

# **Forest harvest residue bioenergy - key information needs related to climate impacts**

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# Forest harvest residue bioenergy - key information needs related to climate impacts

1. Effects on the carbon balance of forest
  - How much biomass is removed
  - How much carbon the removed biomass would store over time if left in forest
    - Decomposition of woody litter
  - How the carbon balance of the forest site is affected
    - Soil disturbance
    - Plant productivity
2. Means to improve the climate impacts
  - How the carbon losses can be compensated for
    - Efficiency of various means
    - Validity of results
    - Feasibility of the means

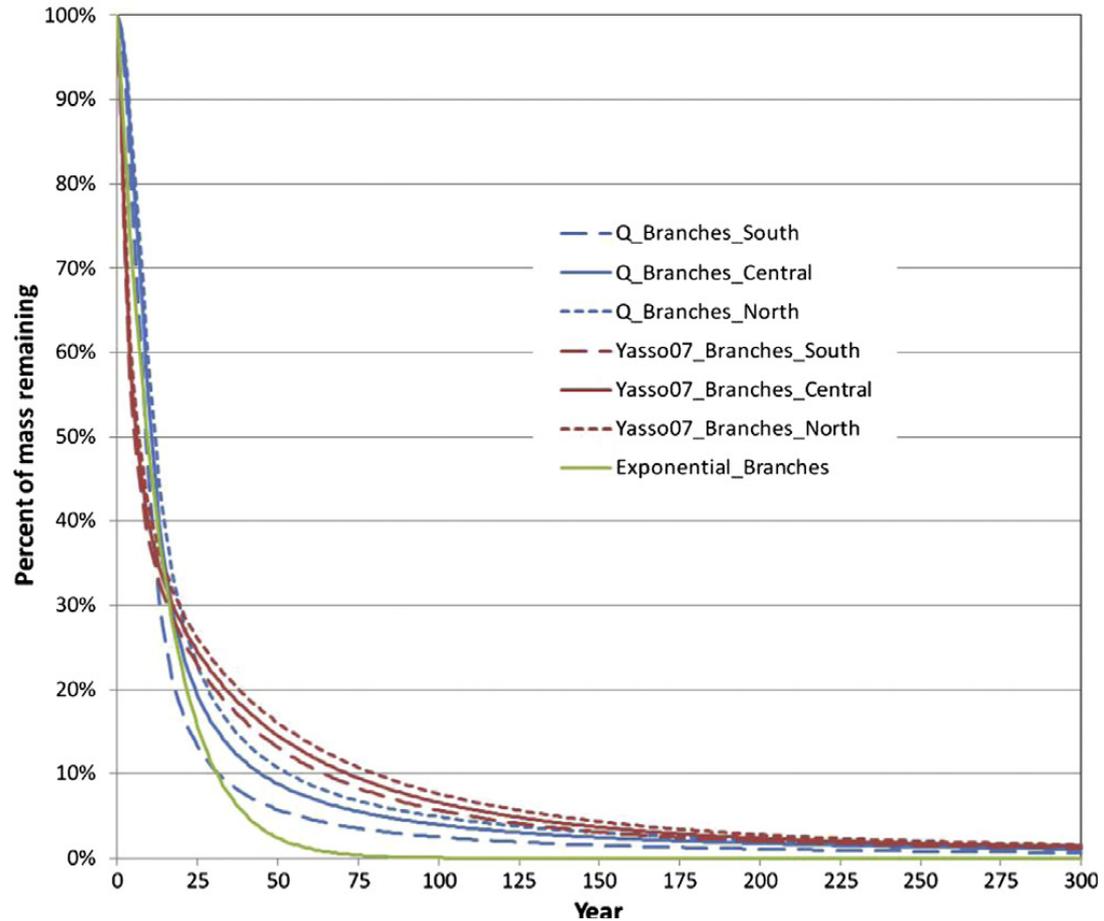


# Forest harvest residue bioenergy - key information needs related to climate impacts

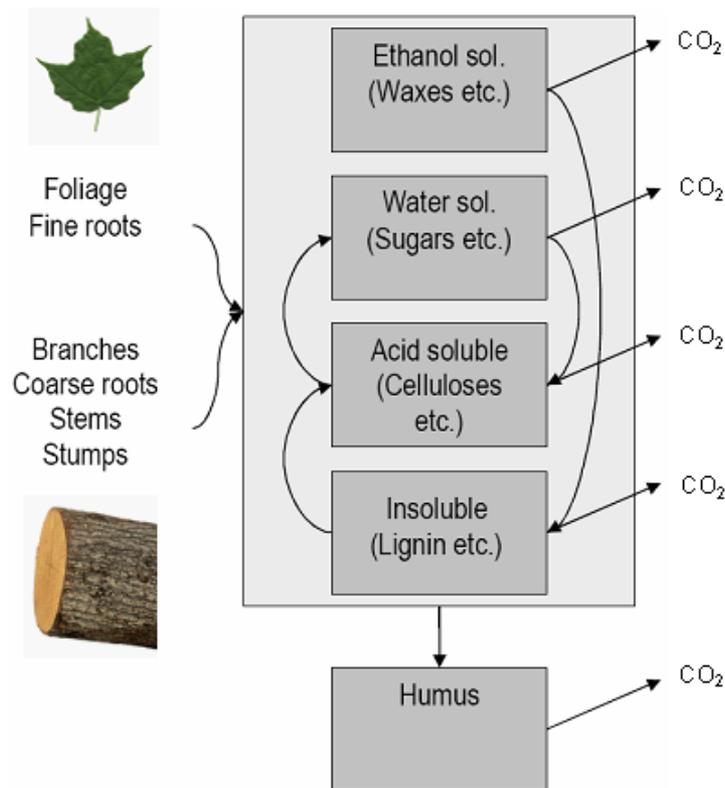
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# Decomposition estimates of stumps



# Yasso soil carbon model: flow chart and parameter values



- Decomposition rates (1/year)

- $\alpha_A$ : 0.635054
- $\alpha_W$ : 6.34657
- $\alpha_E$ : 0.253494
- $\alpha_N$ : 0.0383713

- Fluxes between fractions

- $p_{W \rightarrow A}$ : 0.534469
- $p_{E \rightarrow A}$ : 0.0731845
- $p_{N \rightarrow A}$ : 0.870729
- $p_{A \rightarrow W}$ : 0.994589
- $p_{E \rightarrow W}$ : 0.0911629
- $p_{N \rightarrow W}$ : 0.0261311
- $p_{A \rightarrow E}$ : 0.000596846
- $p_{W \rightarrow E}$ : 0.000526268
- $p_{N \rightarrow E}$ : 0.0955249
- $p_{A \rightarrow N}$ : 0.000884934
- $p_{W \rightarrow N}$ : 0.066174
- $p_{E \rightarrow N}$ : 0.814426

- Litter bag scaling

- $w_1$ : -0.160691 (leaching)
- $w_2$ : -0.0200463 (leaching)
- $w_3$ : -0.000617722 (leaching)
- $w_4$ : -0.000415913 (leaching)

- Climate effects

- $\beta_1$ : 0.084745
- $\beta_2$ : -0.000109568
- $\gamma$ : -1.61538

- Humus

- $p_H$ : 0.00226577 (humus)
- $\alpha_H$ : 0.000962473 (humus)

- Woody litter

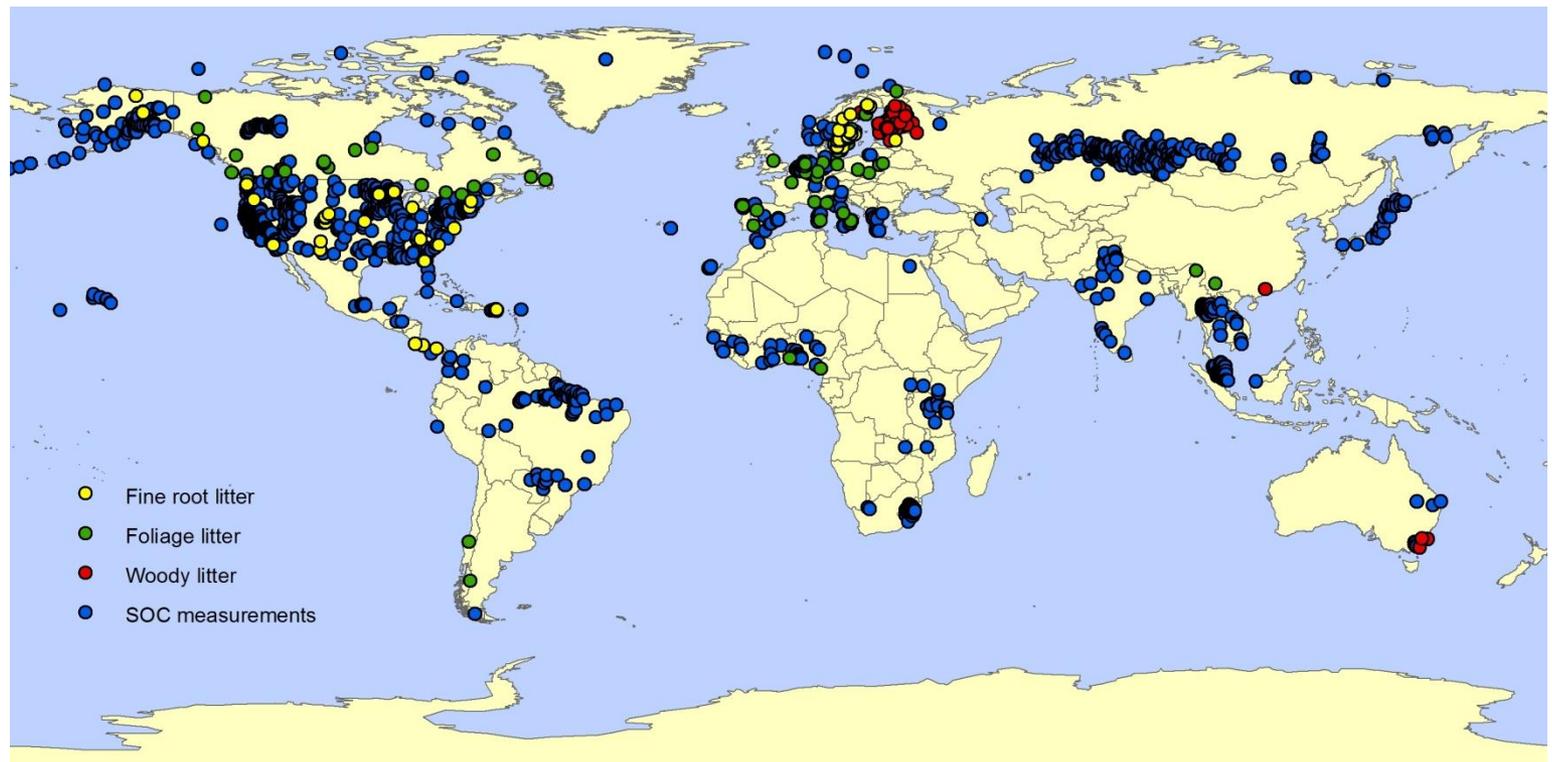
- $\theta_1$ : -0.436139 (woody)
- $\theta_2$ : 1.42323 (woody)
- $r$ : 0.251026 (woody)

