Forest soil organic carbon (SOC) monitoring in Denmark – challenges and needs for the future

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Kick-off meeting in the SNS Annual Network, Integrating Soil Monitoring in Nordic Forests – data harmonization, future designs and studies to examine soil function at different scales (NorForSoil)

NIBIO, Ås, Norway, 8-9 February 2023

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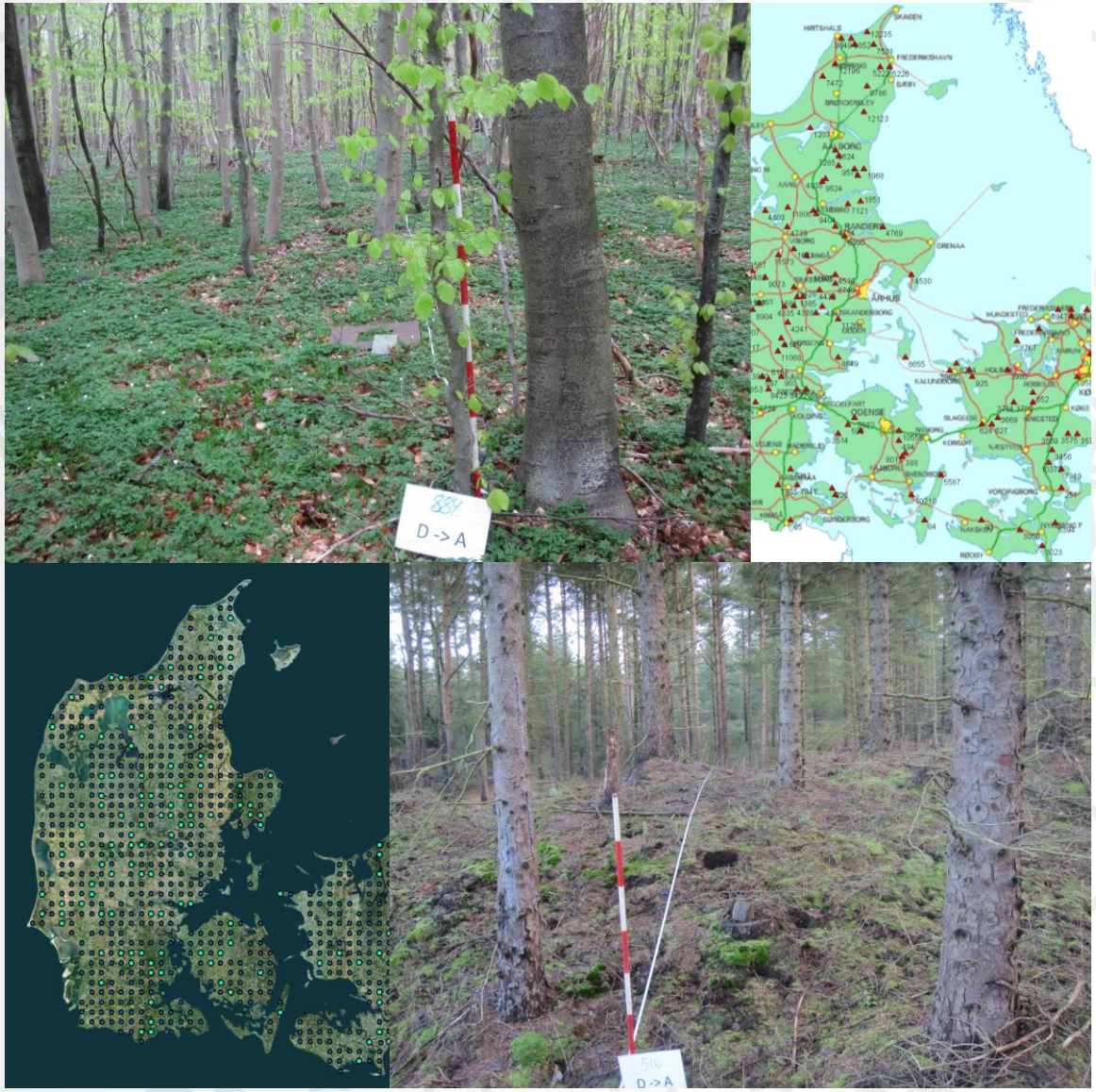


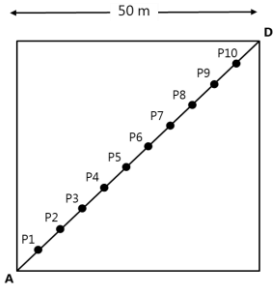
Expected improvements from the SINKS2 project

