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Spatial variability of the net ecosystem production and its component fluxes across a managed boreal forest landscape in Sweden: A biometric and chamber data-based analysis

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SITES Swedish Infrastructure for Ecosystem Science

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Chat time: Friday, 8 May 2020, 08:30–10:15 h

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1. Background

A managed boreal forest landscape is a diverse successional mosaic of clear-cuts to old-growth stands of different species growing on a variety of soil types (*Chi et al., 2020*).

This high spatial heterogeneity strongly impacts the forest net ecosystem productivity (NEP) across the managed landscape (*Goulden et al., 2011*).

Our understanding of patterns of boreal forest NEP and its component fluxes remains limited in three broad aspects: tree species, forest age and forest-floor C fluxes.

1. Background

1. Tree species

• Boreal forests have been reported as ecosystems with high C sink capacity (*Liski et al. 2003*).

• However, the differences regarding the ecosystem C balance between forest stands dominated by the two main tree species of the Swedish forest landscape (i.e., Scots pine and Norway spruce) are not conclusive.

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1. Background

2. Forest age

- Recognized effects of forest ageing in controlling spatial variability of NEP and its component fluxes (*Besnard et al.*, *2018*; *Coursolle et al.*, *2012*; *Curtis and Gough*, *2018*; *Drake et al.*, *2011*; *Goulden et al.*, *2011*; *Litvak et al.*, *2003*, *Tang et al.*, *2014*).

- There is still debate about how age modulates annual boreal forest C estimates, being especially important for old-growth forests.

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1. Background

3. Forest-floor C fluxes

• Understory vegetation and soil and their associated forest-floor C fluxes can be significant components of the C balance in these boreal forests (*Kolari et al., 2006*; *Misson et al., 2007*).

• Our knowledge about the below-canopy contribution to stand-level NEP, which influence can be expected to be significantly different among tree species stands and forest age-class structures, remains limited.

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2. Motivation and objectives

Motivation

- We report for the first time 3-year mean estimates of NEP and its component fluxes in 50 forest stands spanning across different successional stages of a managed boreal forest landscape in northern Sweden.
- These estimates were derived from a combination of comprehensive biometric and chamber-based flux data over 2016-2018.

Objectives

Integrate the various annual stand-level C flux components to estimate the forest NEP across the boreal landscape:

1) Quantifying the forest NEP across the boreal catchment.
2) Identifying the age-related patterns and relative contributions of the individual component fluxes to the forest NEP.
3) Assessing the effects of local key drivers (including tree species and stand age) on the variability of the NEP and its component fluxes.

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3. Our approach

Krycklan Catchment Study (KCS, 68 km^2, 64°14′50″N, 19°47′50″E)

KCS cover:

