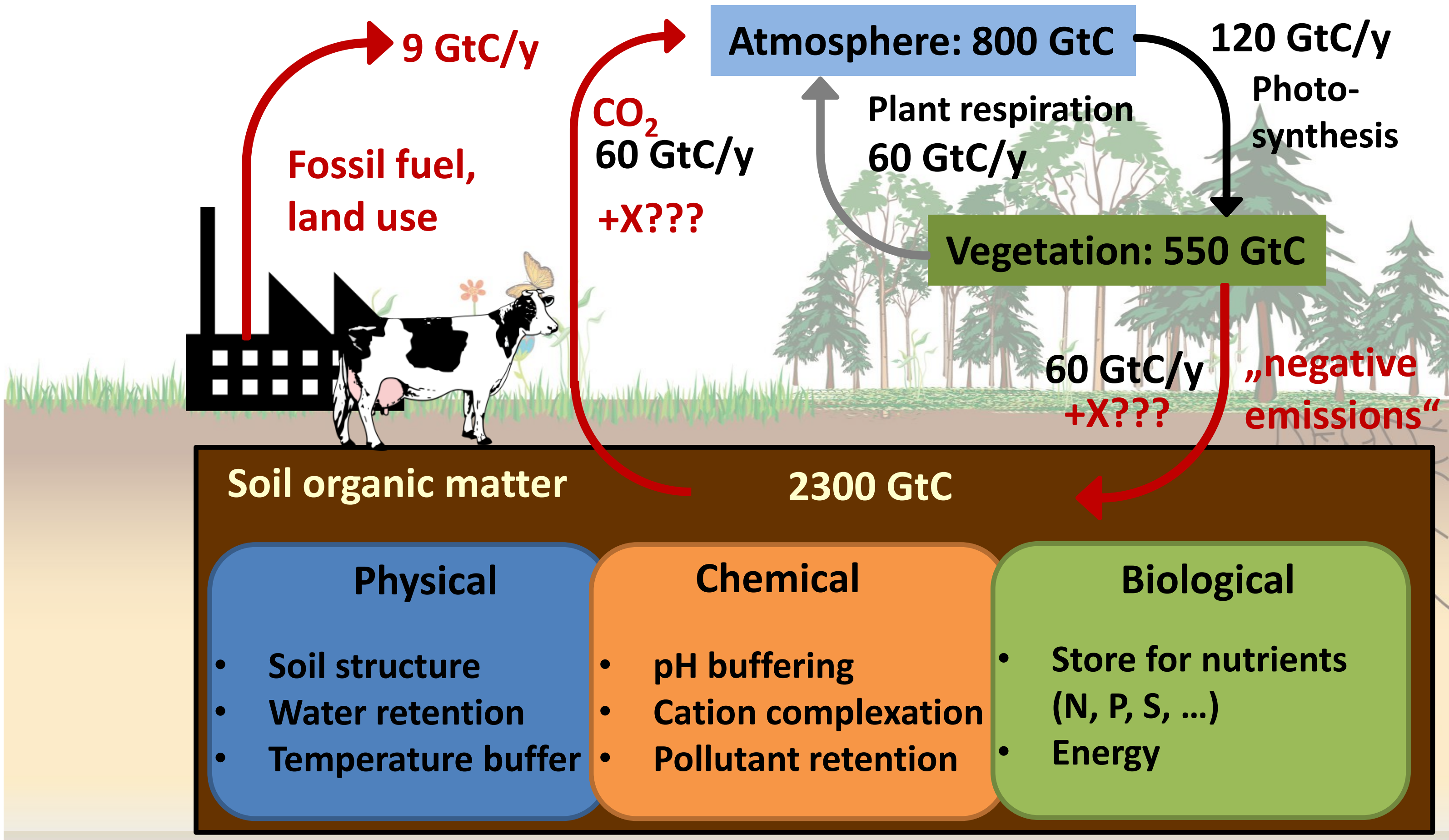
Factors controlling radiocarbon contents in forest soils

Marion Schrumpf, Ingo Schöning, Ernst-Detlef Schulze, Susan Trumbore

Max Planck Institute
for Biogeochemistry

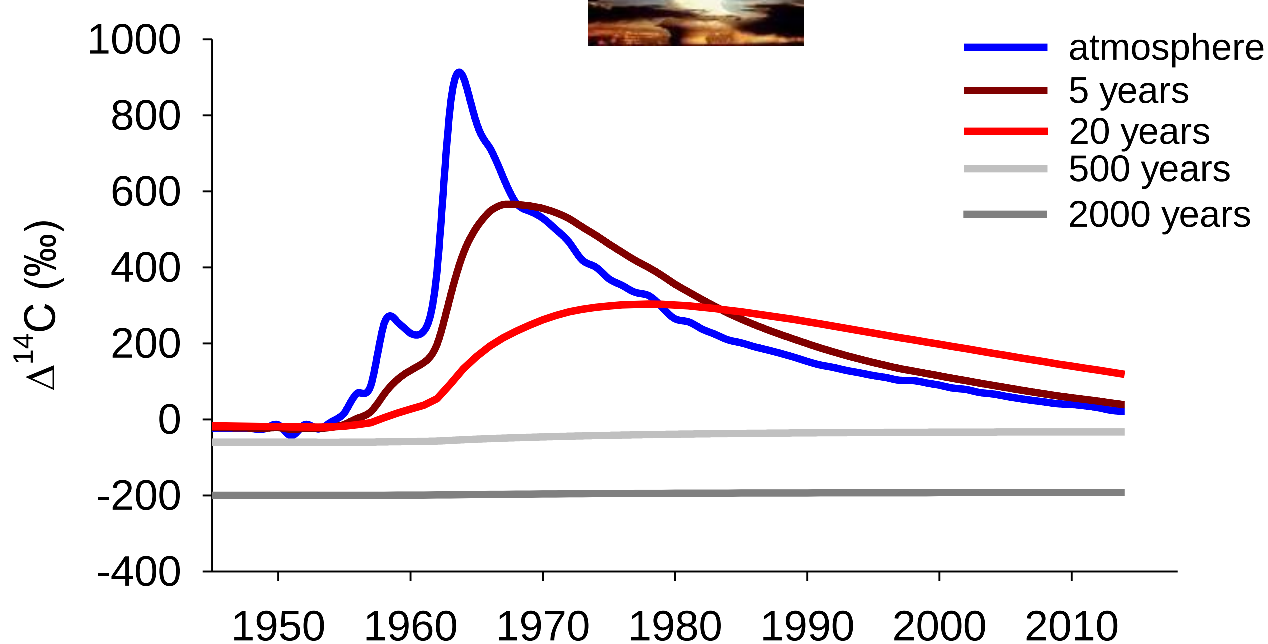
Carbon cycling



What makes soil organic matter persistent and how sensitive is it to global environmental and land use changes?

Radiocarbon (^{14}C) as tracer for soil C dynamics

- Radioactive isotope; half-life: 5730 years; cosmogenic radiation
- Radiocarbon dating: 300 to 50,000 years
- Peak of ^{14}C in atmospheric CO_2 in 1960s: indicator for C with fast turnover



Outline

1. Comparison of ^{14}C in soils of forests and grasslands: from roots to respired CO_2
2. Application of temporal changes in ^{14}C
3. Studying ^{14}C along environmental gradients