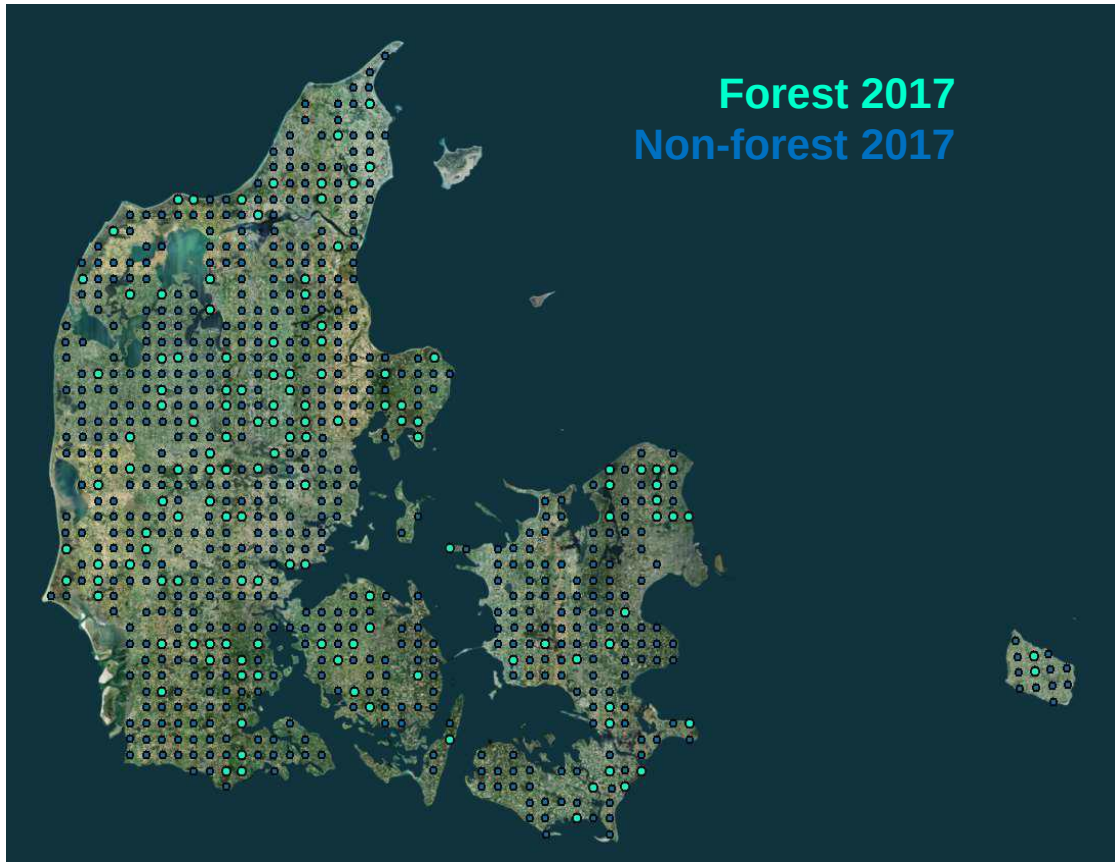
- Bulk density functions: National bulk density functions for forest floor and soil 0-50 cm to improve SOC estimates, especially for soils with > 6% C at depth 0-25 cm ("organic"/ hydromorphic soils).
- Forest SOC stocks and stock changes: Evidence of country-wide stable or changing forest floor and mineral SOC pools for forest remaining forest (FRF) and afforestation of cropland (AFF)?
- Explaining variation in SOC stock and stock changes, FRF and AFF: Test if site, stand and soil characteristics can explain differences in SOC stocks and stock changes among plots?
- Forest SOC modelling: Better understanding of modelling opportunities to predict developments in SOC stocks and SOC stock changes (Transpar2CU to learn about factors that influence soil carbon dynamics, and Yasso15 to test validity for SOC stocks and stock changes after cropland afforestation).

The monitoring networks

"Nitrate Network" (KN)

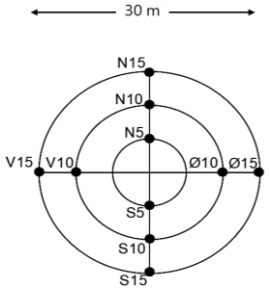
- 7 x 7 km
- 126 forest plots
- Square plots, 50 x 50 m
- 10 subsampling points per plot