# Yasso soil carbon model methodology

- Aims: avoidance of subjective decisions, transparency, lots of data, diverse data, state-of-the-art mathematics
- Model structure based on explicit hypotheses (5) about decomposition and SOC cycle
- Choices between alternative details based on Bayesian model selection theory
- Parameter values estimated using Markov chain Monte Carlo
- -> Uncertainty estimates representing uncertainty caused by the parameter values

# Yasso database

Litter bag data (n=12 578), Woody litter decomposition (n=4318), SOC stock (n=4996), SOC accumulation (n=26)



## Woody litter decomposition in Yasso

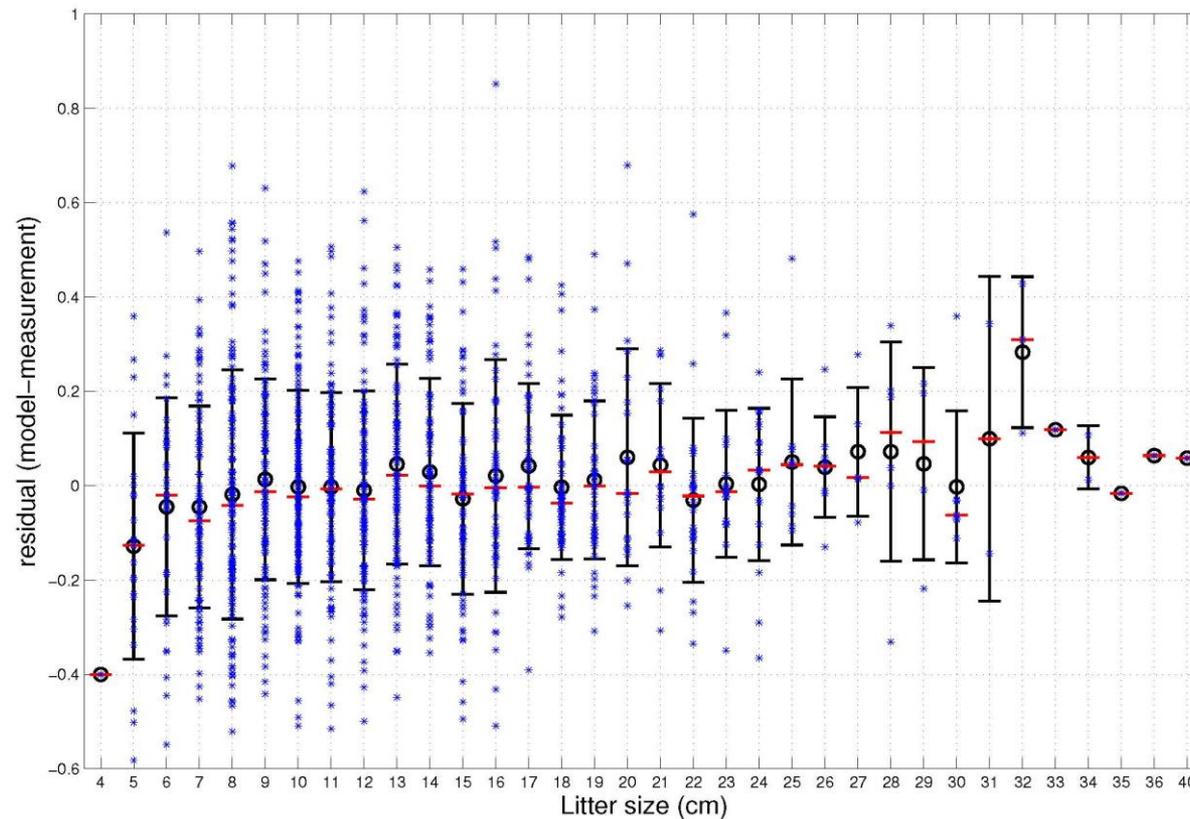
- Different alternative model structures tested using Bayesian criteria
- The best alternative, given the data available, chosen
- Decomposition of woody litter is similar to that of non-woody litter except that the decomposition rates of the AWEN fractions are decreased according to the size of the woody litter (diameter)
  - $h_S(d) = \min\{(1 + \alpha_1 d + \alpha_2 d^2)^r, 1\}$

## Woody litter decomposition datasets

- Pine, spruce and birch stems in Finland (n=1281, Mäkinen et al. 2006)
- Spruce stems and stumps in western Russia (n=107, Tarasov and Birdesy 2001)
- Pine, spruce and birch branches in Finland (n=360)
- Pine branches in Finland and Estonia (n=354)
- Tropical hardwood dowels across the USA and Central America (n=2272, LIDET, analyses not completed)

# Yasso residuals against initial woody litter diameter

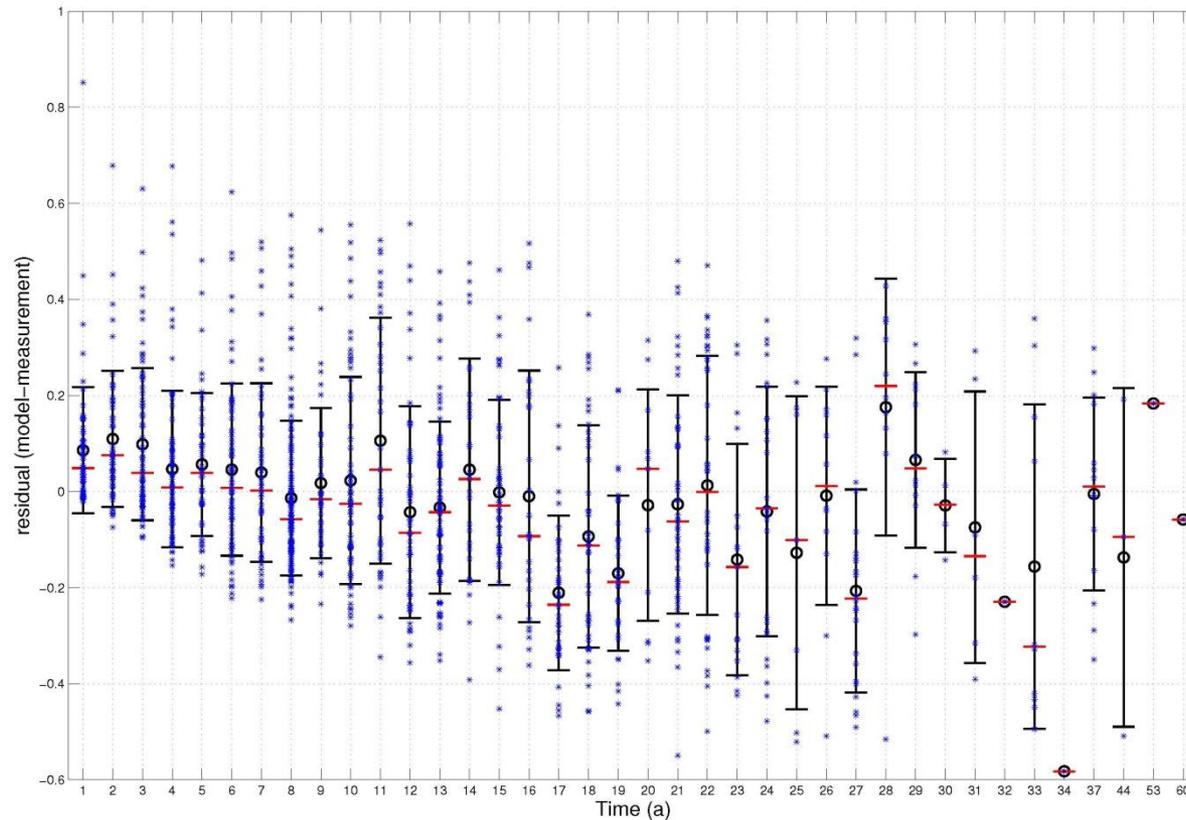
Pine, spruce and birch stems in Finland (Mäkinen et al. 2006)



New Yasso15 version (In preparation)