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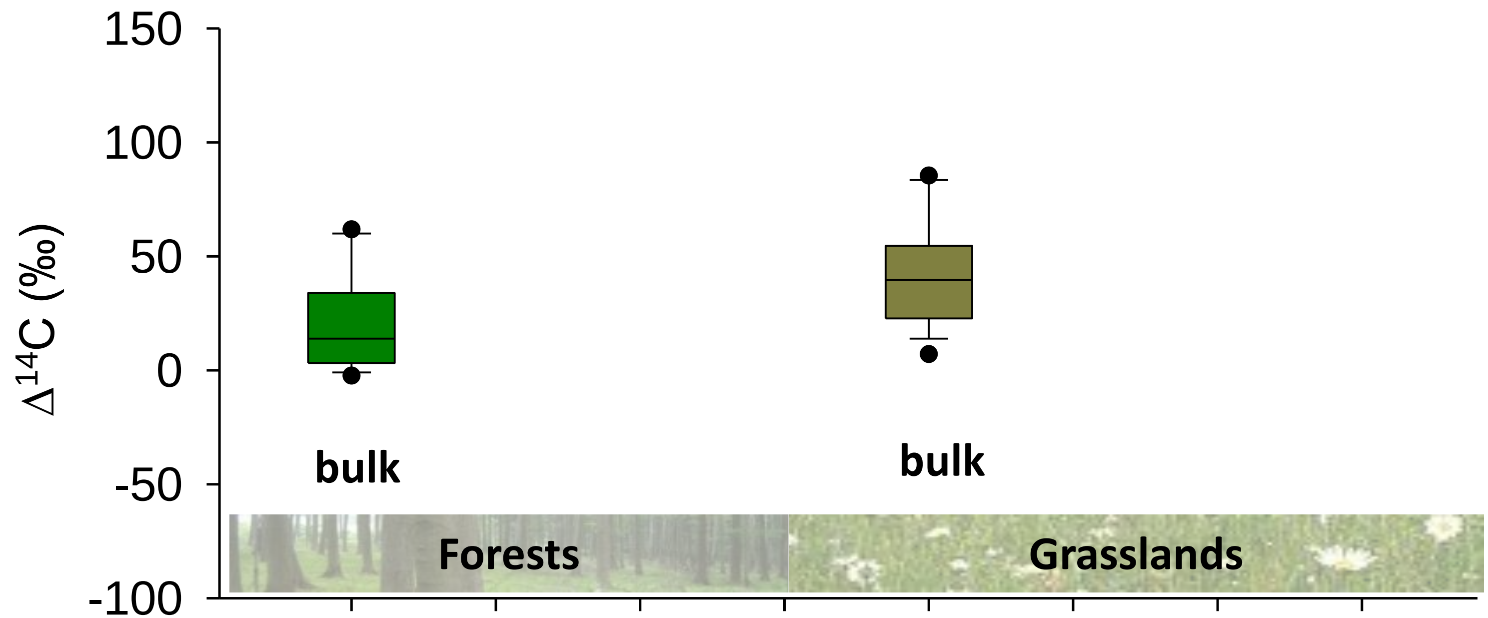
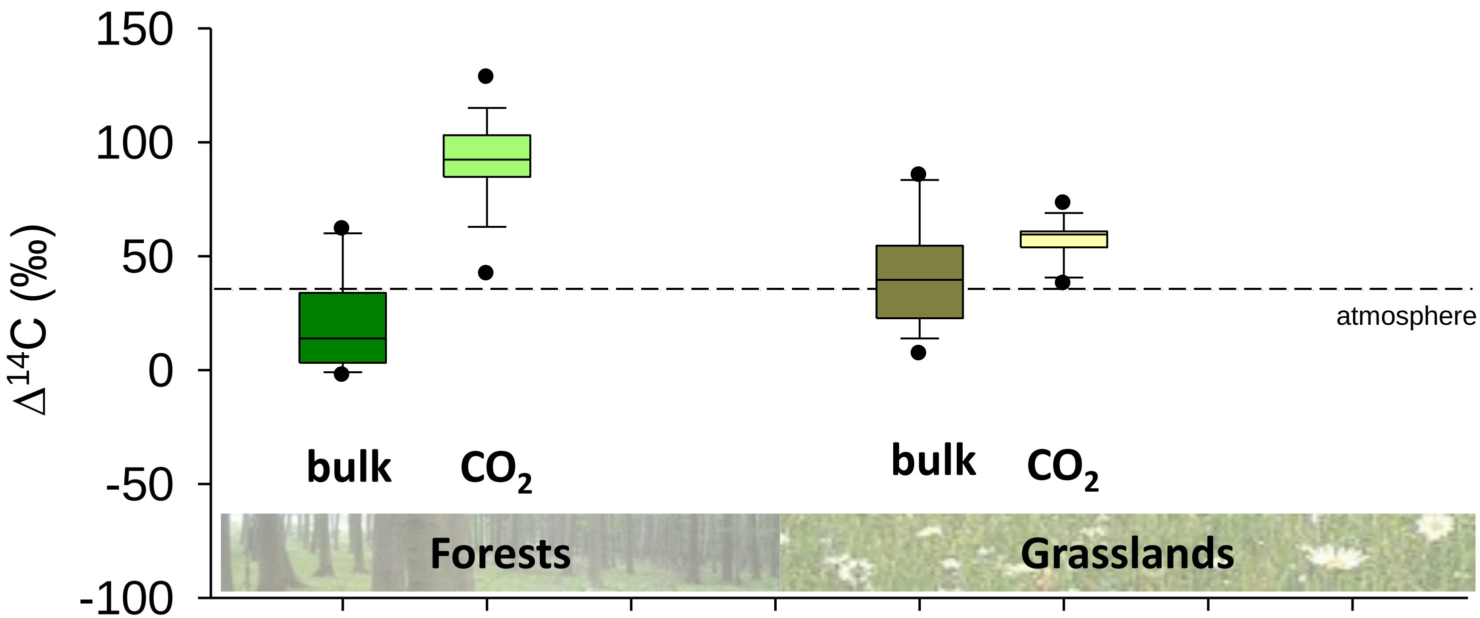
Forests and grasslands: ^{14}C in bulk soil, 0-10 cm



2011

topsoil (0-10 cm)
mixture of 14 points per plot
up 50 plots per land use and region

Forests and grasslands: ^{14}C in respired CO_2

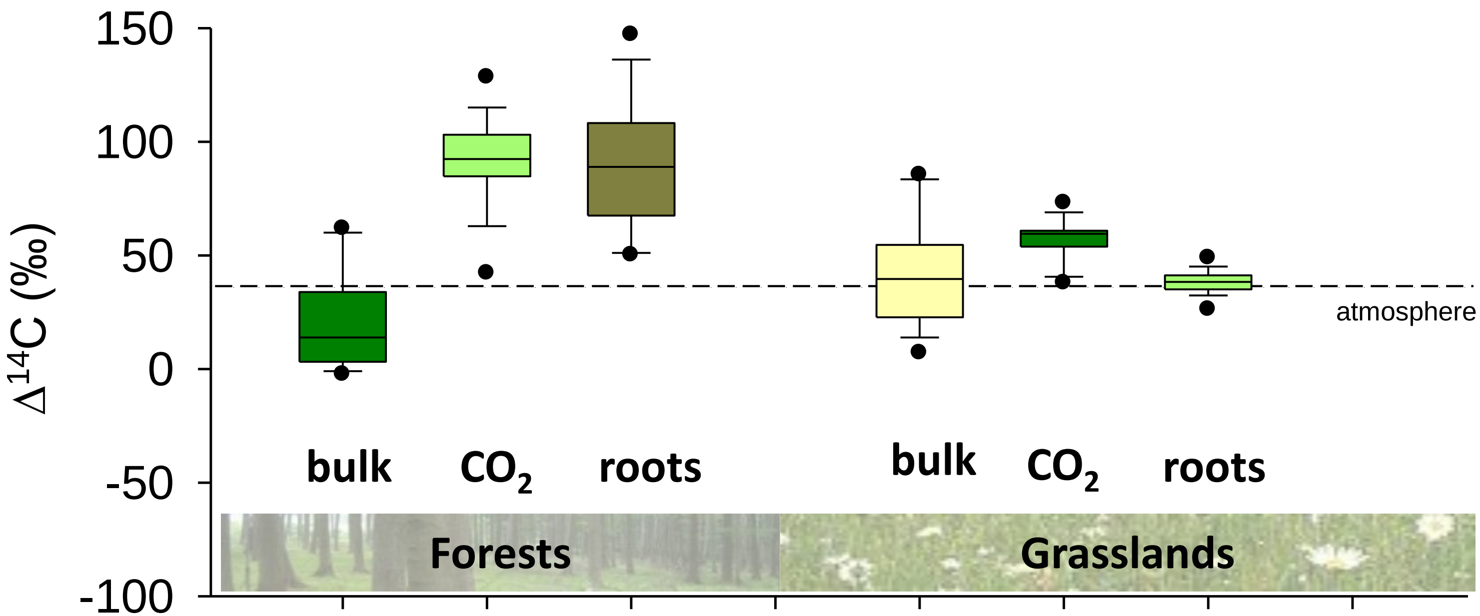


Soil incubation at
20°C and 60% WHC

Respired OC

- **younger than bulk OC**
- **older in forests than in grasslands**
  → slower turnover of fast pool
  in forests?