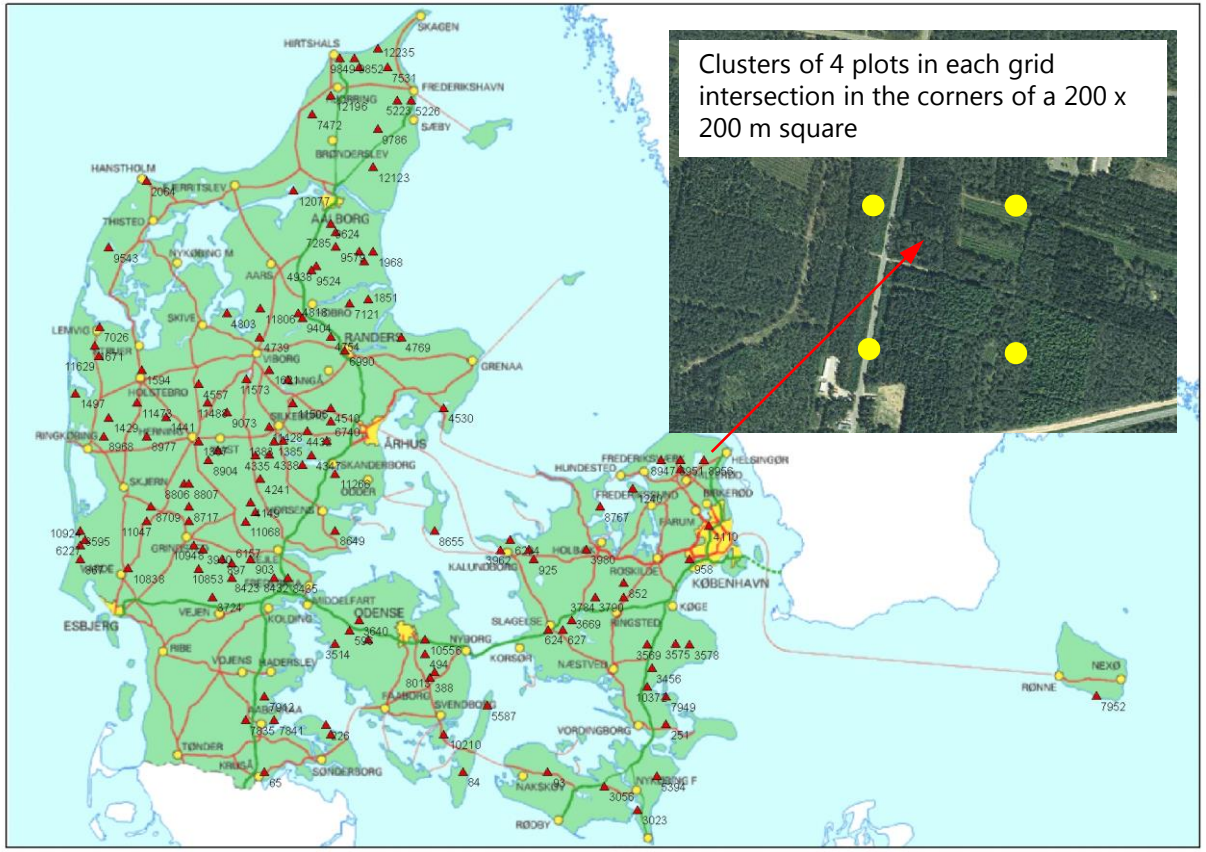




"National Forest Inventory" (NFI)

- 2 x 2 km
- 140 clusters ~285 selected plots
- Circular plots, r = 15 m
- 10 subsampling points per plot





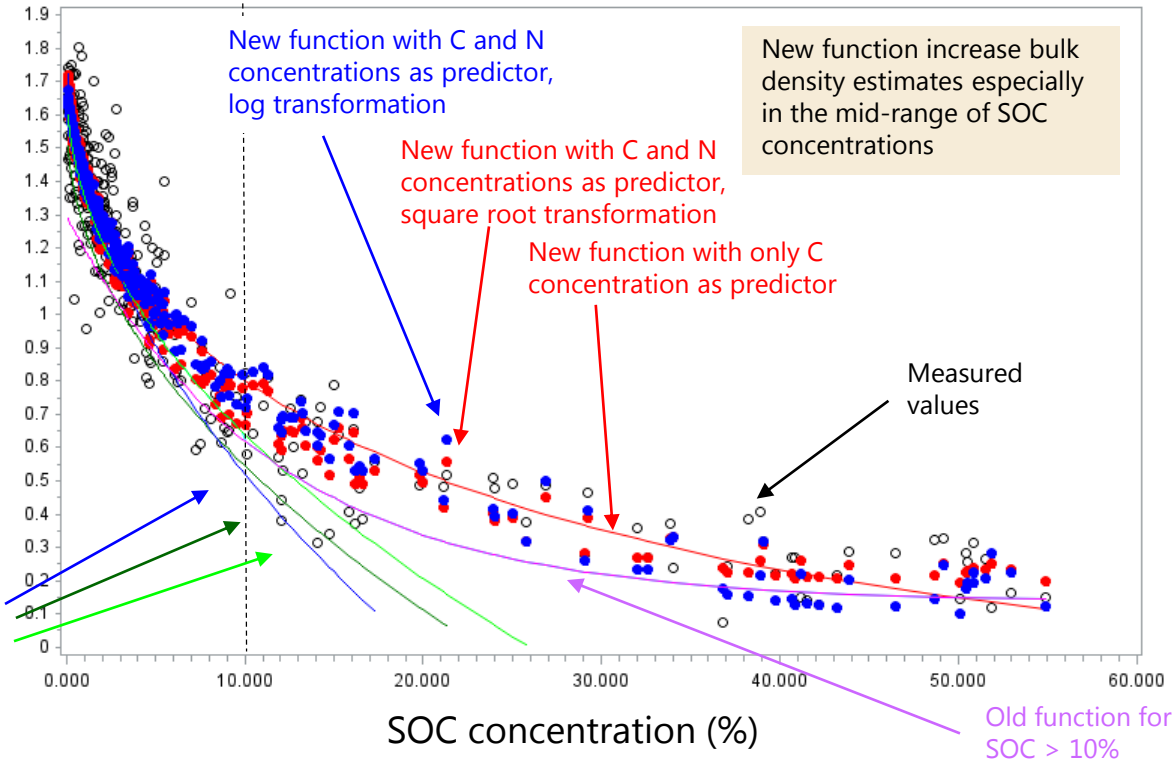
Inventory times and methods

- Forest floor sampled in 2008 and 2018
- Mineral soil sampled in 1990, 2008, and 2018