# Yasso residuals against time since the start of decomposition

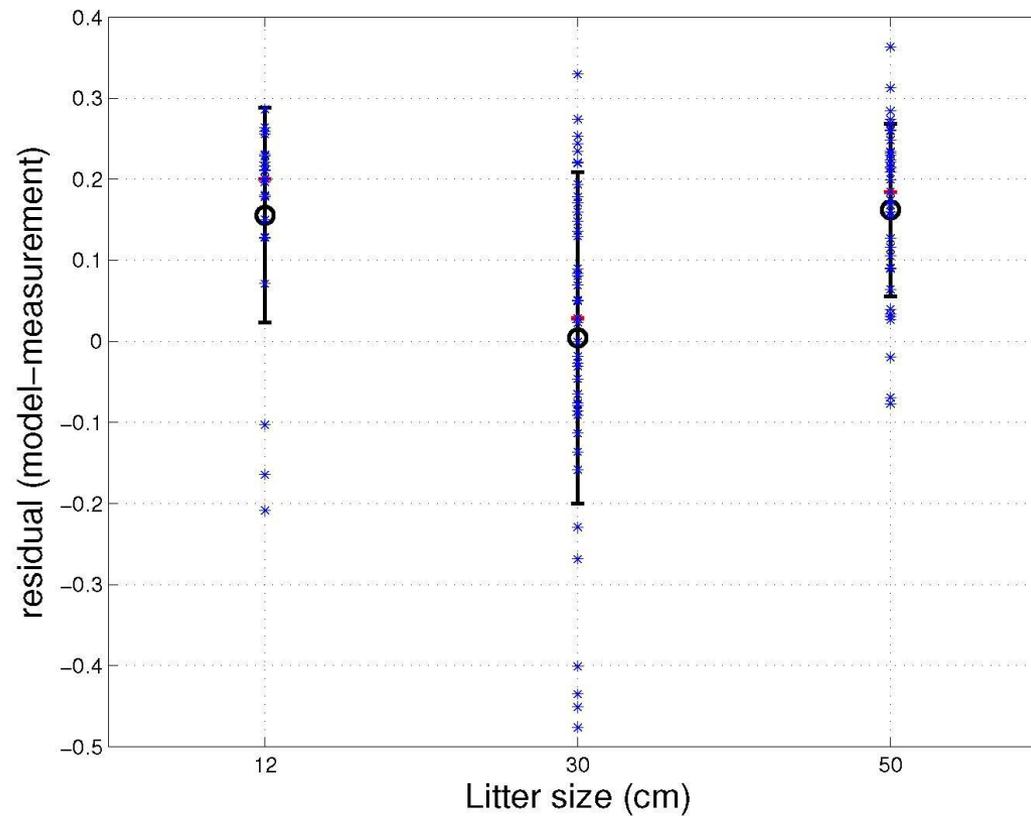
Pine, spruce and birch stems in Finland (Mäkinen et al. 2006)



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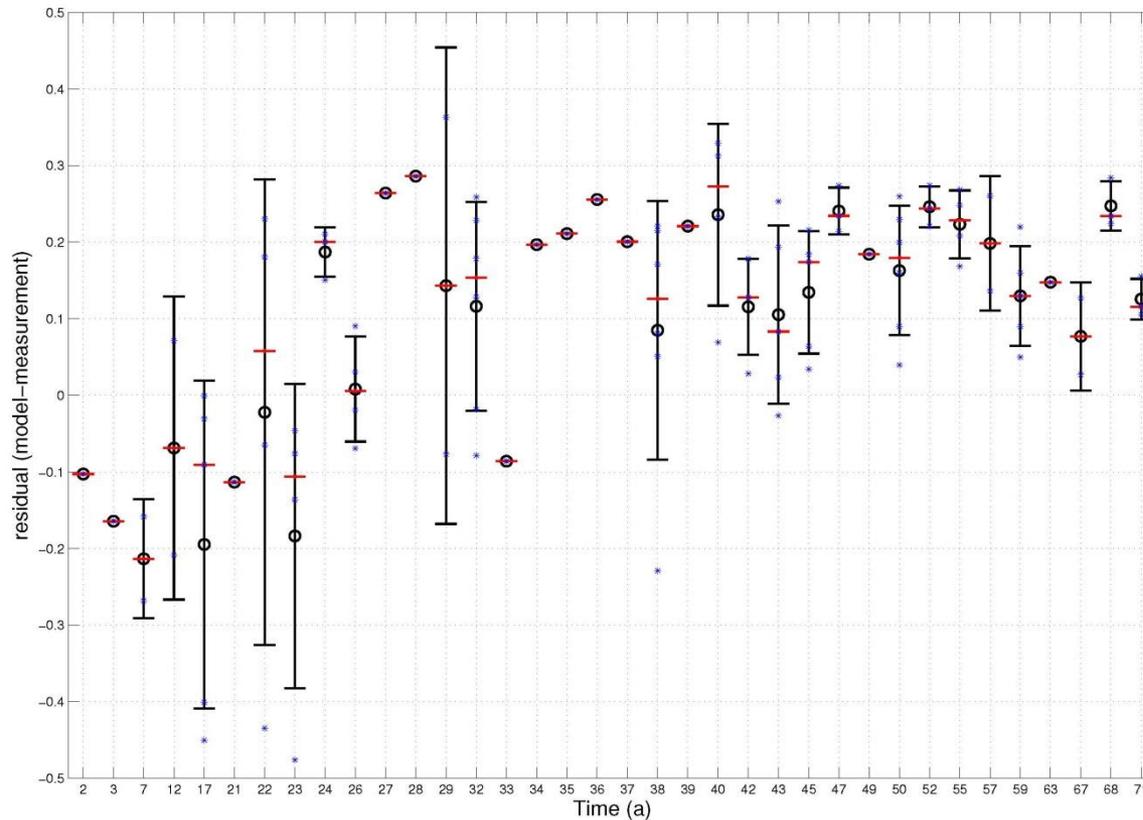
# Yasso residuals against initial woody litter diameter

Spruce stems and stumps in western Russia (Tarasov and Birdsey 2001)



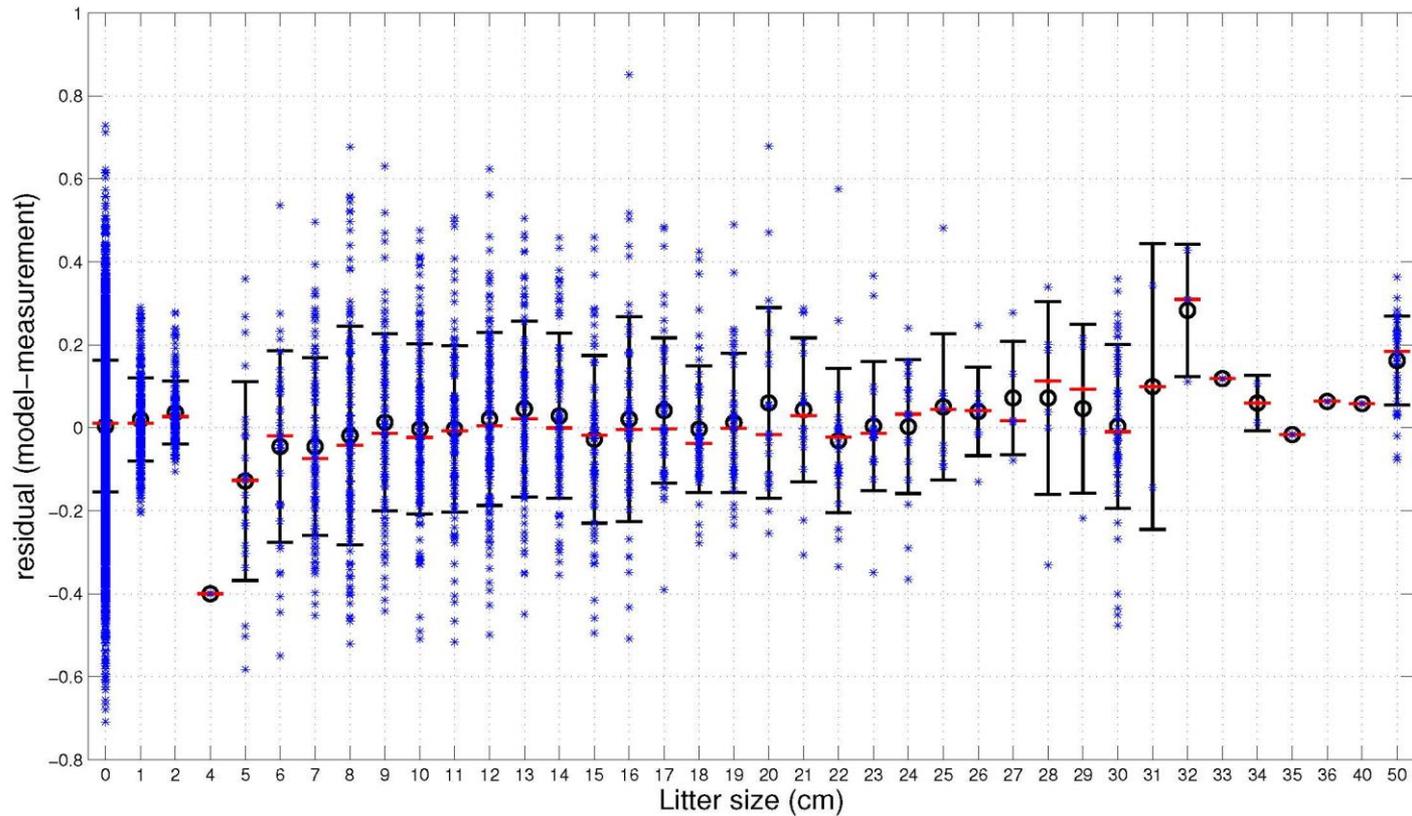
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Spruce stems and stumps in western Russia (Tarasov and Birdsey 2001)