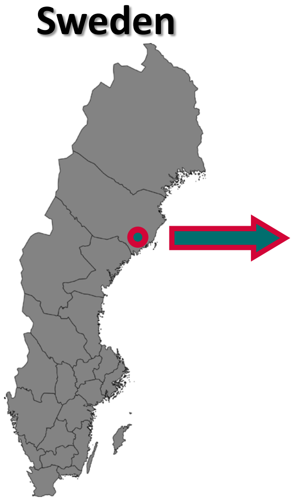
Forests: 87%

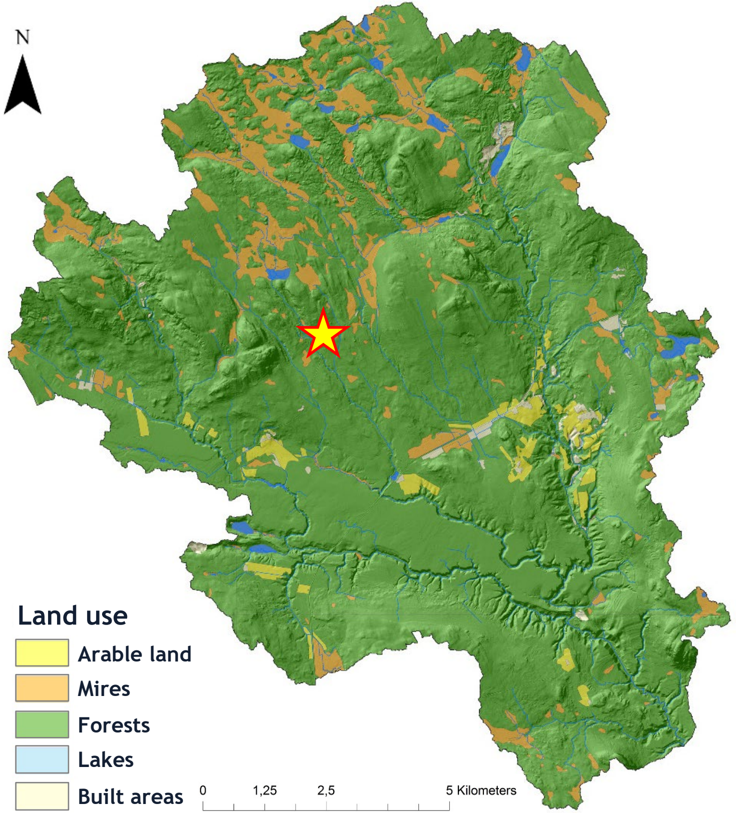
Mires: 9%

Arable land/built areas: 2%

Lakes: 1%

☆ ICOS-Svartberget station





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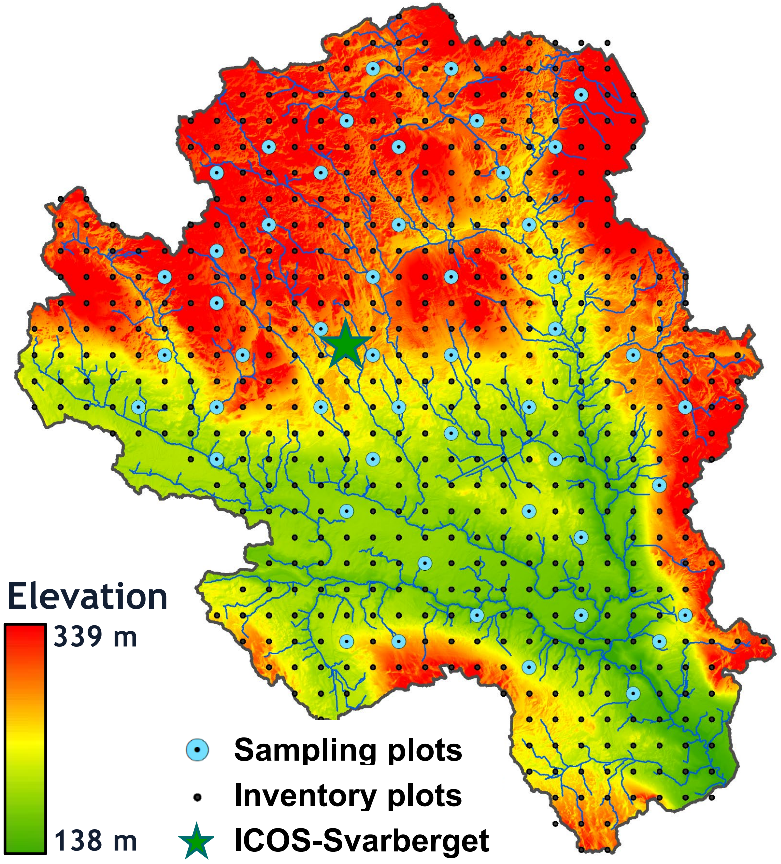

Experimental design

50 sampling plots (10 m radius) spanning from clear-cuts to old-growth stands were selected from a systematic regular grid (spacing 350 m) in 2016

Sampling plots were classified by:

- *Dominant tree species (DT)*:

Scots pine (SP) - Norway spruce (NS)

- *Stand developmental stage (SDS)*:

20, 50, 65, 70, 75, 80 and 120 years

n Plots

	Stand developmental stage (SDS)							
Dominant tree species (DT)	20	50	65	70	75	80	120	Total
Scots pine	6	3	3	4	4	3	5	28
Norway spruce	2	2	2	2	6	2	6	22

3-year study period (2016-2018)