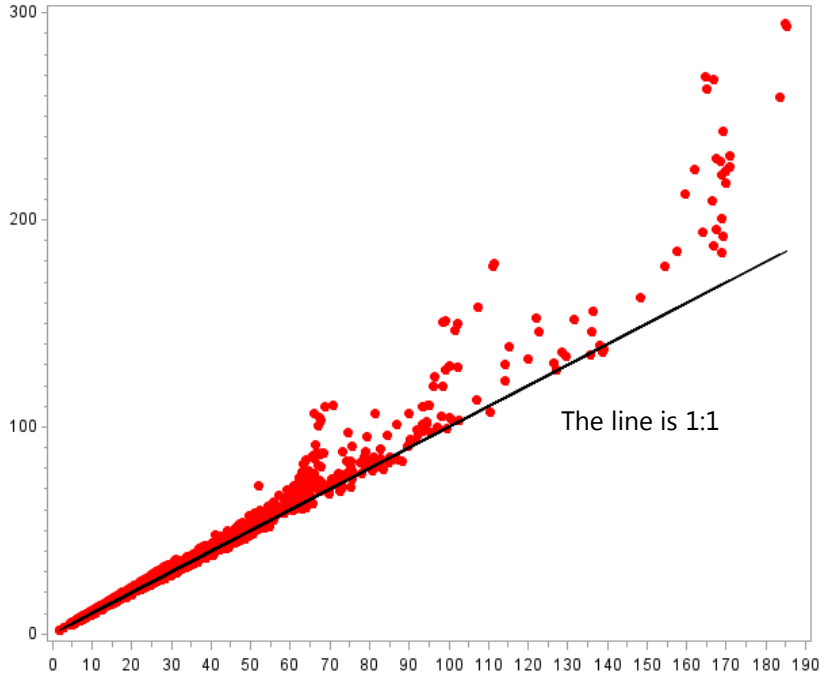
- Forest floor sampled using frame
- Mineral soil sampled in 5 layers: 0-10, 10-25, 25-50, 50-75, 75-100 cm
- Sampling to establish national bulk density functions

Soil bulk density (0-100 cm) - old and new functions

Bulk density (g cm-3)



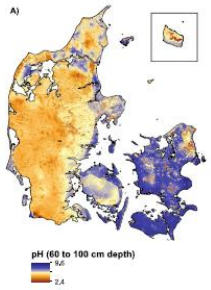
SOC stock (t2) - **new** bulk density functions (Mg C ha-1)



SOC stock (t2) - **old** bulk density functions (Mg C ha-1)

$$\sqrt{\delta_{soil,ij}} = 1.36027291 - 0.104451818 \cdot \sqrt{C_{ij}} - 0.340103445 \cdot \sqrt{N_{ij}} + 0.032995439 \cdot \sqrt{C_{ij}} \cdot \sqrt{N_{ij}}$$

$$\sqrt{\delta_{soil,ij}} = 1.308340368 - 0.130556736 \cdot \sqrt{C_{ij}}$$



- No significant effect of depth, soil texture class or (JB number), or clay percentage
- Significant effect of sand percentage (p=0.0392) and marginally of pH(CaCl2) (p=0.0598), but only increase R2 from 0.9261 to 0.9285 and 09290, respectively. Not included at the moment.

