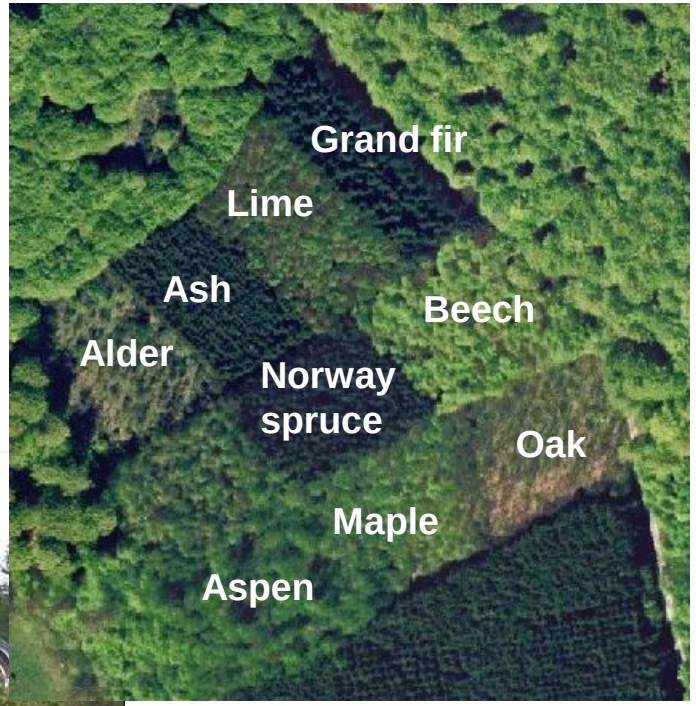
Responses of soil carbon to forest management

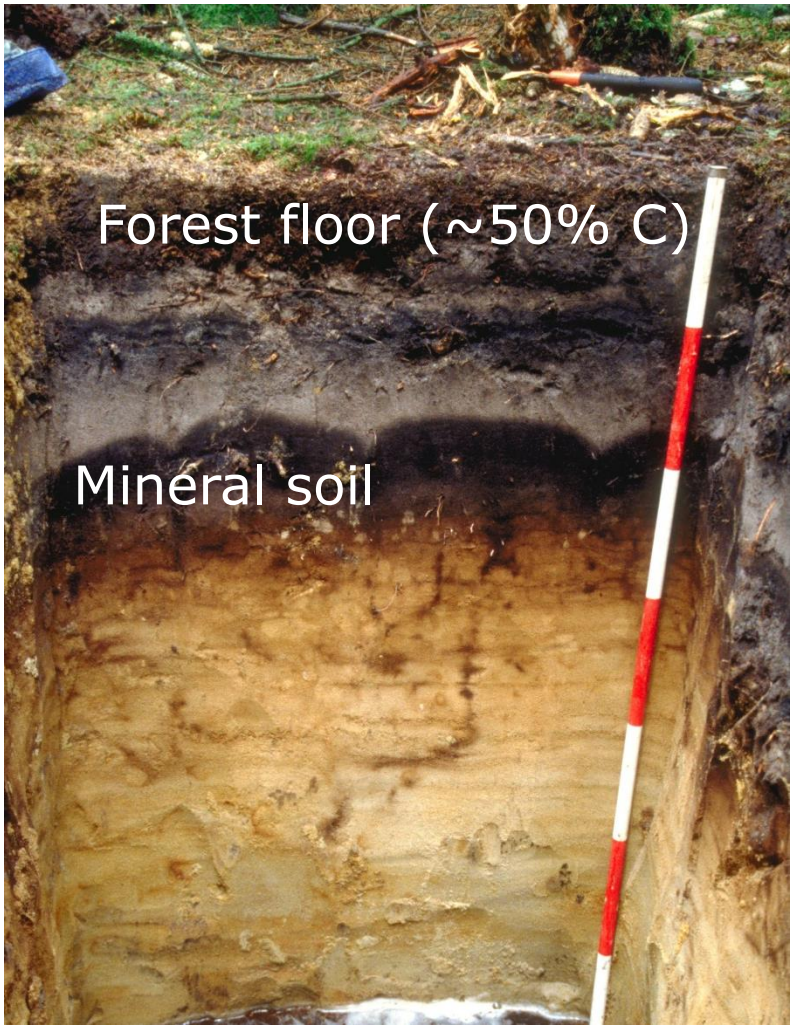
Lars Vesterdal
University of Copenhagen



Key Note at 7th ICP Forests Scientific Conference "European forests in a changing environment: Air pollution, climate change and forest management", 23 May 2018

Two Danish forest soils - where is the carbon?

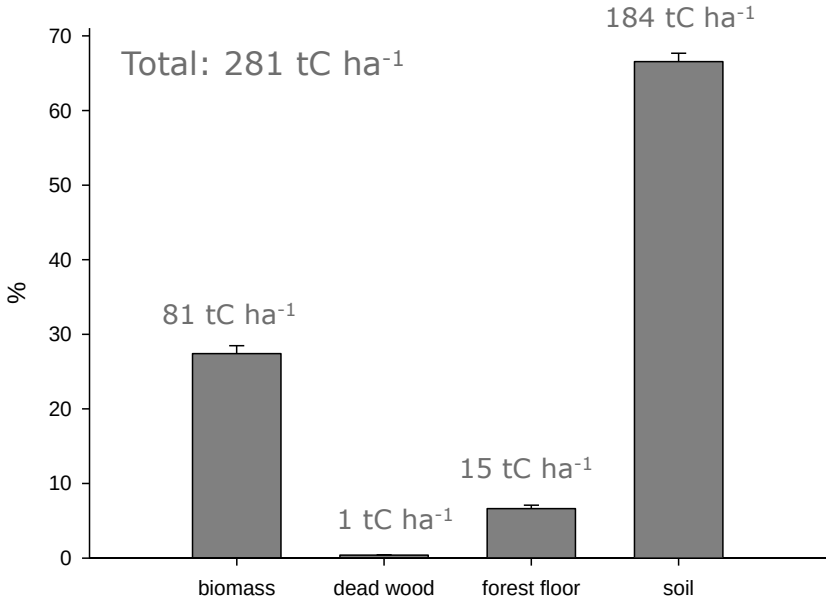
Christianssæde Skov, Lolland
Beech forest, Luvisol



Nørlund Plantage, Jutland
Norway spruce forest, Podzol

Contribution of soils to forest ecosystem carbon stocks

National Forest Inventory (277 plots):



Boveland (2012)

Which C pools?

- Aboveground biomass
- Dead wood
- Forest floor
- Mineral soil
- Root biomass

- European forest soils contain 62% of total ecosystem C stock (De Vos et al. 2015, Level I)
- *Can we change the stocks ~sequester carbon?*

Outline

- How do forest management practices affect SOC stocks?

- This is not the full story in 30 minutes!

Focus on empirical evidence for selected management parameters:

- Tree species selection: identity and diversity (mixtures)
- Harvesting
- Silvicultural systems
- Drainage

Synthesis of tree species identity effects

-based on common garden, paired plot and single-tree studies in temperate and boreal forests