# Yasso residuals against initial litter diameter

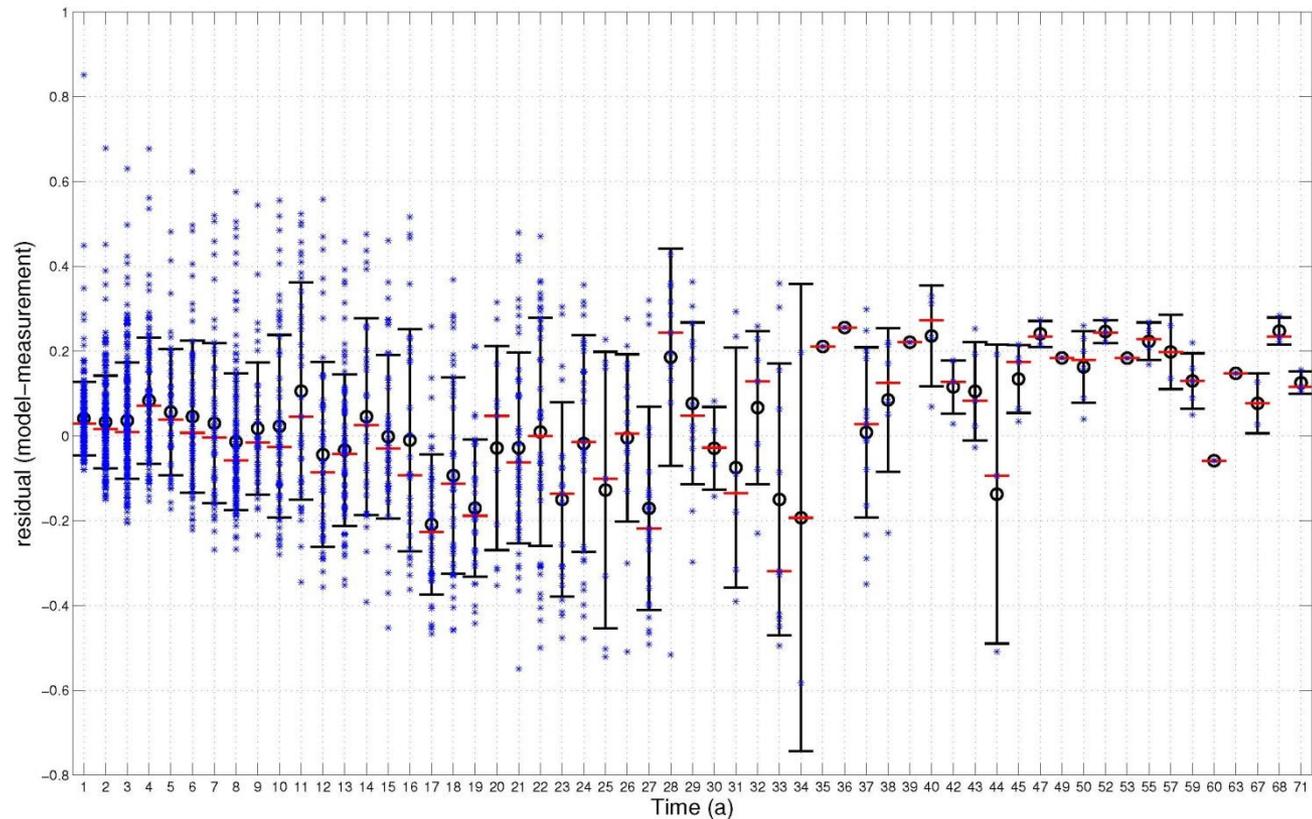
All litter data



New Yasso15 version (In preparation)

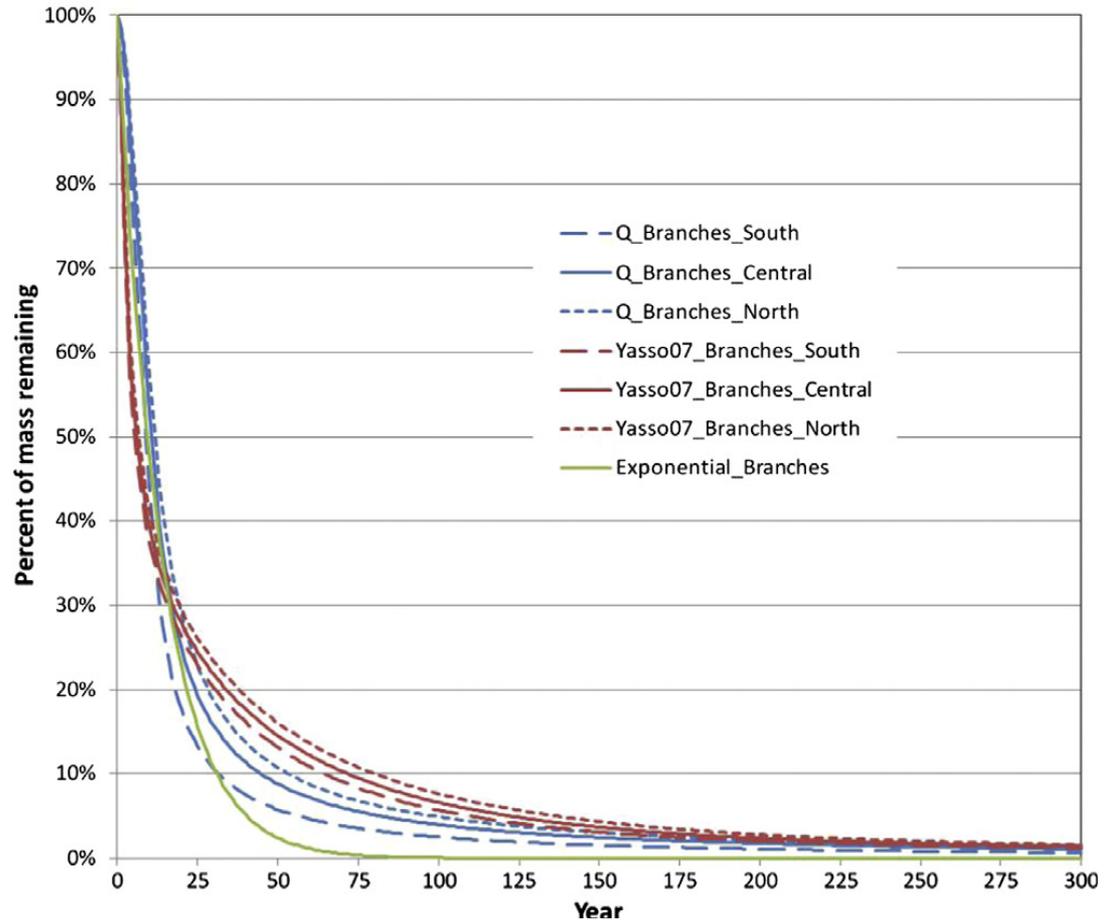
# Yasso residuals against time since the start of decomposition

All woody litter data



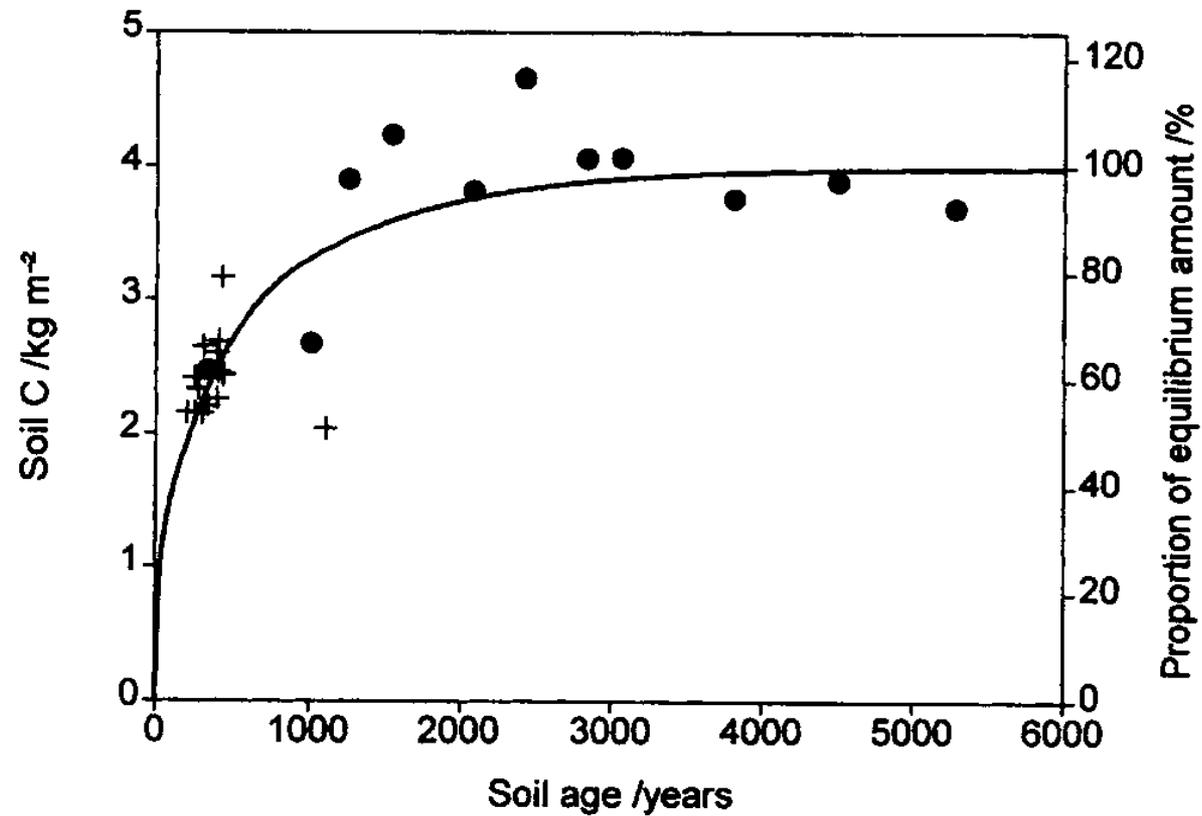
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# Decomposition estimates of stumps



# SOC accumulation in Finland

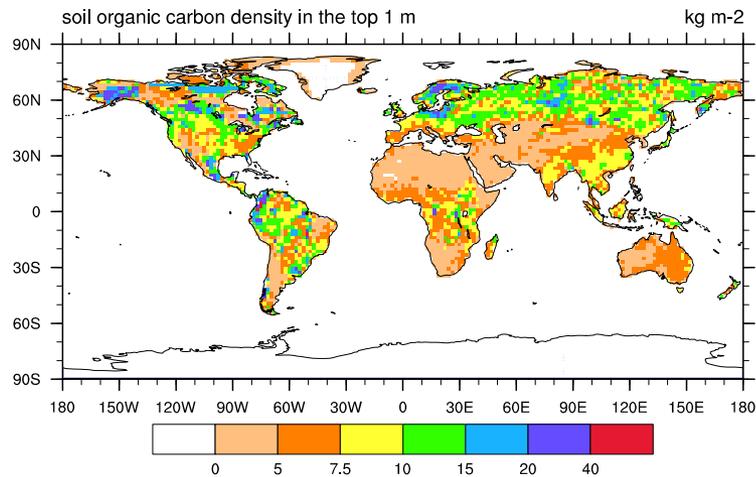
Note: the line is not a Yasso fit



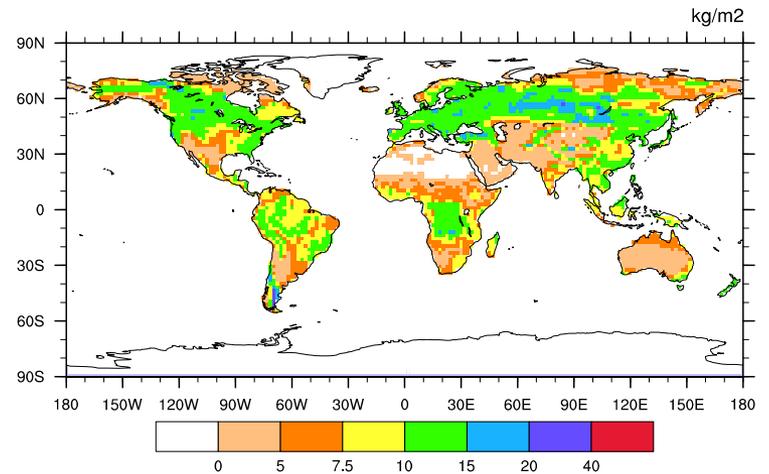
Liski et al. 1998. European Journal of Soil Science.

