Modelling soil carbon balance at large scales

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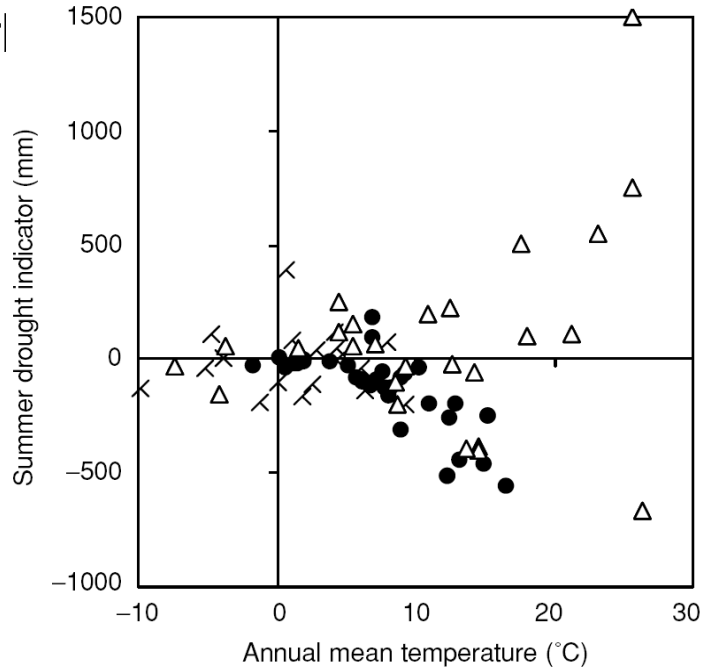
Outline: Modelling soil carbon balance at large scales

1. Need for soil carbon modelling
2. Requirements for soil carbon modelling
3. Specific questions
4. Summary

Need for soil carbon modelling

- To understand functioning of soil carl
- To upscale experimental results
  - Interpolation
  - Extrapolation
- To estimate scenarios (what if)
  - Environmental
  - Management
- Users
  - Scientists
  - Policy-makers
  - Consultants



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Requirements for soil carbon modelling

- Reliability
  - Reliable answers to questions asked
- Relevance
  - Answers to the questions asked
- Feasibility
  - Possibility to conduct the calculations

Reliability: Determinants

- Structure of a model
  - Correct and comprehensive description of processes and affecting factors
- Parameter values of a model
  - Accurate (free of systematic error)
  - Precise (small uncertainty)

Reliability: Evaluation methods

- Model structure
  - General knowledge, purpose of use of a model
  - Comparison of results to measurements
  - Comparison of different models
- Parameter values
  - Comparison to measurements
  - Sensitivity analysis
  - Uncertainty analysis

Relevance

- Model structure
  - Relevant processes included
- Driving factors
  - Relevant included

Feasibility

- Technical possibilities to conduct calculations
  - Computing resources, user resources
- Calibration data availability*
- Input data availability*
- *availability
  - Variables needed
  - Spatial and temporal resolution

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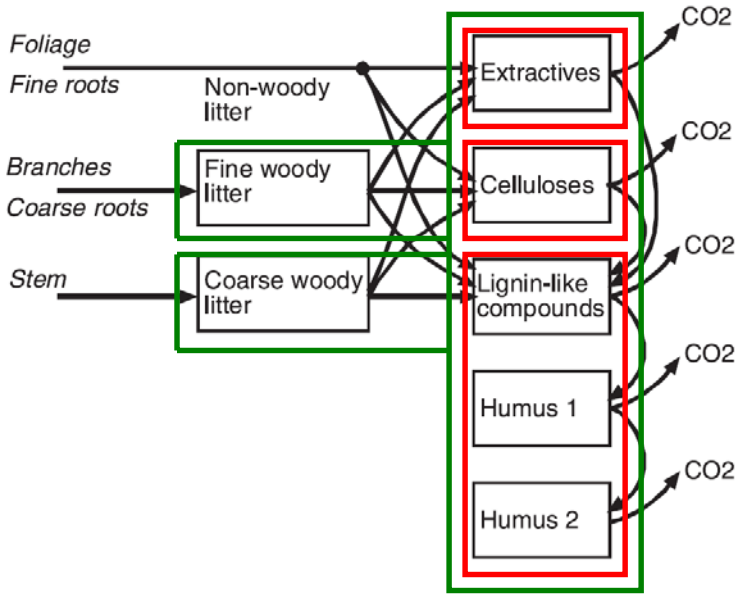
Specific questions

1. Identifiability of soil carbon models
2. Uncertainty analysis of the Yasso model
3. Soil texture effects on soil carbon
4. Mapping soil carbon using statistical models in Finland

Identifiability of soil carbon models

- High requirements for the results of soil carbon models
  - Reliability, objectivity, transparency
- Possibility of estimating parameter values of a model unequivocally from measurements available
- Objective and transparent determination of parameter values, statistical uncertainty estimates

Identifiability of the Yasso model



- The present model not identifable
- Additional measurements needed
  - X_lig and X_hum1, or X_hum2
  - p_lig and p_hum1, k_hum1 or k_hum2
- Changes in the model needed
  - (X_hum1 + X_hum2) and X_lig or X_hum measured or p_lig, k_lig, k_hum known

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Palosuo et al. manuscript

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Identifiability of soil carbon models: Discussion

- Identify mismatch between the structure of a model and calibration measurements
  - To develop the model
  - To develop the measurements
- Identifiability requires simple models
  - Adequate description soil processes?
  - Relevance?
- Strengthen the link between modelling and measuring

Uncertainty analysis of the Yasso model

1. Uncertainty estimates for the parameter values
2. Sensitivity of steady-state soil carbon estimate to changes in the parameter values
3. Uncertainty in the results of the model