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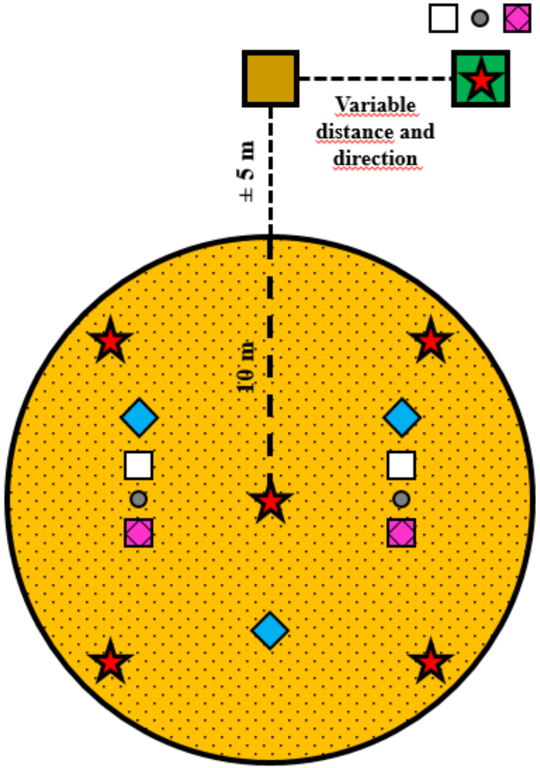
3. Our approach

Sampling and plot design for biometric- and chamber-based C fluxes



- Sampling plot
- Flux plot (F_{plot}) non-vegetated trenched (NV-T)
- Flux plot (F_{plot}) vegetated non-trenched (V-NT)

Trenching experimental set up

- Litterfall traps
- Forest-floor vegetation clipping quadrat - June
- Forest-floor vegetation clipping quadrat - August
- Sequential cores + Ingrowth cores
- Leaf area index measurements

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3. Our approach

Estimated annual C fluxes

Biometric-based C fluxes

Net primary production of trees and forest-floor vegetation (**NPP_{tree}** and **NPP_{FF}**)

Heterotrophic respiration of dead wood decomposition (**Rh_{DW}**)

Chamber-based C fluxes

V-NT Flux plot	Light/Dark measurements
NV-T Flux plot	Dark measurements

Trenching set up

Net forest-floor C exchange (**NE_{FF}**) and its contributing components, gross primary production of forest-floor vegetation (**GPP_{FF}**) and forest-floor respiration (**R_{FF}**)

Soil heterotrophic respiration (**Rh_{FF}**)

Autotrophic respiration of forest-floor vegetation (**Ra_{FF}**) was then derived as $GPP_{FF} – NPP_{FF}$

Net ecosystem production (NEP)

NEP = $NPP_{tree} + NPP_{FF} - Rh_{FF} - Rh_{DW}$

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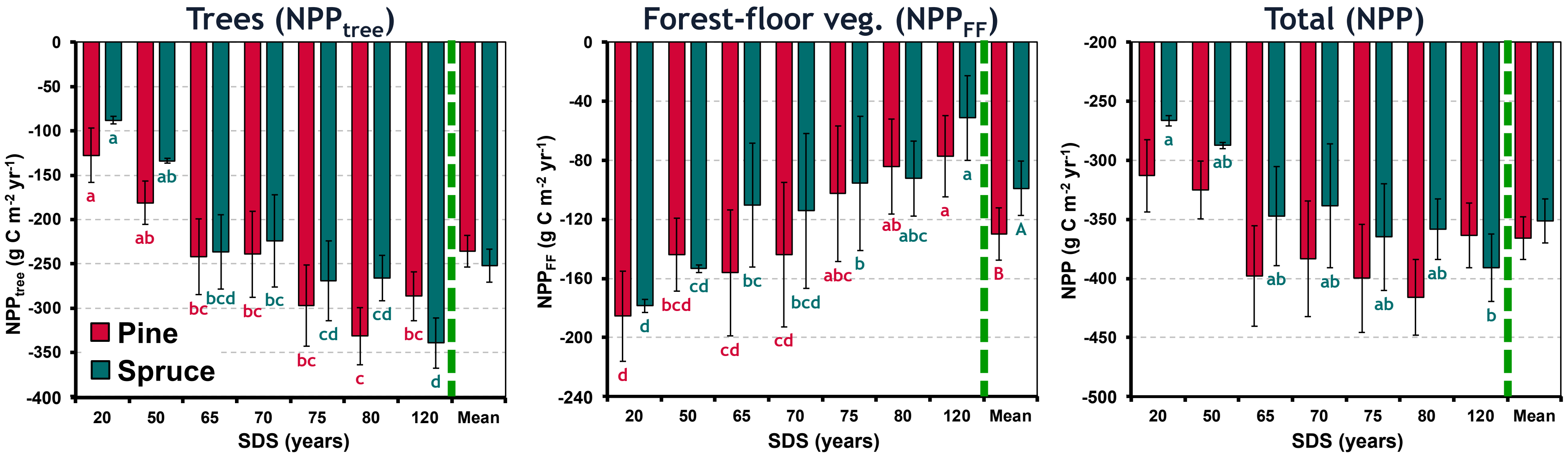
4. Main results

