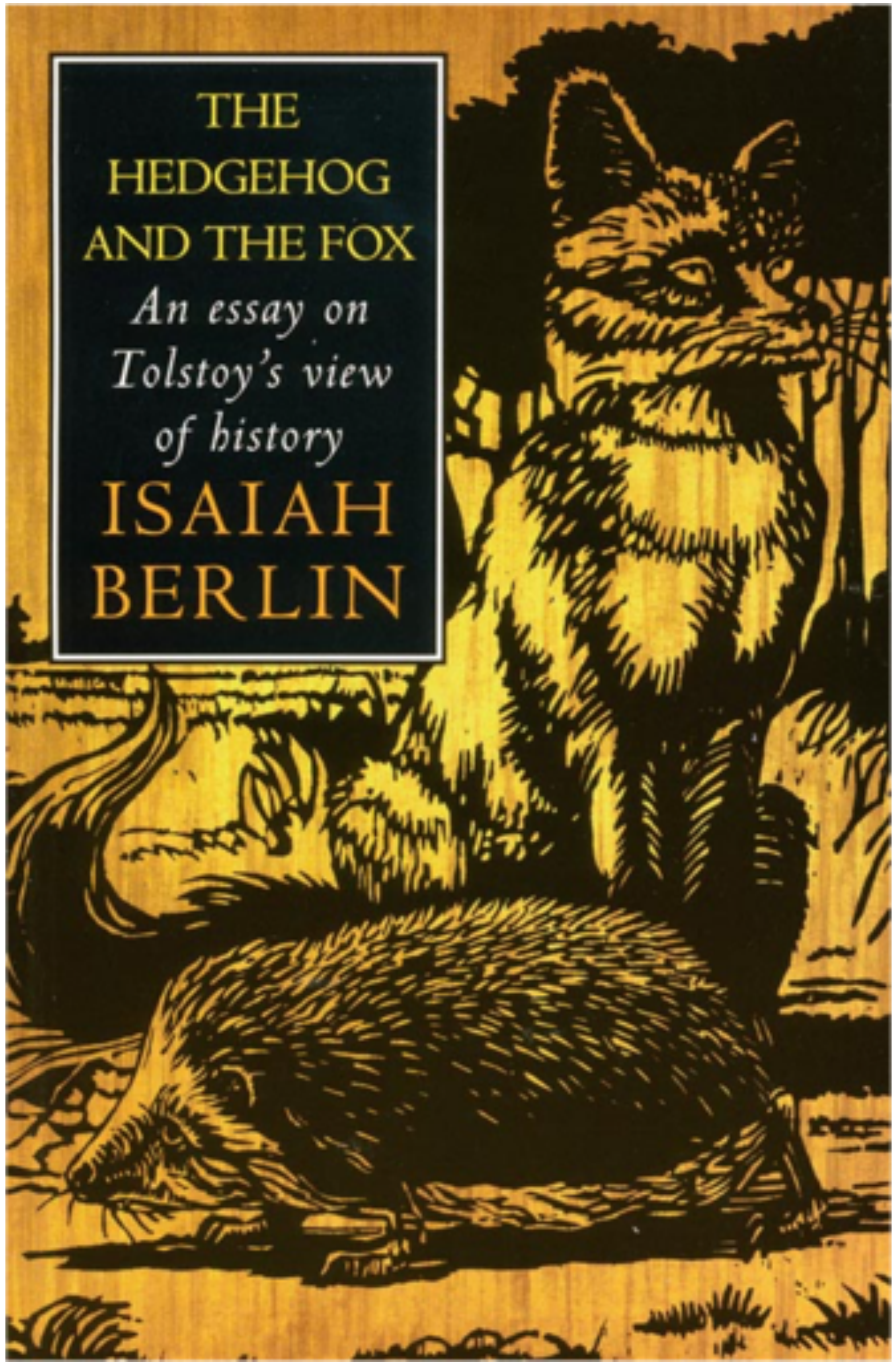
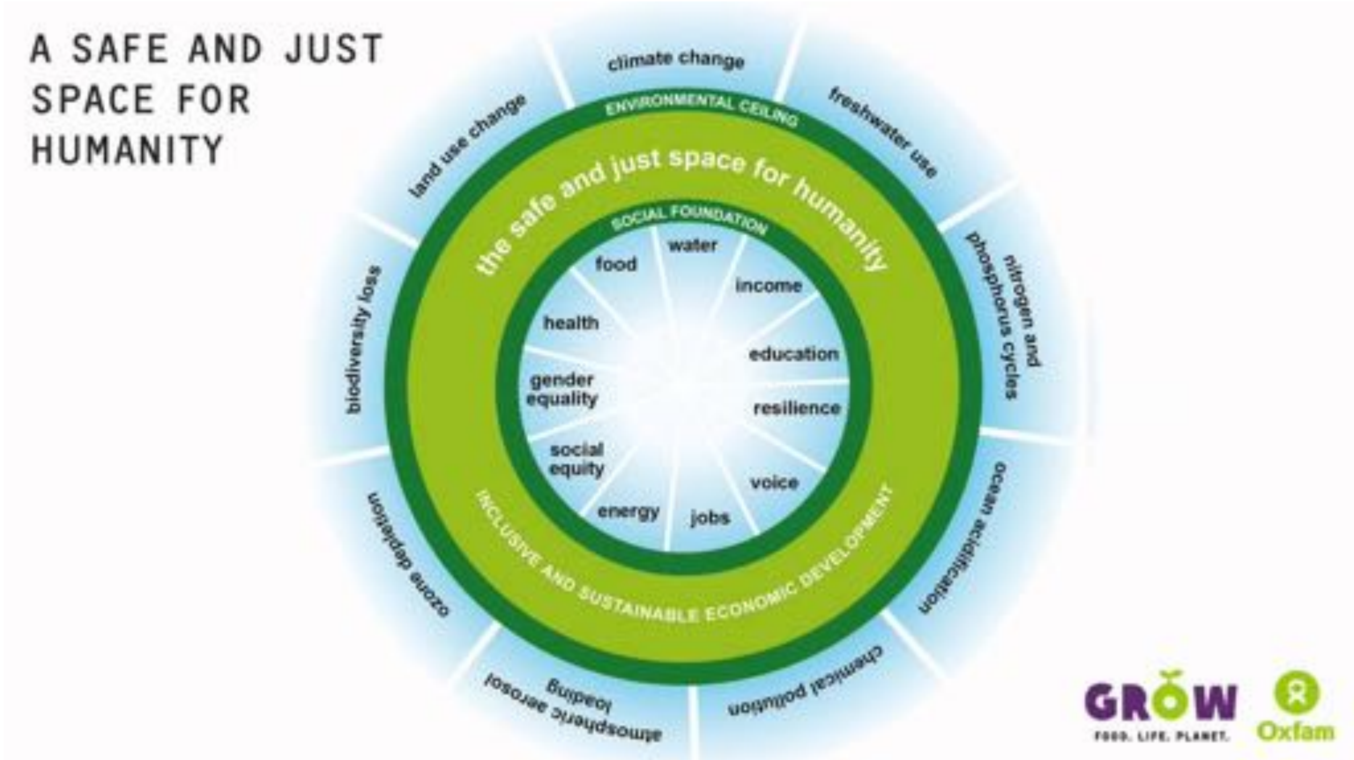
The hedgehog and the Fox

Can forestry absolve Sweden's carbon emissions?

Salim Belyazid
Physical Geography
Stockholm University



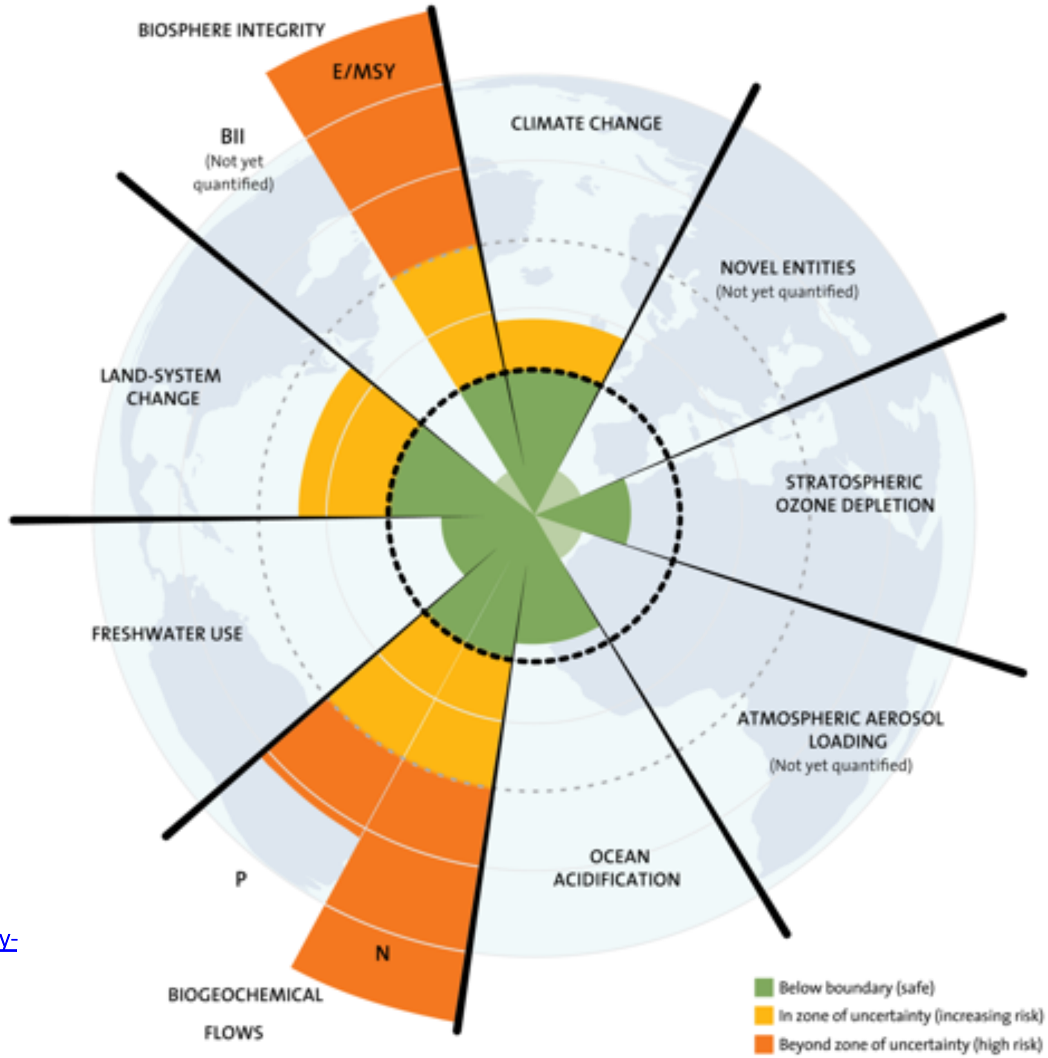
Doughnut and the nine planetary boundaries



De nio planetära gränserna

1. Climate change
2. Biodiversity
3. Stratospheric ozone
4. Ocean acidification
5. Biogeochemical cycles
6. Land use change
7. Freshwater use
8. Aerosols in the atmosphere
9. New chemical substances

Planetary boundaries



[Find legend here: https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html](https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html)

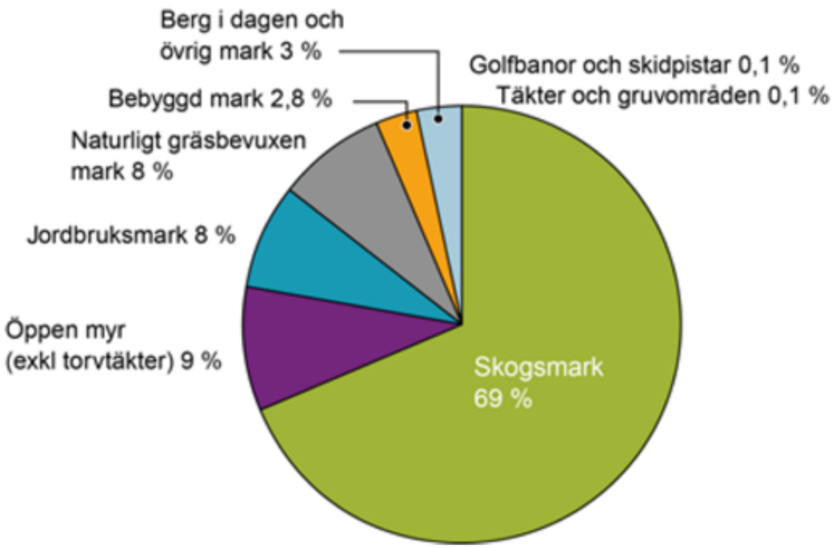
Global EU’s energy and climate goals by 2030:

- 40% lower GHG emissions compared to 1990
- 27% renewable energy
- 27% energy saving

Swedish Governmental Framework Agreement on energy

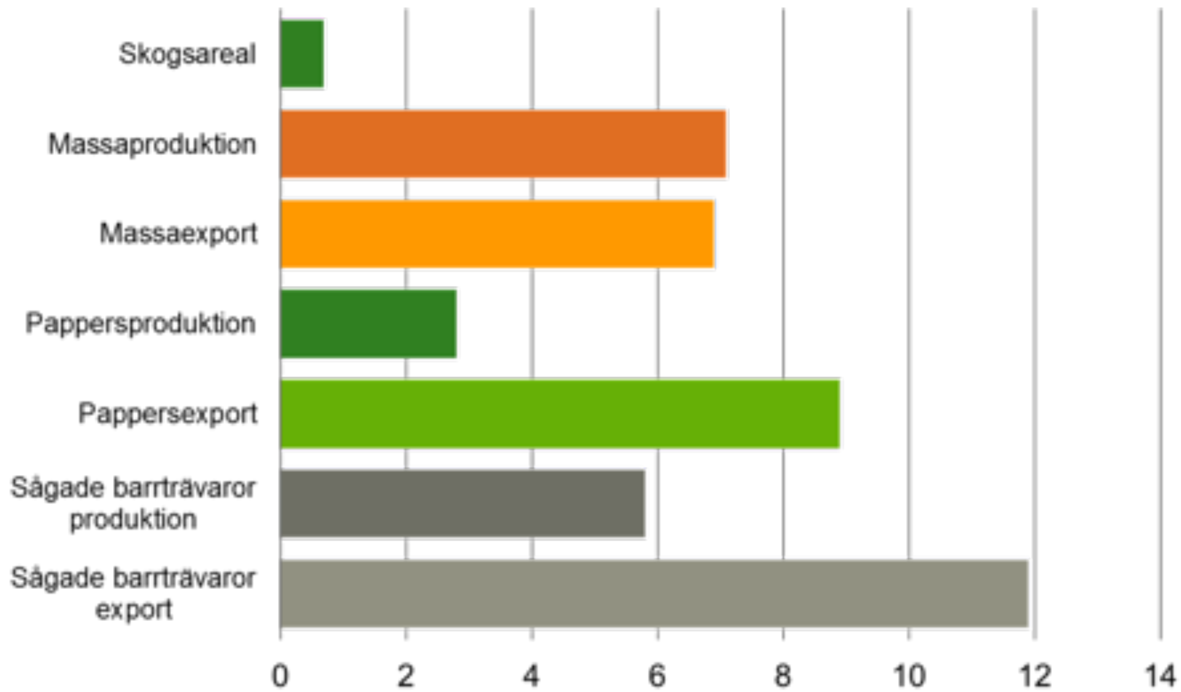
- By 2020: 40% GHG emissions (vs. 1990) & 50% renewable energy
- By 2040: 100% renewable electricity
- By 2045: No net emissions of GHGs - thereafter achieve negative emissions.

Where is the renewable energy?



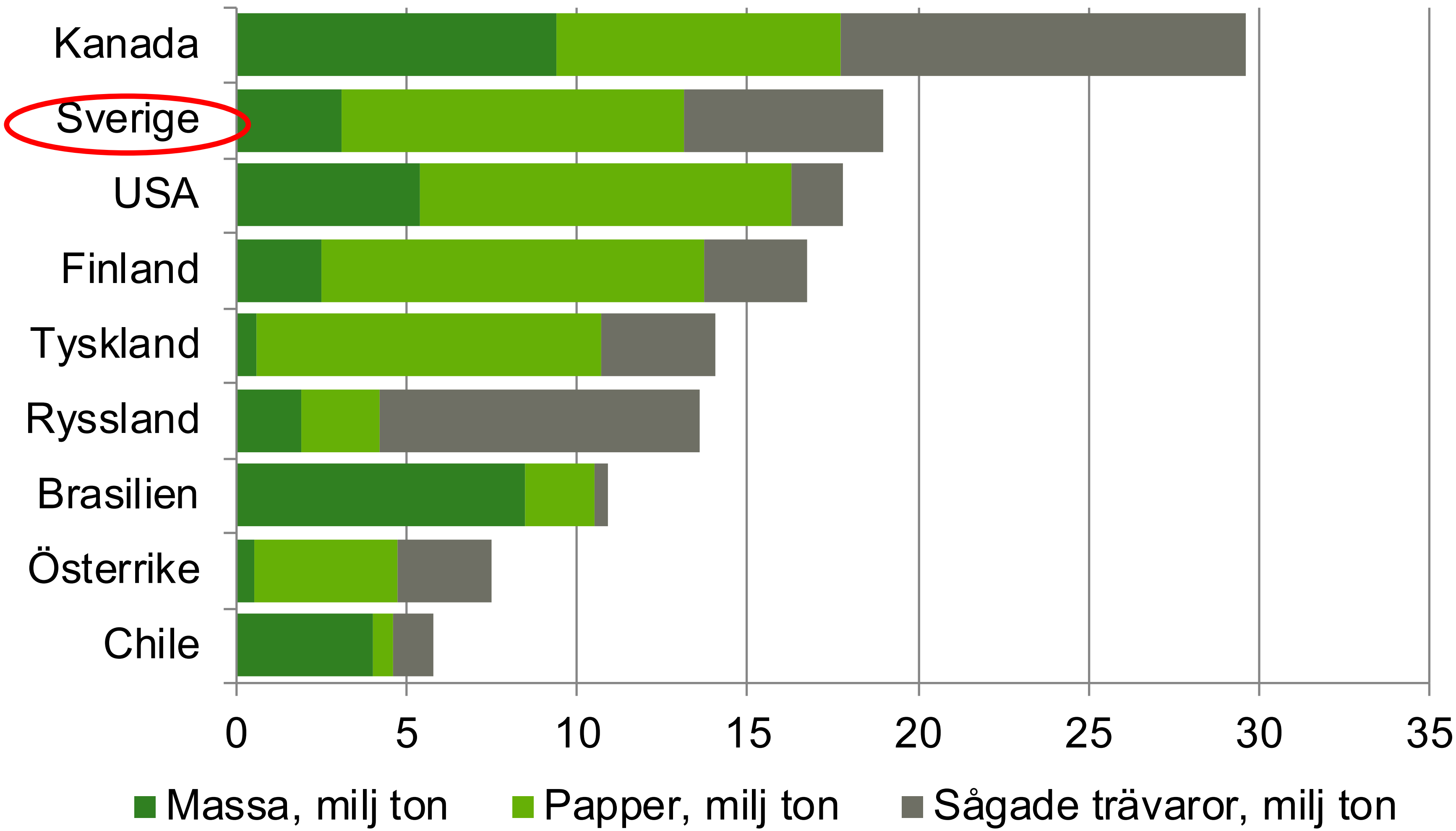
(Stats Sweden)

Sweden’s share of the world’s forests



(Skogsindustrierna, CEPI, PPI, FAO, Nationella Föreningar)

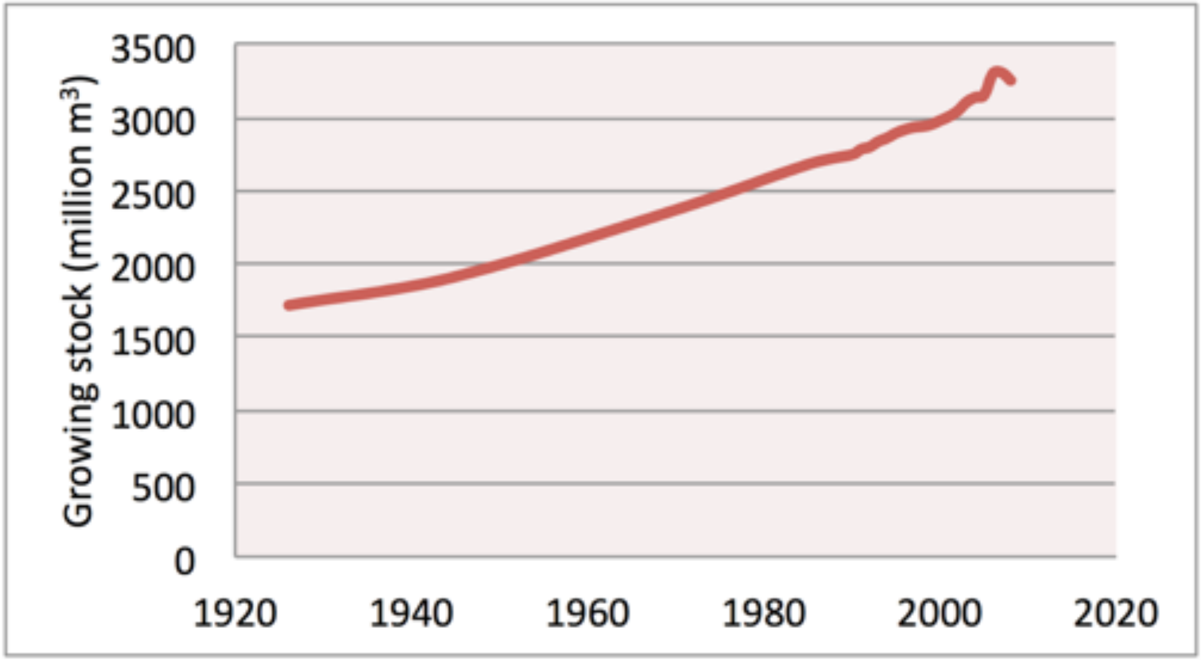
Världens ledande exportörer
av massa, papper och sågade trävaror 2011



Källa: Skogsindustrierna, CEPI, PPI, FAO, Nationella Föreningar

Skogs Industrierna

Can the forest stock deliver even further?



(Gustav Egnell, SLU)

Demand for biomass from forests

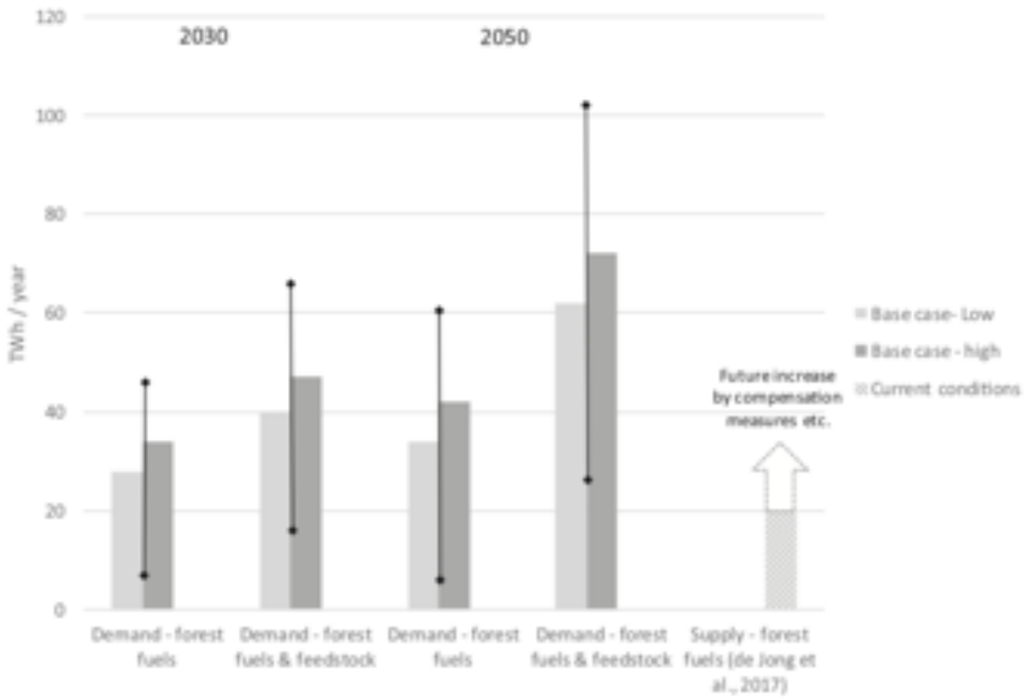


Fig. 2. Summary of potential increased demand of forest fuels for energy purposes in Sweden, and as feedstock in the chemical and petrochemical industry replacing fossil feedstock, in 2030 and 2050, respectively, and in comparison with potential sustainable increased supply of forest fuels based on current conditions, according to de Jong et al. (2017). The uncertainty intervals indicate the differences in forest fuel demand due to the magnitude energy efficiency improvement and electrification in the various sectors (see also Table 1). Potential additional increase in future sustainable supply of forest fuels by implementing various compensation measures in forestry is also indicated.