Contents lists available at SciVerse ScienceDirect

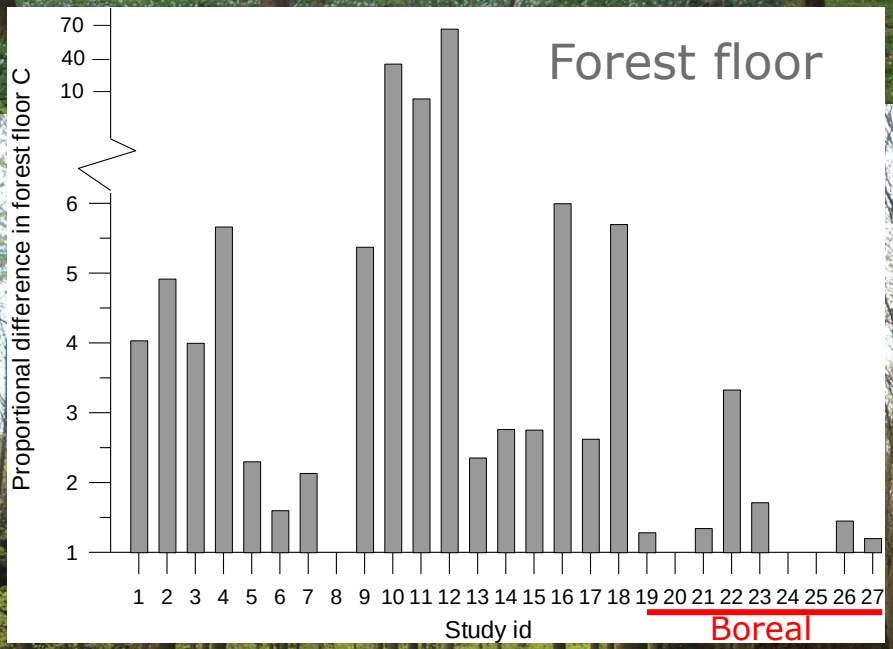
Forest Ecology and Management

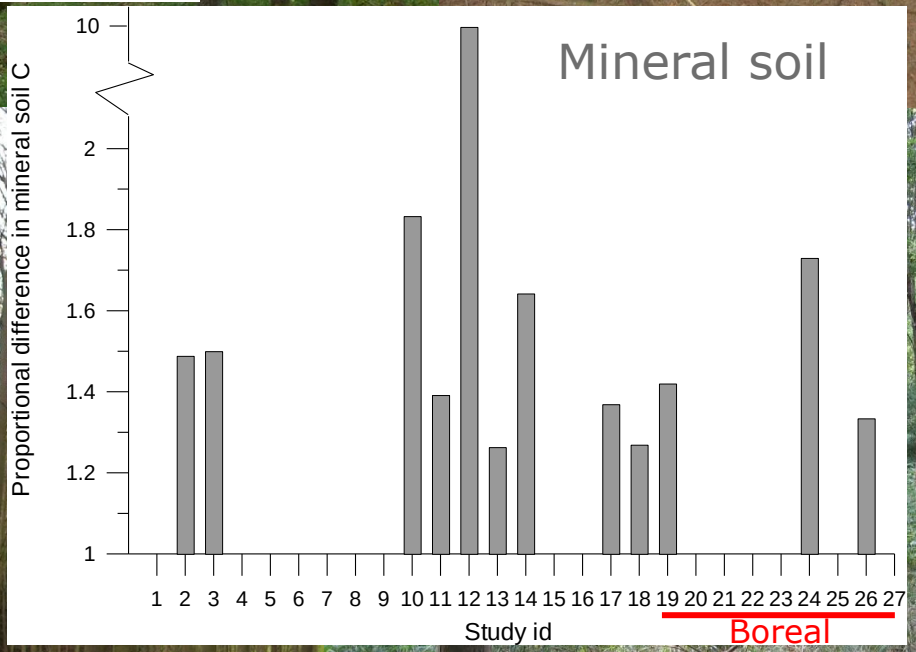
journal homepage: www.elsevier.com/locate/foreco

Do tree species influence soil carbon stocks in temperate and boreal forests?

Lars Vesterdal [a,*], Nicholas Clarke [b], Bjarni D. Sigurdsson [c], Per Gundersen [a]

[a] Department of Geosciences and Natural Resource Management, University of Copenhagen, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark
[b] Norwegian Forest and Landscape Institute, P.O. Box 115, N-1431 Ås, Norway
[c] Agricultural University of Iceland, Hvanneyri, IS-311 Borgarnes, Iceland

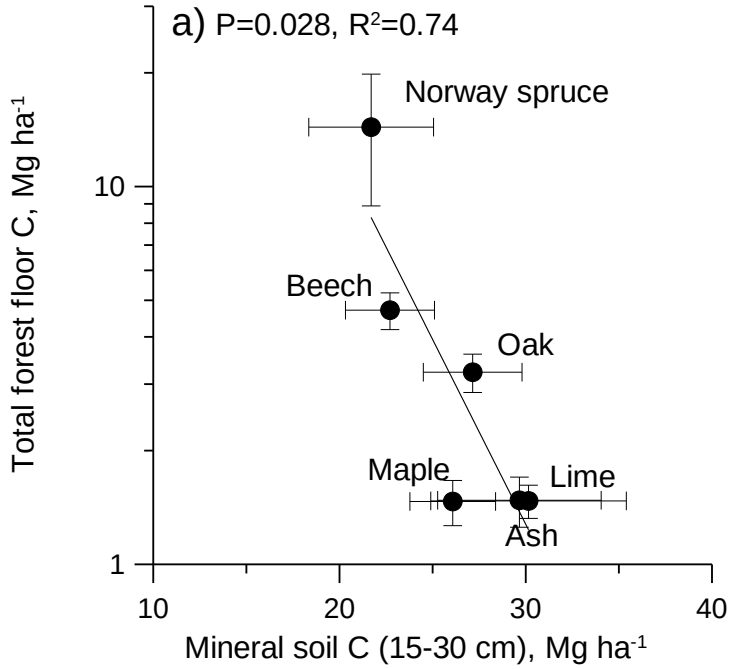




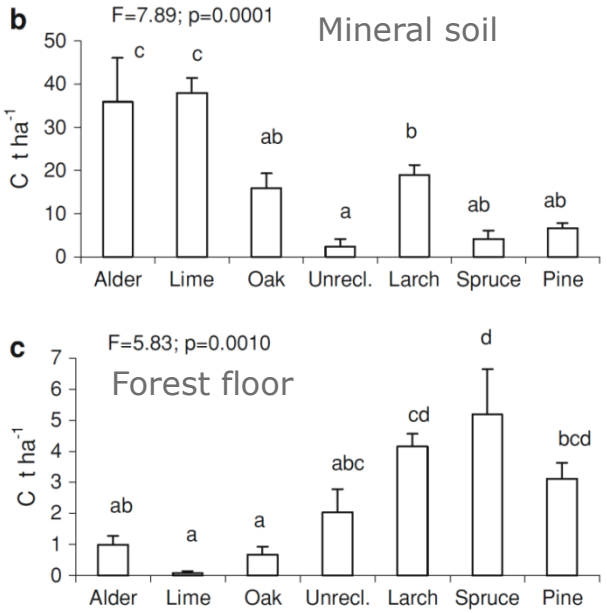
C stock differs by 2-5 fold:
Ash, maple<beech<conifers

C stock differs by 40-50%
Conifers, beech<ash

Do tree species affect soil C distribution rather than soil C stock?



Vesterdal et al. 2008, Denmark

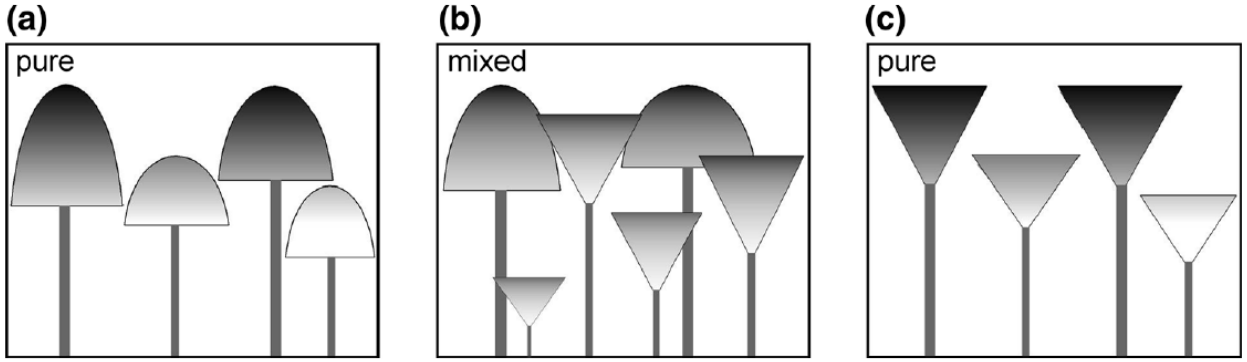


Frouz et al. 2009, Czech Republic, reclaimed soils

- Trade-off between C sequestration in forest floor and mineral soil?
- Mediating role of soil fauna (earthworms) at some sites/soil types
- Differences in *stability* rather than magnitude of C stock?

Tree species diversity effects on soil carbon?