Net Primary Production (NPP, mean ± SE) (1/2)



Pine (P<0.001), Spruce (P<0.001), Mean (P=0.35)

Pine (P<0.001), Spruce (P<0.001), Mean (P<0.001)

Pine (P=0.12), Spruce (P<0.05), Mean (P=0.37)

NPP_{tree} consistently increased with forest ageing, while an opposite pattern was observed for NPP_{FF}

In general, pine stands showed higher NPP compared to spruce stands at each given SDS

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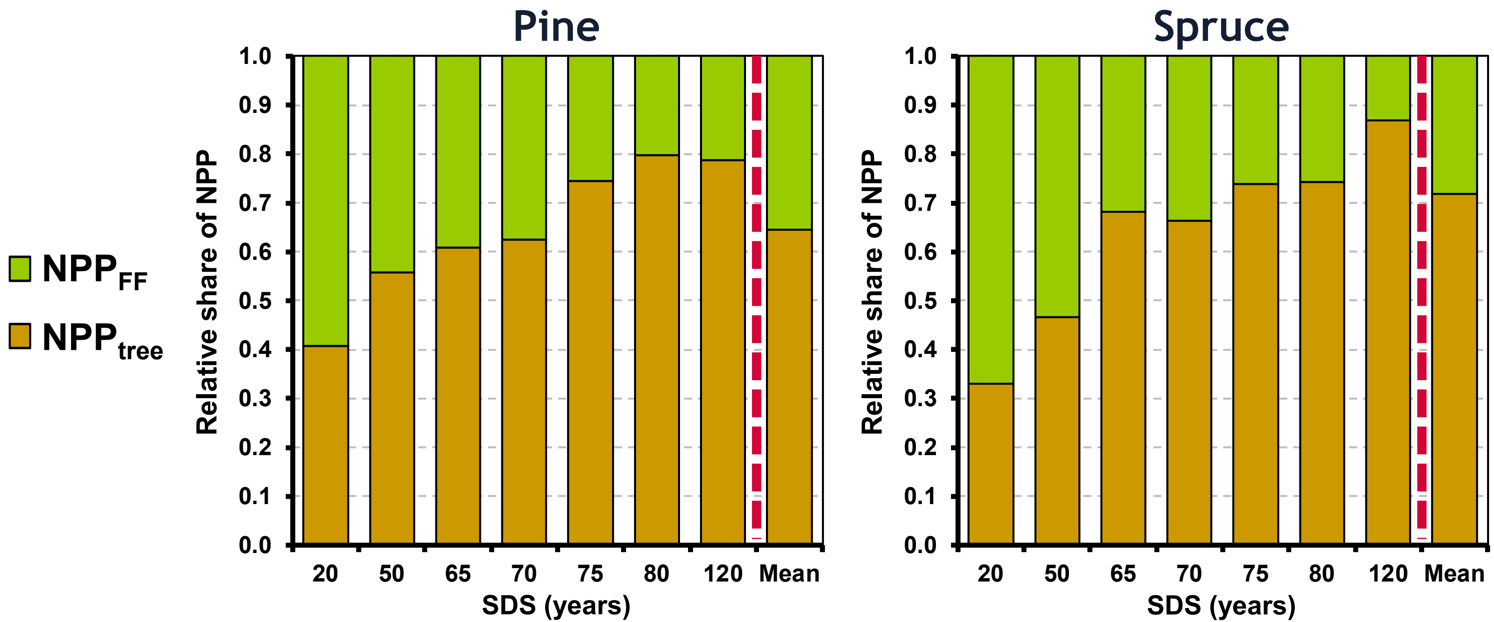
4. Main results

Net Primary Production (NPP, relative share) (2/2)



40:60% ⟷ 79:21%
Tree:FF

33:67% ⟷ 87:13%
Tree:FF

	Tree:FF%
Pine:	65:35%
Spruce:	72:28%

On average, higher NPP_{FF} contribution in pine stands

Decrease in NPP_{FF} contribution with forest ageing in both species, more accentuated in spruce stands

