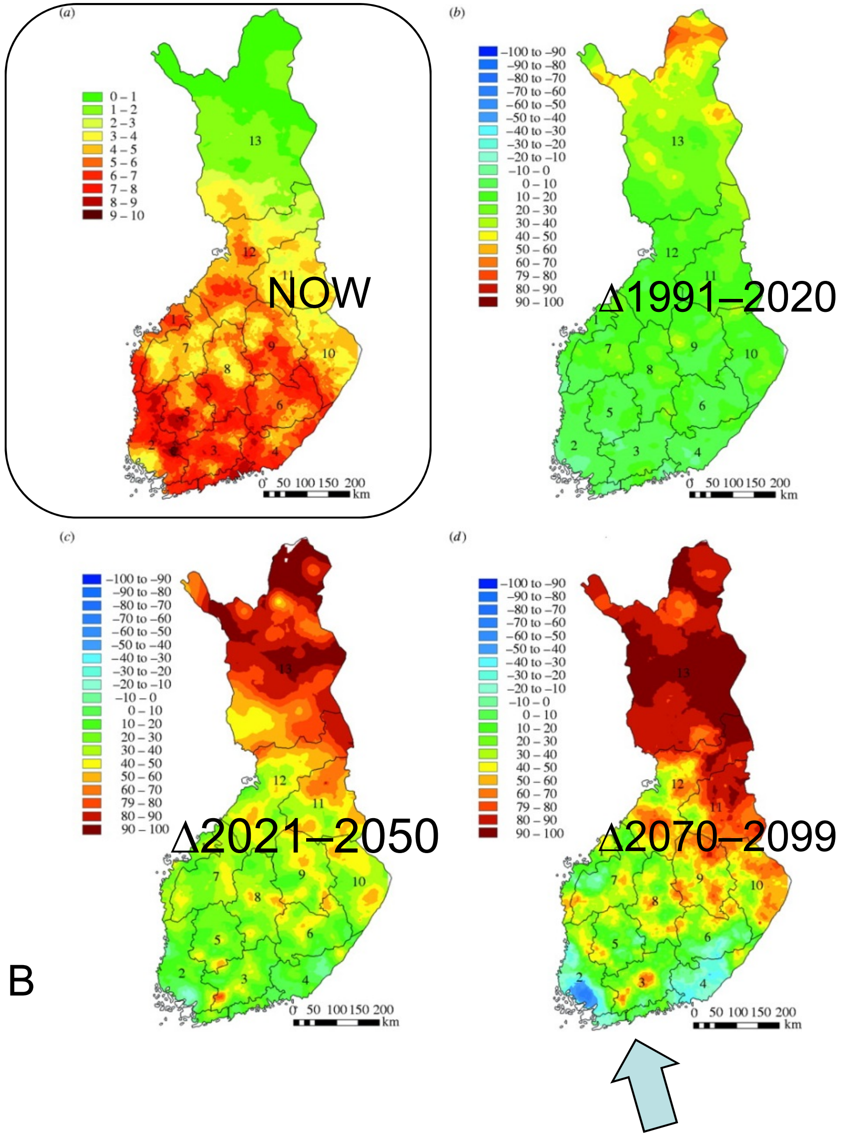
Increasing soil temperatue by ~4 °C did however increase 3-year growth by +115% (Strömgren & Linder 2002)

Effects of climate warming on regional forest growth

Integrated growth of all tree species under the current climate, and the change in growth under climate change: (a) total current growth ($m^3 ha^{-1} yr^{-1}$); percentage of total growth change for (b) 1991–2020, (c) 2021–2050 and (d) 2070–2099.



Whole tree chambers on mature Sotch pine forest in E-Finland



Seppo Kellomäki et al. Phil. Trans. R. Soc. B 2008;363:2339-2349

Univ. of Eastern Finland / Joensuu

But even if forests grow better, they might change!

Soil water may become an issue in more southern locations!

Shift towards more Scots pine and birch?