- for targeted *use of tree species and their mixtures* to sequester carbon in soils

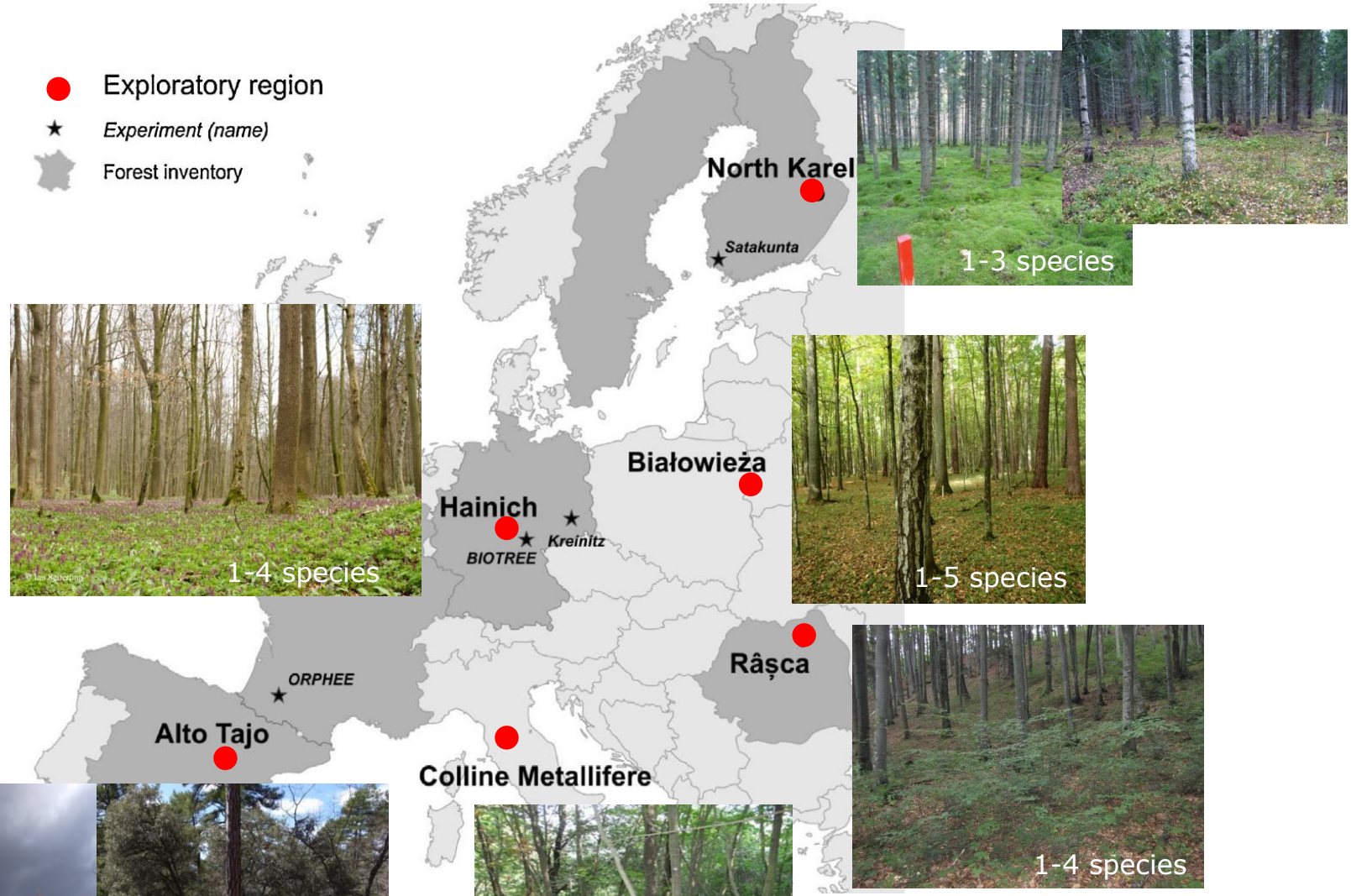


Pretzsch et al. (2015): beech and Scots pine across Europe

- Complementarity effects in forest stands: Higher aboveground productivity in mixtures, e.g. Jucker et al. (2014), Pretzsch et al. (2015)

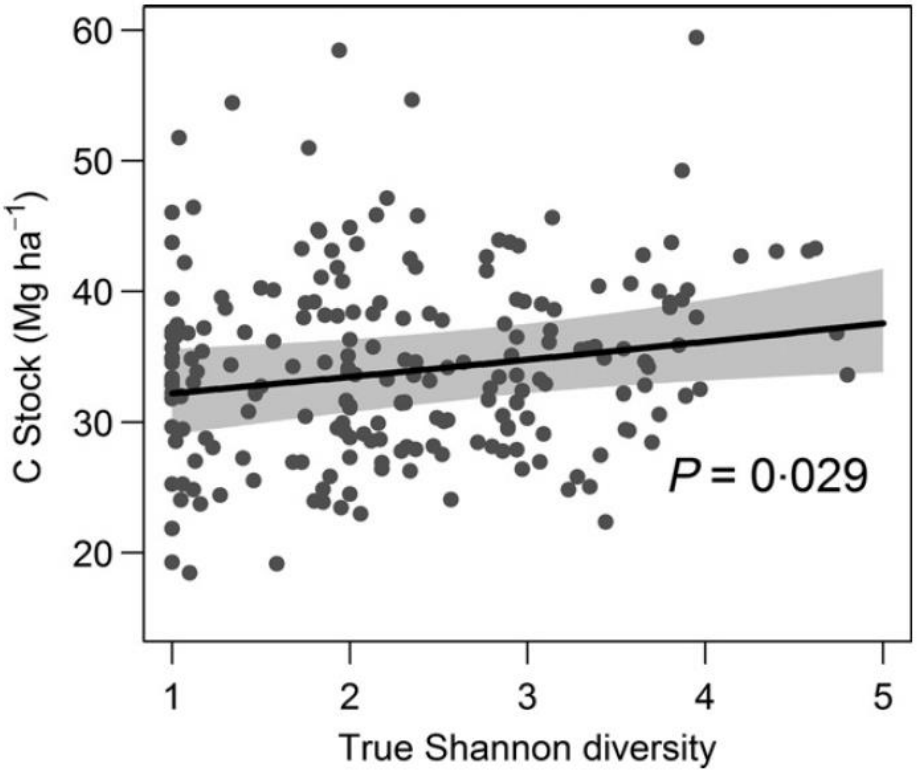
- Higher litter inputs to soils above- and belowground due to niche differentiation?

FunDivEurope exploratory platform

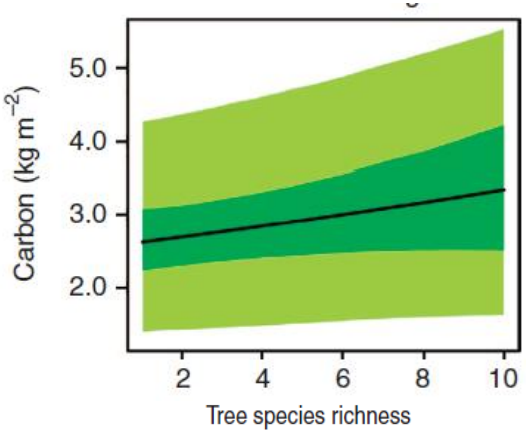


Species identity ~
0-100% coniferous basal area

Consistent but weak response of soil C to tree species diversity across Europe



Dawud et al. (2017), Functional Ecology



Gamfeldt et al. (2013, Swedish NFI)

Ecosystems (2016) 19: 645–660
DOI: 10.1007/s10021-016-9958-1

ECOSYSTEMS

Species diversity and identity effects in Polish plots – vertical patterns in SOC

Is Tree Species Diversity or Species Identity the More Important Driver of Soil Carbon Stocks, C/N Ratio, and pH?