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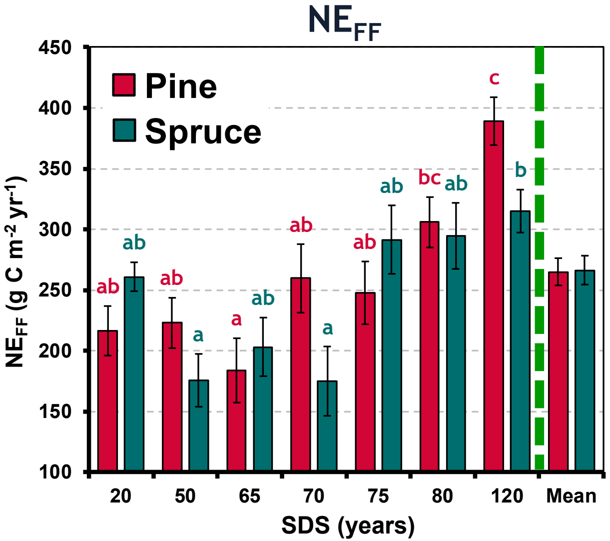
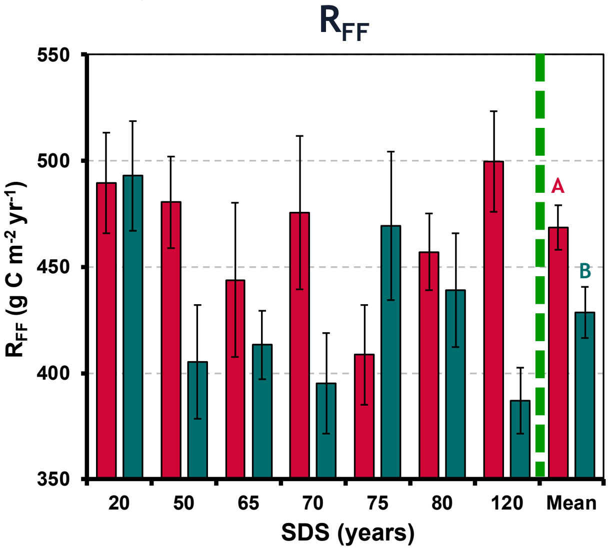
4. Main results

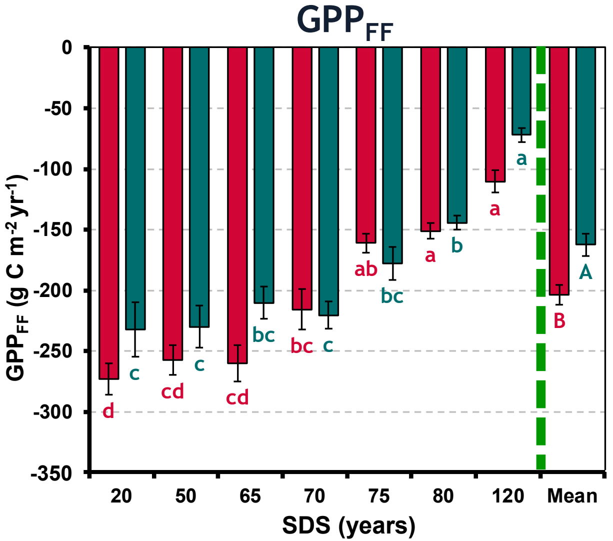
Forest-floor C fluxes (mean ± SE) (1/2)



Pine (P<0.001), Spruce (P<0.001), Mean (P=0.93)



Pine (P=0.23), Spruce (P=0.11), Mean (P<0.001)



Pine (P<0.001), Spruce (P<0.001), Mean (P<0.001)

Forest floor was a net C source, which increased with stand age due to the progressive decrease in GPP_{FF}, while the R_{FF} remained similar among all SDS