Forests and grasslands: ^{14}C in living roots



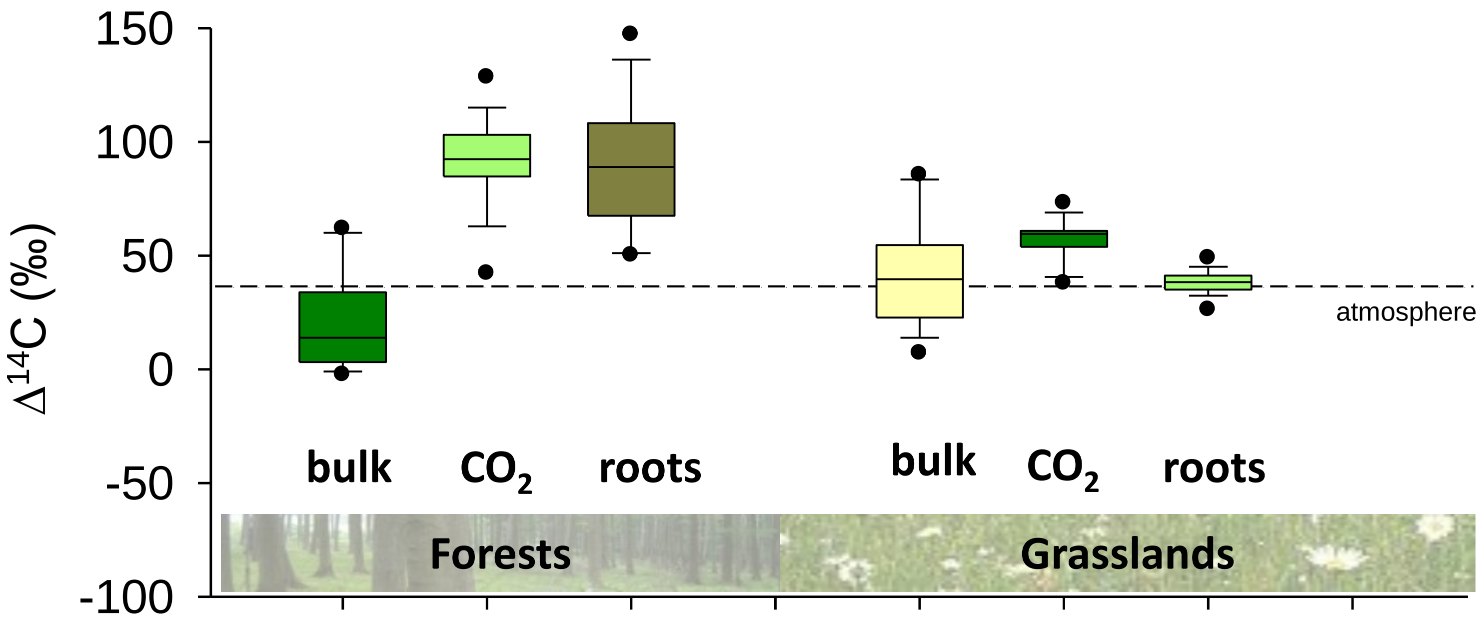
Living root biomass

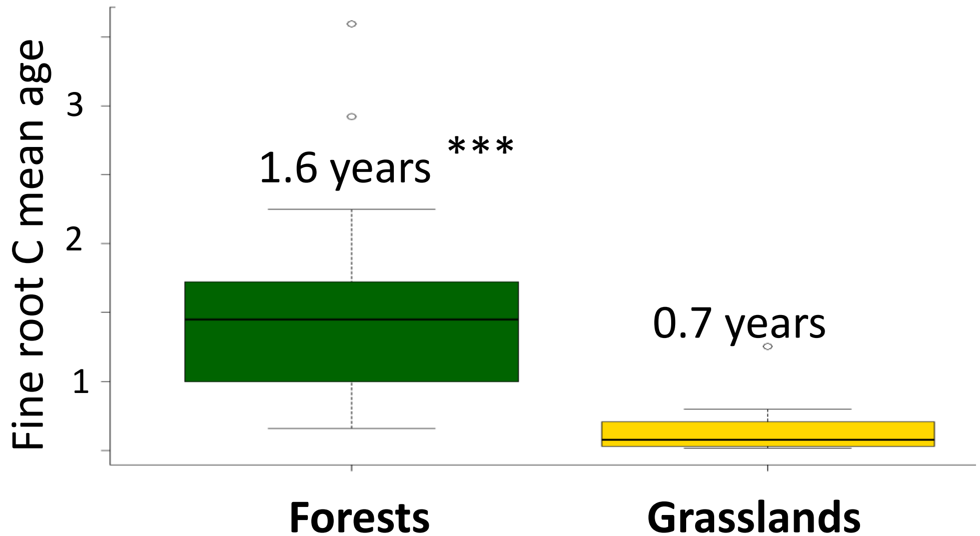
OC in living fine roots

- **Older fineroots in forests than in grasslands**
  → more longlived roots or usage of storage compunds in forests
- **Similar ^{14}C than in respired CO_2 in forest**
  → roots as source for fast soil OC?

Root data from Solly et al. (2013), Biogeosciences

Forests and grasslands: ^{14}C in living roots



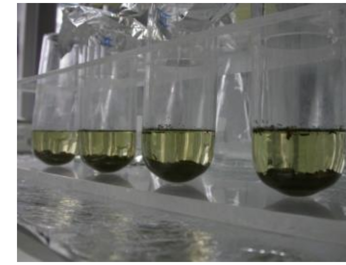


Max. 1 year old roots

Forests and grasslands: ^{14}C in density fractions

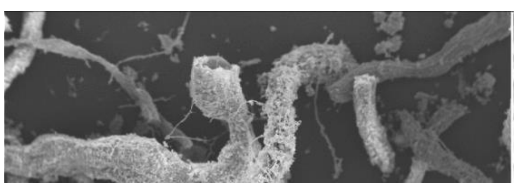
Bulk sample

Density fractionation (1.6 g cm^{-3})



Free light fraction (fLF)	Occluded light fraction (oLF)	Heavy fraction (HF)
unprotected OC	OC inside aggregates ?	mineral-associated OC

⟵ Chemical composition, CN ratio, $\delta^{13}C$, $\Delta^{14}C$ age ⟶



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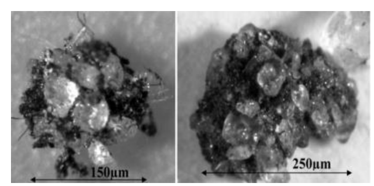
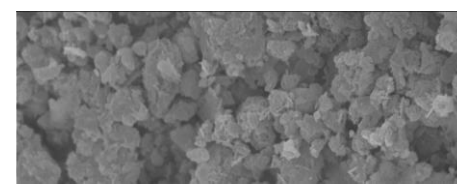


Sarkhot *et al* 2006 SSSAJ



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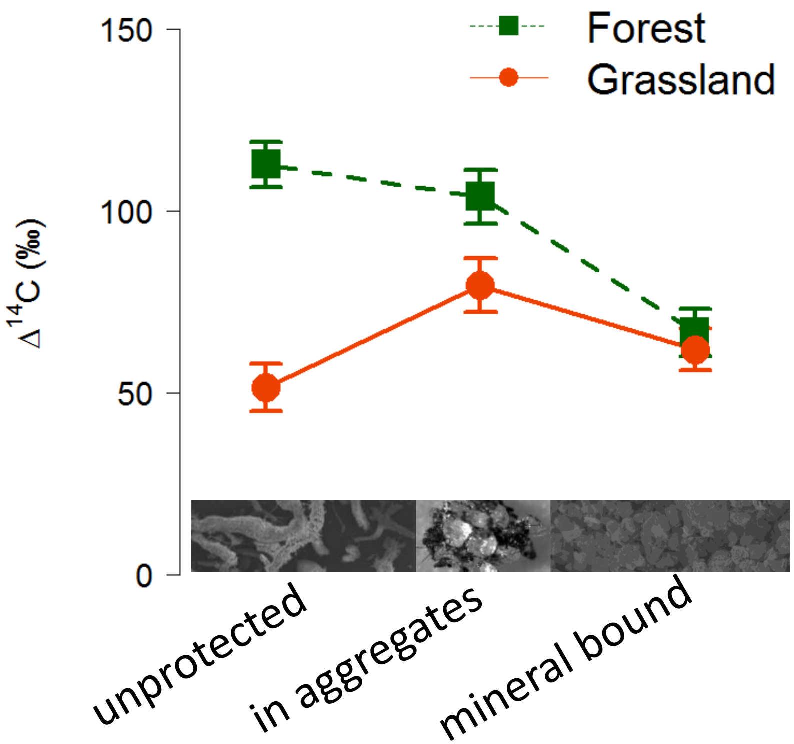
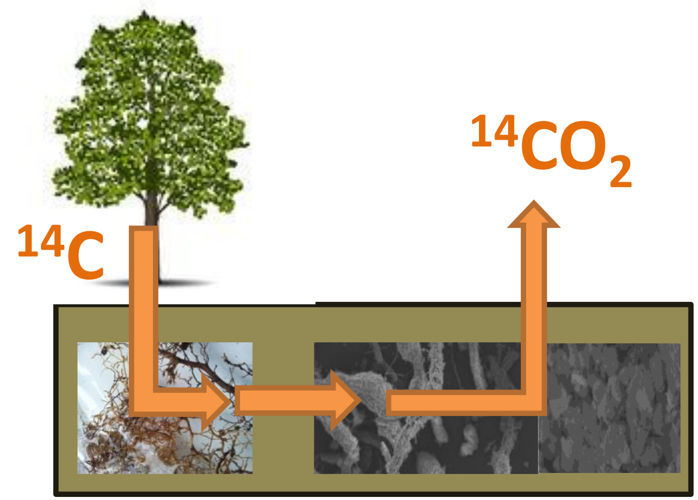
Forests and grasslands: ^{14}C in density fractions

Herold et al. (2014), Biogeochemistry





- ^{14}C from plant litter input can be followed through soil to respired CO_2

→ lag time until OC is entering the soil has to be considered

- decomposition in forests really slower than in grasslands?