Seid Muhie Dawud,[1]* Karsten Raulund-Rasmussen,[1] Timo Domisch,[2] Leena Finér,[2] Bogdan Jaroszewicz,[3] and Lars Vesterdal[1]

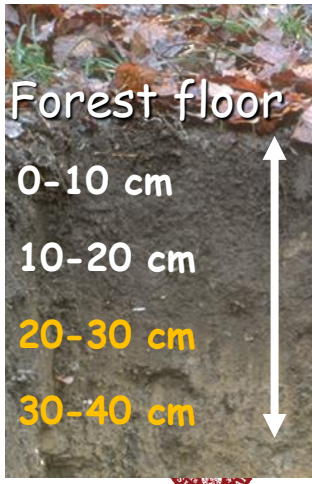

1 species - Norway spruce


2 species – oak, hornbeam


3 species – oak, hornbeam, birch

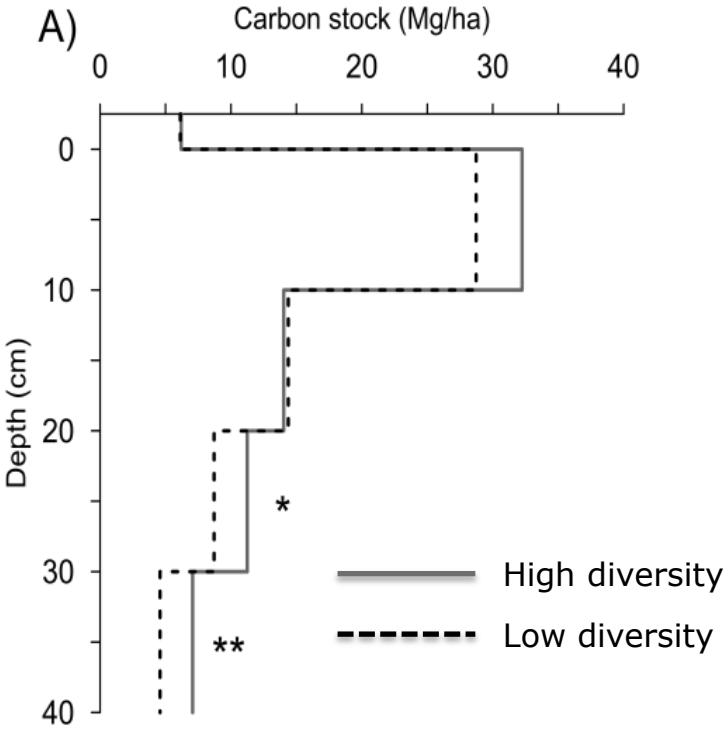

4 species - spruce, hornbeam, oak, birch


5 species - spruce, hornbeam, oak, pine, birch

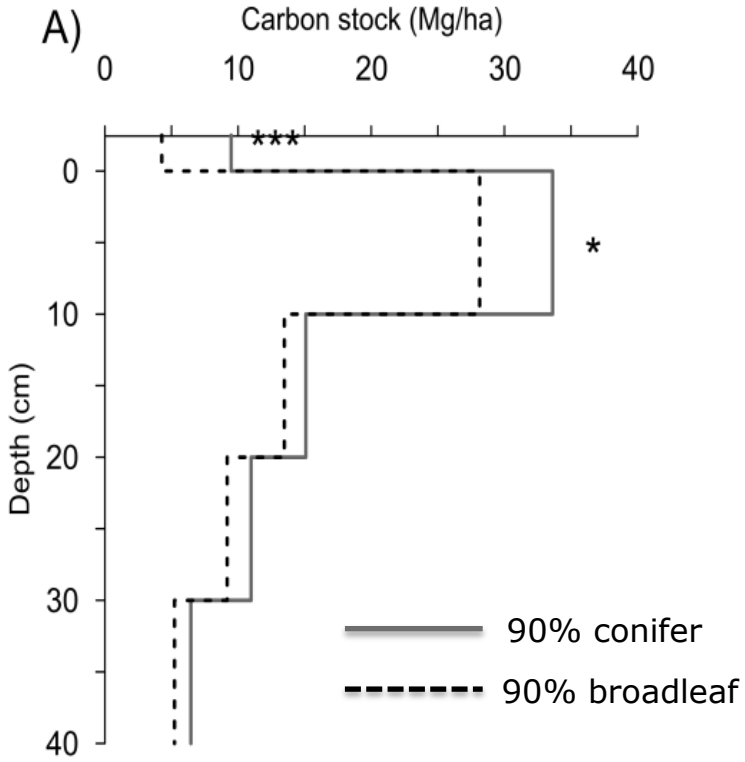


Vertically stratified effects of species diversity and identity in Poland

Tree species diversity

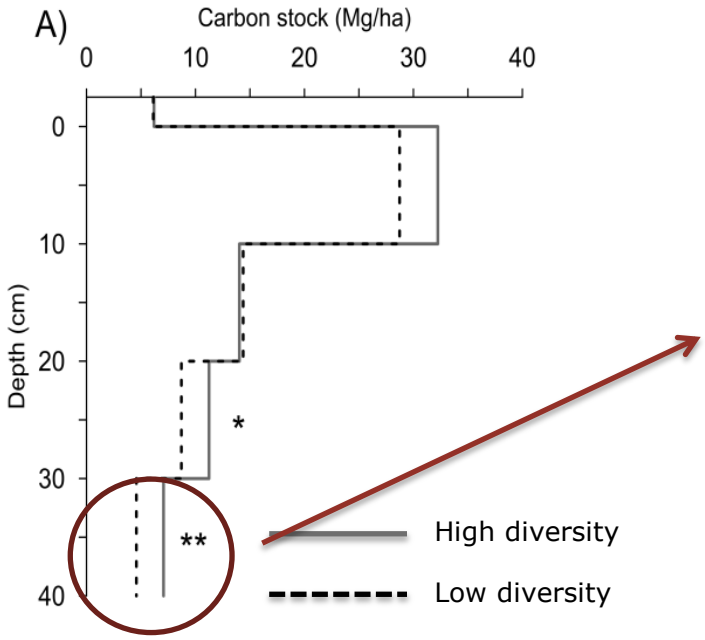


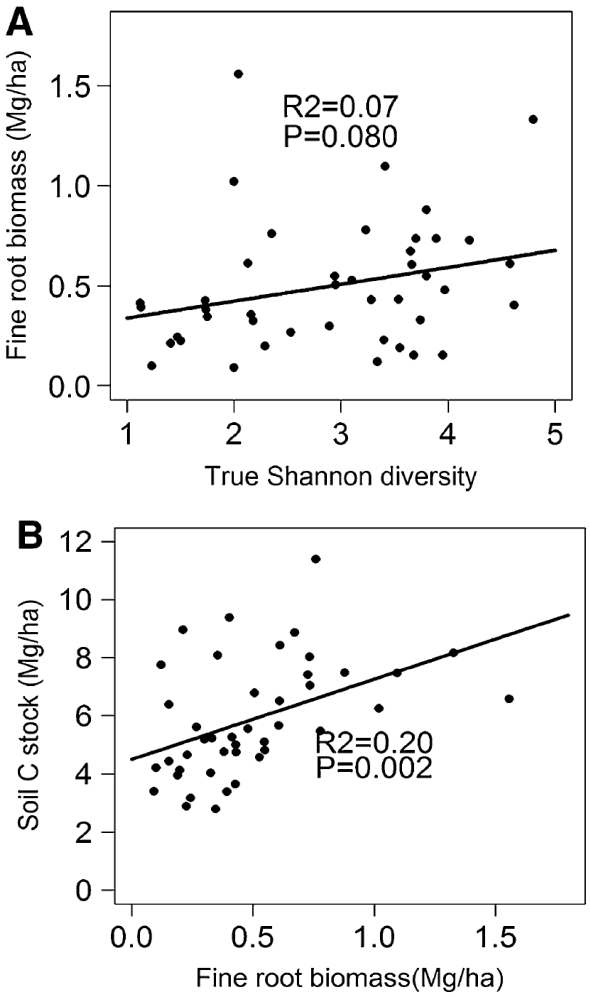
Tree species identity (group)



Dawud et al. (2016), Ecosystems

Which mechanism drives more subsoil C in diverse forests?