(Börjesson et al., 2017)

Balancing other ecosystem services

Assortment	Harvesting scenario				Forest production Objective		Environmental Quality Objectives									
	Proportion (%) of fellings in the landscape in which additional biomass is harvested		Harvested proportion (%) of total available residues in the landscape		Final cutting only	Final cutting and thinning	"Sustainable Forests""A Rich Diversity of Plant and Animal Life"	"A Non-Toxic Environment"	"Zero Eutrophication"			"Natural Acidification Only"				
									Soil-water		Surface-water	Soil, stand-level		Soil-water, stand-level	Surface water	
	Slash	Stump	Slash	stump					Short-term	Long-term		Short-term	Long-term		Headwater streams, shallow soils + NaCl	Larger water bodies
Slash and stump	80	30	56	21	↘	↘	↘	→	→	→	→	↘	↘	↘	↘	→
	60	30	42	21	→	↘	↘	→	→	→	→	↘	↘	↘	↘	→
	40	30	28	21	→	↘	↘	→	→	→	→	→	→	→	→	→
	80	20	56	14	↘	↘	↘	→	→	→	→	↘	↘	↘	↘	→
	60	20	42	14	→	↘	→	→	→	→	→	↘	↘	↘	↘	→
	40	20	28	14	→	↘	→	→	→	→	→	→	→	→	→	→
	80	10	56	7	→	↘	↘	→	→	→	→	↘	↘	↘	↘	→
	60	10	42	7	→	↘	→	→	→	→	→	↘	↘	↘	↘	→
	40	10	28	7	→	↘	→	→	→	→	→	→	→	→	→	→
Slash only	80	0	56	0	↘	↘	↘	→	↗	→	→	↘	↘	↘	↘	→
	60	0	42	0	→	↘	→	→	↗	→	→	↘	↘	↘	↘	→
	40	0	28	0	→	↘	→	→	↗	→	→	→	→	→	→	→

(de Jong et al., 2017)

”Ground” to sustain forest growth?

(Freeman et al., 2005)

Foreseeing feedback effects

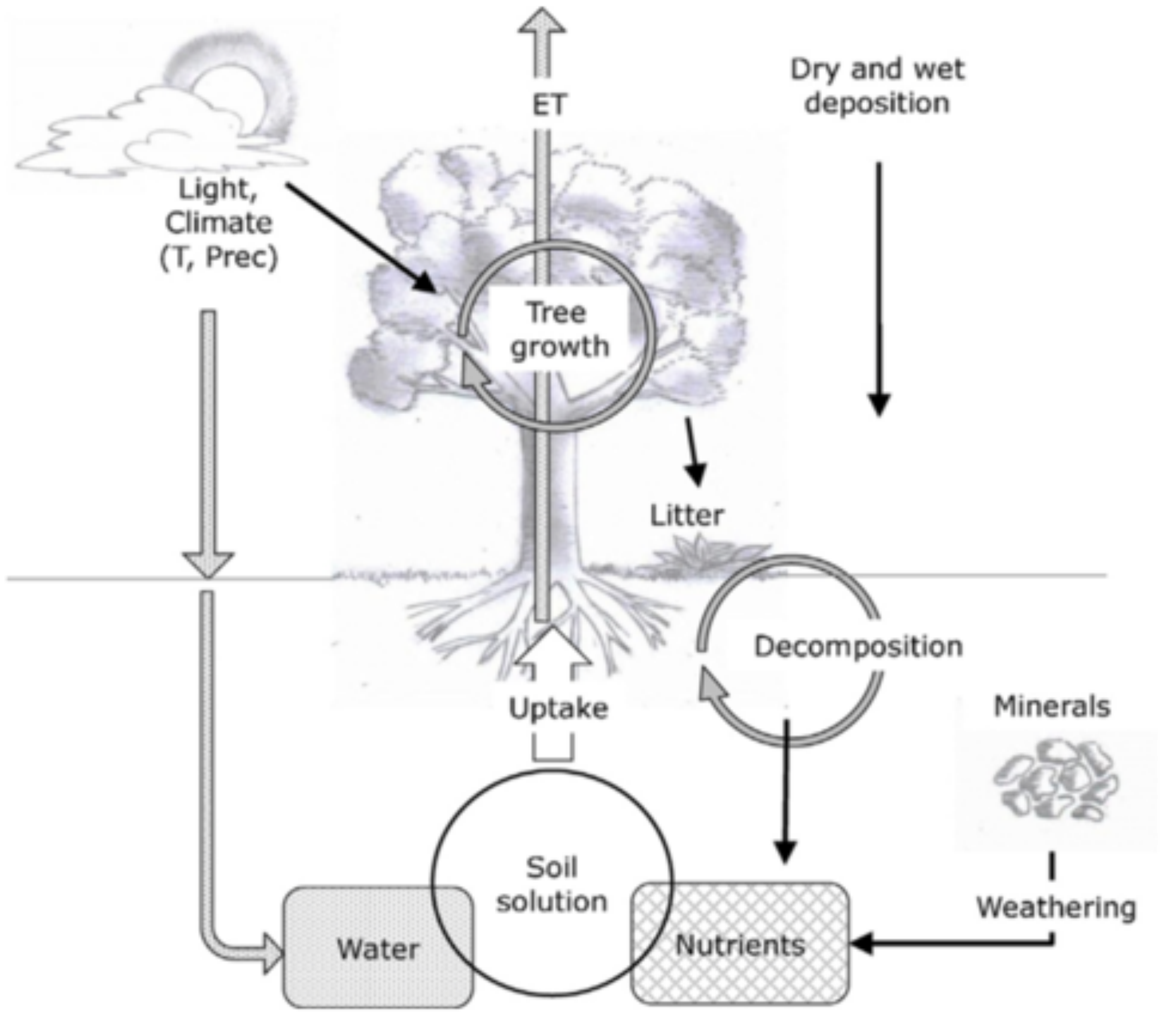
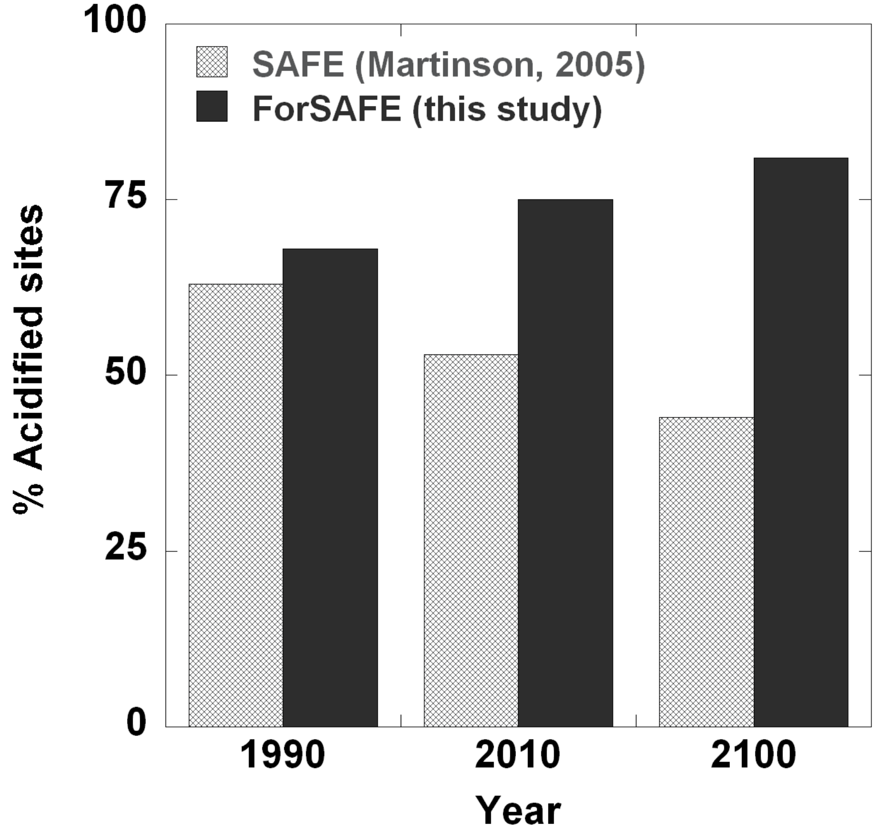


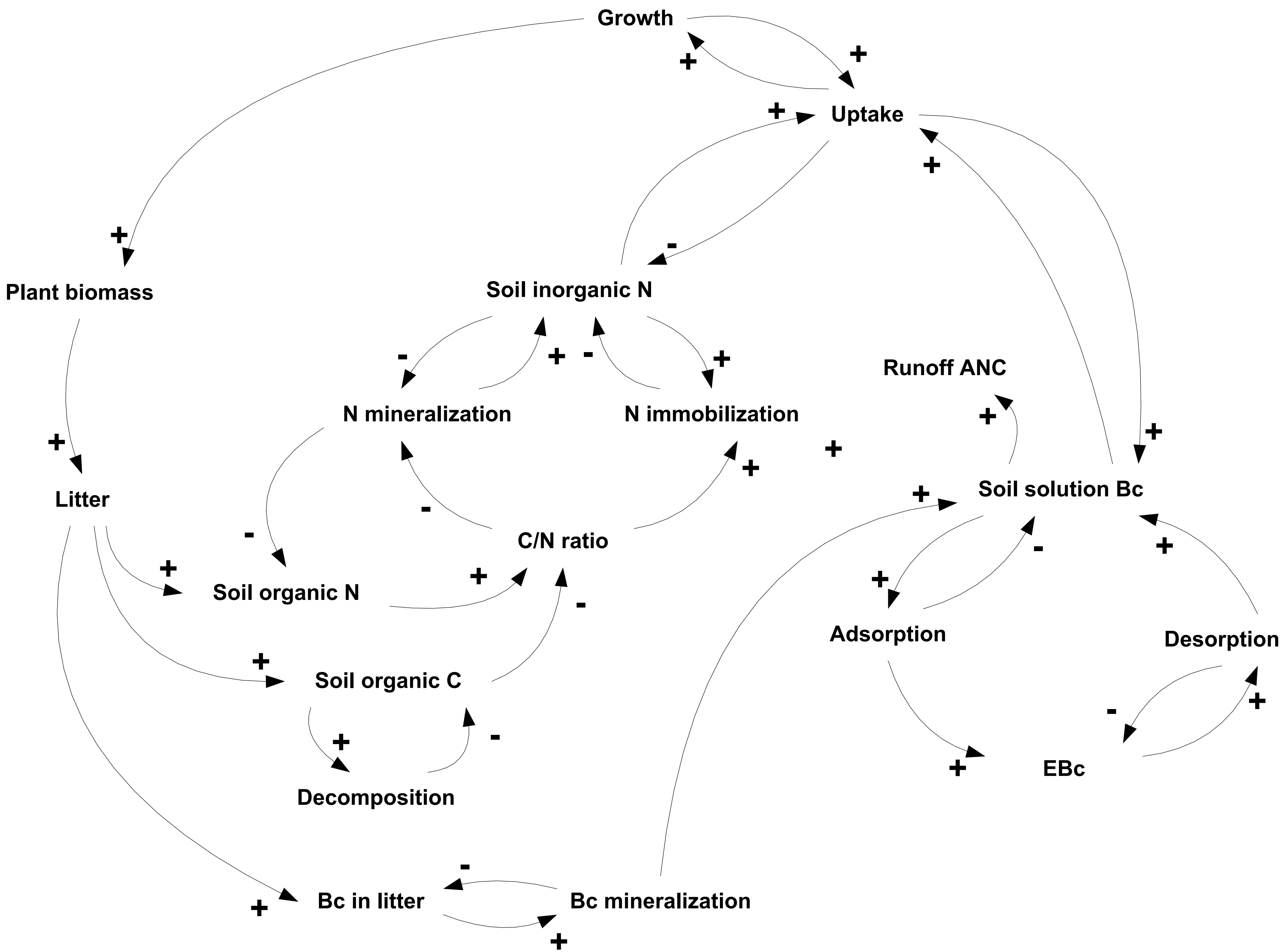
Fig. 1. The ForSAFE model. Climate input parameters (temperature and radiation) drive the potential vegetation growth. Nutrient and water availability constrain the potential growth to actual biomass growth and accumulation.