Pine stands showed higher R_{FF} and GPP_{FF} compared to spruce stands

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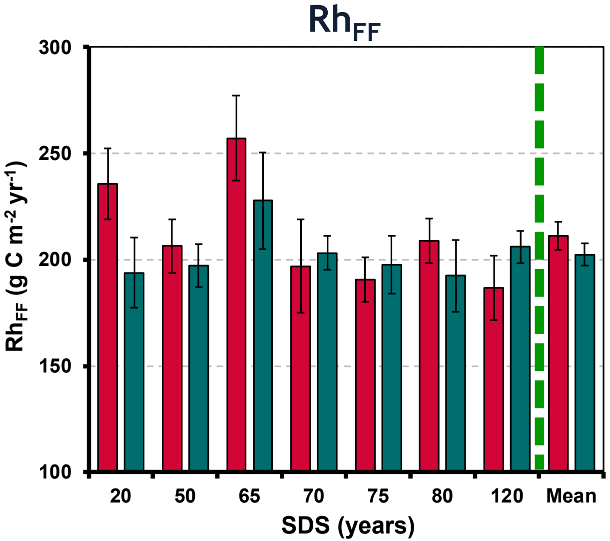
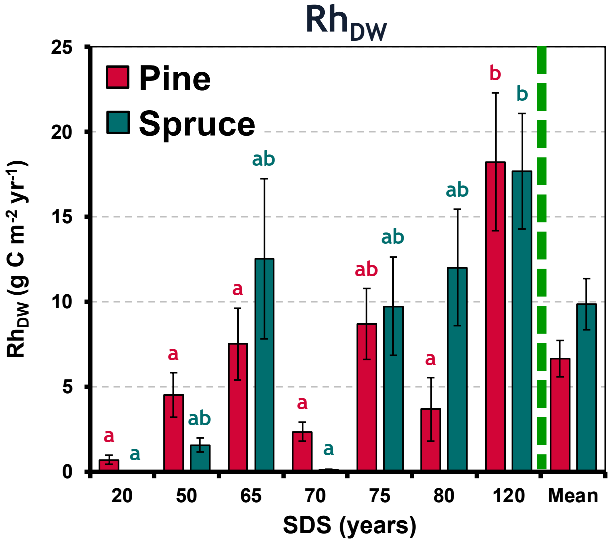
4. Main results

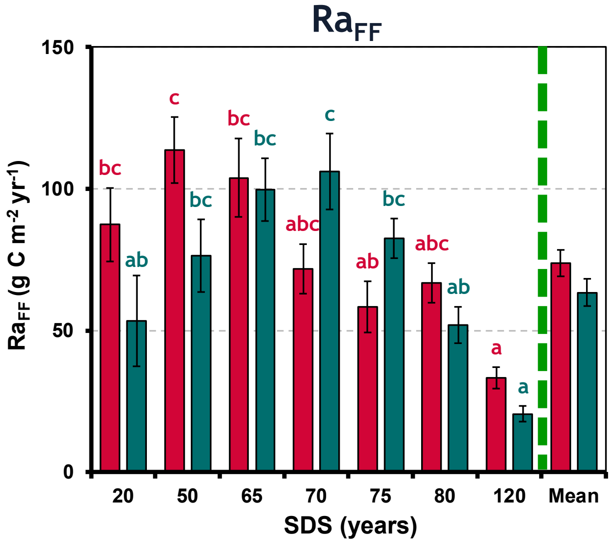
Forest-floor C fluxes (mean ± SE) (2/2)



Pine (P=0.06), Spruce (P=0.80), Mean (P=0.31)



Pine (**P<0.001**), Spruce (**P<0.001**), Mean (P=0.21)



Pine (**P<0.001**), Spruce (**P<0.001**), Mean (P=0.13)

Rh_{FF} was similar among all SDS, while Rh_{DW} increased with SDS in both species

Ra_{FF} peaked at intermediate ages (earlier in pine stands compared to spruce stands), decreasing then with forest age

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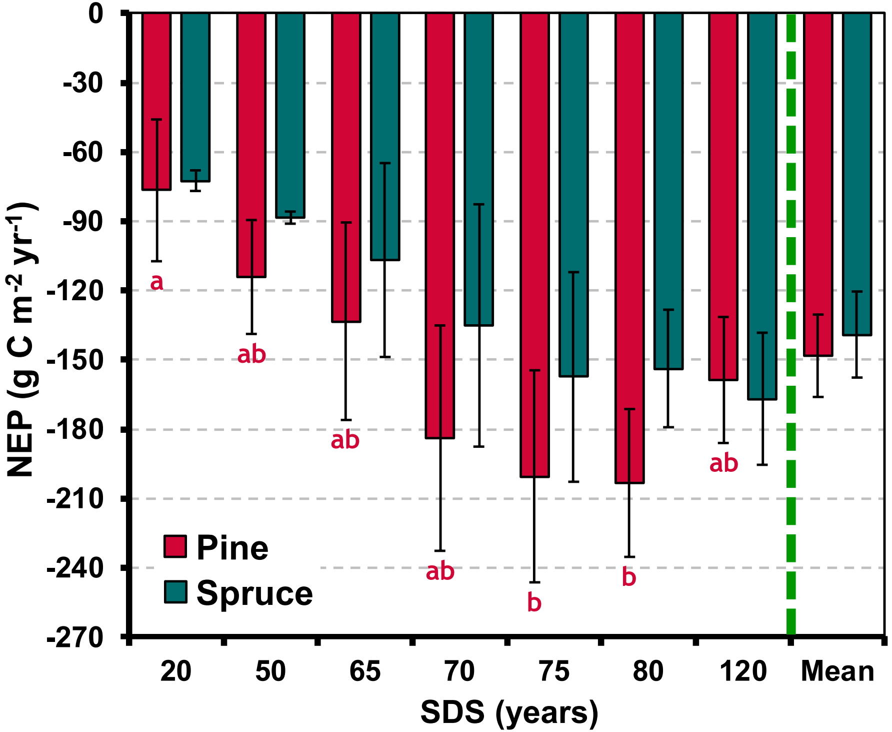
4. Main results