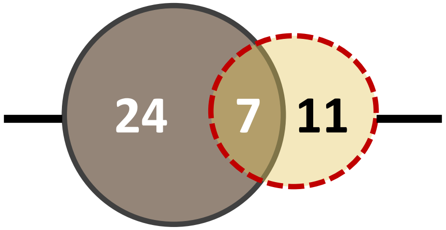
Forests and grasslands: root decomposition

Solly et al. (2014)

> 5 000 litter bags at 300 sites

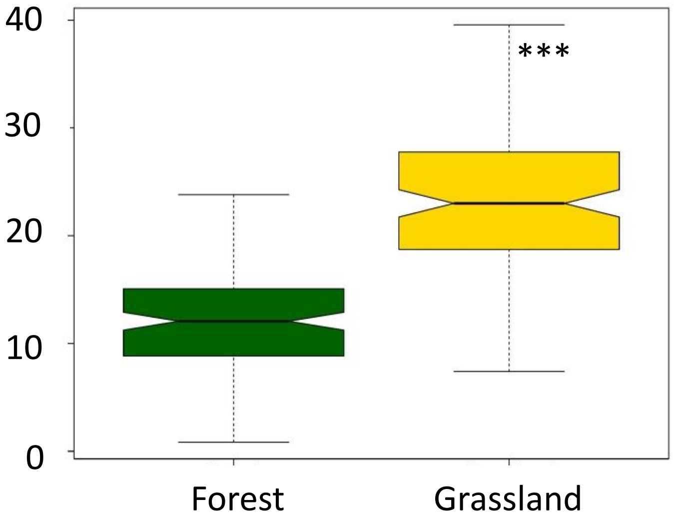
Abiotic conditions — **Species composition**

Soil moisture,
Soil temperature



Lignin : N
roots

Mass loss (%) after 1 year



Root litter decomposition

- Slower in forests than in grasslands
  → **slower soil OC turnover in forests**
- Driven by climate and litter quality

biodiversity exploratories
functional biodiversity research

Outline

1. Comparison of ^{14}C in soils of forests and grasslands: from roots to respired CO_2
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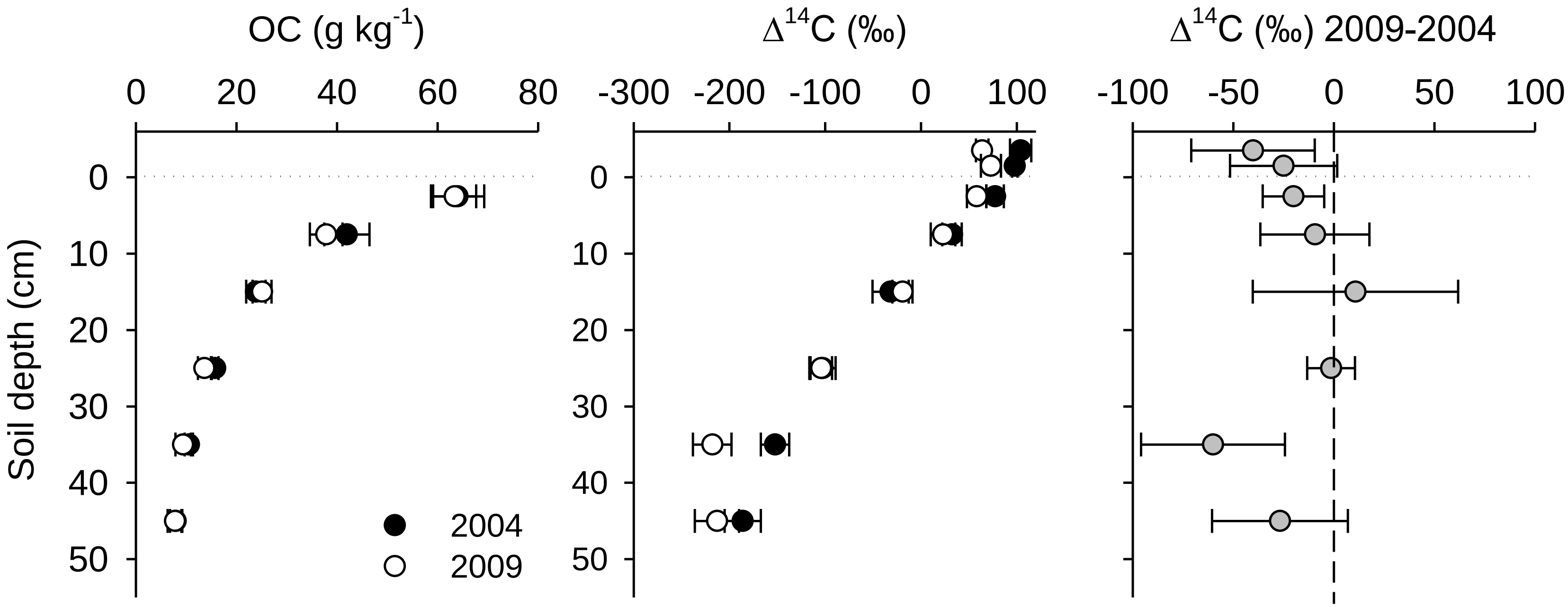
3. Studying ^{14}C along environmental gradients

Repeated soil carbon inventories

Hainich National Park:

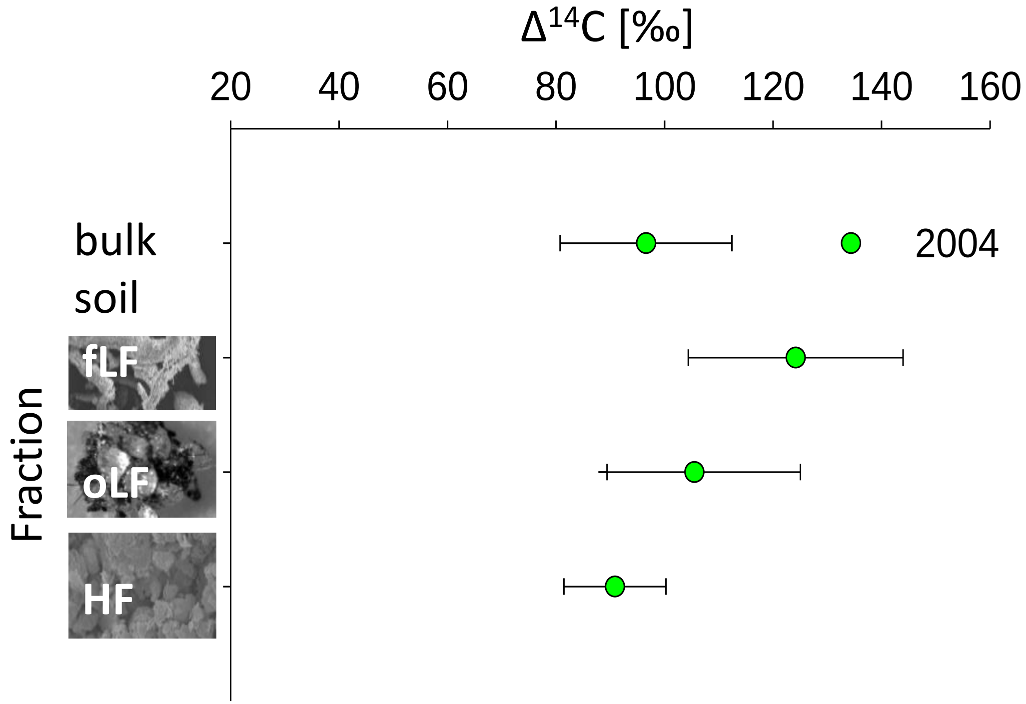


- Decline in ^{14}C concentrations not detectable below 0-5 cm
  → less contribution of active carbon in subsoils
- We do not know why we find the significant change in 30-40 cm depth…