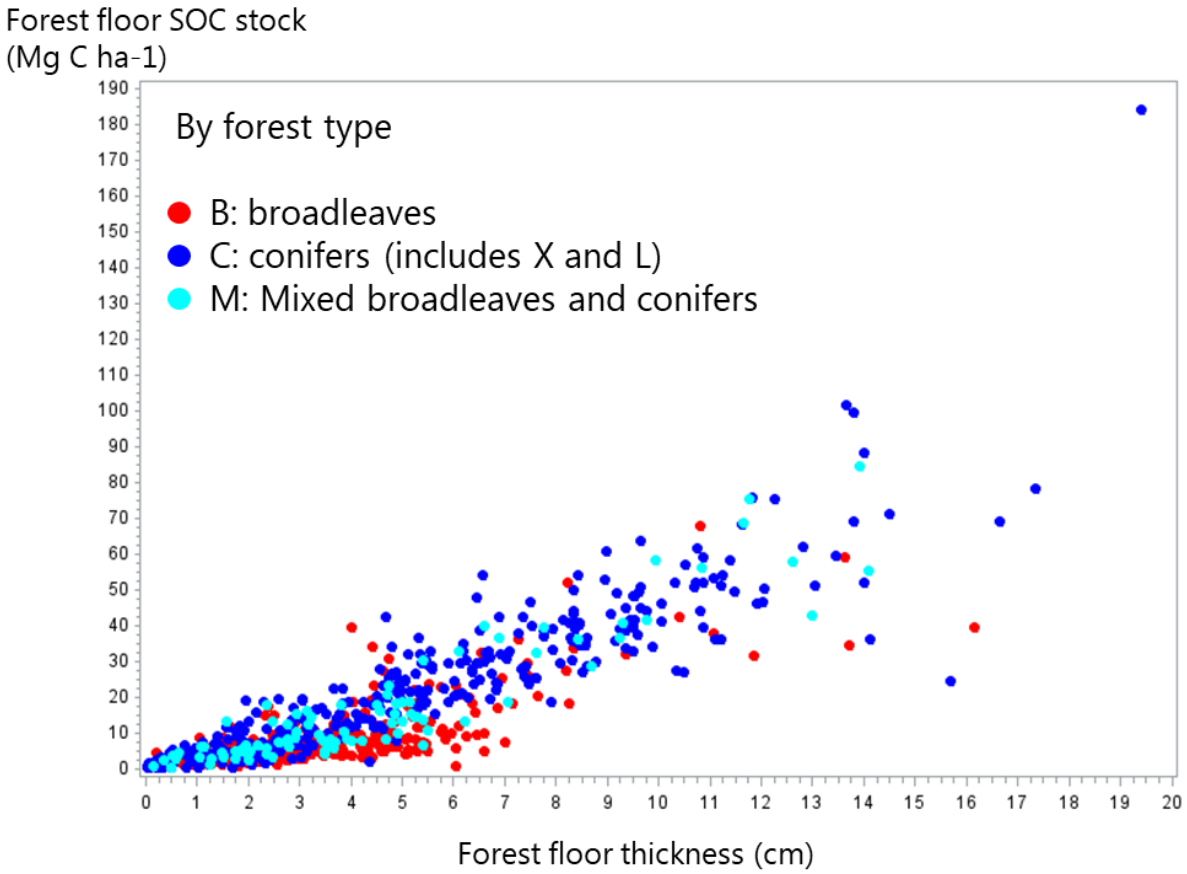
Preliminary results

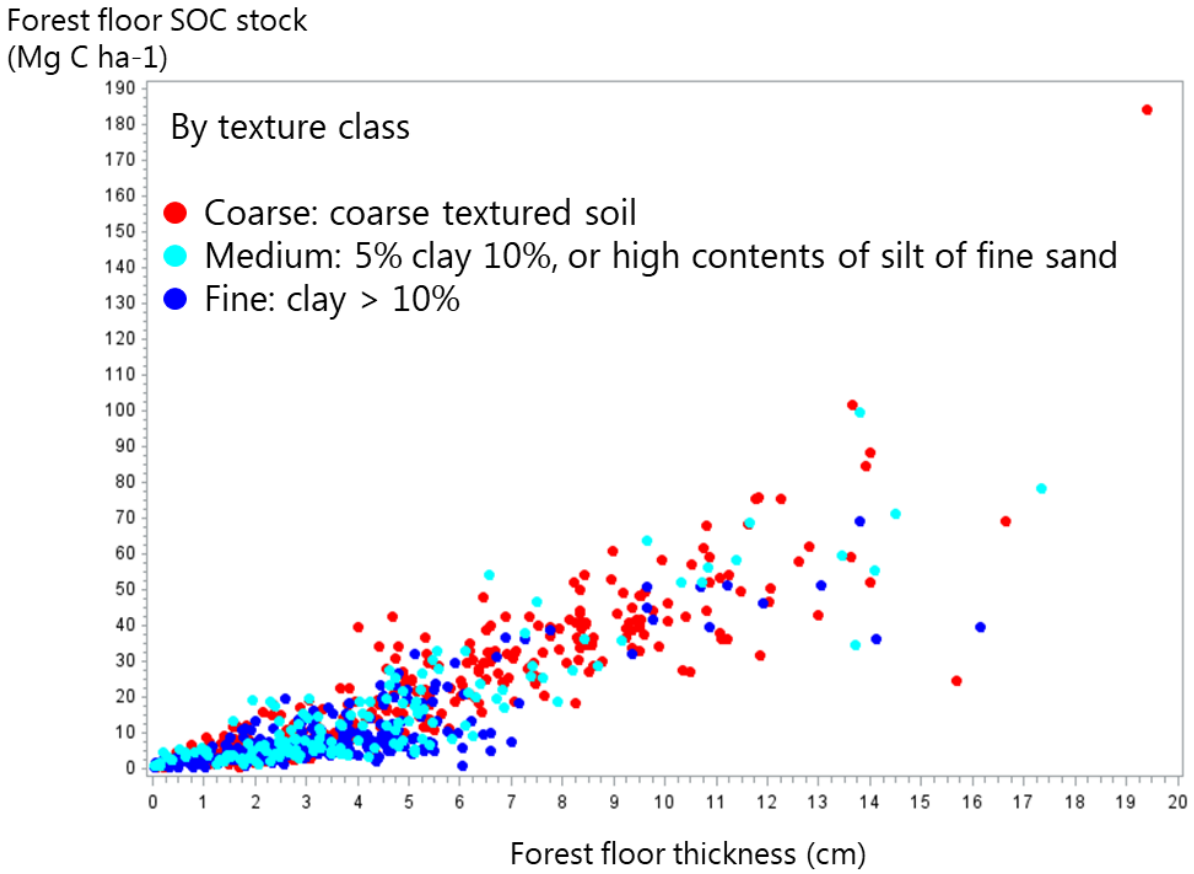
Forest floor "carbon density" functions

- Significant effect of forest type and texture (when forest floor thickness is taken into account).

Confounding effects

Forest type	Soil texture			
	Coarse	Medium	Fine	Total
	%			
Conifers	**64**	**17**	**19**	**100**
Mixed	**40**	**32**	**28**	**100**
Broadleaves	**26**	**20**	**54**	**100**