Net Ecosystem Production (NEP, mean ± SE)



Pine (*P*<0.001), Spruce (*P*=0.15), Mean (*P*=0.58)

Increasing NEP with SDS from about 75 g C m^{-2} yr^{-1} during the initial stages of development to a maximum (about 200 and 160 g C m^{-2} yr^{-1} for pine and spruce, respectively) in middle-aged stands

Old-growth forests steadily continue to accumulate C, especially clear in spruce stands

Higher NEP was generally observed for pine compared to spruce stands

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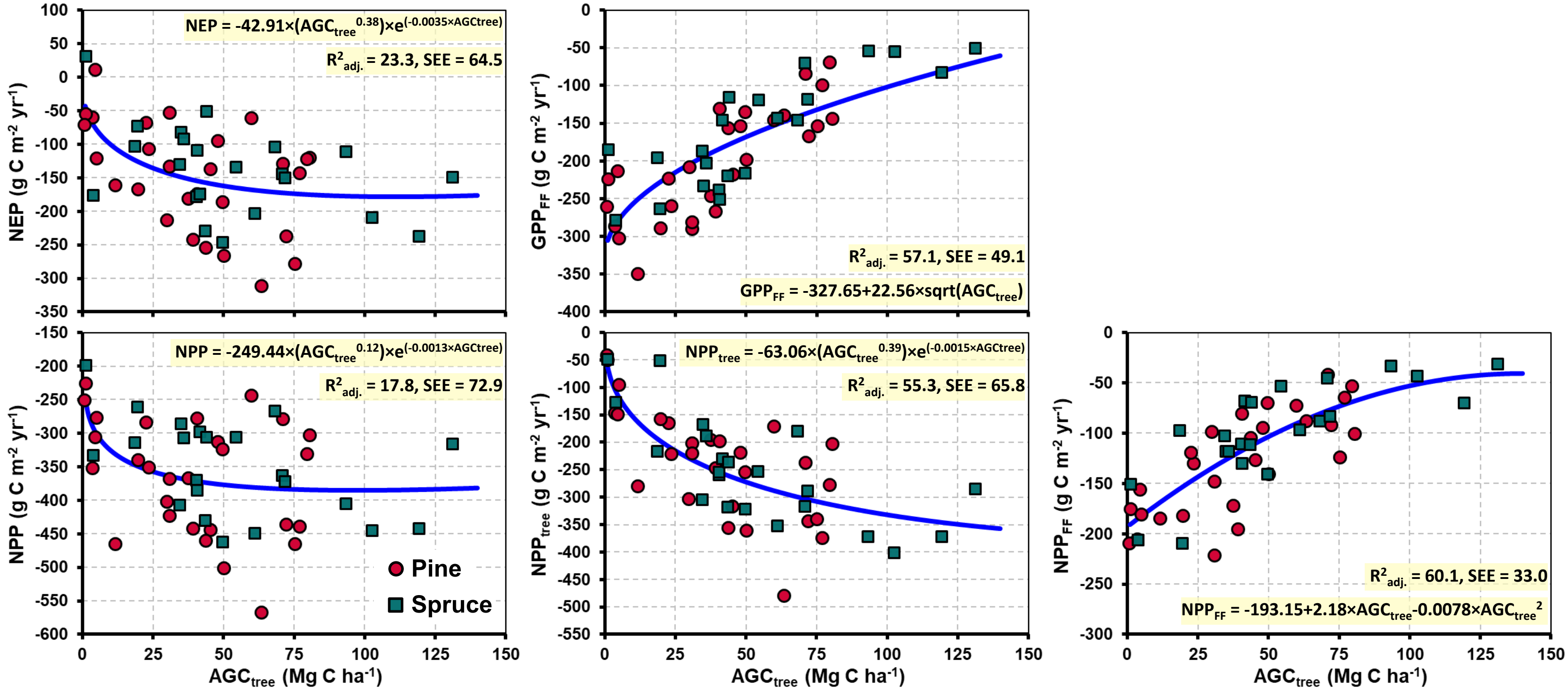
4. Main results