Repeated soil carbon inventories

0-5 cm

OC flux ca. **100 g C m^{-2} yr^{-1}**



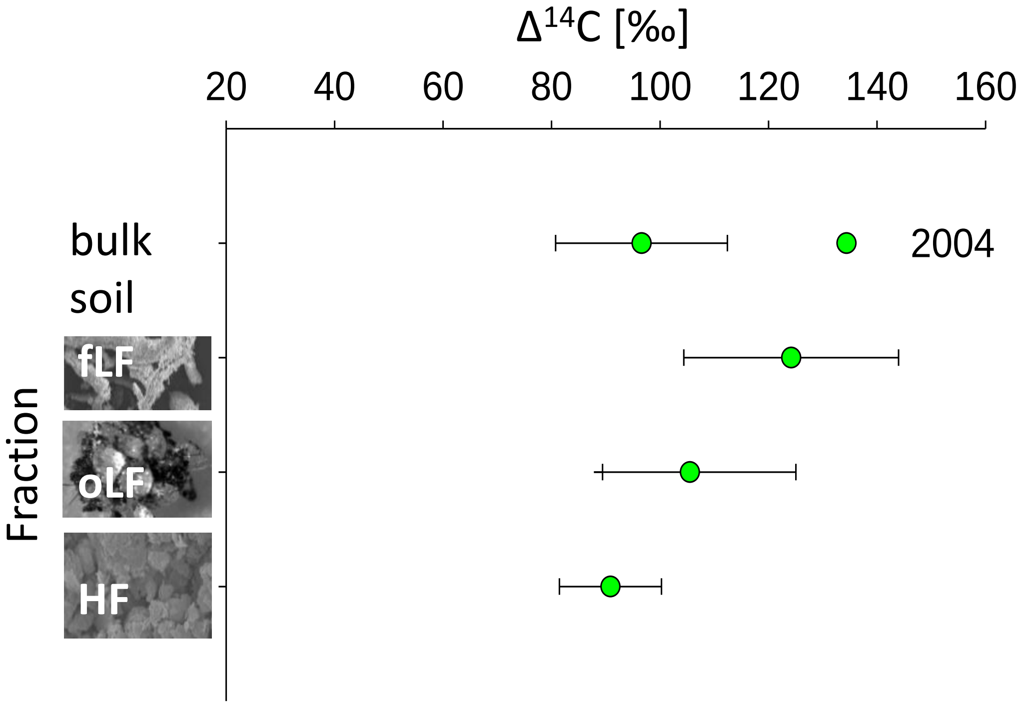
Data: Schrumpf et al. 2015

Repeated soil carbon inventories

0-5 cm

OC flux ca. **100 g C m^{-2} yr^{-1}**

lag time 8 yr



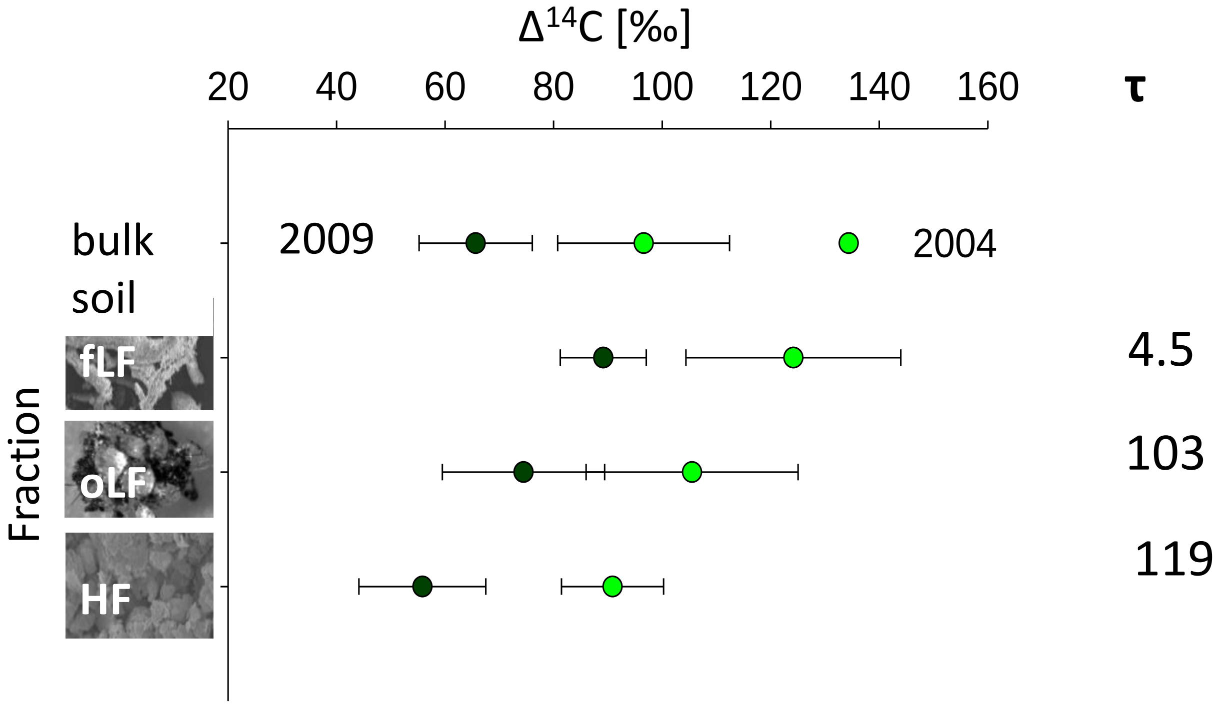
τ	g C m^{-2} yr^{-1}
4.5	39
103	1
119	17
	57

- Fluxes are too small: an active soil carbon pool is still missing

Data: Schrumpf et al. 2015

Repeated soil carbon inventories

OC flux ca. **100 g C m⁻² yr-¹ (τ: 24 yr)**



- Given the estimated **τ,** only fLF should respond, but all fractions did:
  → also oLF and HF have a portion of active carbon
  → both are still composed of mixtures between fast and slow cycling OC

Repeated soil carbon inventories

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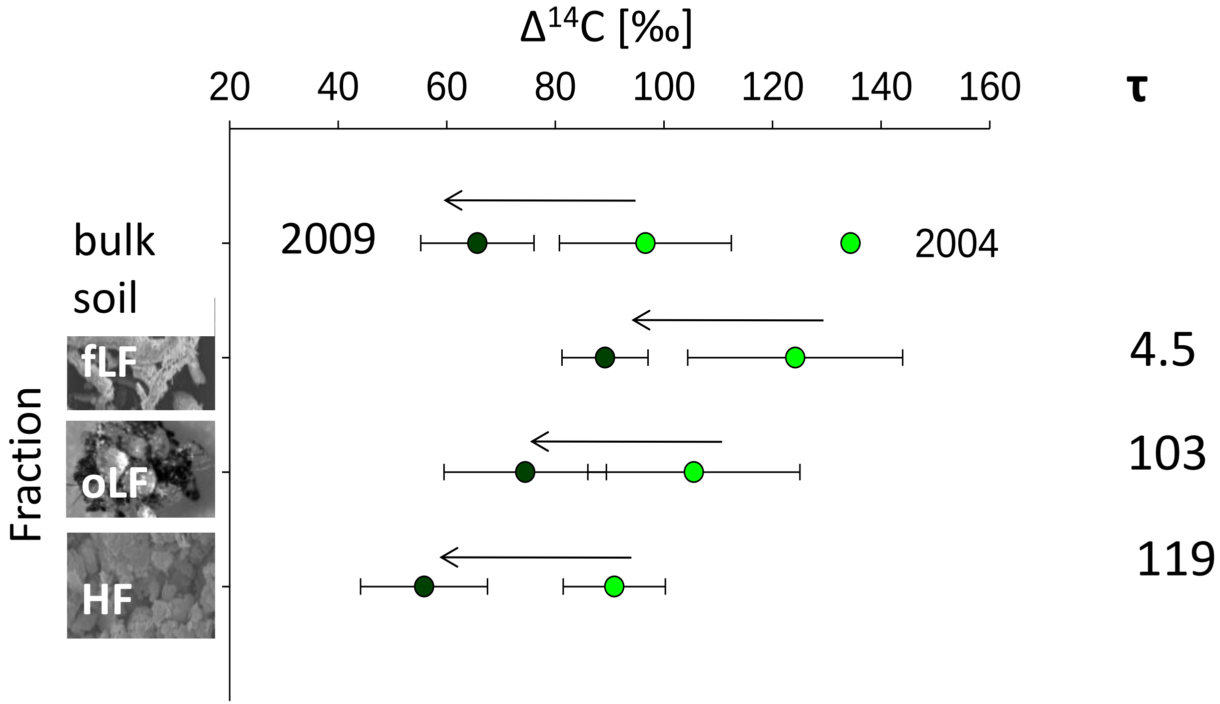