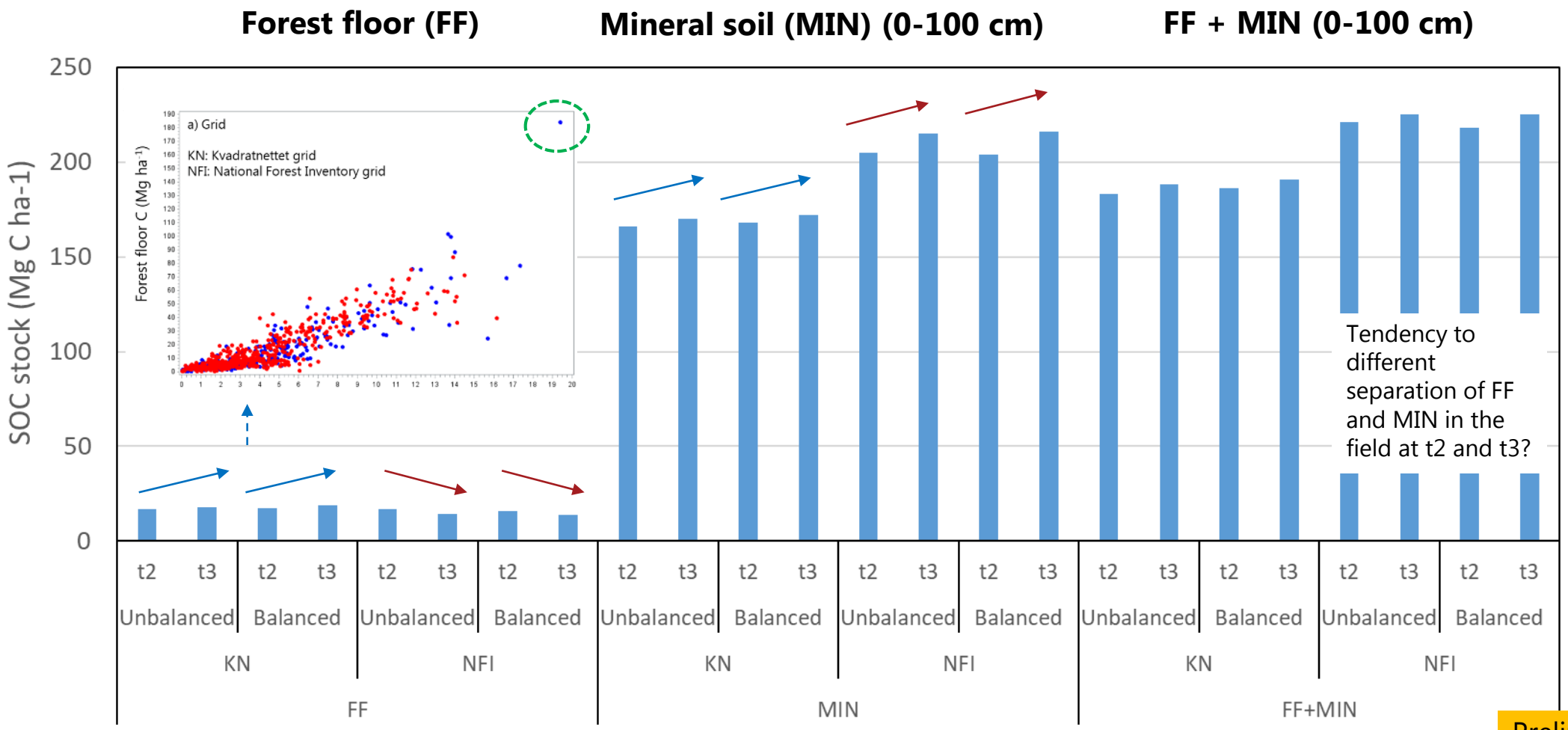




Preliminary results

Mean SOC stocks – inventory time and grid

- Significant effect of grid, but it explains less than 1-3% of the variation.
- No significant effect of time
- No immediate difference between analyses of unbalanced or balanced data sets



Preliminary results

SOC stocks – forest type, soil type, and previous land use

Forest floor (FF) – least square means

Forest type		Soil texture group		Previous land use	
Value	C Mg ha^{-1}	Value	C Mg ha^{-1}	Value	C Mg ha^{-1}
Conifers	14.7^{a}	coarse	15.1^{a}	FRF	17.1^{a}
Mixed	11.4^{b}	medium	11.4^{b}	AFF	5.5^{b}
Broadleaves	7.8^{c}	fine	7.5^{c}		

Forest floor SOC stock

Source	Num DF	Den DF	F Value	Pr>F
Inventory time (t2, t3)	1	672	2.64	0.1044
Forest type (broadleaf, mixed, conifer)	2	672	13.6	<.0001
Soil type group (coarse, medium, fine, organic >12% C in 0-25 cm)	3	672	7.55	<.0001

Cov Parm	Estimate
grid	0.0046
AR(1)	0.7209
Residual	1.0402

Soil 0-100 cm SOC stock

Source	Num DF	Den DF	F Value	Pr>F
Inventory time (t2, t3)	1	672	9.75	0.0019
Forest type (broadleaf, mixed, conifer)	2	672	10.66	<.0001
Soil type group (coarse, medium, fine, organic >12% C in 0-25 cm)	3	672	53.54	<.0001