Modelling C fluxes (production) vs. tree aboveground C stock (AGC_{tree}, Mg C ha^{-1})



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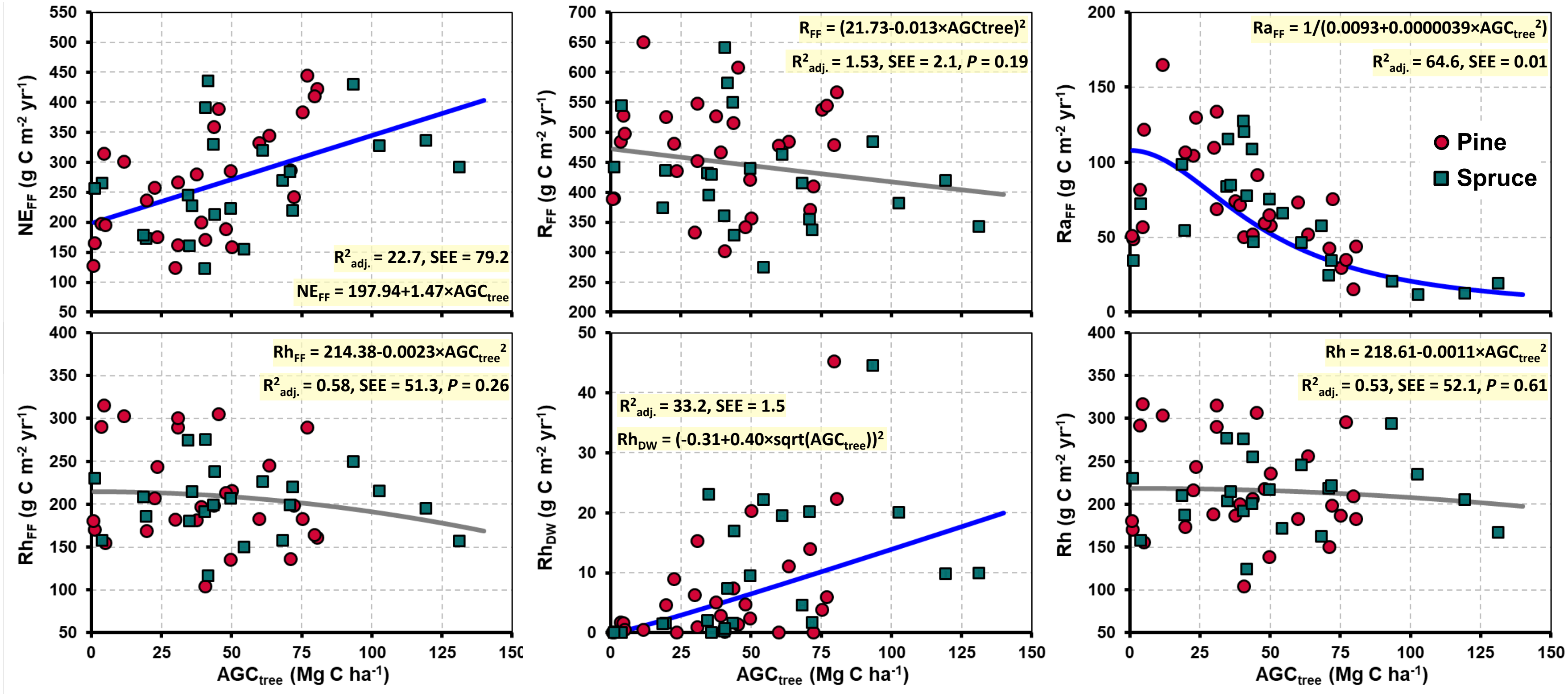
4. Main results

Modelling C fluxes (respiration) vs. tree aboveground C stock (AGC_{tree}, $Mg\ C\ ha^{-1}$)



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5. Summary

- This comprehensive study improves our understanding of the spatial variability of the C balance over the heterogeneous regional forest landscape in northern Sweden, identifying tree species, forest ageing, and forest-floor vegetation as key drivers.

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THANK YOU FOR YOUR INTEREST!

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