# Estimates of the global SOC pool

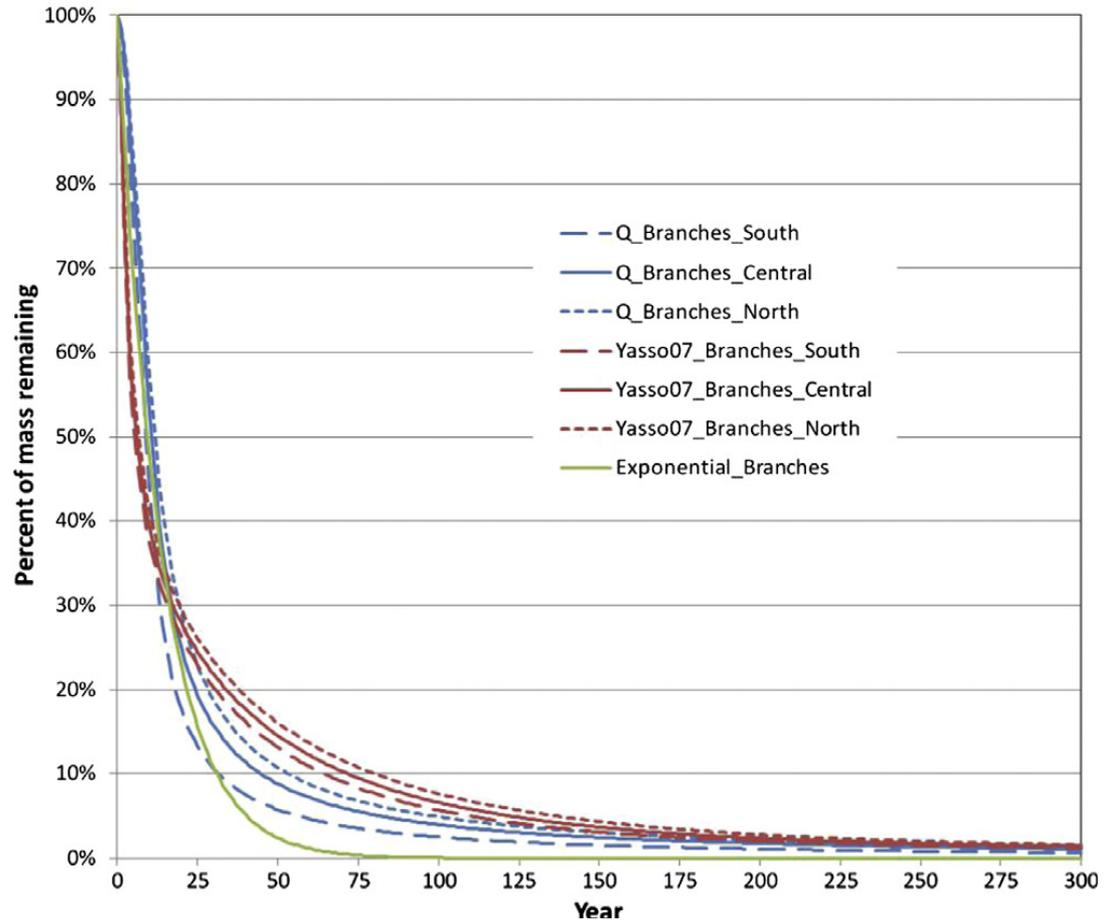
Harmonized world soil database



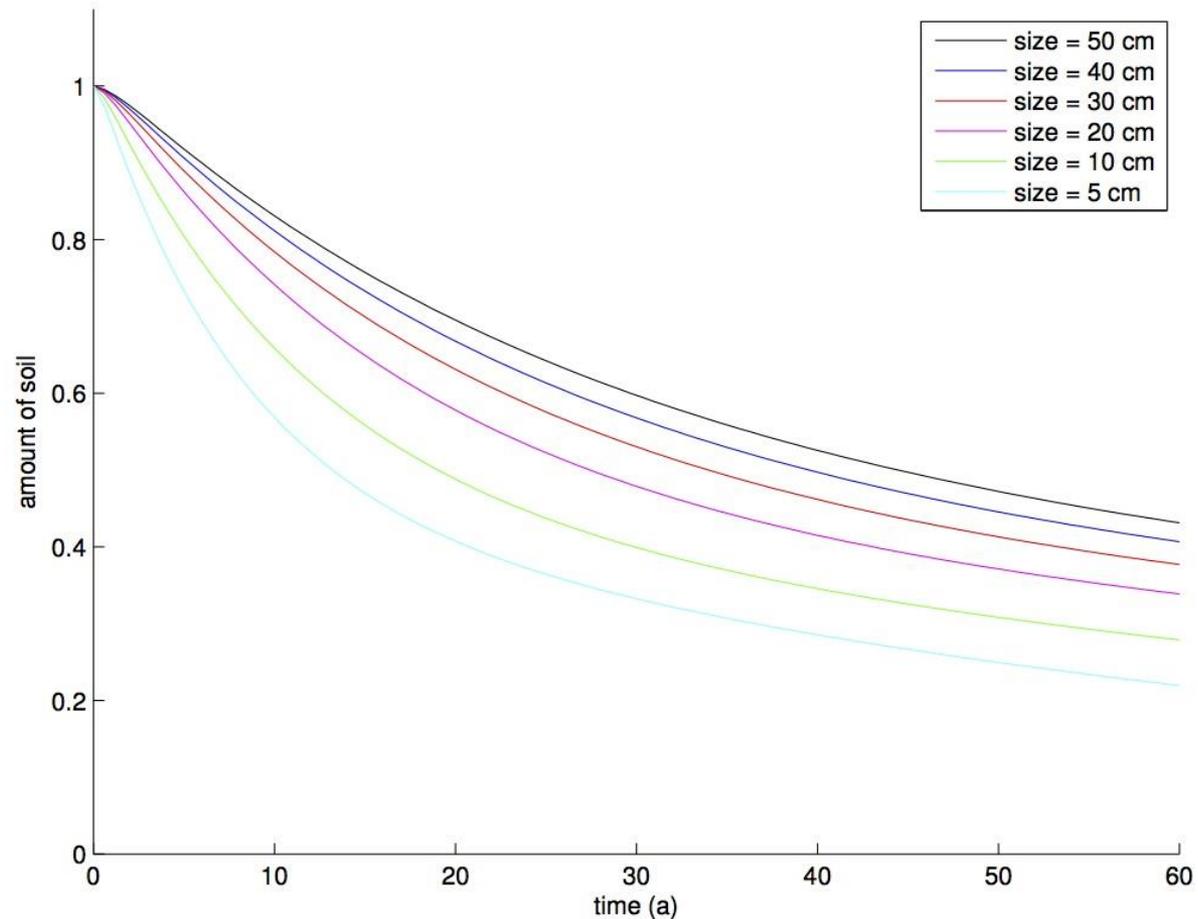
Yasso07 + Max Planck Institute Earth System Model