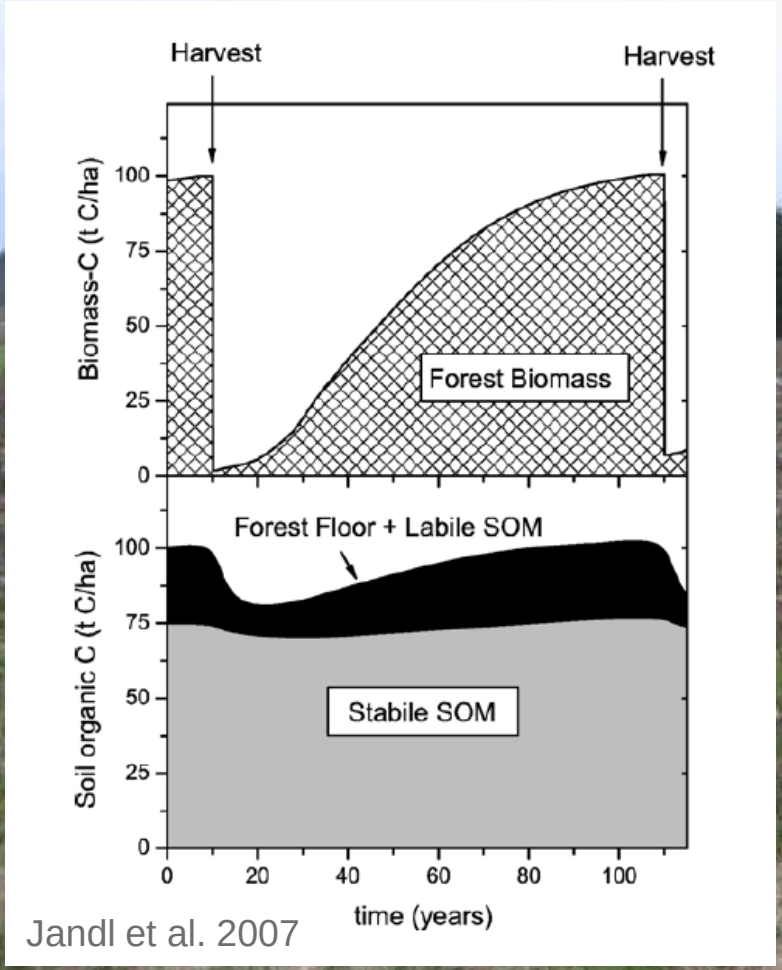




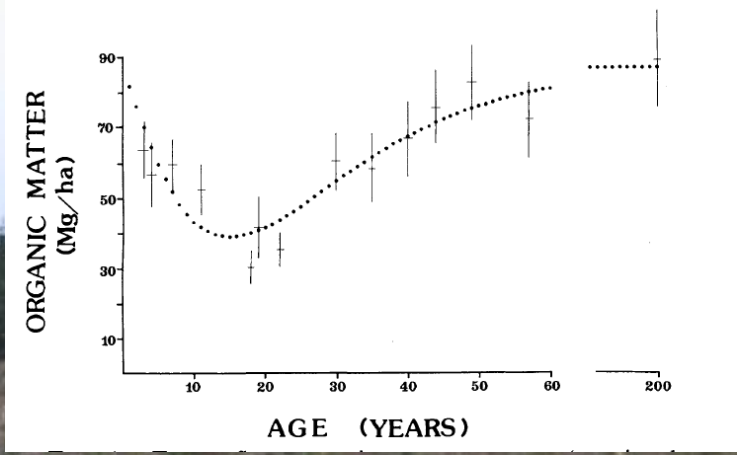
- Roots are important drivers of species diversity effect on soil C?

  Dawud et al. (2016), Ecosystems; Finér et al. (2017), For Ecol. Manage.

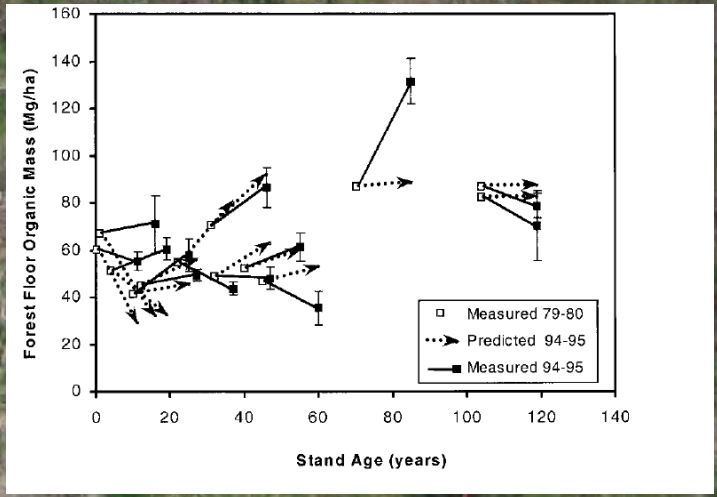
Effects of harvesting and reforestation



Jandl et al. 2007



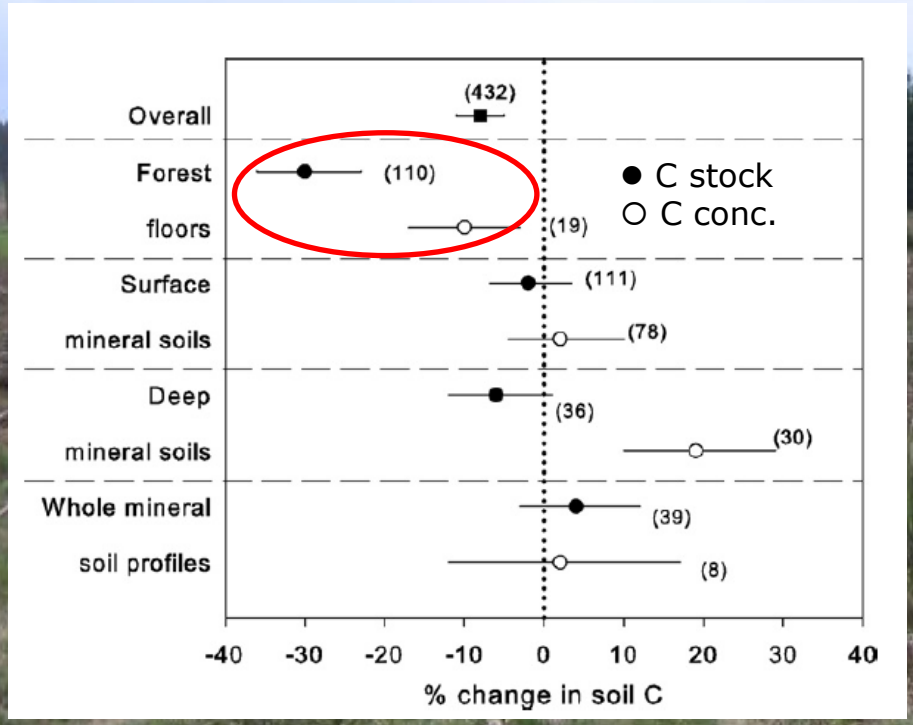
Covington, 1981



Resampling by Yanai et al. 2003

Soil C stocks are usually restored within a new rotation

Harvesting effects – meta-analysis



Nave et al. (2010)

- Overall loss of C: 8%
- Forest floors more likely to lose C than mineral soils (ns)
- Losses not permanent

Trend 1:
More biomass for energy – cause for concern?