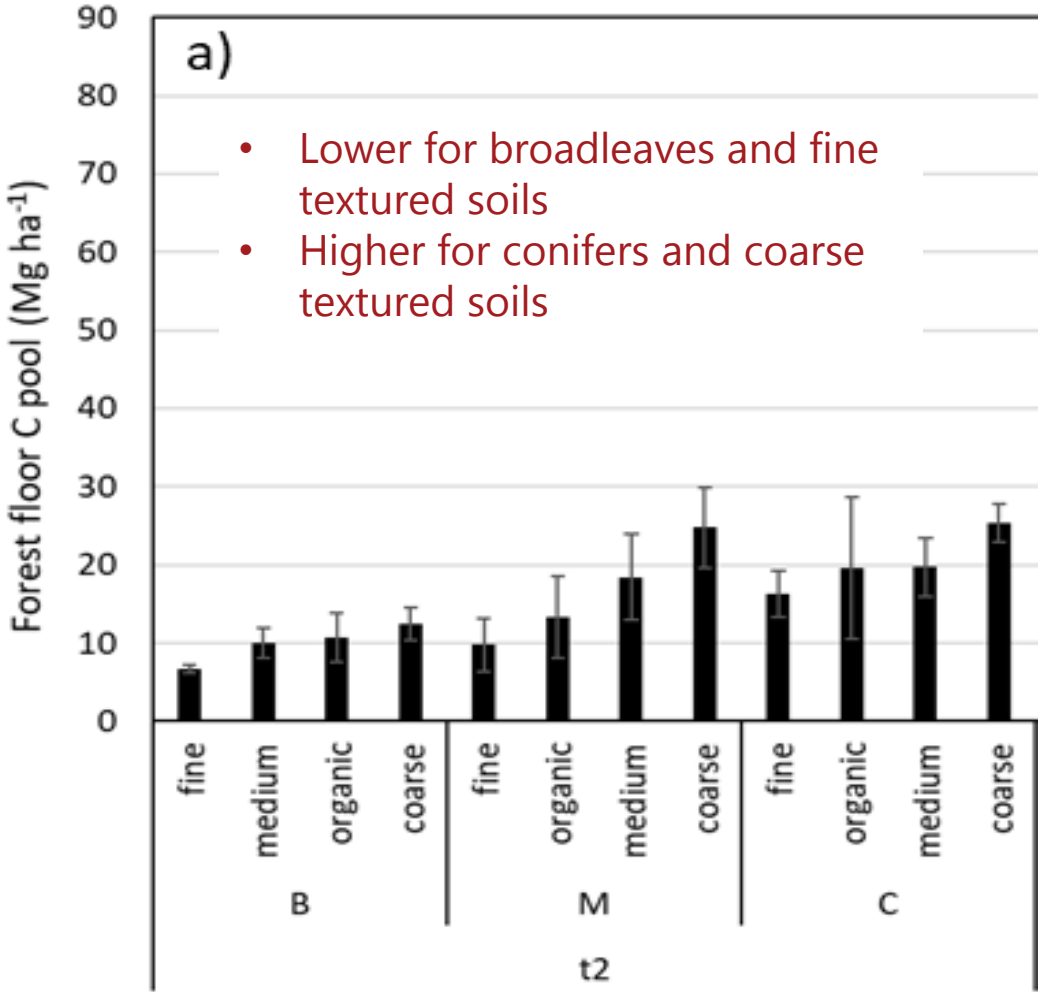
Cov Parm	Estimate
grid	0.0034
AR(1)	0.9076
Residual	0.1943

- Significant effects of forest type, soil type group, and previous land use (and time) (PROC MIXED, with grid as random effect)
- The amount of explained variance is around 17% and 38% for forest floor and mineral soil, respectively (PROC GLM)

Preliminary results

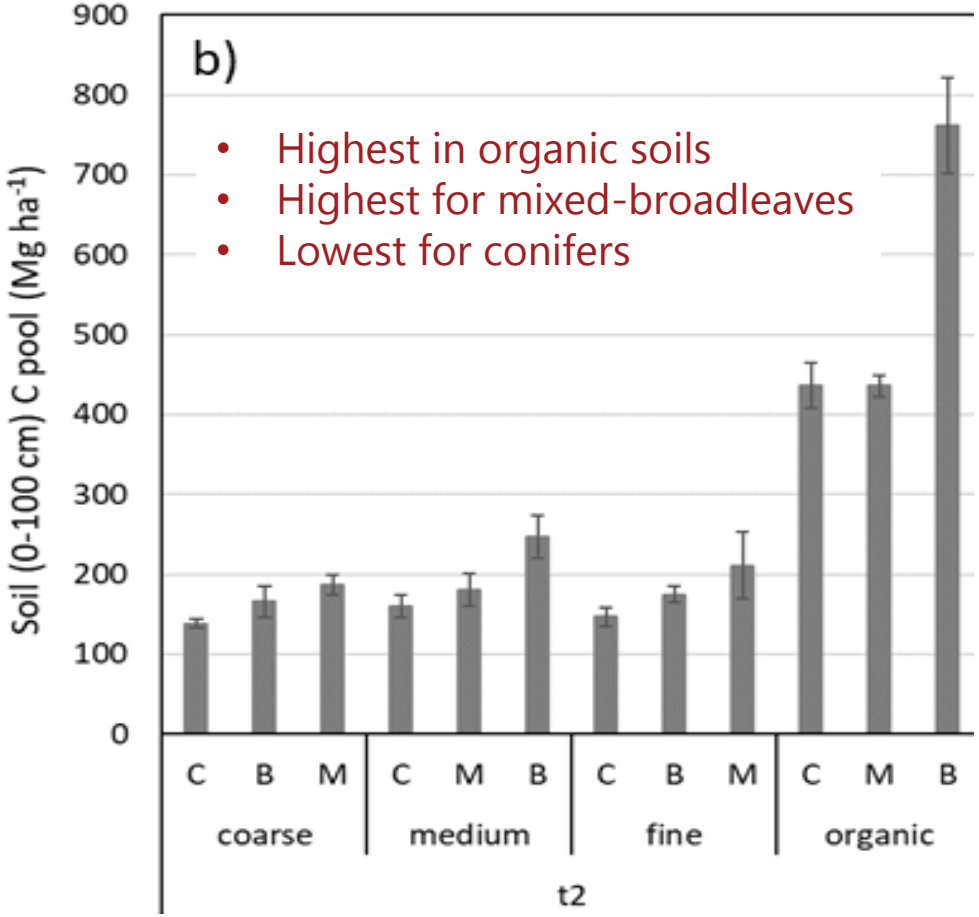
SOC stocks – forest type and soil type group