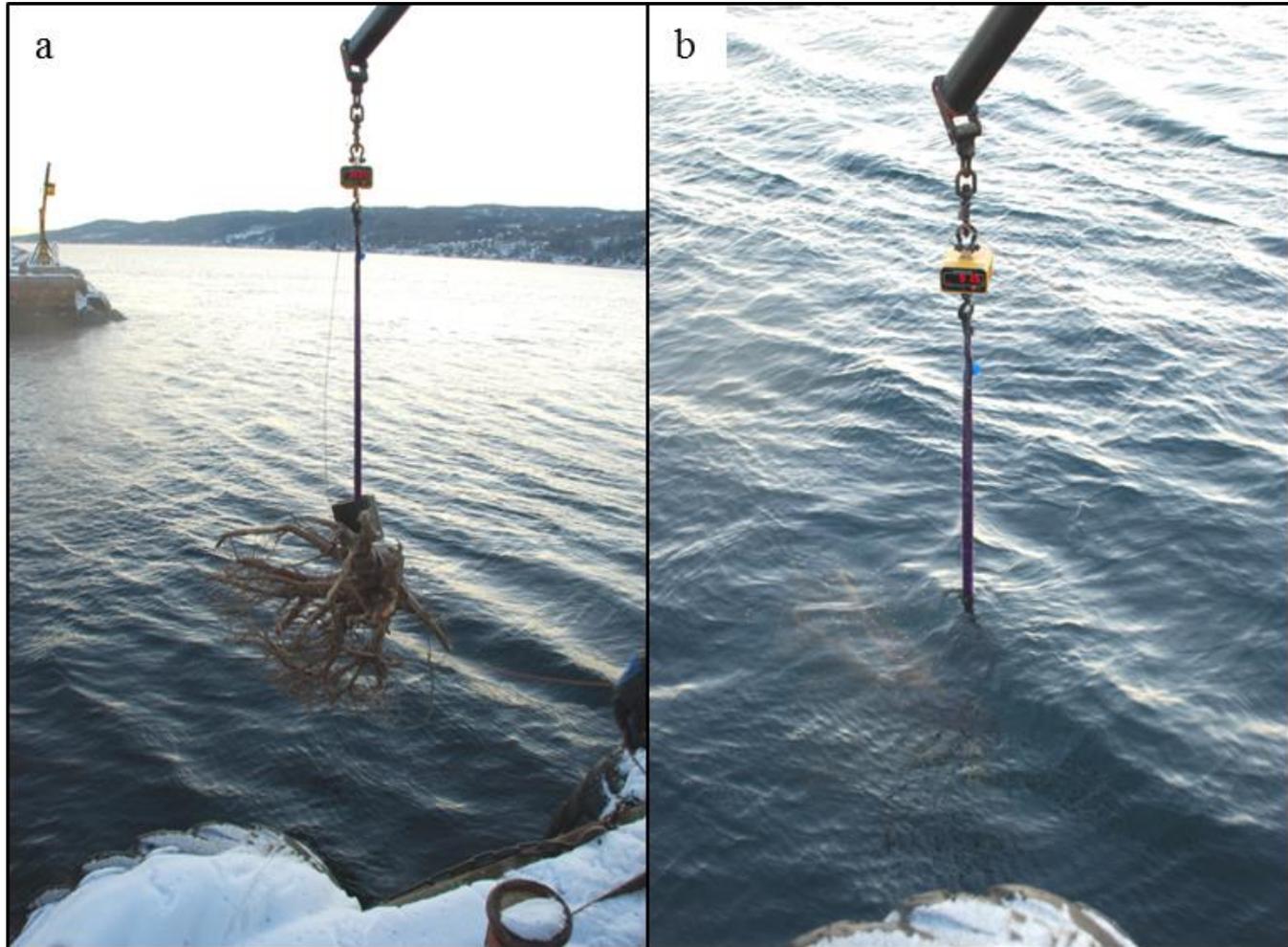
# Decomposition estimates of stumps



# Yasso estimates for mass remaining of decomposing spruce woody litter

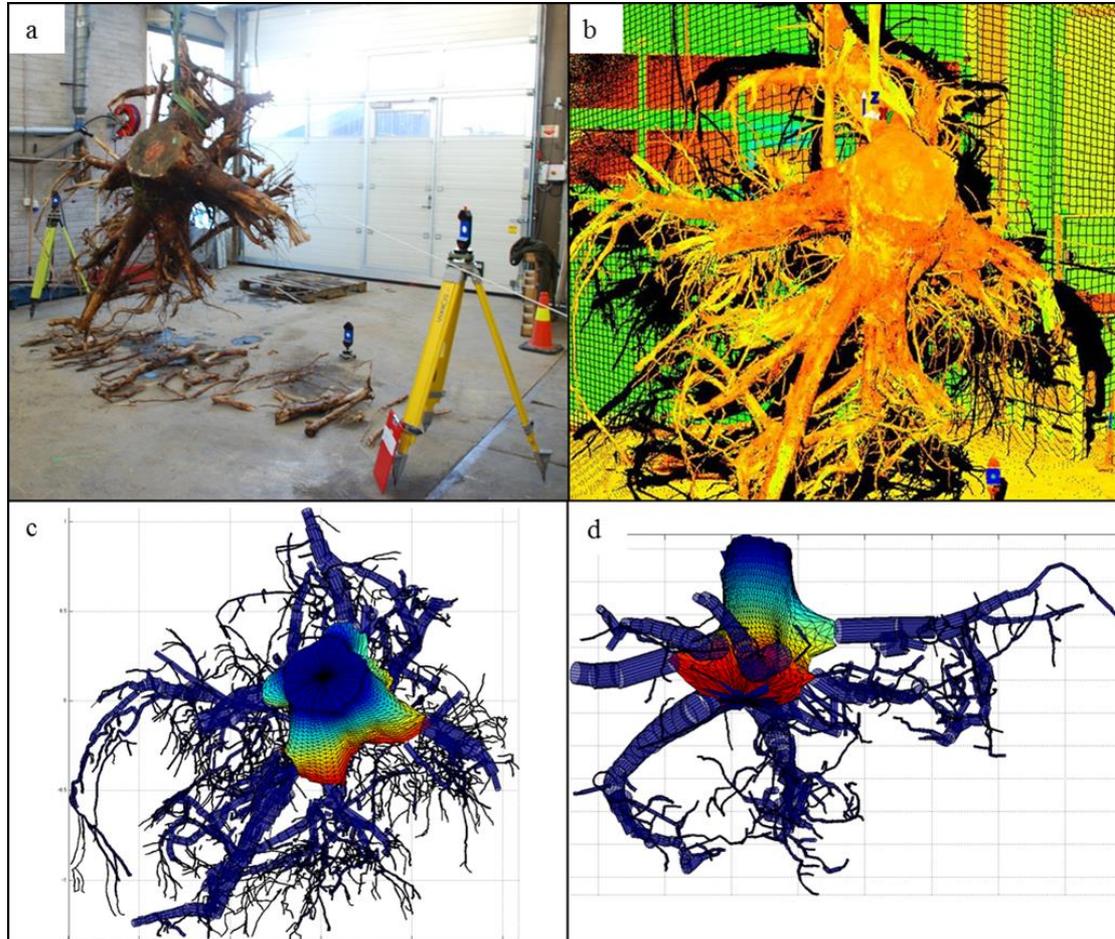


# Tree root system characterization and volume estimation by terrestrial laser scanning and quantitative structure modelling

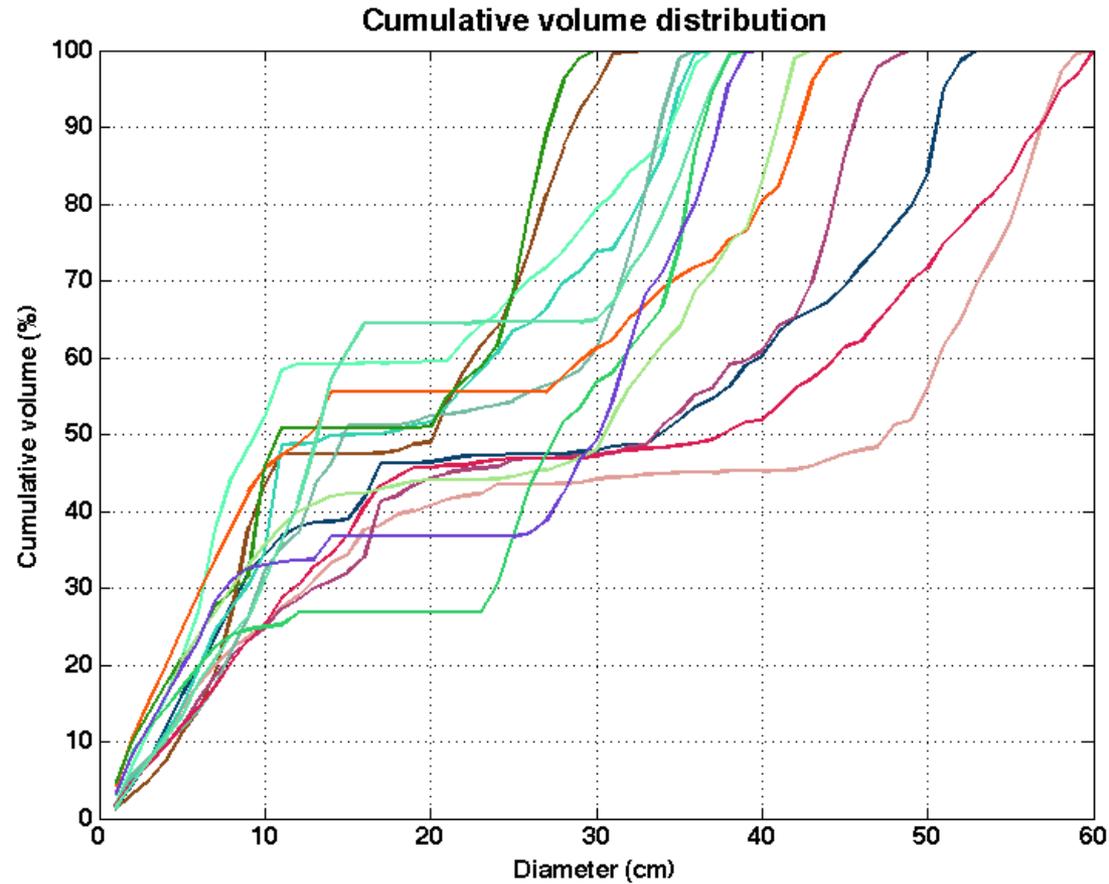


Smith et al. 2015. Forests (Accepted).

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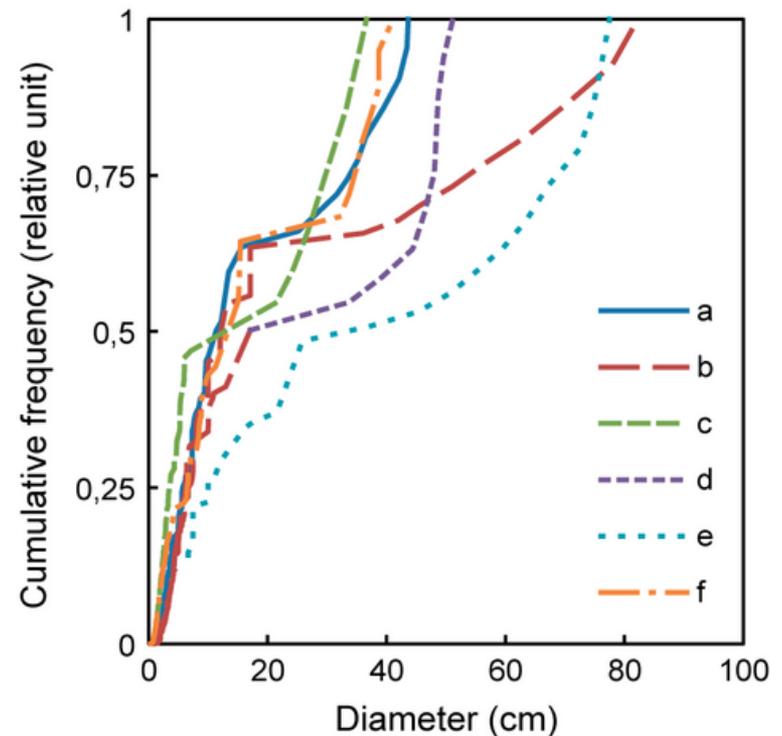


# Division of the stump-root biomass to diameter classes



# Detailed size information affecting estimates of decomposition and emissions

- “The present decomposition estimates were slightly faster. For example, the stump-root systems of this study had 52 to 63% of their original mass remaining after 20 years of decomposition whereas an earlier estimate for stumps in southern Finland was 64% (Repo *et al.*, [2011](#)). Consequently, the present estimates of the indirect emissions were slightly lower than the earlier ones namely 71–81 g CO<sub>2</sub> MJ<sup>-1</sup> after 20 years of constant use compared with an earlier estimate equal to 92 g CO<sub>2</sub> MJ<sup>-1</sup> (Repo *et al.*, [2011](#)).”