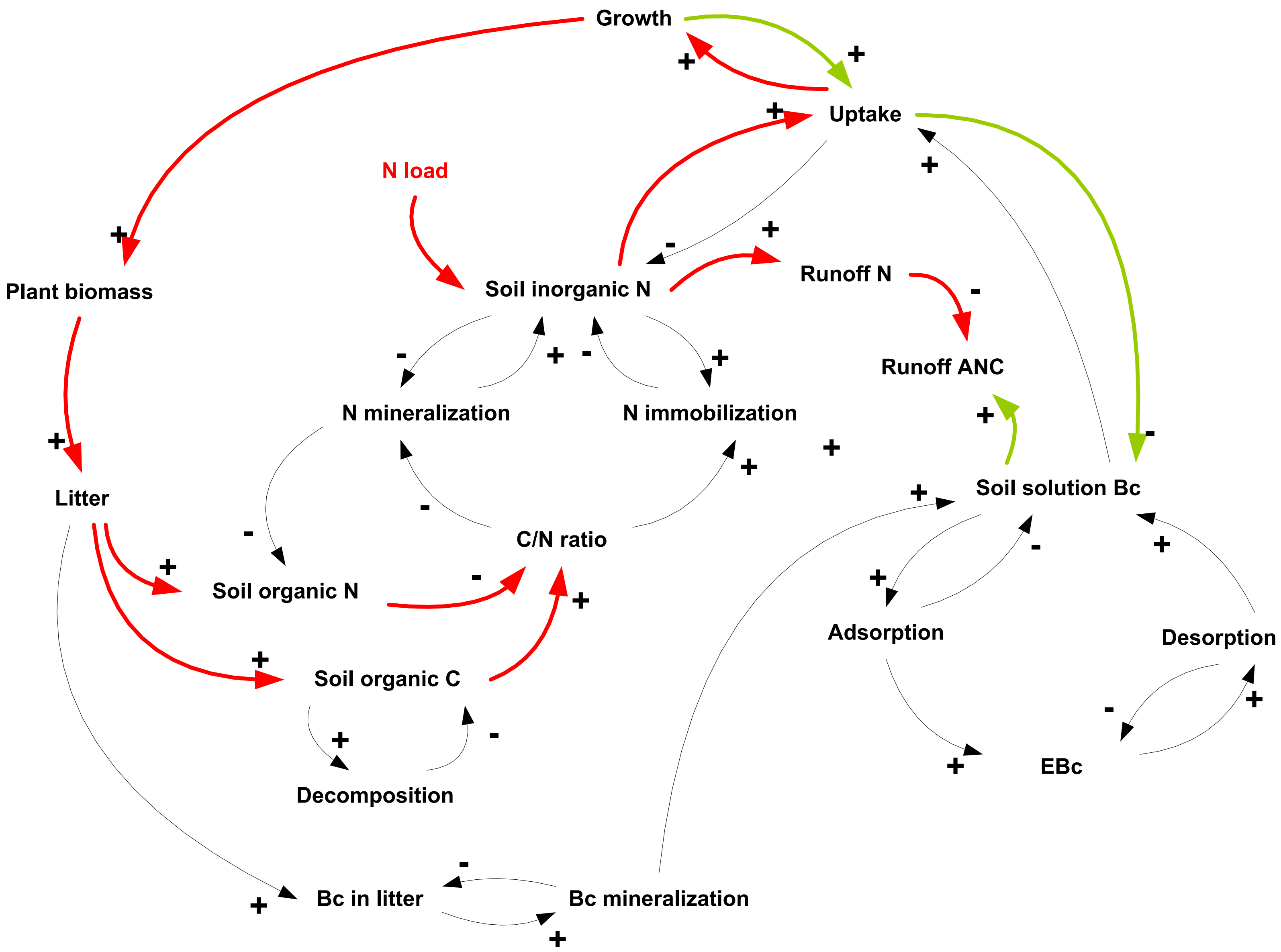
(Zanchi et al., 2014)

Acidification & nutrient imbalances



(Belyazid et al., 2006)


Growth
Uptake
Plant biomass
Soil inorganic N
N mineralization
N immobilization
Runoff ANC
Litter
Soil solution Bc
C/N ratio
Soil organic N
Adsorption
Desorption
Soil organic C
Decomposition
EBc
Bc in litter
Bc mineralization



Growth
Uptake
N load
Plant biomass
Soil inorganic N
Runoff N
Runoff ANC
N mineralization
N immobilization
Litter
Soil solution Bc
C/N ratio
Soil organic N
Adsorption
Desorption
Soil organic C
EBc
Decomposition
Bc in litter
Bc mineralization

Empirical evidence of "biological acidification"

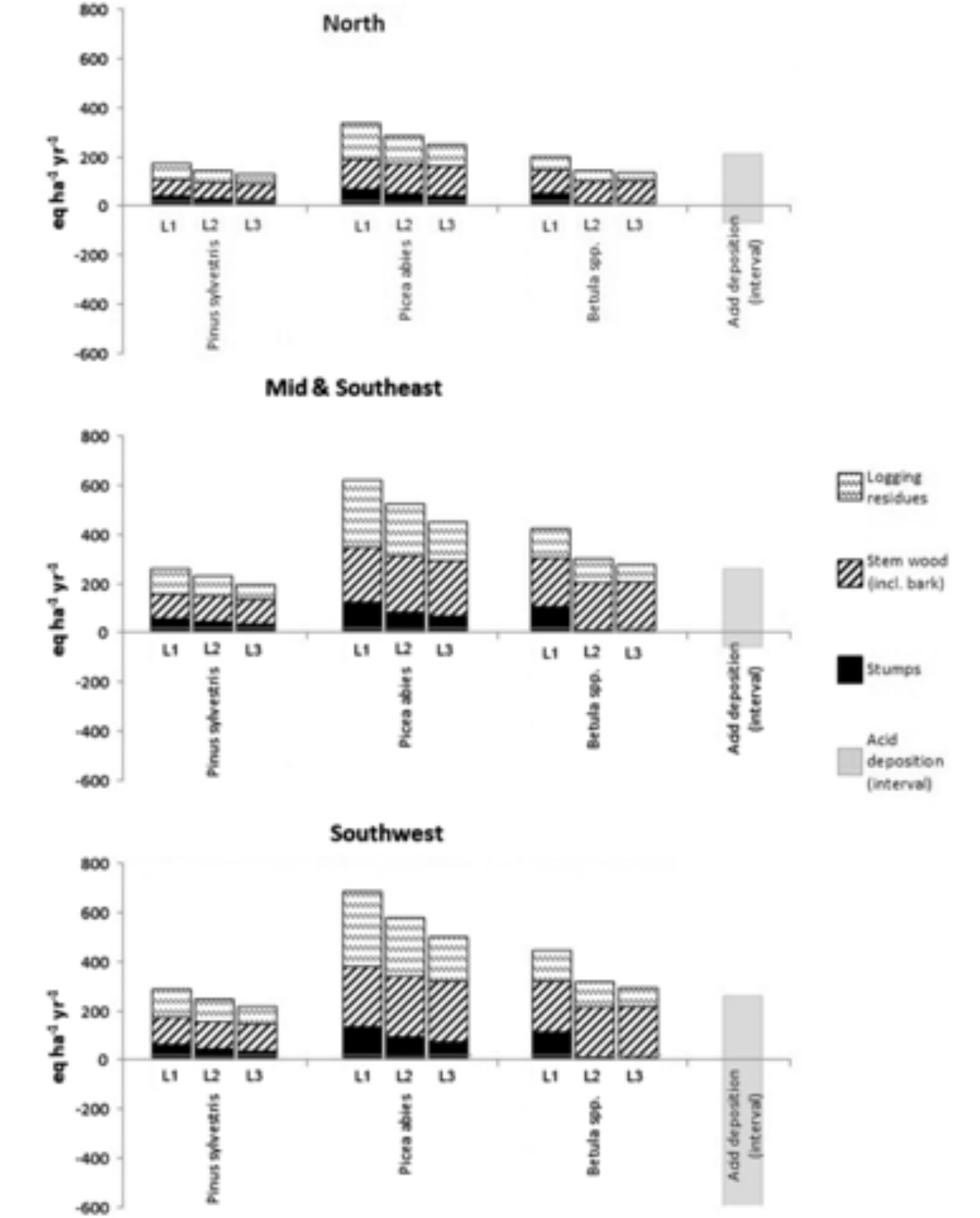


Fig. 2. Estimated net cation extraction by harvesting of tree parts in three regions of Sweden during 2010–2019. L1, L2 and L3 indicate levels 1, 2 and 3, respectively. For birch, no stumps are harvested in levels L2 and L3. For comparison, acid deposition (negative ANC range during the period 1996–2009 – see Section 2.2) is presented.

(Iwald et al., 2013)

Nutritional imbalances

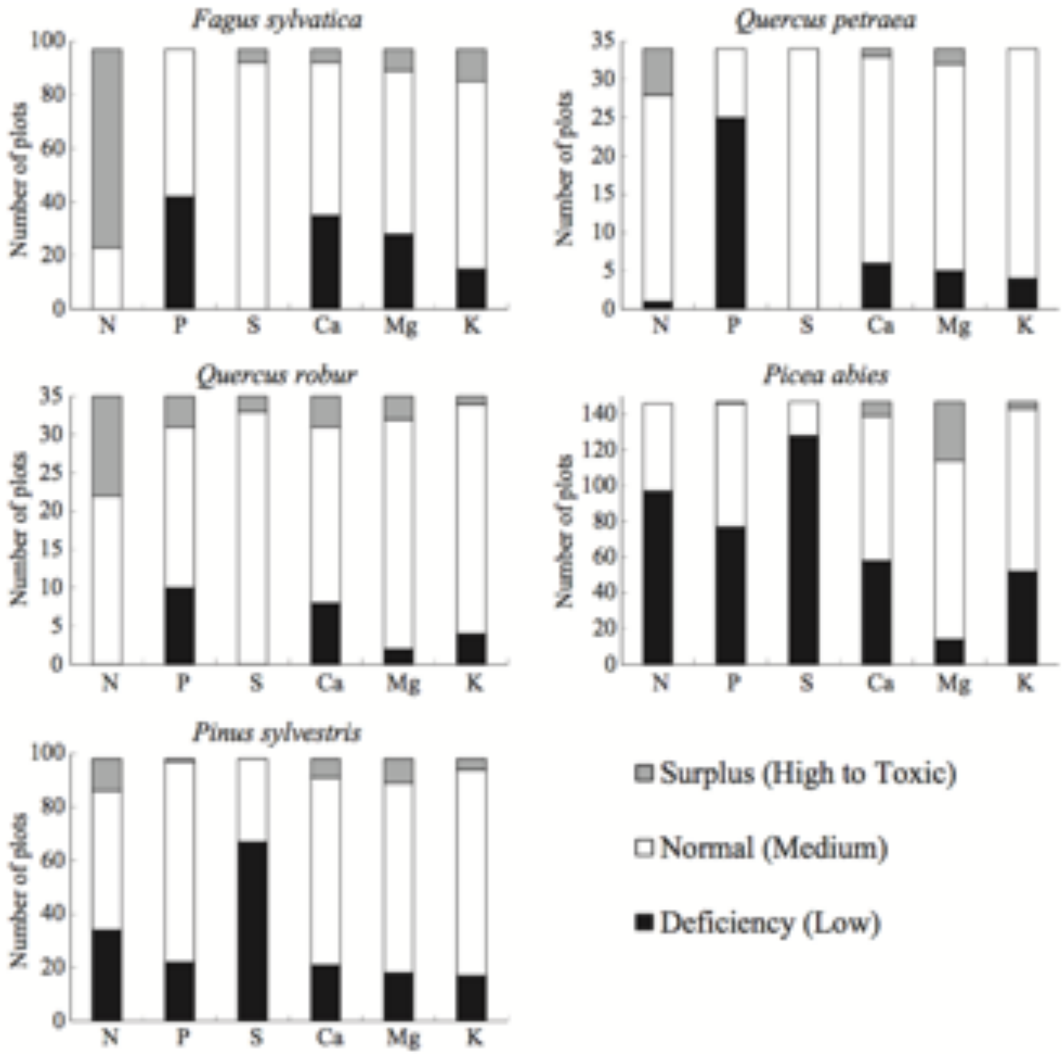
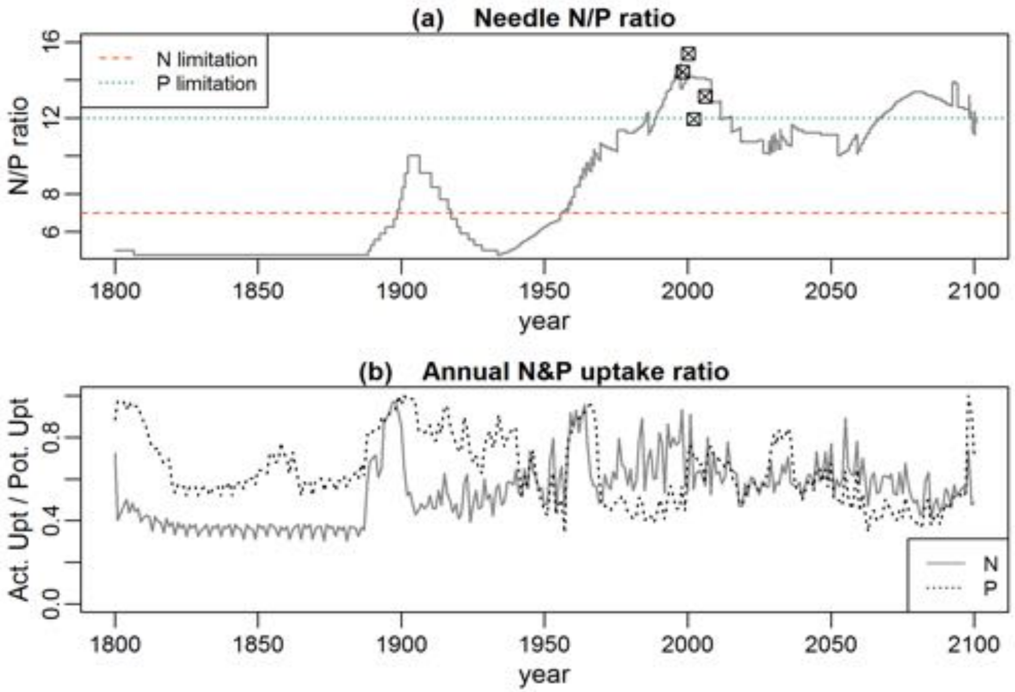
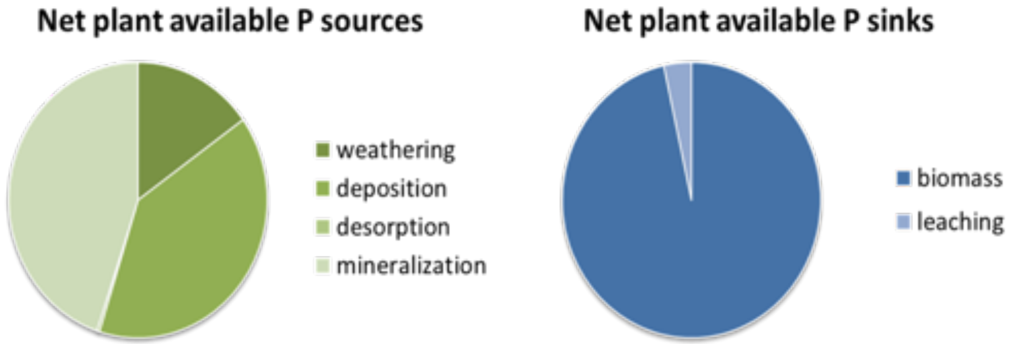