Whole-tree harvesting

Conventional stem-only

Stump harvesting
Photo: J.P. Skovsgaard

Forest Ecology and Management
Contents lists available at SciV
Forest Ecology and
journal homepage: www.elsevi
ELSEVIER
Preface
Environmental consequences of tree-stump harvesting

Forest Ecology and Management 371 (2016) 1–4
Contents lists available at ScienceDirect
Forest Ecology and Management
journal homepage: www.elsevier.com/locate/foreco
ELSEVIER
Editorial
Stump harvesting – impact on climate and environment ☆

- Loss of C in forest floor (12%), not in mineral soil
- Whole-tree harvesting has a more negative effect than stump removal alone
- The soil C stock regenerates within a rotation

Persson (2013), Persson (2016), Strömgren et al. (2013), Eliasson et al. (2013)

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Review

Influence of different tree-harvesting intensities on forest soil carbon stocks in boreal and northern temperate forest ecosystems

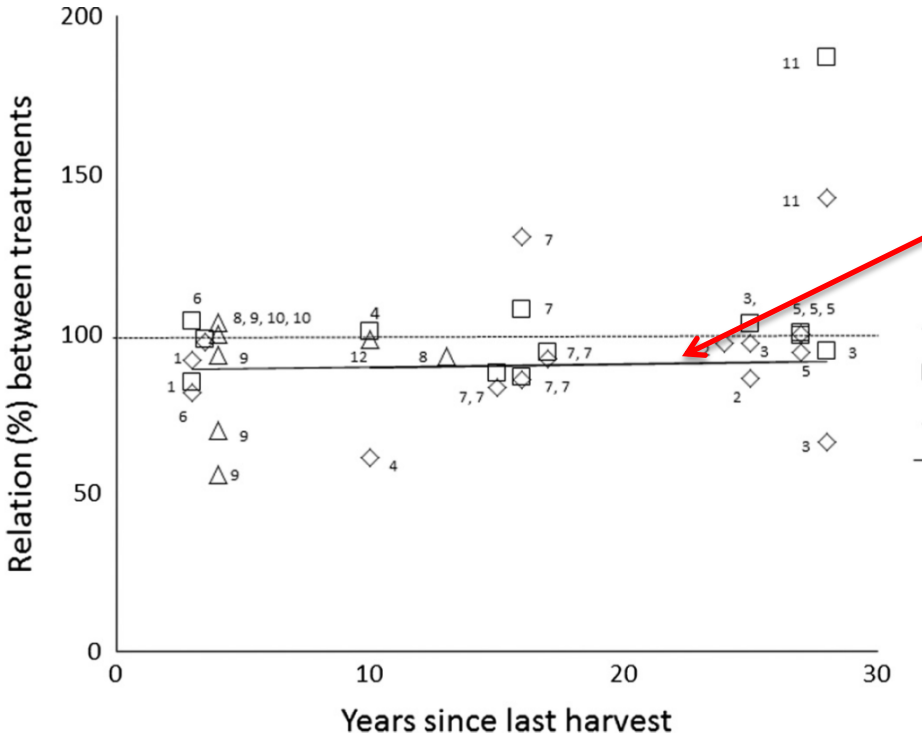
Nicholas Clarke [a,*], Per Gundersen [b], Ulrika Jönsson-Belyazid [c], O. Janne Kjønaas [a], Tryggve Persson [d], Bjarni D. Sigurdsson [e], Inge Stupak [b], Lars Vesterdal [b]

norden
Nordic Forest Research (SNS)

CAR-ES

WTH>SOH

SOH>WTH

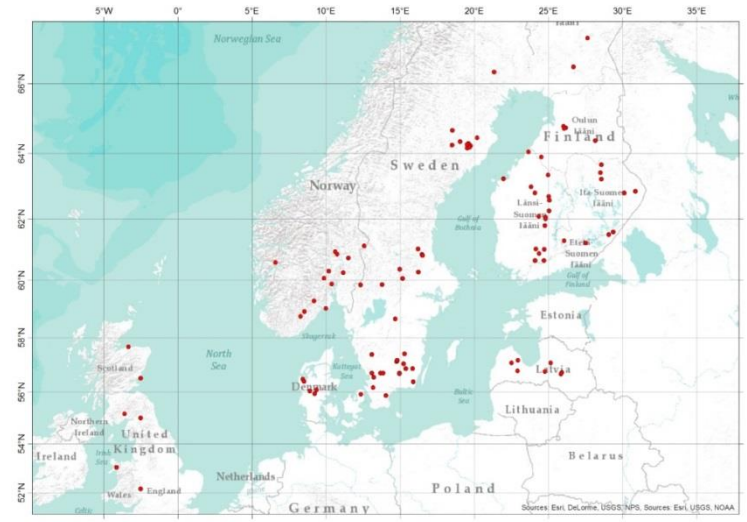


Forest floor:
WTH/SOH ~90% (SD 16%),

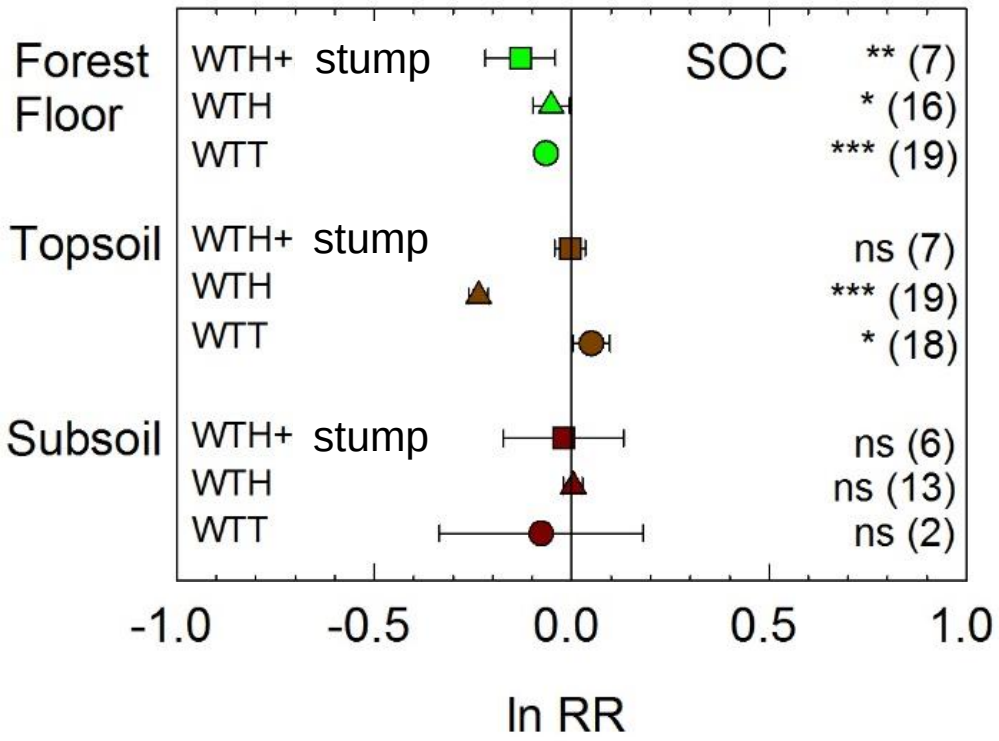
- Whole-tree/stem harvest, FF
- Whole-tree/stem harvest, min. soil
- WT /SO thin, FF
- Regression for WTH/SOH, FF

- Increased biomass harvesting may lead to loss of SOC – but large variation!
- C loss may be compensated through targeted management

Nordic meta-analysis of whole-tree harvesting effects



Study sites. Map: Sigmundur H. Brink, AUI



- Intensified harvesting reduces carbon stocks, also in mineral soil
- WTH with stump harvesting results in largest FF C loss
- WTH alone: largest mineral soil C loss

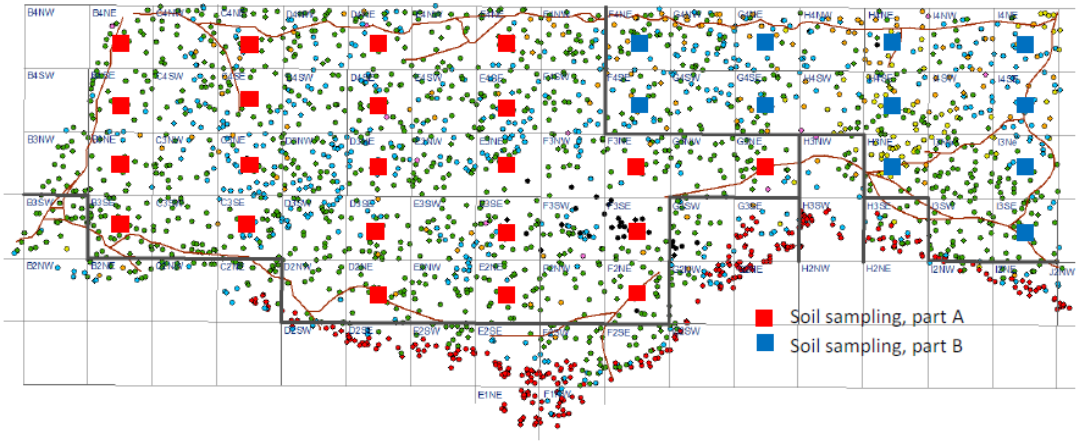
CAR-ES (Clarke et al. in prep.)