Tree species composition in per cent of the total stocking in (slices divided between southern and northern Finland. (North includes the regions 11–13 above approximately 63° N, and s Finland the regions 1–10 below approximately 63° N.)

region and species	current	1991–2020	2021–2050	2070–2099
southern Finland				
Scots pine (%)	42	44	54	62
Norway spruce (%)	49	45	33	8
birch (%)	9	11	13	30
northern Finland				
Scots pine (%)	62	63	68	77
Norway spruce (%)	27	26	22	14
birch (%)	11	11	10	8

Seppo Kellomäki et al. Phil. Trans. R. Soc. B 2008;363:2339-2349
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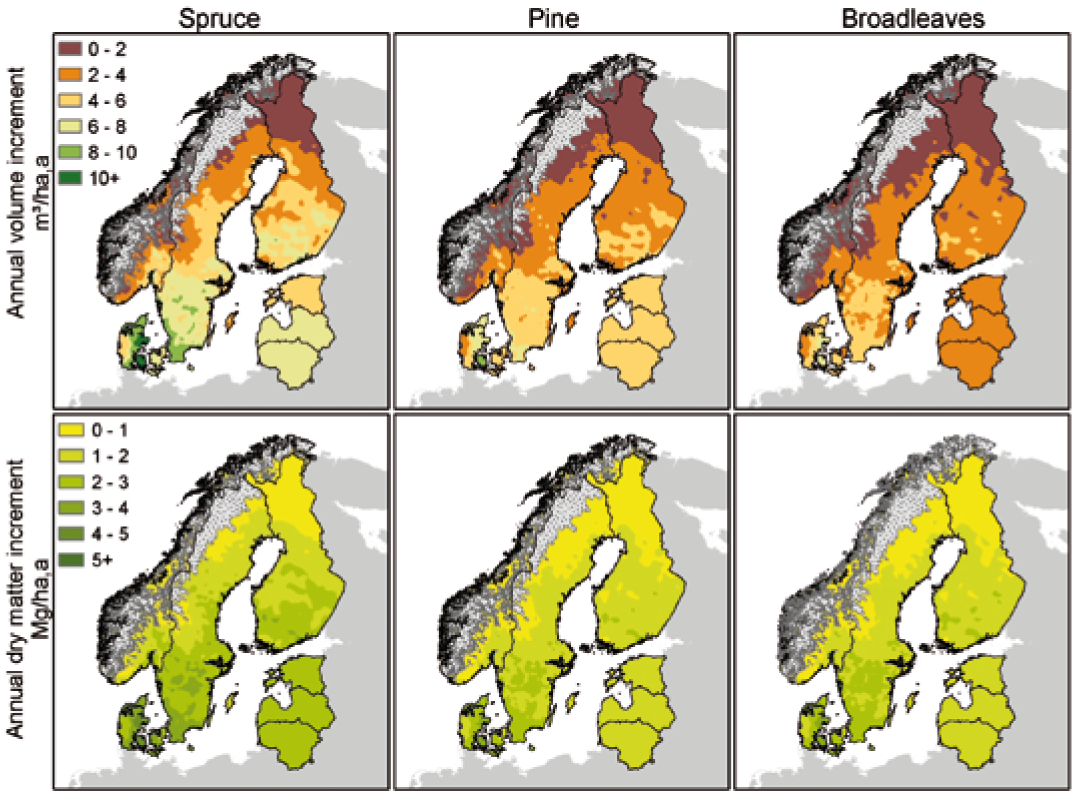
Regional studies II

- Total biomass growth increases between 20% and 25% over large areas of Fennoscandia.
- An increase of up to 35% in (wet) maritime conditions.
- Smaller under continental conditions because of more frequent drought episodes.
- Available forest biomass production in the Nordic and Baltic countries may increase to 760 million Mg during this century.