Fig. 4 Number of plots in the three foliar nutrient status classes. Each bar presents the number of plots in which the mean foliar concentration of the current-year leaves or needles falls within the thresholds set by Mellert & Göttlein (2012) for N, P, Ca, Mg and K and by Stefan *et al.* (1997) for S (in parenthesis).

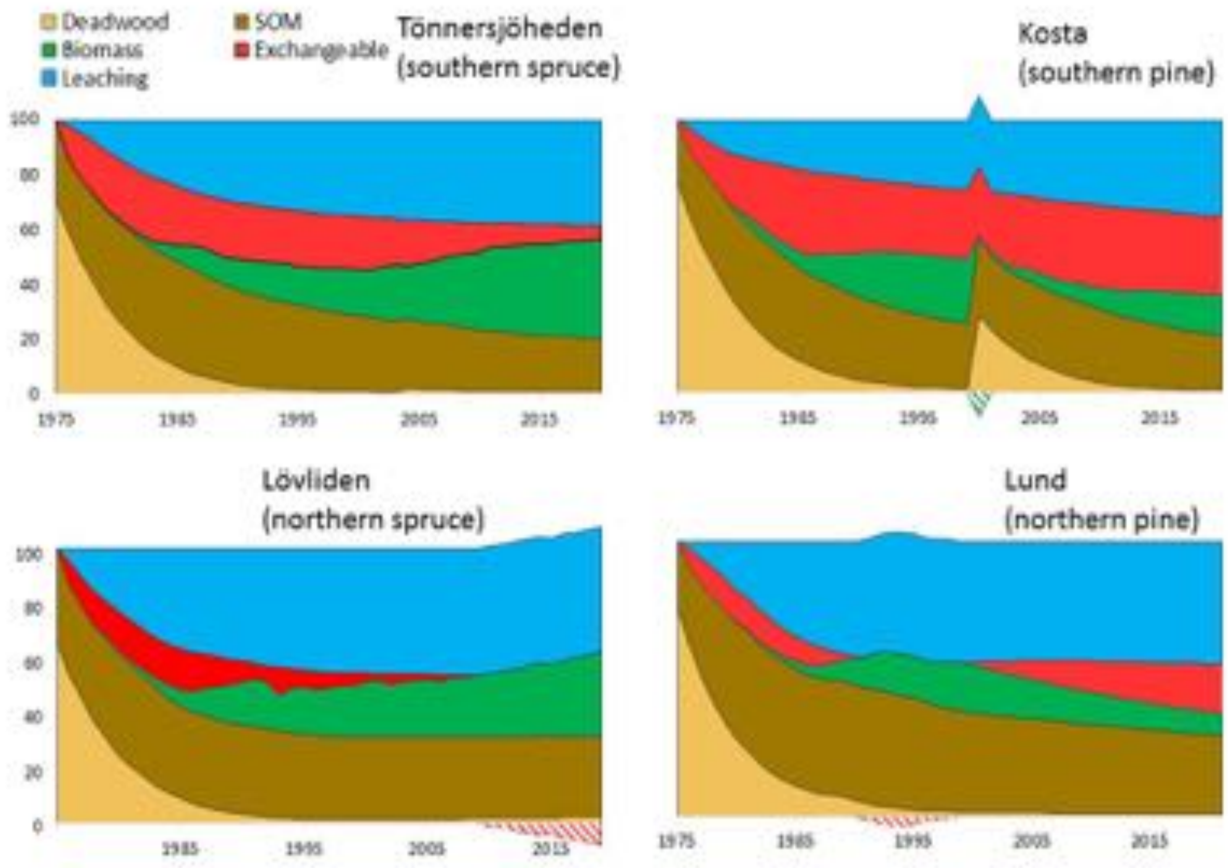
(Jonard et al., 2014)


(a) Needle N/P ratio
N limitation
P limitation
N/P ratio
16
12
8
6
1800
1850
1900
1950
2000
2050
2100
year
(b) Annual N&P uptake ratio
Act. Upt / Pot. Upt
0.0
0.4
0.8
N
P
1800
1850
1900
1950
2000
2050
2100
year


Net plant available P sources
weathering
deposition
desorption
mineralization
Net plant available P sinks
biomass
leaching

(Yu et al., 2017)

Mapping nutrient budgets with ForSAFE



(Erlandsson et al., 2019)

Upscaling

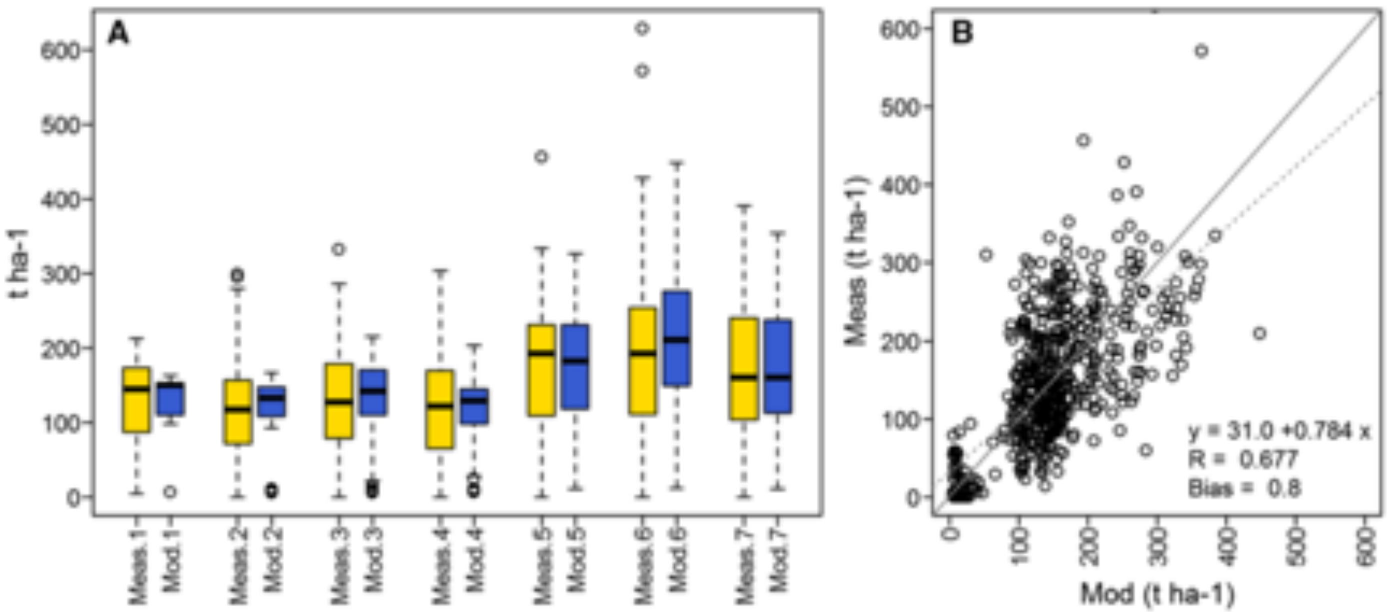


Fig. 3 Modelled tree biomass as compared to the estimated one based on SNFI data. **a** Comparison at the regional level (Meas: estimated tree biomass based on SNFI data; Mod: modelled tree biomass; 1–7: climate regions from northern to southern Sweden). **b** One-to-one comparison between measure-based (Meas) and modelled tree biomass (Mod)

Upscaling

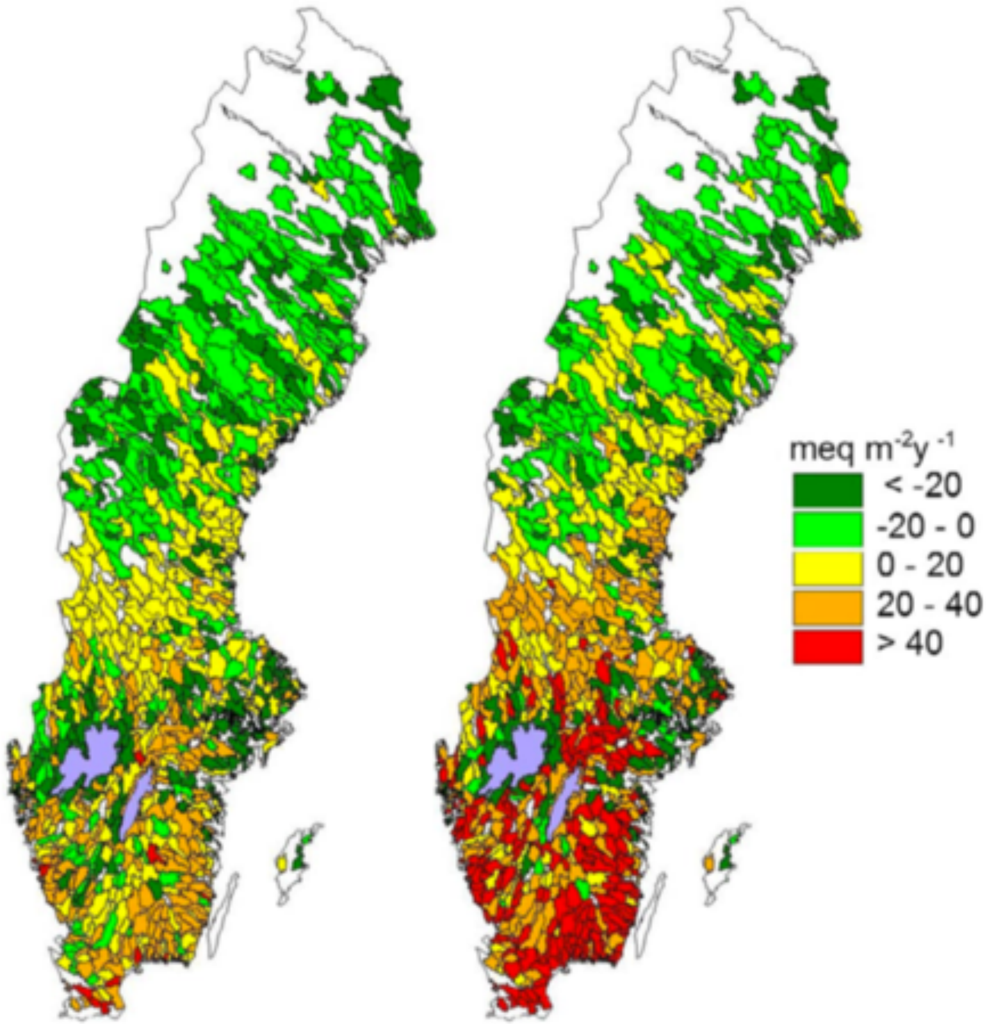


Fig. 3. Exceedance of critical harvesting in spruce forest at stem harvesting (a) and whole-tree harvesting (b).