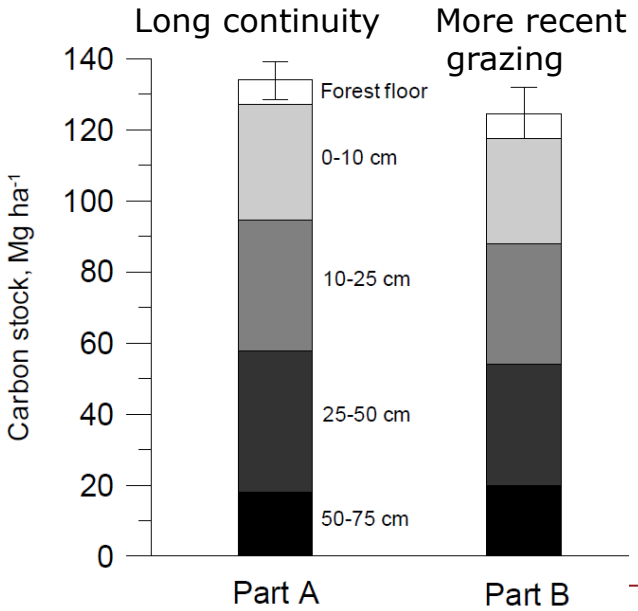
norden
Nordic Forest Research (SNS)

Trend 2: Conservation of forests: Combine aims to conserve habitat for biodiversity and C stocks?

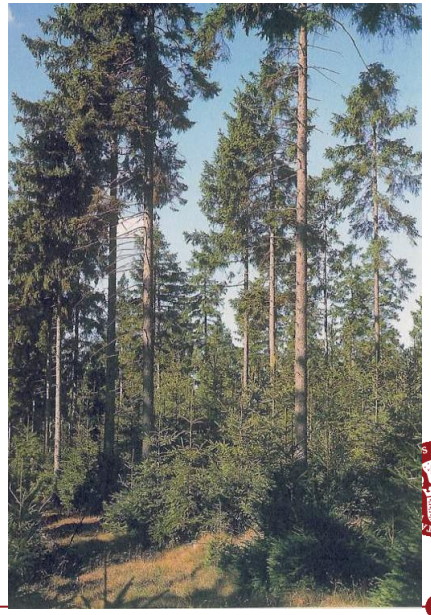
Suserup Forest Reserve, Denmark
Photo: Morten Christensen

- More forest floor C in N. Am. old-growth stands, but no difference in mineral soil (Hoover et al. 2012)
- More forest floor C in German unmanaged forests (Grüneberg et al. 2013)
- In *Suserup Forest Reserve* (DK) the soil stores 134 t C/ha vs. ~100 t C/ha in managed beech forests





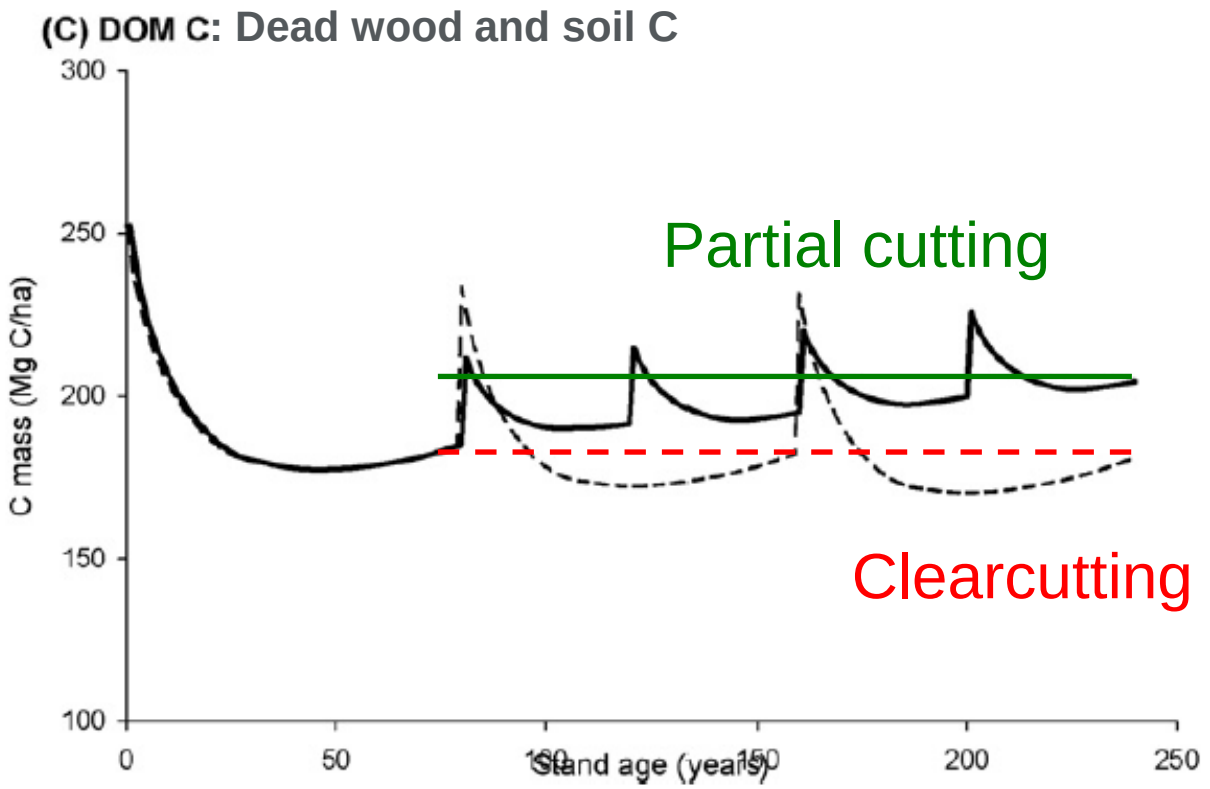
Conversion from clearcutting system to continuous cover forestry



Change in silvicultural system: Continuous cover forestry

Red spruce in Canada, modelling
(Taylor et al., 2008)

Partial cutting
vs.
clearcutting



- Limited simulated effect of CCF on litter C sequestration:
  0.02 ➡ 0.05 Mg C/ha/yr (Lundmark et al. 2016)

- In 130 inventory plots in Germany no legacy effect of past and present management on SOC pools (Wäldchen et al. 2013)

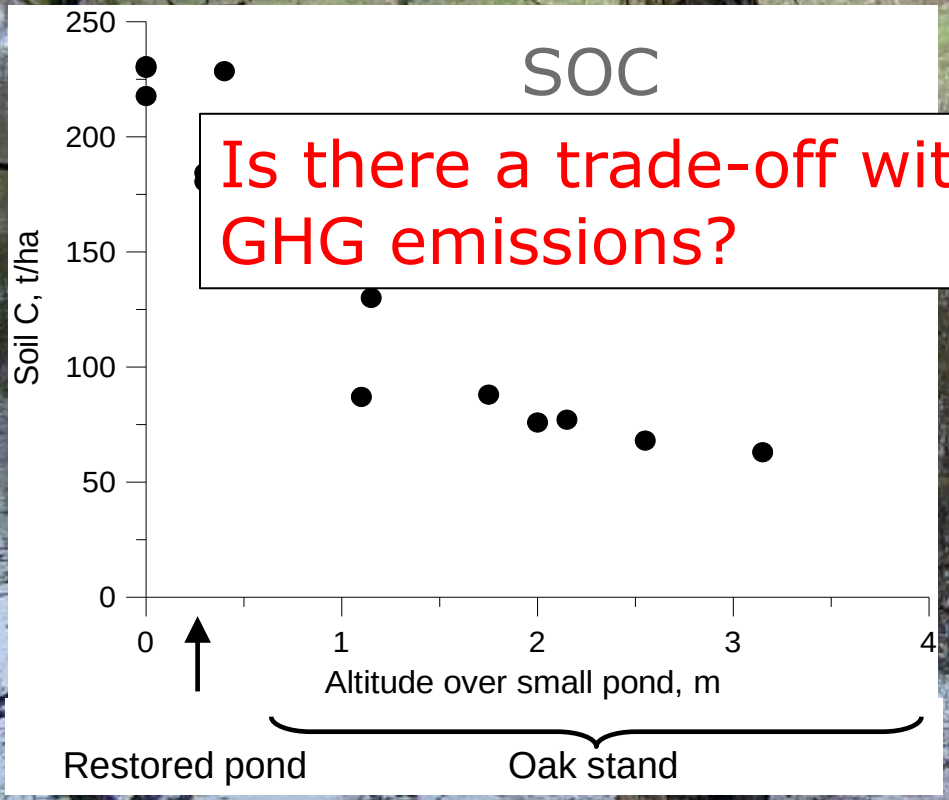
Restoration of drained wetlands in forests - implications for soil carbon and greenhouse gases?