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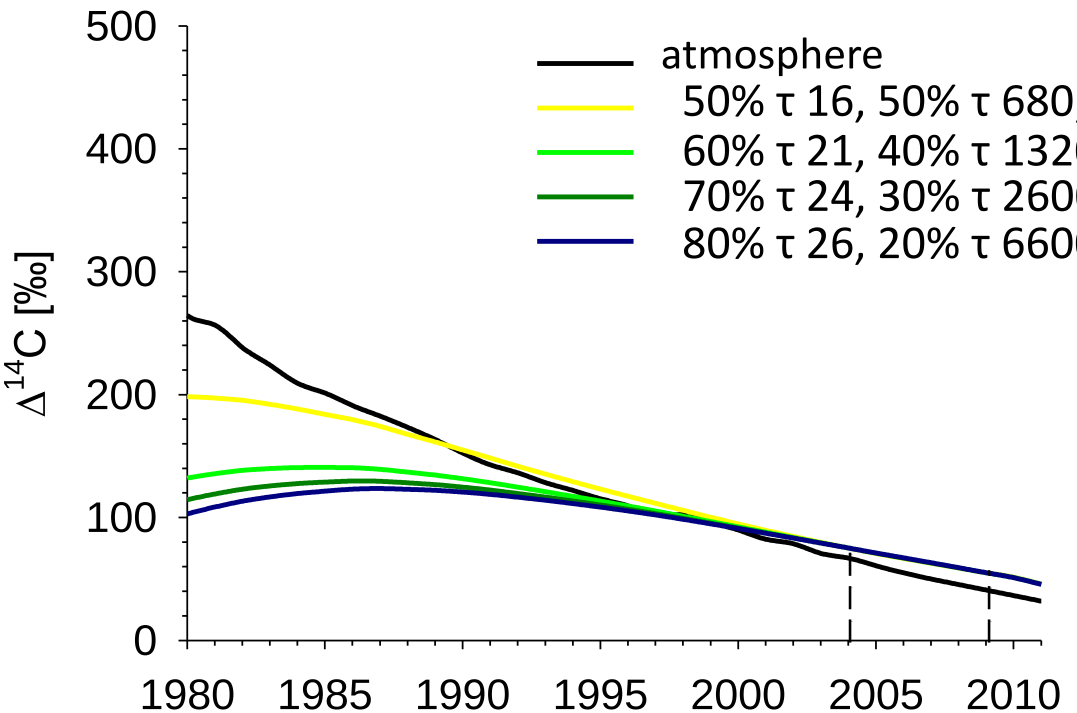
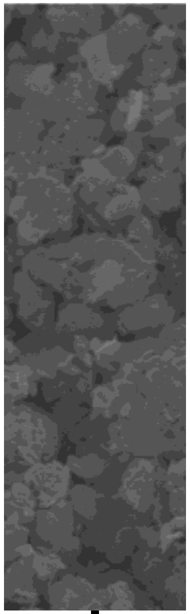


Schrumpf et al. 2015

- No unique solution: fast pool: 15-25 years turnover, 50-85% of total OC
- Not much difference between fluxes but: different response to change scenarios

  total flux: 98-102 g C m^{-2} yr^{-1}
- Temporal change in ^{14}C identifies active portions, but not the mechanisms