Forest floor



- Lower for broadleaves and fine textured soils
- Higher for conifers and coarse textured soils

Mineral soil (0-100 cm)

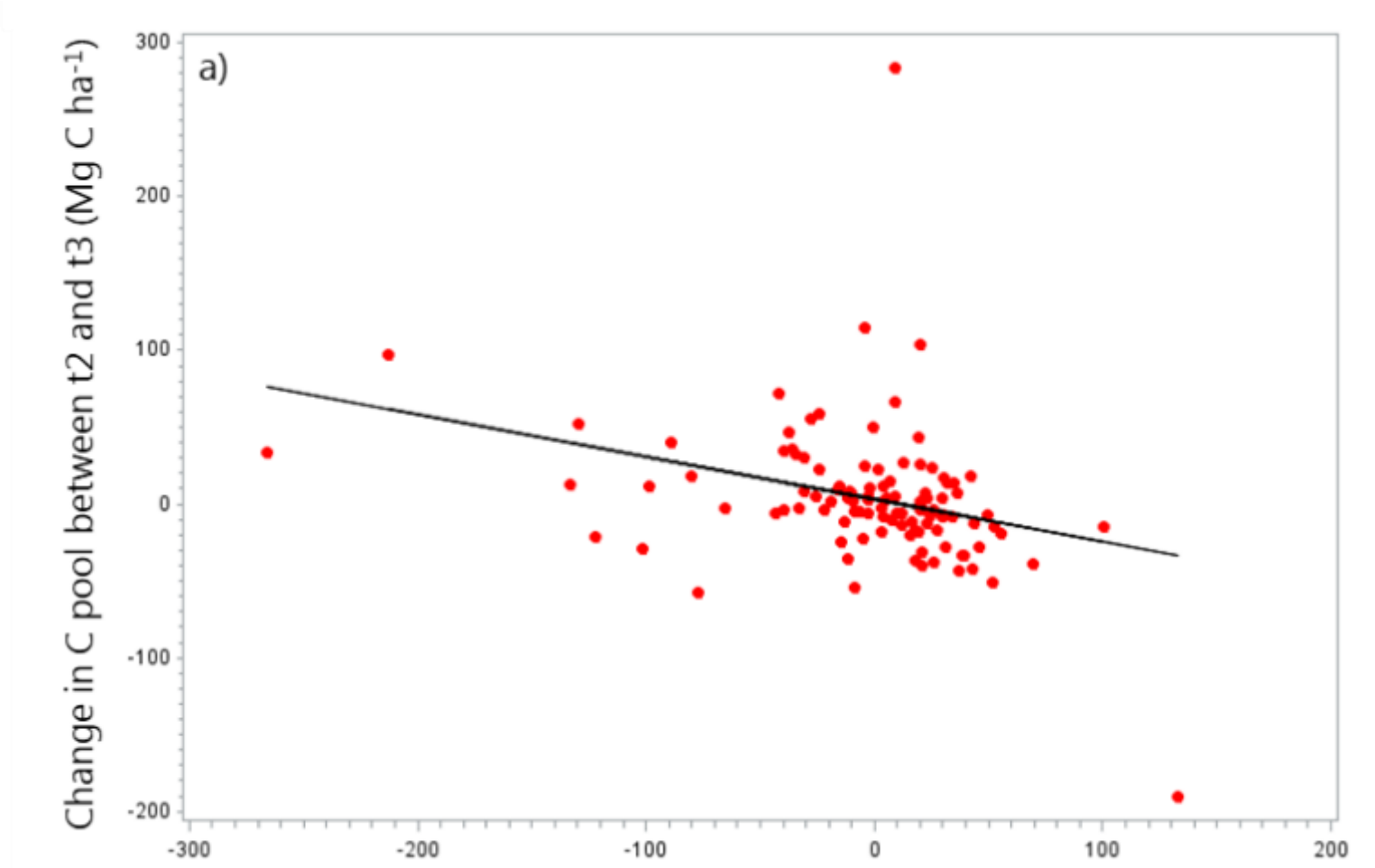


- Highest in organic soils
- Highest for mixed-broadleaves
- Lowest for conifers

t2, but a similar pattern for t3

Preliminary results

SOC stock changes in KN - regression toward the mean



Preliminary results

Future needs and focus points

- **Further data analysis to examine the impact of forest management and former land use**
  - Make existing types of registered information more complete by including all for the KN grid
  - Improve the types of registered information for use as explanatory variables
  - Make the registration of such information more dynamic, i.e. anchored in time
- **Statistical design etc.**
  - Investigate the contribution of regression to the mean for SOC changes, incl. clarify within site variation
  - Improve representativeness by increasing the number of measured plots
  - Improve handling of land use changes in the NFI grid
  - Validate bulk density functions
- **Forest SOC modelling and model validation**
  - Improve model inputs, adapting to national conditions, or conditions for specific strata
  - Improve model contents, based on improved process understanding