Peat soil, ~500 t C/ha
(Well-drained soil ~110 t C/ha)

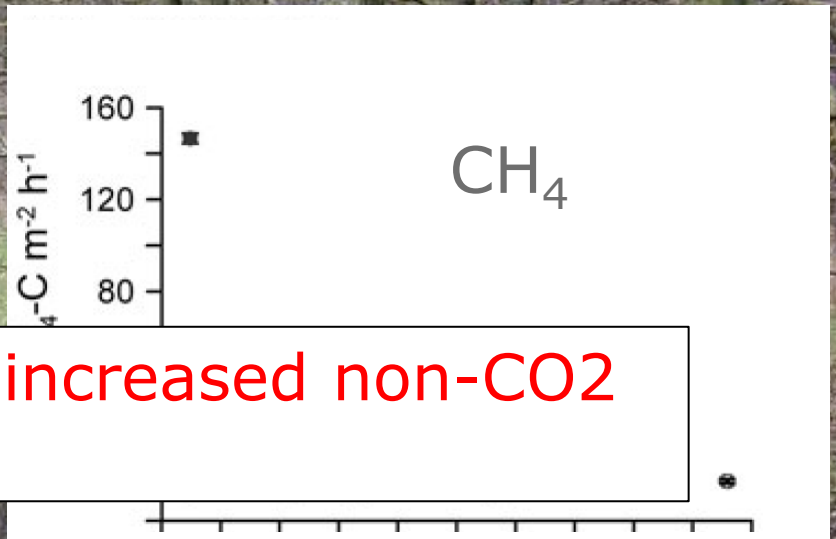
Photo: http://www.soil-net.com/album/Soils_Rocks/slides/Peat%20soil%20profile%2006.html

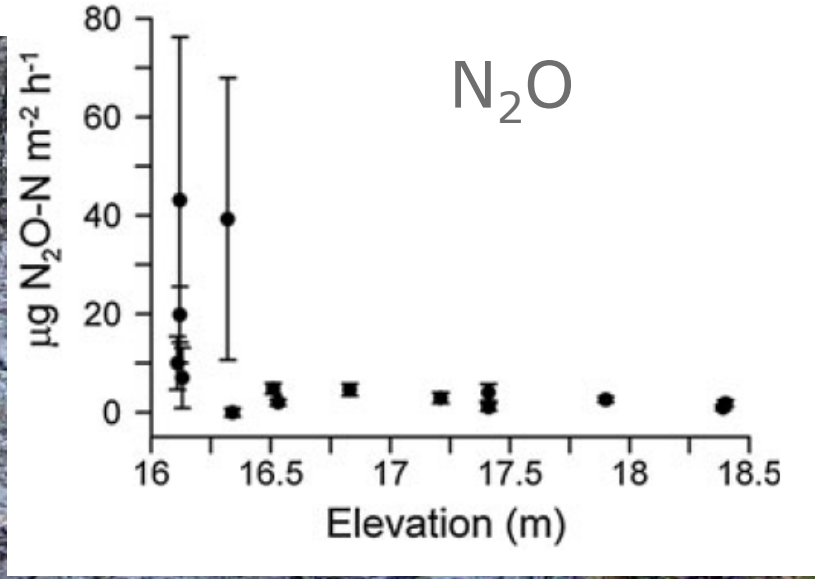
Drainage regime and soil carbon stock

Carbon stocks and GHG fluxes along topographic transect



Is there a trade-off with increased non-CO2 GHG emissions?



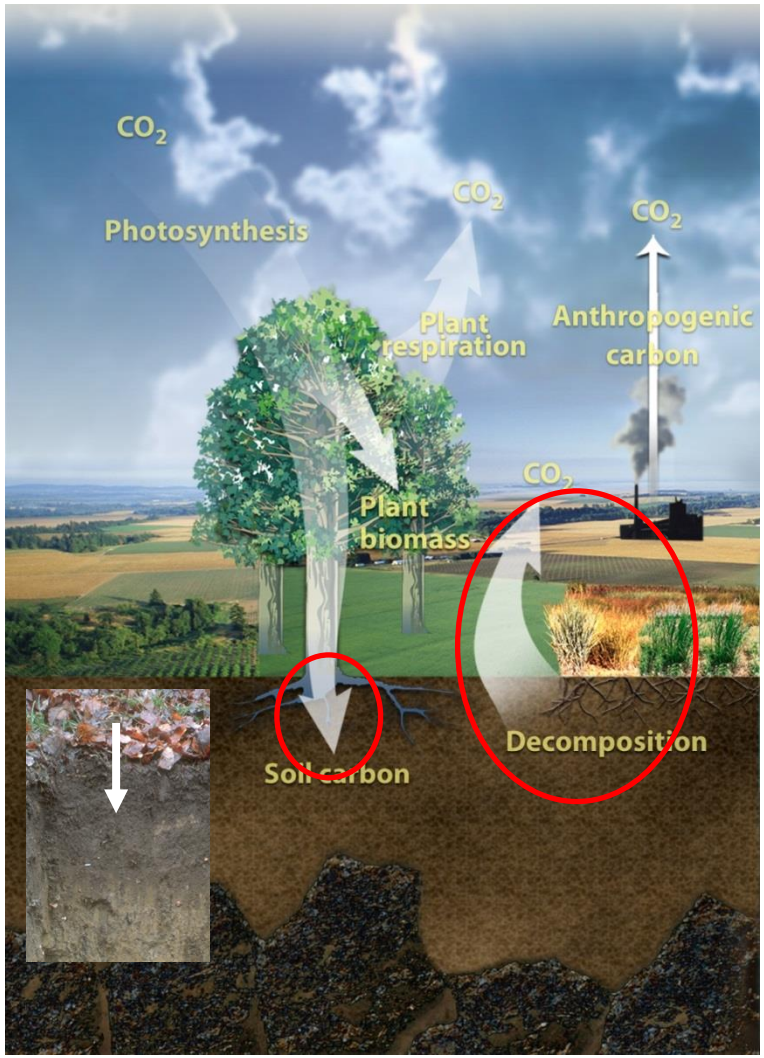


Christiansen et al. (2012)
Vestskoven, Denmark

What do we know?

- Targeted tree species selection can change SOC stocks in forest floor by 2-5 fold and by 40-50% in mineral soil
- Tree species change C distribution within soil profile – *in some sites?*
- Tree species diversity is a weaker driver than species identity
- Harvesting and increased harvesting intensity temporarily decreases SOC, but mainly forest floor C
- Limited legacy effect of past and present management system on SOC – *but lack of dedicated experiments*
- Drainage regime seems most important factor for SOC stock
- Beware of trade-off with non-CO_2 GHGs

Where to go?



- From "bulk C" studies to characterization of *forms of C* and *key processes*
- *Data needed* to validate process-based models
- Move from retrospective designs to *dedicated experiments*
- Potential of *new statistical analyses* for evaluating ICP Forests soils data
- Include N_2O and CH_4 for *concerted climate change mitigation* effect
- Evaluate SOC sequestration along with other ecosystem services: *synergies and trade-offs*?

http://genomicscience.energy.gov/carboncycle/

Thank you!

Christianssæde Skov, Lolland
Beech forest, Luvisol

Nørlund Plantage, Jutland
Norway spruce forest, Podzol