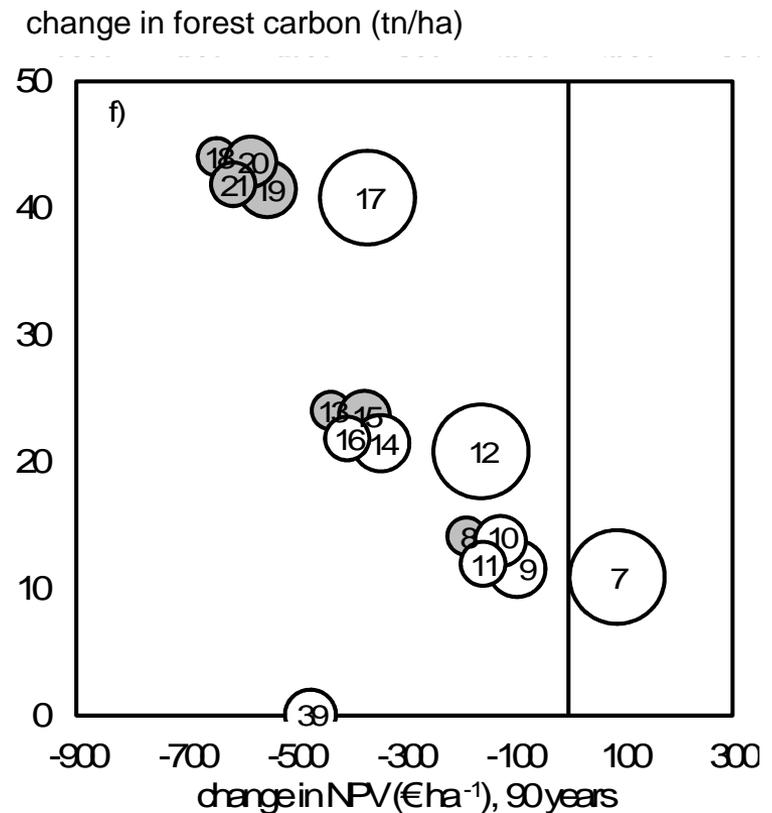
# Production of carbon neutral bioenergy from forest harvest residues

Scenario	Biomass (t C ha <sup>-1</sup> )	Soil (t C ha <sup>-1</sup> )	Total (t C ha <sup>-1</sup> )
No residue removal	63	96	159
Bioenergy	63	87	150
Bioenergy + 10% CAI	69	90	159
Bioenergy + 38% CAI	87	96	183
Bioenergy rotation period 100 years	69	88	157
Bioenergy rotation period 110 years	76	88	164
Bioenergy rotation period 120 years	83	88	172
Bioenergy -21% decomposition rate	63	96	159



# Costs of producing carbon neutral bioenergy from forest harvest residues

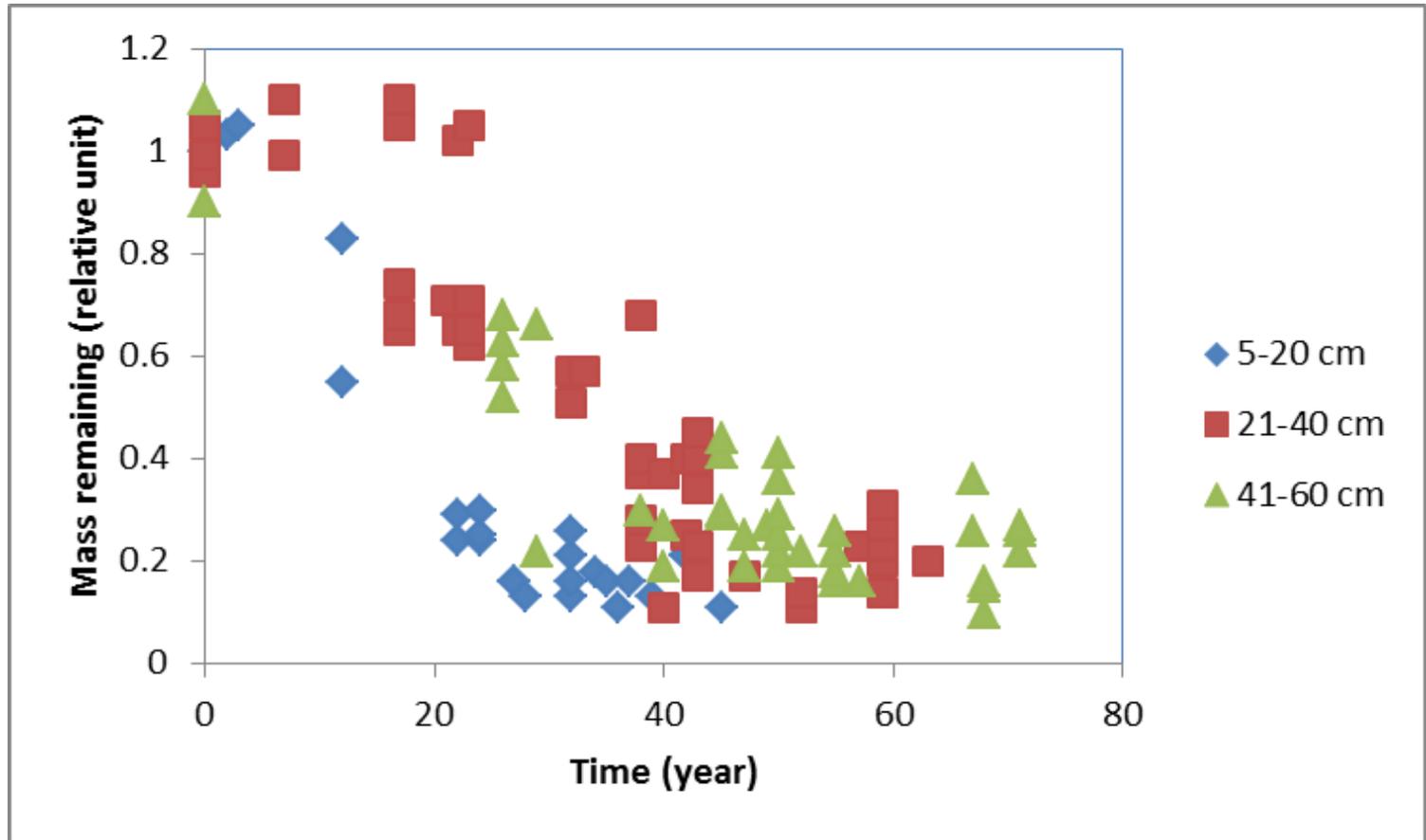
- Forest residue harvesting options studied
  - All, branches, unmerchantable tops, stump-root systems
- Forest management options studied
  - Fertilization, longer rotation periods, leaving high stumps
- Forest carbon increased in several options (Fig)
- Costs varied widely from 5 to 4000 euro per ha
  - At lowest <10 % of electricity price



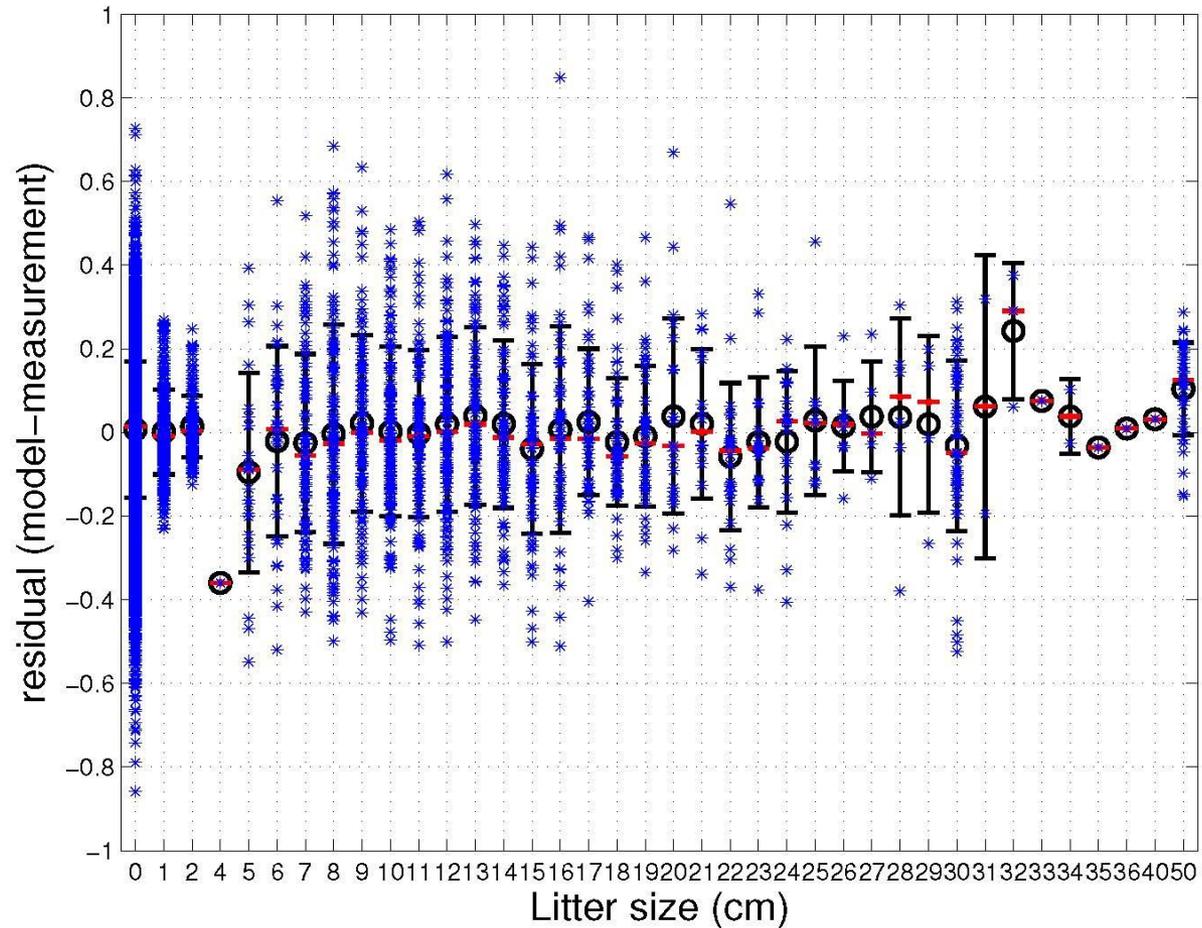
# Conclusions

- Decomposition of woody litter
  - The level of knowledge level does not meet the importance of the knowledge
  - Link to soil carbon cycle is important
  - More data, better data, more diverse data, more innovative data
- Improving the climate impacts of forest residue bioenergy
  - Seems very possible; is it true?
  - Efficiency of various means
  - Validity of results
  - Feasibility of the means
  - Landscape-scale options