Chemical fractionation of soils



Dialysis to remove salts

Extraction in a mixture of 0.8 M NaF + 0.2 M NaOH

1

Total C, N and ^{14}C in freeze-dried extracts, FTIR

Total C, N and ^{14}C in residues

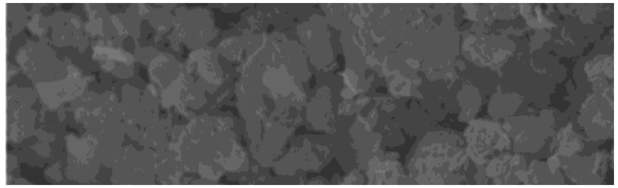
HF-OC, 1.6 g cm^{-3}

2

Oxidation of HF-OC in 50°C, 10% H_2O_2

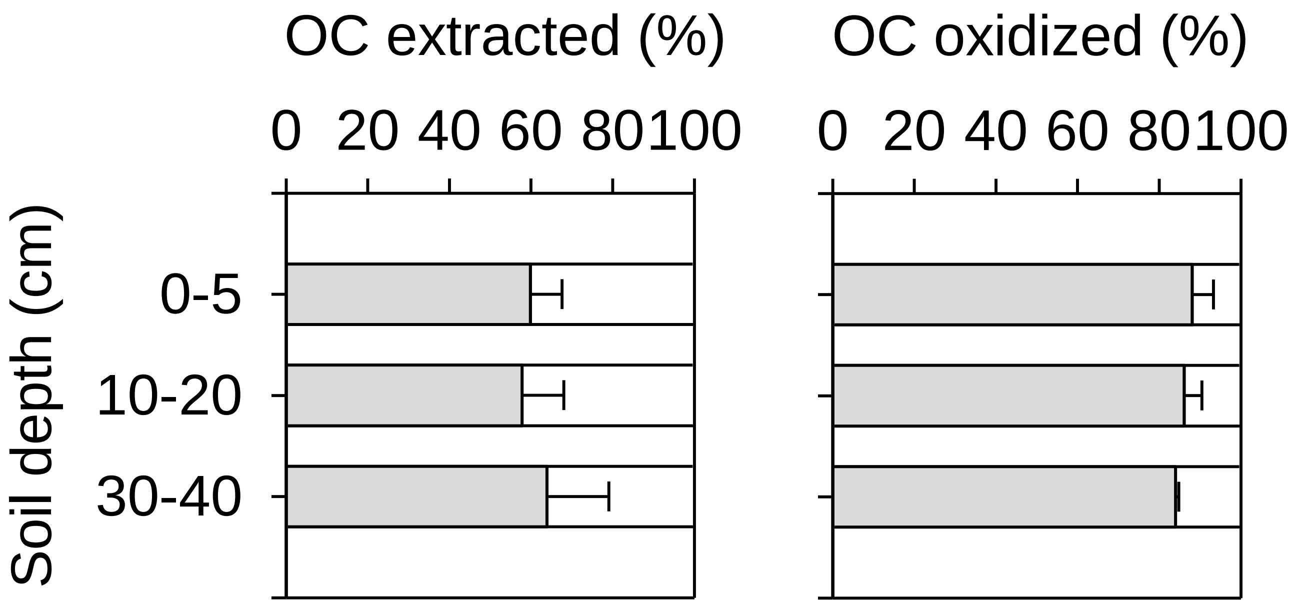
Total C, N and ^{14}C in residues

Chemical fractionation of soils

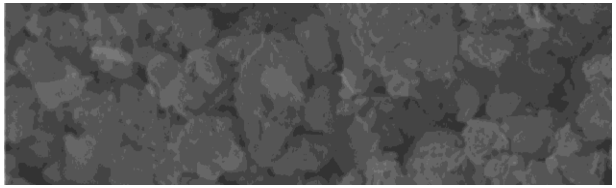


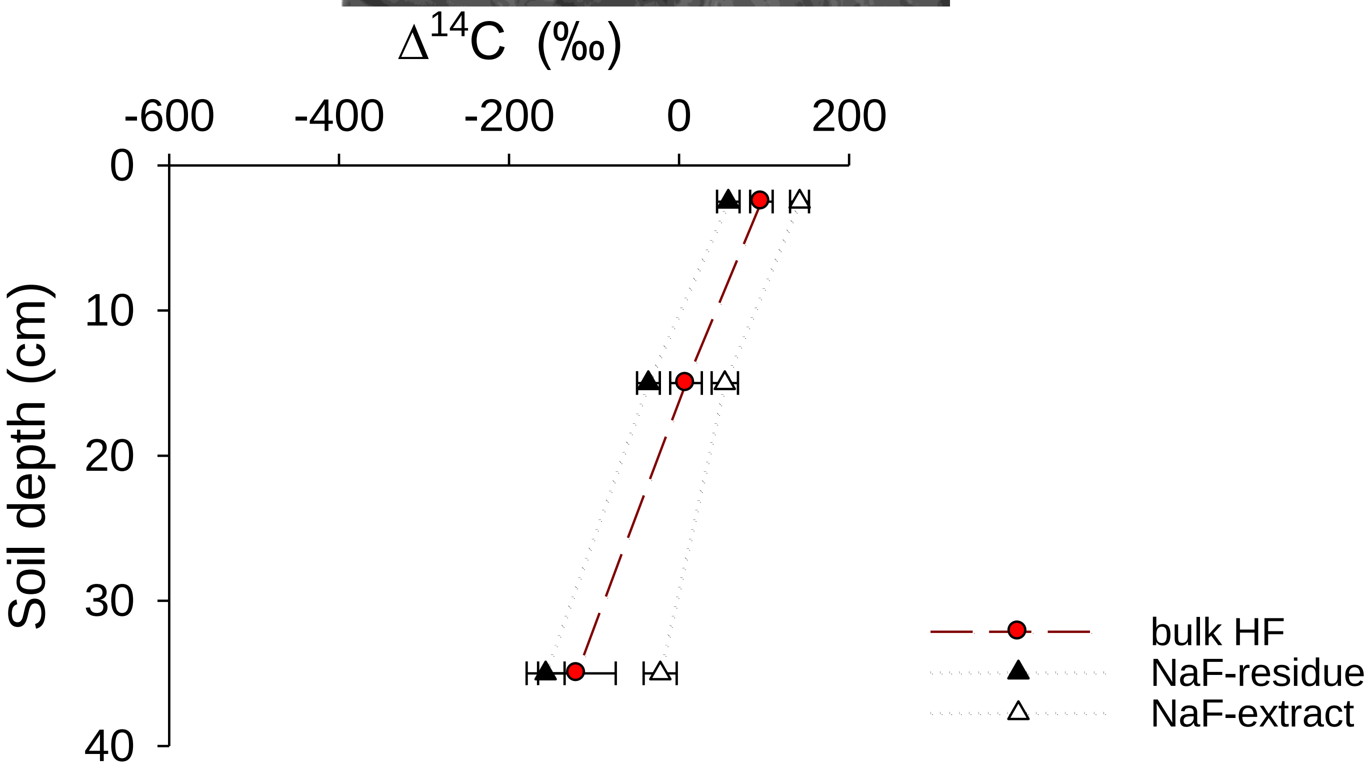
NaF/NaOH extracts

Heated H_2O_2 treatment



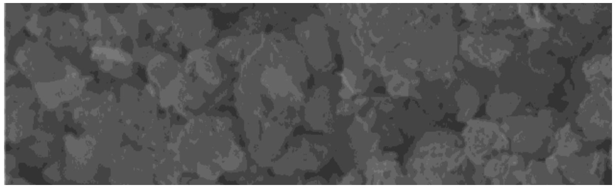
Chemical fractionation of soils

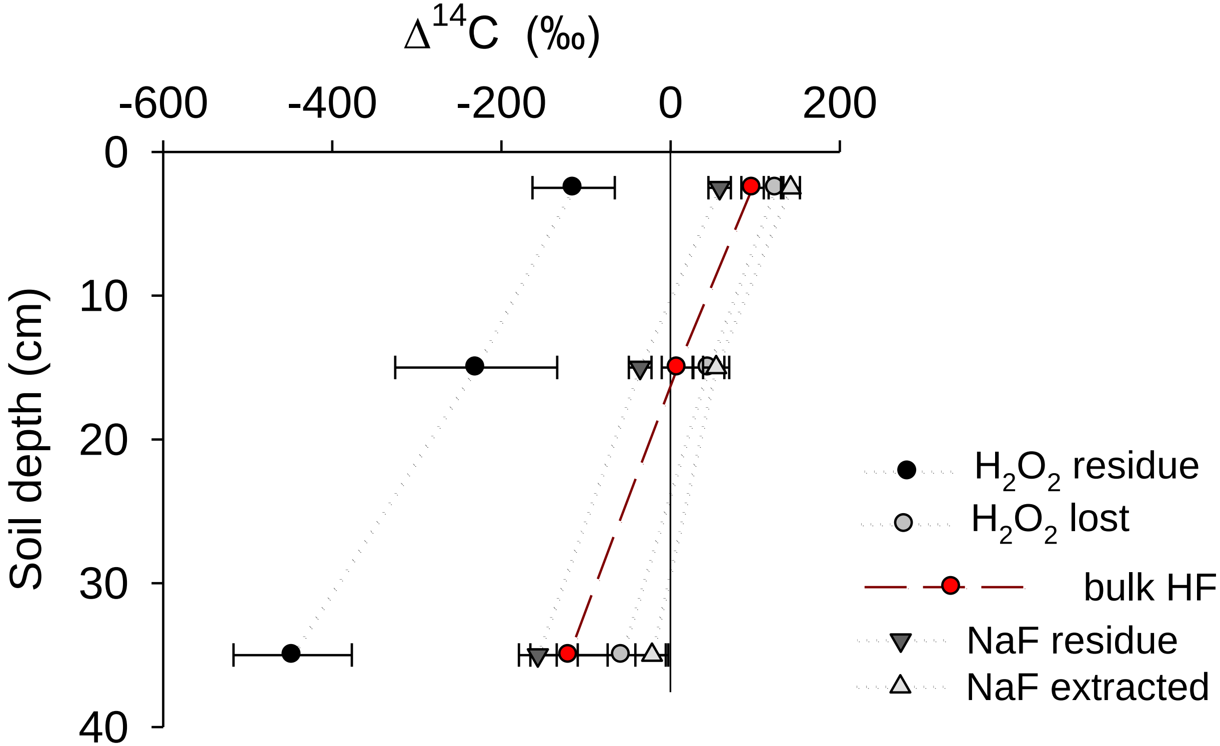




- OC extracted with NaF is younger than bulk soil HF-OC
- OC extracted with NaF is increasing in age with soil depth

Chemical fractionation of soils





- OC surviving H_2O_2 treatment is much older than NaF residue
- ^{14}C of OC lost during H_2O_2 treatment similar to NaF extracts

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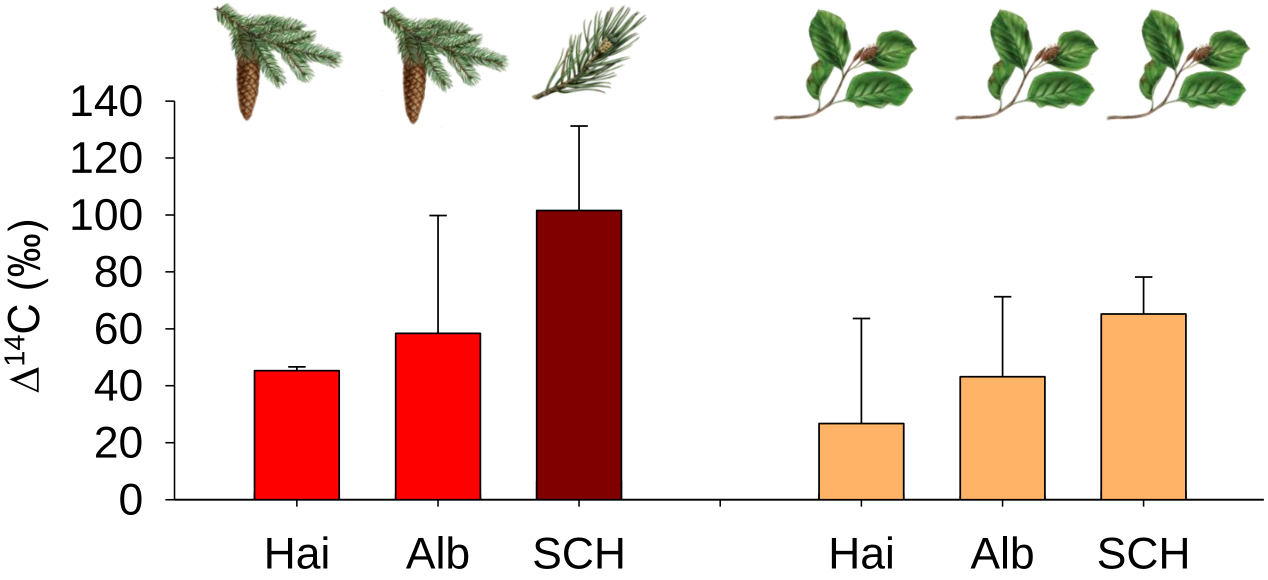
Tree species: ^{14}C in mineral soil (0-10 cm)