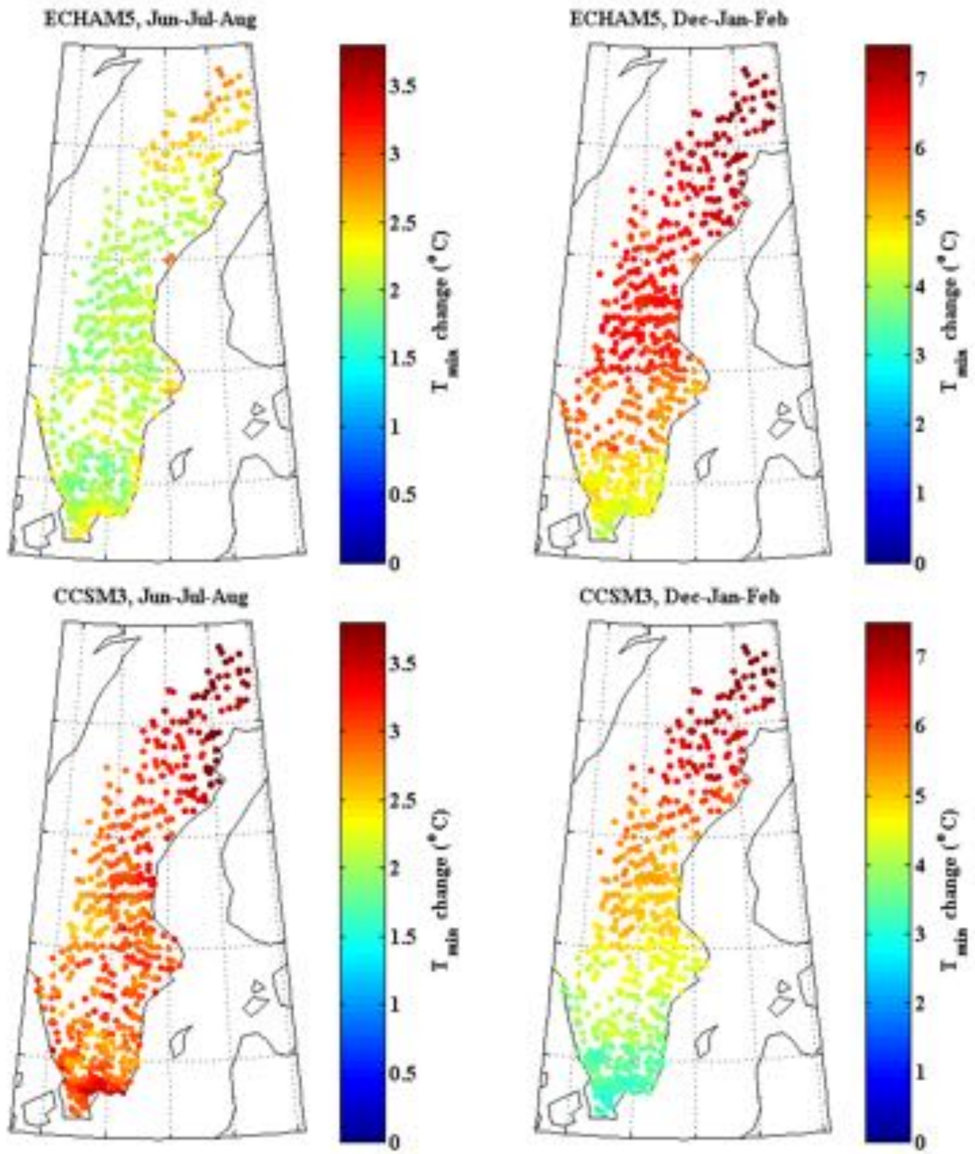
Can climate change help redress the imbalance?

$k=A*exp^{(-Ea/R*T)}$

(Arrhenius, 1903)

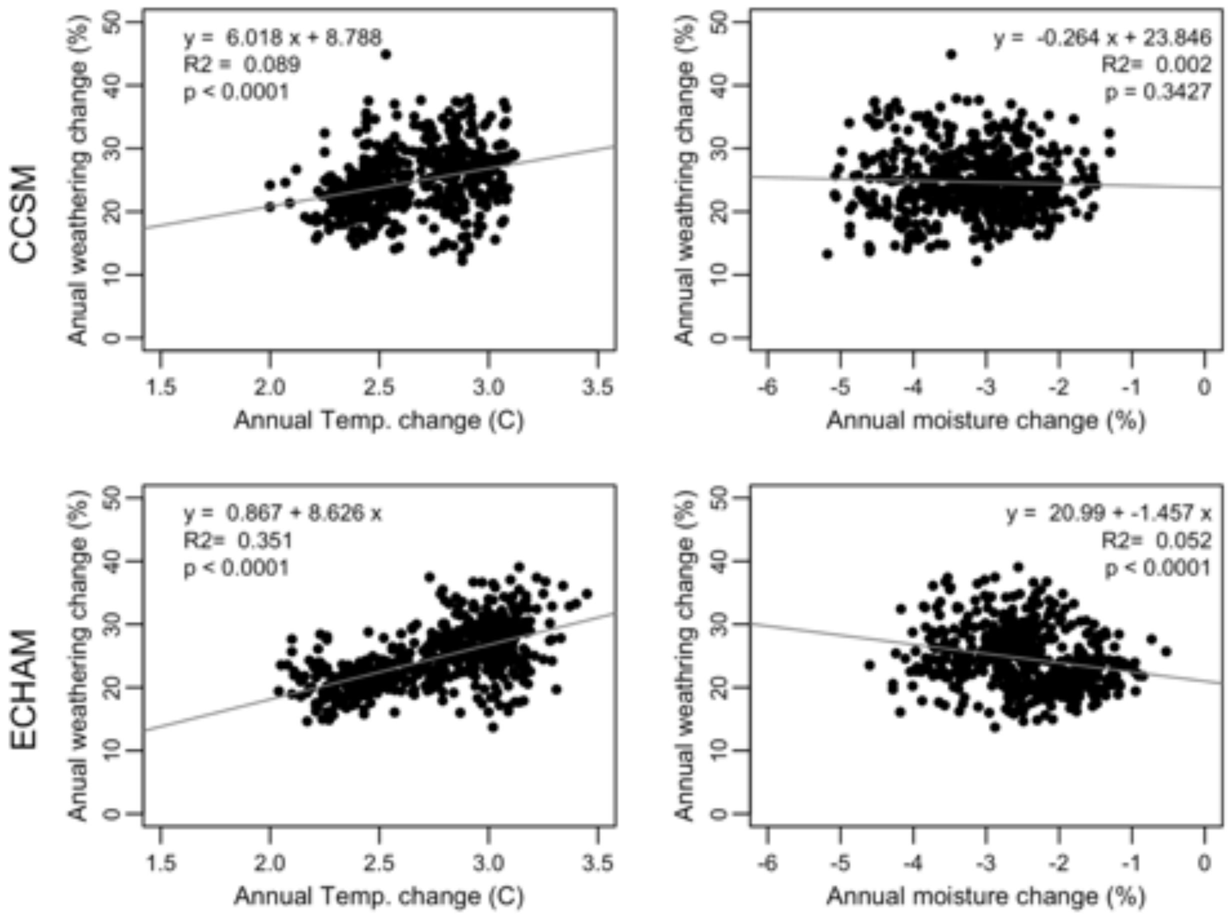
2-4C -> 20-40% faster Biogeochemical processes

2-3 weeks longer growth periods



(Ryner, pers. comm.)

Weaker increase in mineral weathering than expected



(Belyazid et al., in review)

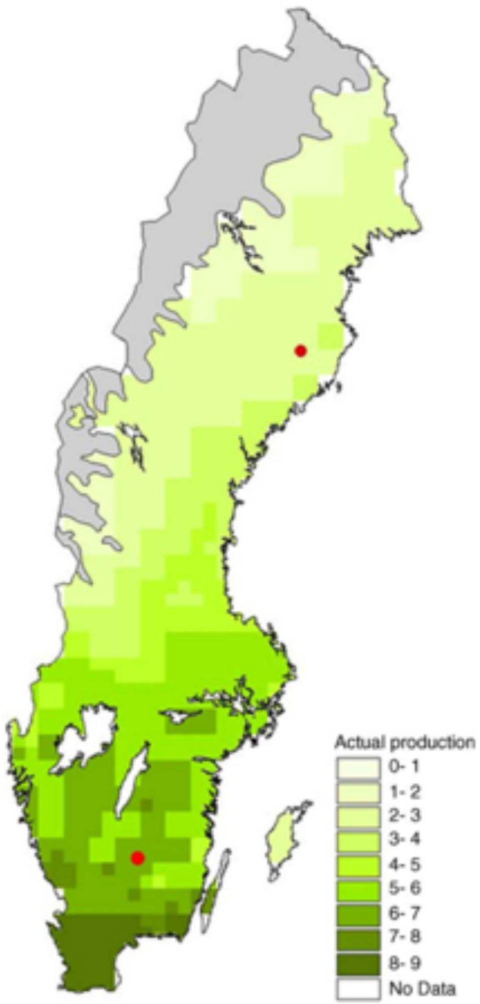
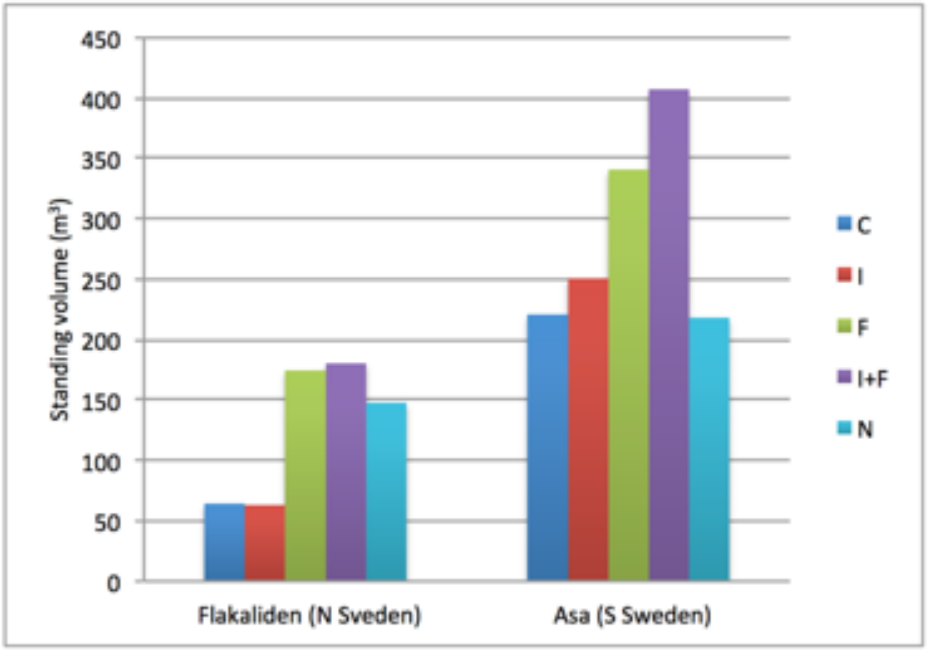