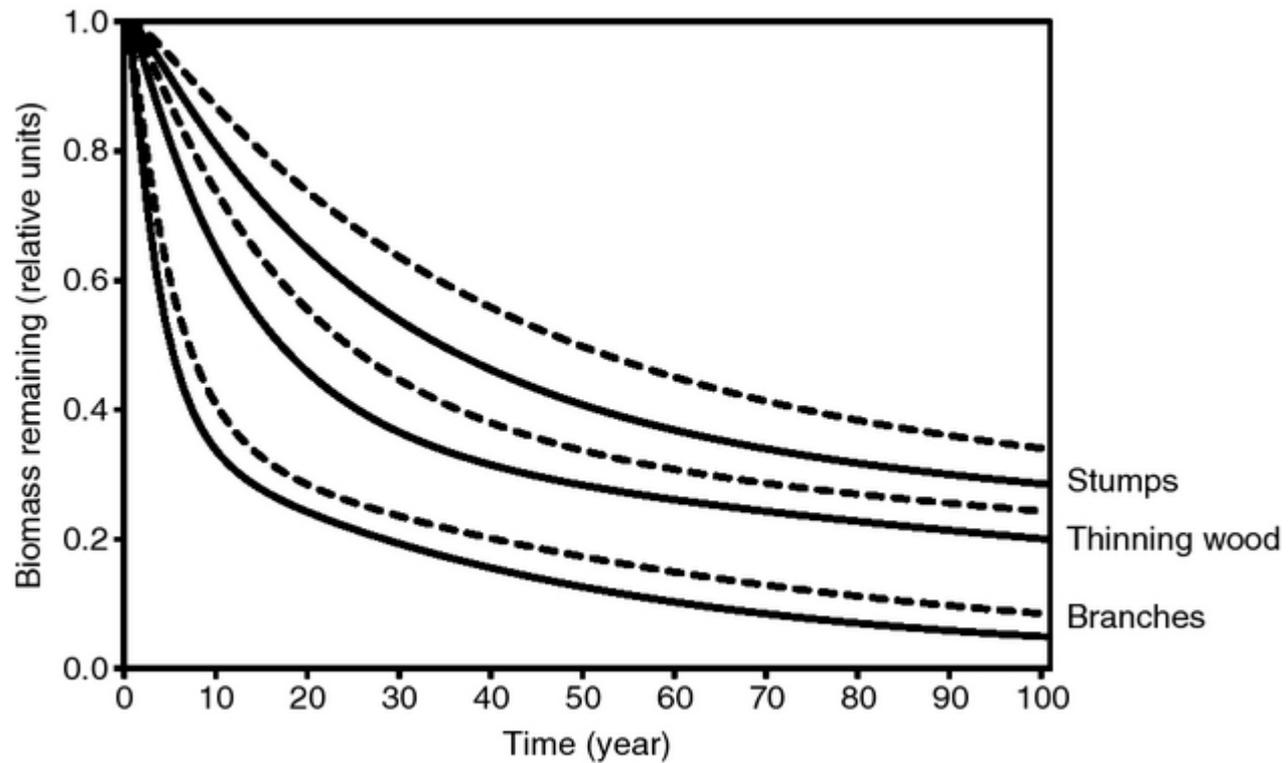
# Example of woody litter decomposition data: Norway spruce stems and stumps (Tarasov and Birdsey 2001)



# Residuals of Yasso plotted against litter size



# Yasso estimates for mass remaining of Norway spruce woody litter (2, 10 and 30 cm)





# **Esityksen nimi**

*(kuvallinen kansidia)*

Esityksen pitäjä, organisaatio,  
tilaisuus, päivämäärä

# Otsikko Arial Black 24pt sininen

- Ensimmäinen taso
  - toinen taso
    - kolmas taso

# Otsikko Arial Black 24pt sininen

## Alaotsikko tai ingressi

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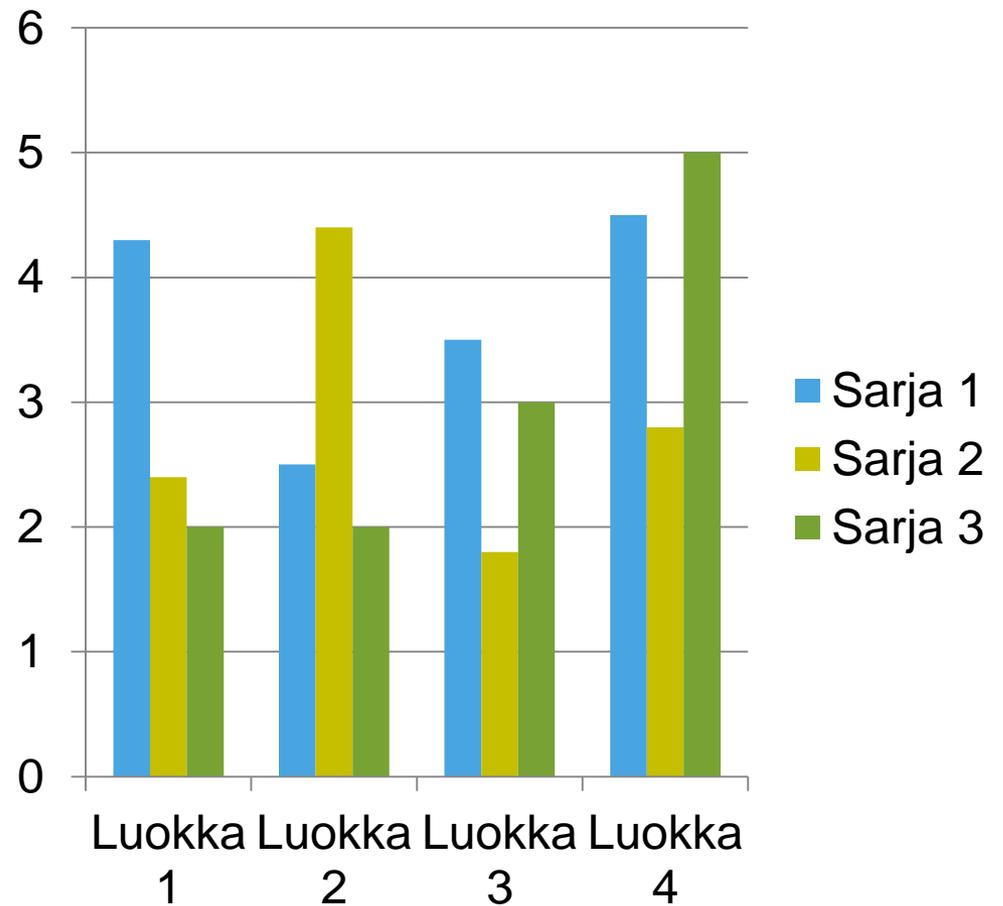
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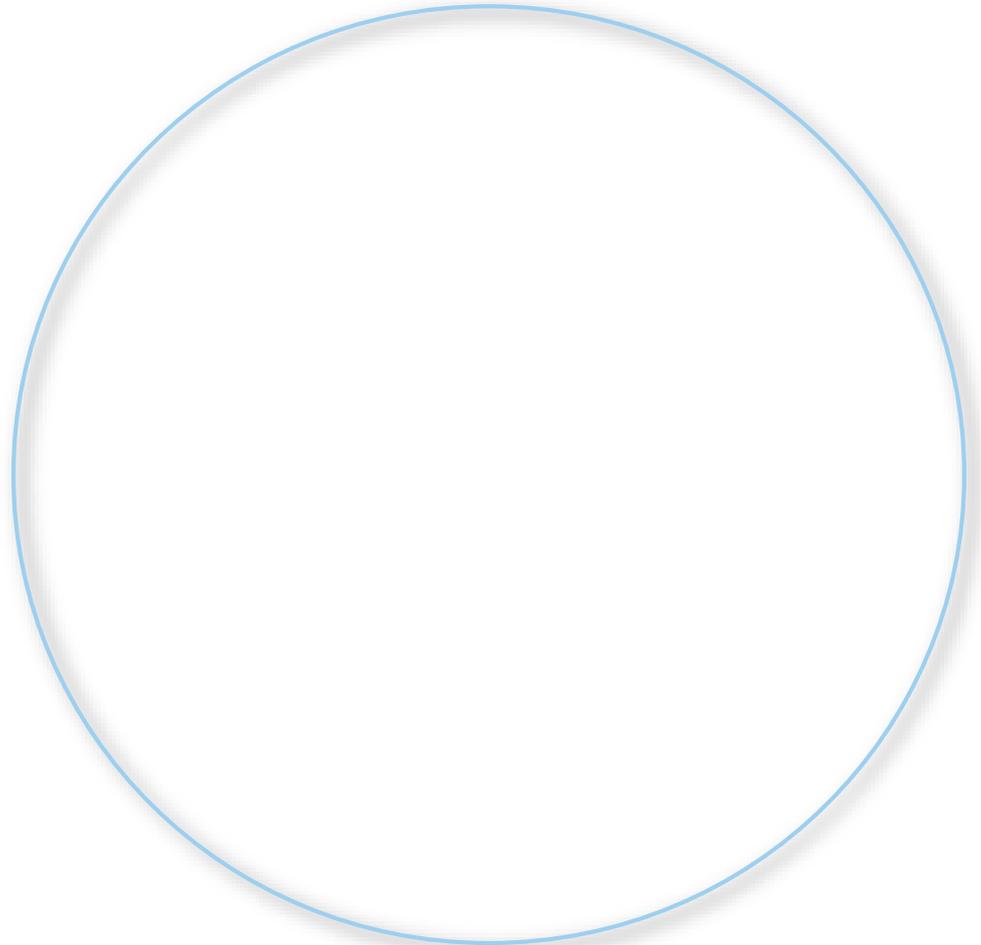
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Kuvateksti