Bulk mineral soil 0-10 cm



study region ***
tree species *

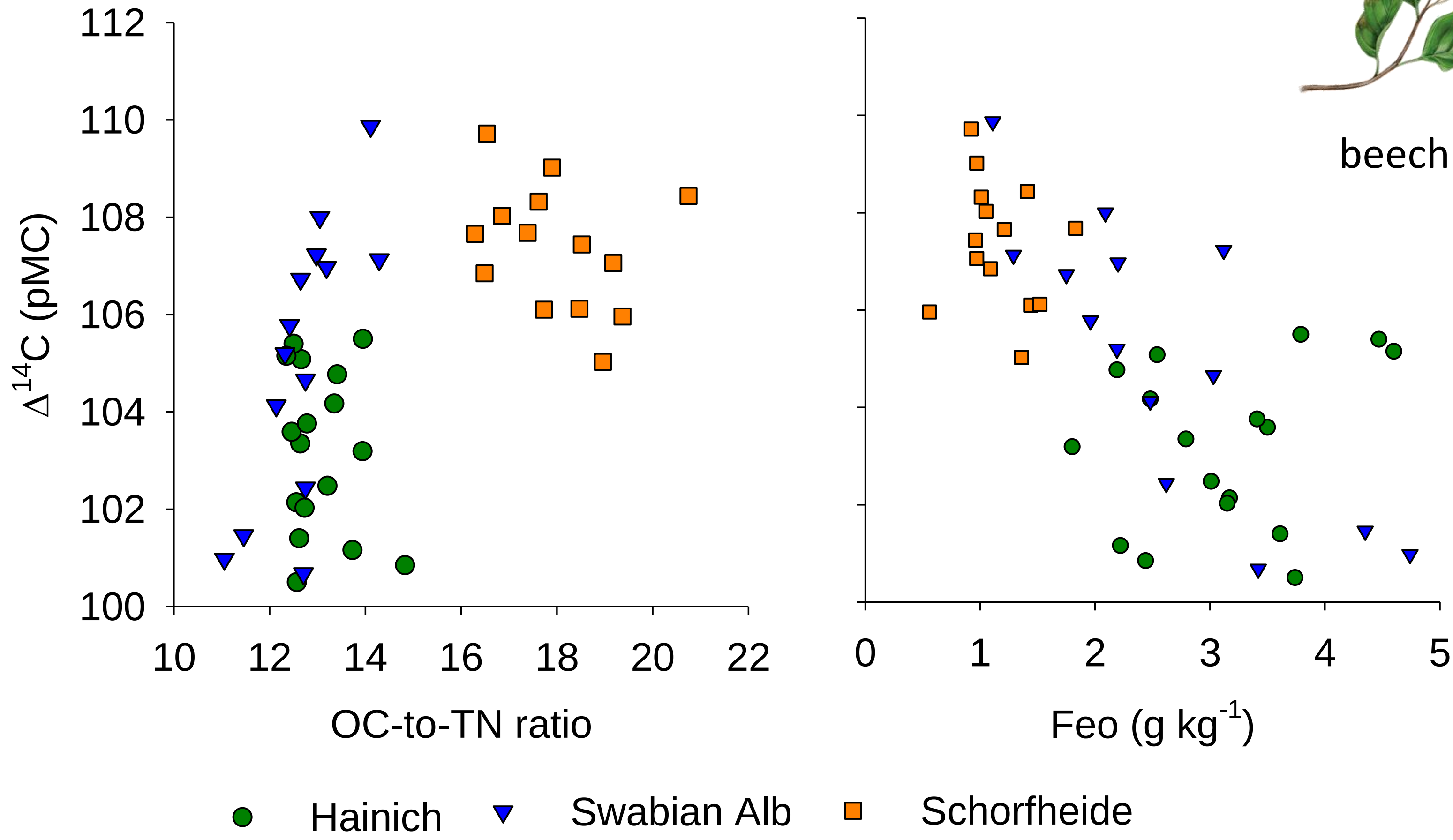
^{14}C of soil organic matter in mineral soil 0-10 cm:

- Larger for coniferous than deciduous species:
  → **slower turnover** of mineral soil OC **for coniferous species**
- again: **larger difference between regions** than between species

  → **what is driving this huge variation?**

Tree species: ^{14}C in mineral soil (0-10 cm)

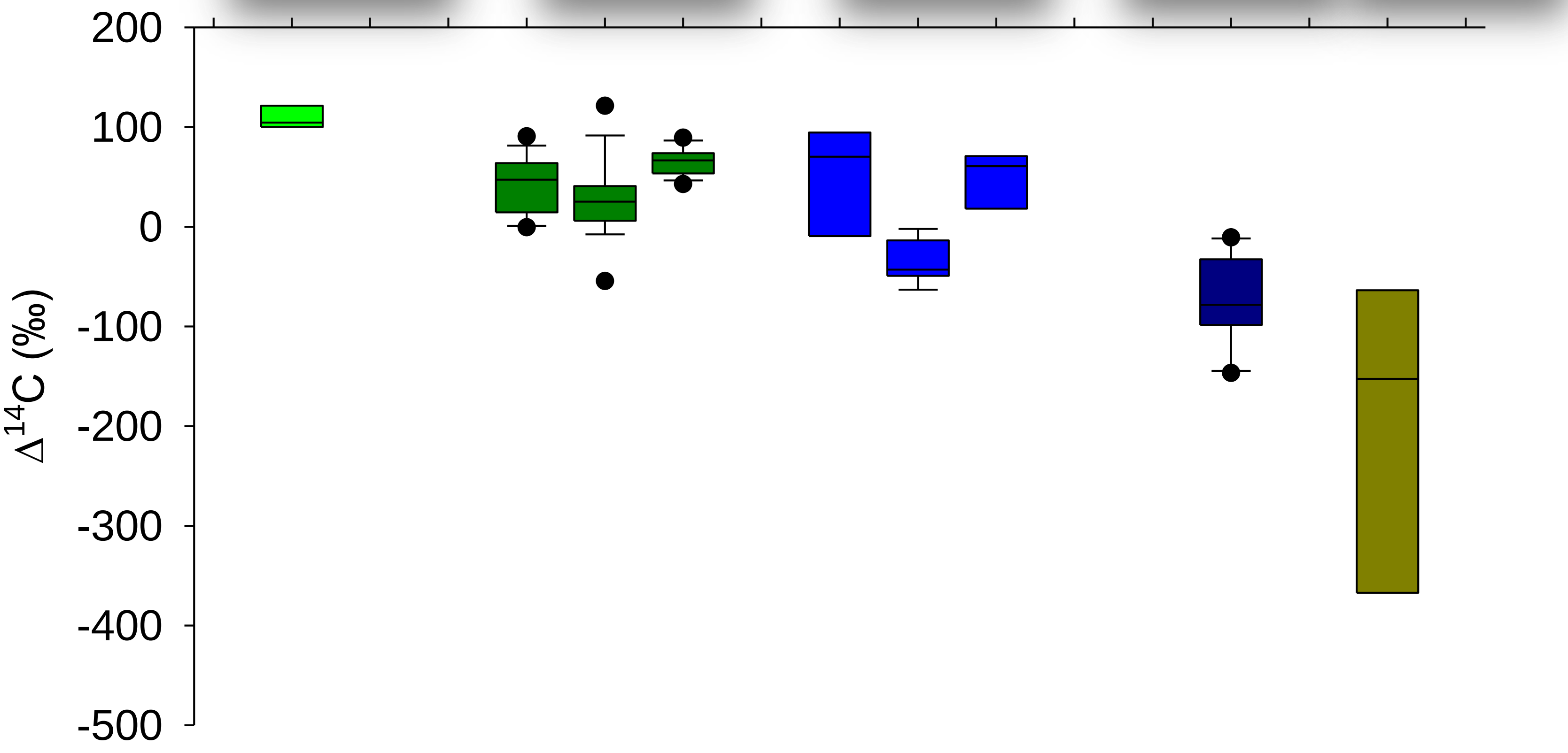
Bulk mineral soil 0-10 cm



- Study regions differ in climate and various soil properties
- Not possible to identify a single factor explaining ^{14}C within and across regions

Comparison of ^{14}C in soil across large gradients

Mineral soil, 0-10 cm, 2004-2013



Conclusions

- When using **^{14}C as proxy for OC turnover** consider:

  - **soil is mixture** of faster and slower cycling fractions

  - **lag times** between C fixation and the time C enters soil

  → additional analyses of $^{14}CO_2$ or physical / chemical fractions time series

- ^{14}C values suggest **slower turnover**

  - for **forests than grasslands**

  - **coniferous than deciduous** forests

  - **with increasing latitude** at the global scale

- ^{14}C contents in forest soils stronger affected by study regions than by forest type or management

  → **we do not know the main drivers of ^{14}C variation** (yet)

Thanks for your attention!

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