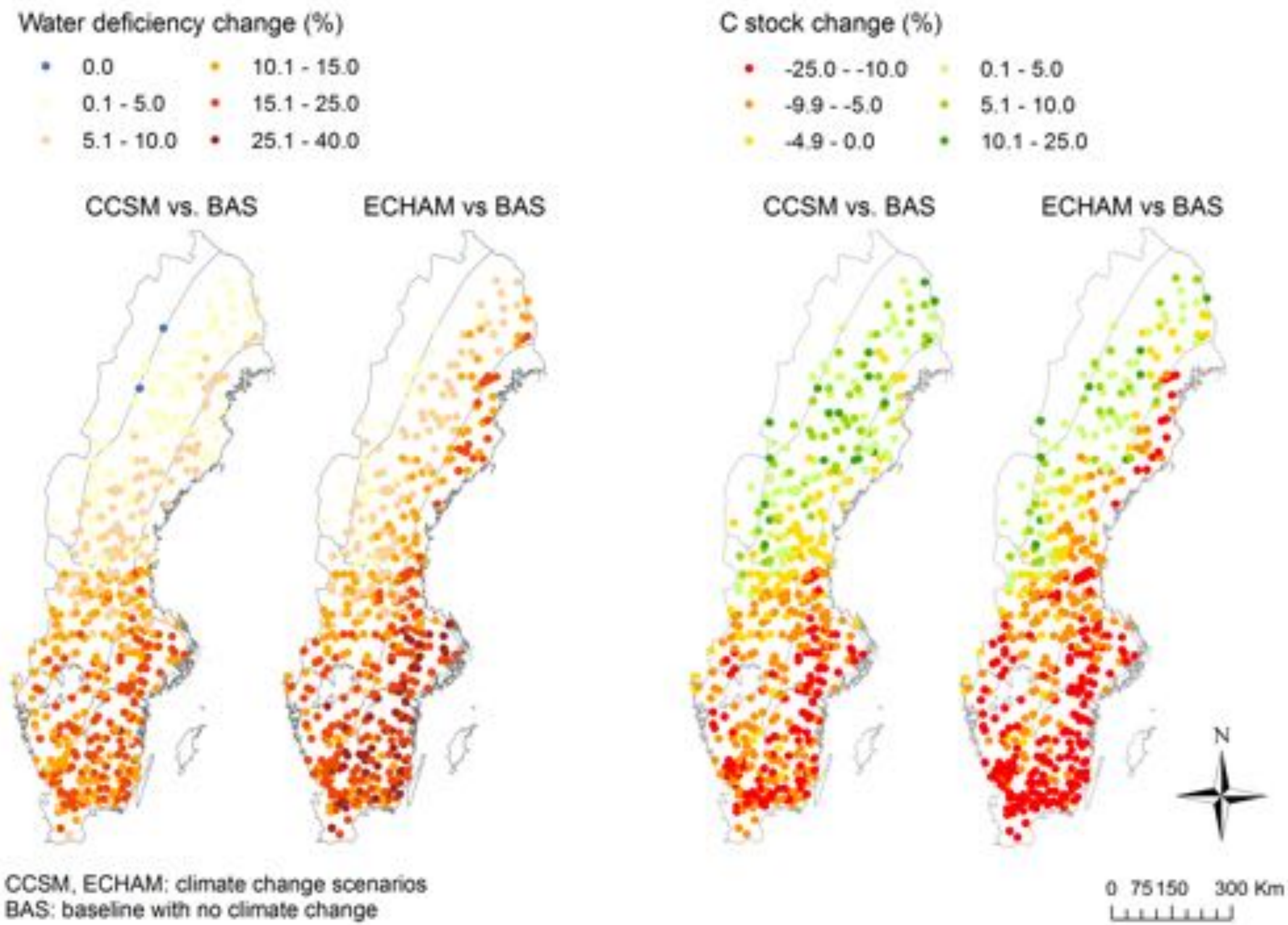
Fig. 1. Actual production of stem volume in $m^3\ ha^{-1}\ a^{-1}$ for different regions in Sweden. The values are the mean annual increment (MAI) for a rotation period. Red circles show the location of Asa in southern Sweden and Flakaliden in northern Sweden.



(Pers. Comm. Gustav Egnell, SLU)

(Bergh et al, 2005)

Combined higher temperatures and lower summer precipitation



(Belyazid and Zanchi, 2019)

Integrated assessment of multiple services

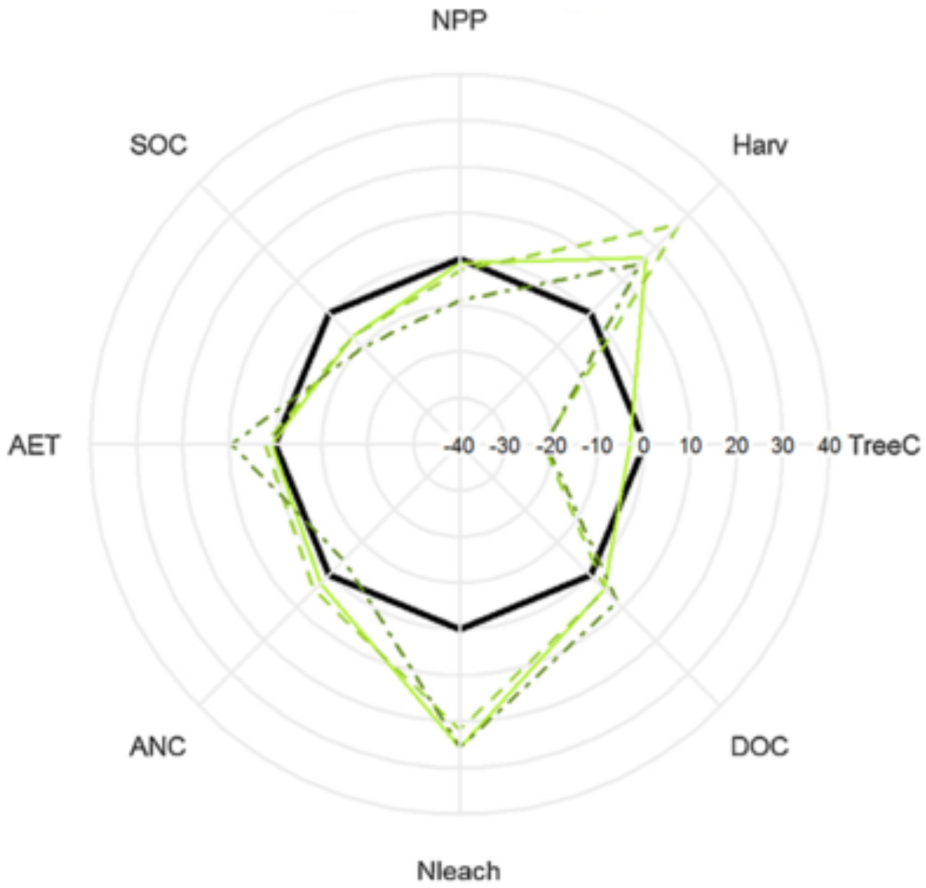


Fig. 8. The grey lines represent the relative change of the indicators, ΔI (%), in the INT scenarios compared to the BAS scenario at the end of the rotation period (option B). Solid green line: INT1 (only residues); green dashed line: INT2 (residues and additional thinnings); dark green dot-dash line: INT3 (residues and shorter rotation). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

(Zanchi et al., 2014)

Driver precedence: Exchangeable base cations

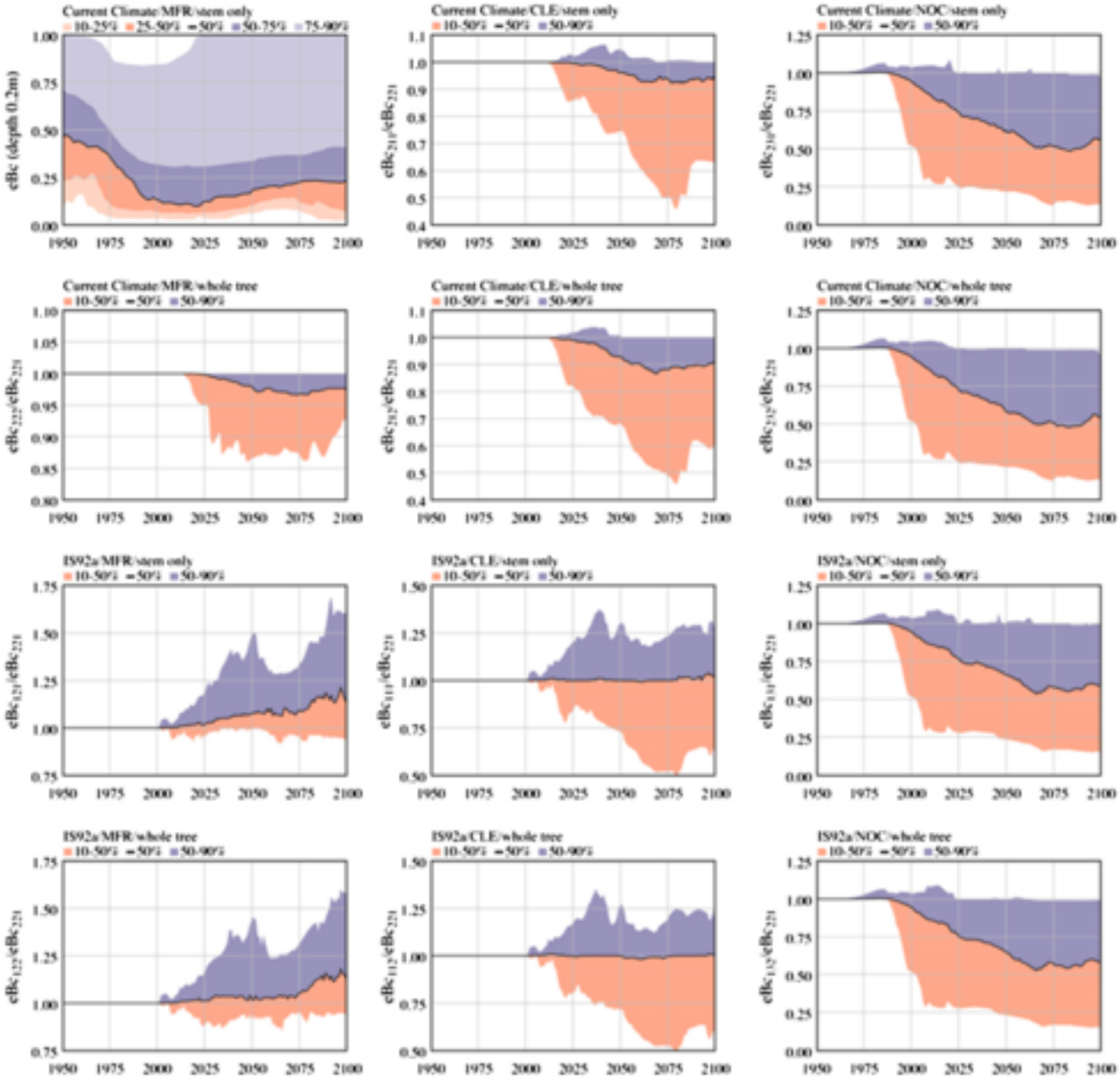


Fig. 9. Medians and ranges of responses of soil base saturation (BS) at 48 sites to climate, deposition and harvest intensity.