  Assuming that the management systems and the use of timber are the same as for today, an increase of 20% in biomass growth would mean that.
- In terms of annual stem volume growth, the increase is roughly 50 million m^3/yr ➔ **One extra "Fennoscandian country"**



Seppo Kellomäki 2007. Biofuels. In: Fenger J (ed.) ***Impacts of Climate Change on Renewable Energy Sources: Their role in the Nordic energy system. Nordic Council of Ministers, Copenhagen, pp. 140-153.***

Mountain Pine Beetle outbreak on Contorta in BC:

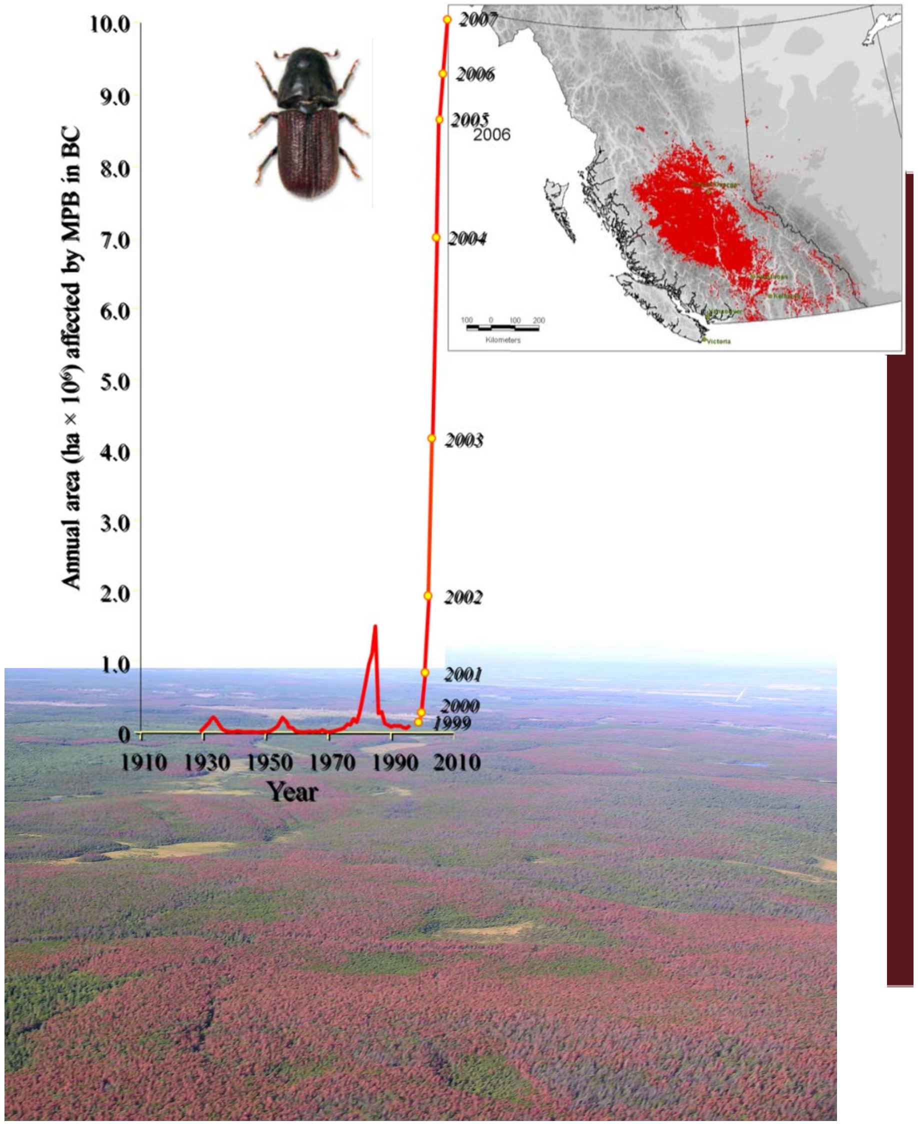
Natural Disaster or Natural Consequence?

Affected stands in BC since 2000:

– 18.3 million ha = 2013 MPB outbraek
  - **1.8 x the size of Iceland!**
  - **4.2 x the size of Denmark!!!**

– 57% of standing Contorta pine volume in BC will be killed by 2020...

– Only 0.2 million ha salvaged per year



Source: Tim Ebata, BC MoFR, Allan Carroll, CFS

Take-home messages:

- In the Boreal forest it is nutrient feedbacks and **soil processes** which govern the response to CC
- Forest growth in Fennosandia expected to increase by 20-30% - or ca. 50 million m^3
- Even if precip increases in Fennoscandia, water limitation may become more important (in S).
- Disturbances and biotic interactions may become more important! But very difficult to predict.

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