Driver precedence:
Nitrogen leaching

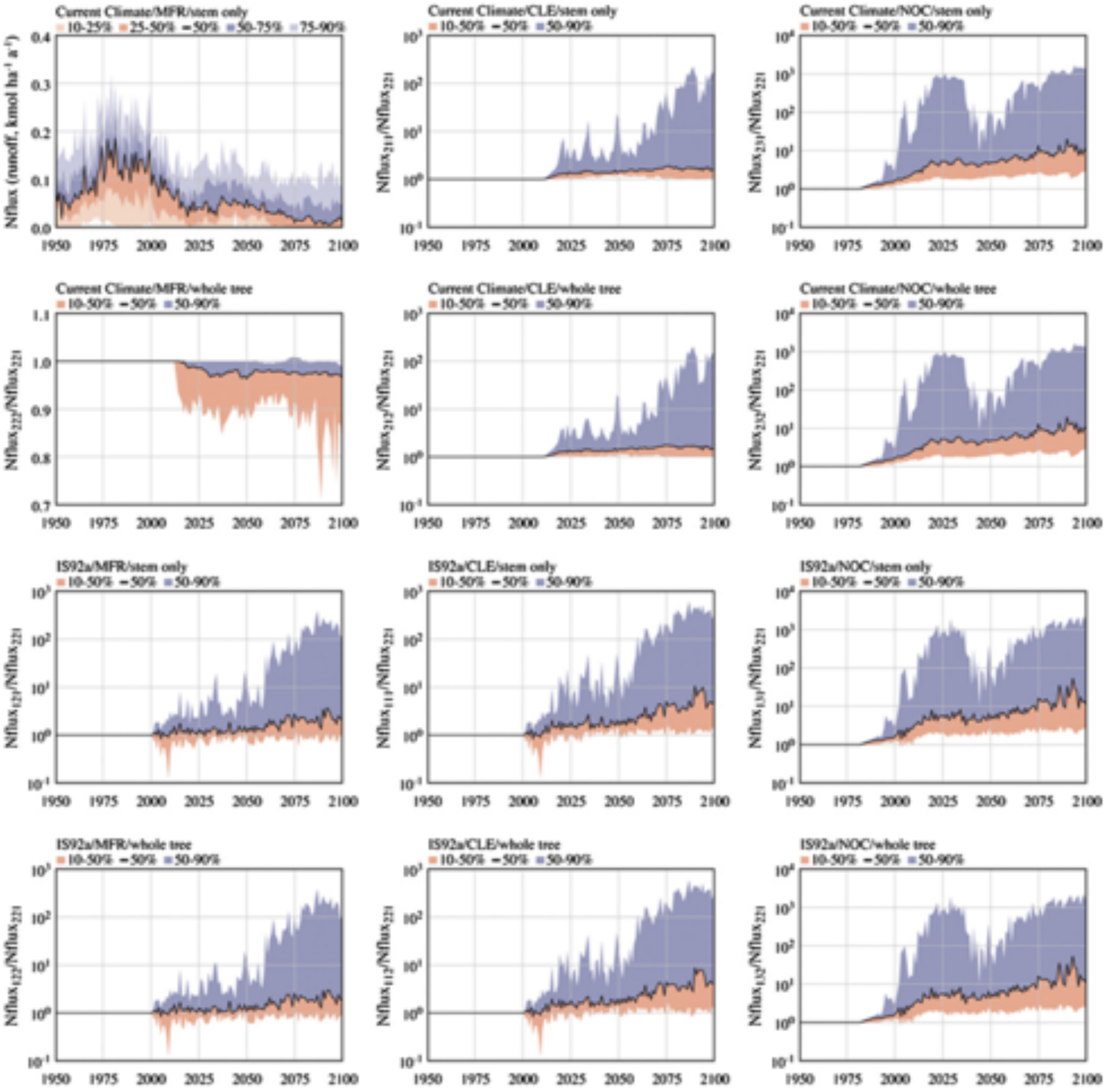


Fig. 10. Median changes in nitrogen leaching fluxes, and the relative deviations from the base scenario: current climate–MFR–stem-only harvest.

Driver precedence: Ground vegetation

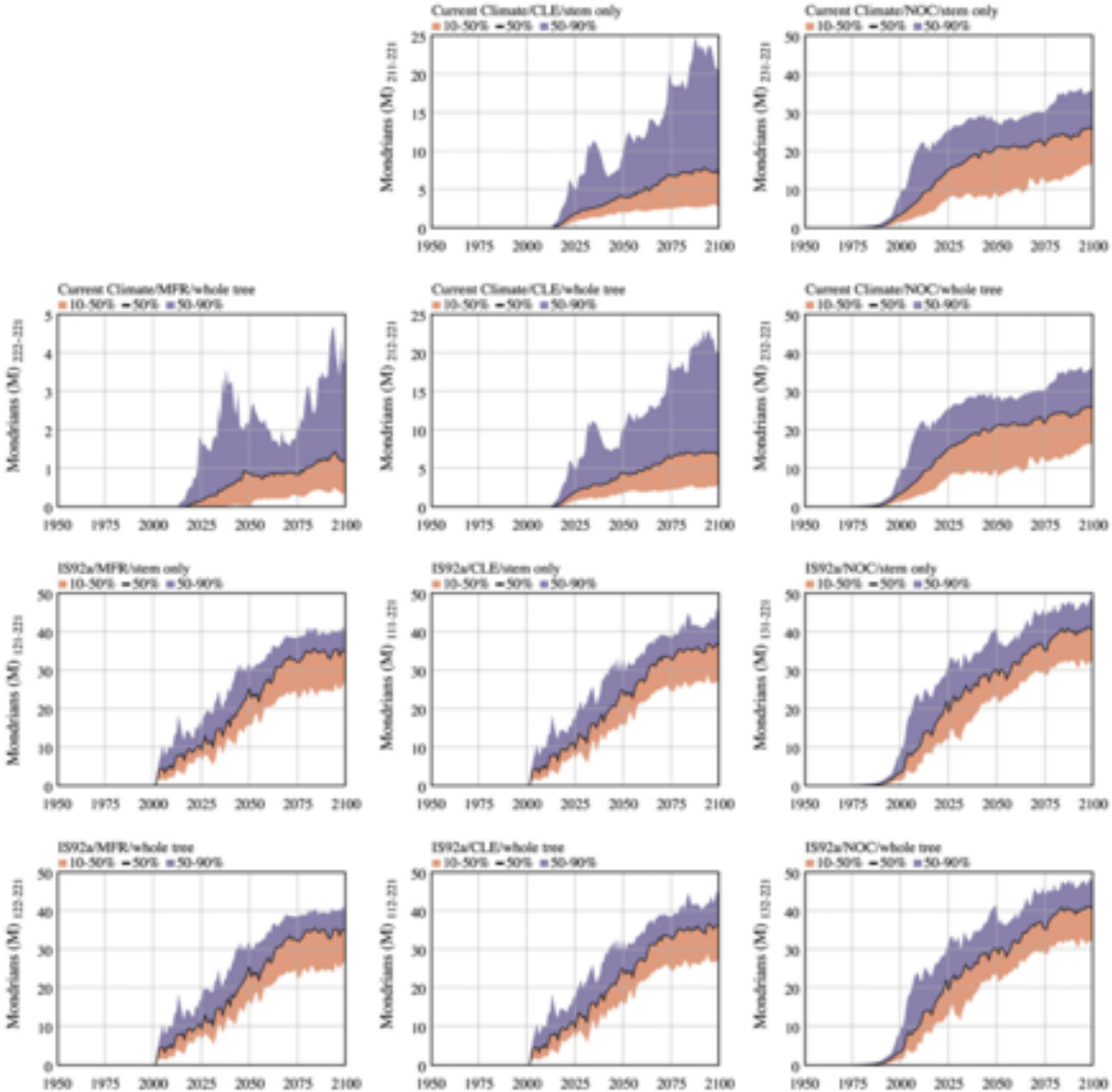
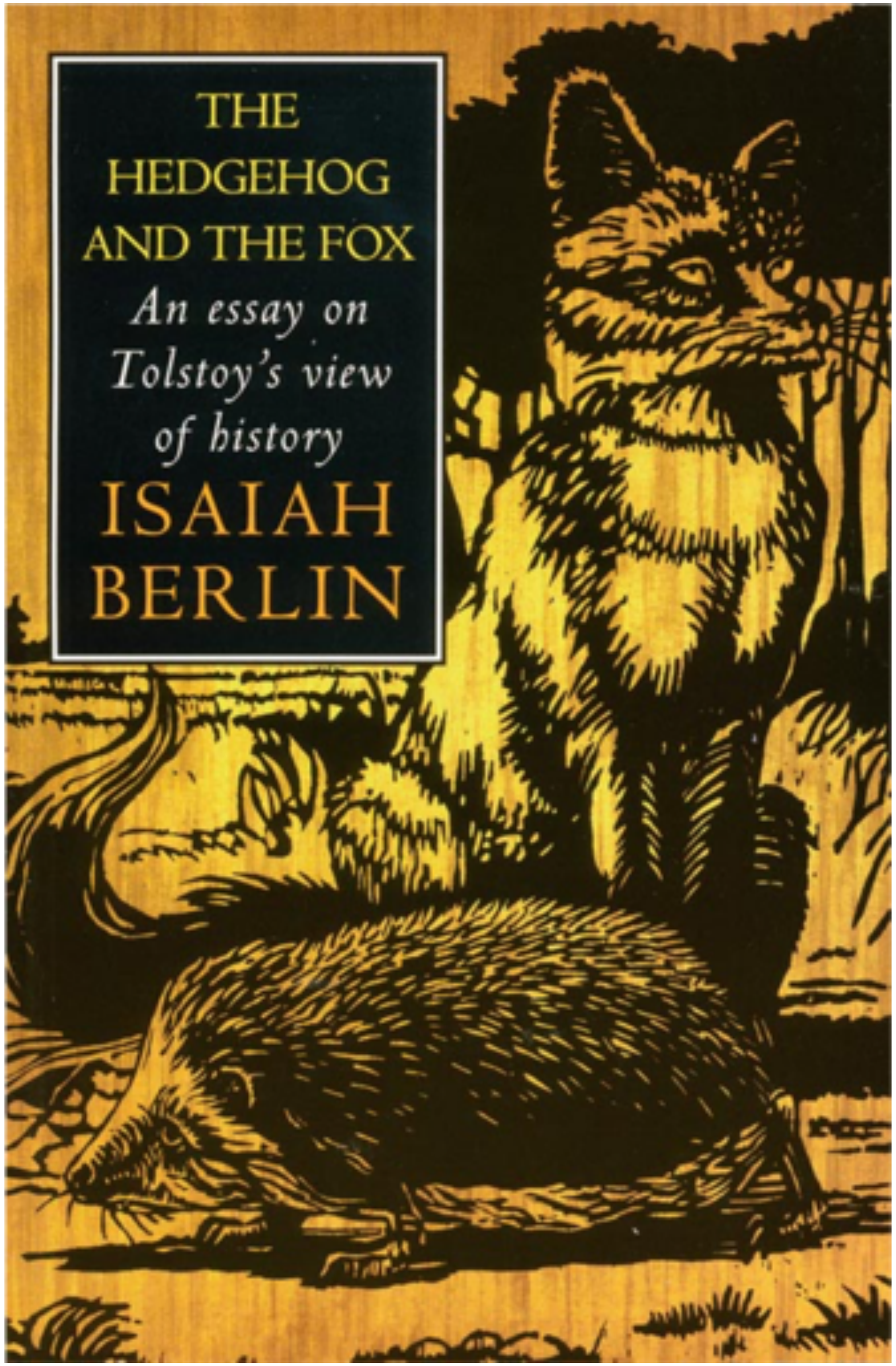
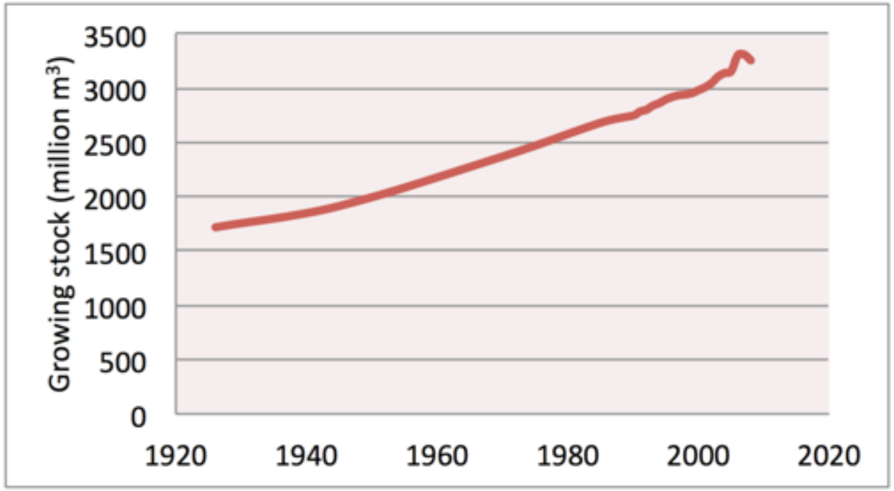


Fig. 12. Medians and 10–90 percentiles of differences in area cover (*M*) of ground vegetation communities due to different climate, deposition and harvest intensity scenarios, compared with the reference scenario.


THE
HEDGEHOG
AND THE FOX
An essay on
Tolstoy's view
of history
ISAIAH
BERLIN


Growing stock (million m³)
3500
3000
2500
2000
1500
1000
500
0
1920
1940
1960
1980
2000
2020