Uncertainty estimates for the parameter values

Parameter	Value	Uncertainty	
		Absolute	Relative
Exposure rates of woody litter to microbial decomposition (year^{-1})			
Fine woody litter (a_{fwl})	0.54	0.077–1.0	±86%
Coarse woody litter (a_{cwl})	0.030 or 0.077	0.028–0.032 or 0.072–0.083	±5% or ±7%
Decomposition rates (year^{-1})			
Extractives (k_{ext})	0.48 or 0.82	0.45–0.51 or 0.71–0.93	±6% or ±14%
Celluloses (k_{cel})	0.30	0.28–0.31	±5%
Lignin-like compounds (k_{lig})	0.22	0.17–0.29	−23–+32%
Faster humus (k_{hum1})	0.012	0.002–0.02	−83–+67%
Slower humus (k_{hum2})	0.0012	0.0017–0.0008	−33–+42%
Formation of more complex compounds in decomposition (proportion of decomposed mass)			
Extractives to lignin-like compounds (p_{ext})	0.2	0.1–0.3	±50%
Celluloses to lignin-like compounds (p_{cel})	0.2	0.1–0.3	±50%
Lignin-like compounds to faster humus (p_{lig})	0.2	0.1–0.3	±50%
Faster humus to slower humus (p_{hum1})	0.2	0.1–0.3	±50%

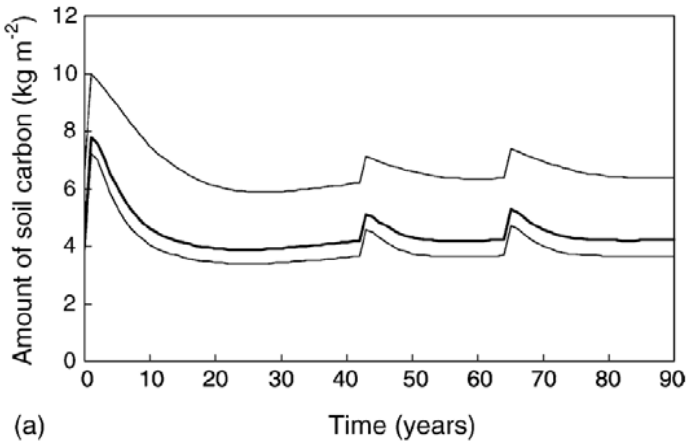
Liski et al. 2005. Ecological Modelling 189.

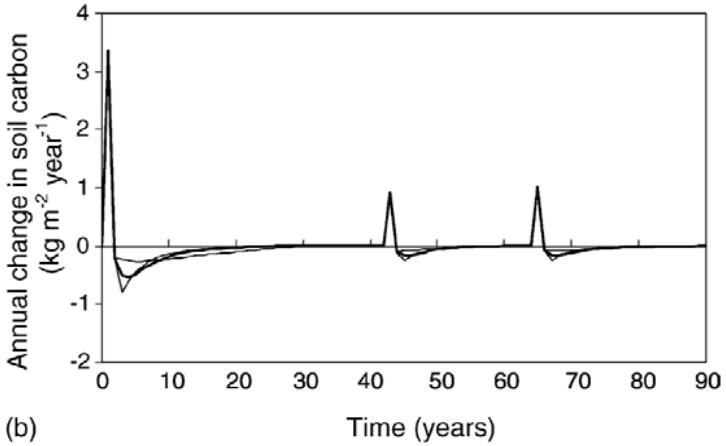
Sensitivity of a steady-state soil carbon estimate

Parameter value	Change in soil carbon (%)
Exposure rates of woody litter to microbial decomposition (year^{-1})	
a_{fwl}	−0.04
a_{cwl}	−0.04
Decomposition rates (year^{-1})	
k_{ext}	−0.01
k_{cel}	−0.07
k_{lig}	−0.07
k_{hum1}	−0.26
k_{hum2}	−0.51
Formation of more complex compounds in decomposition (proportion of decomposed mass)	
p_{ext}	0.05
p_{cel}	0.24
p_{lig}	0.77
p_{hum1}	0.51

Liski et al. 2005. Ecological Modelling 189.

Uncertainty in the results of the model





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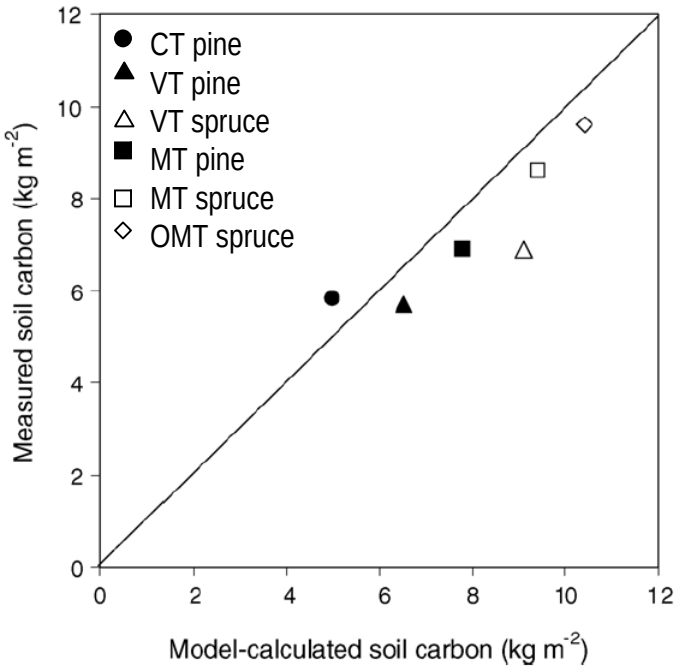
Uncertainty analysis of the Yasso model: Conclusions

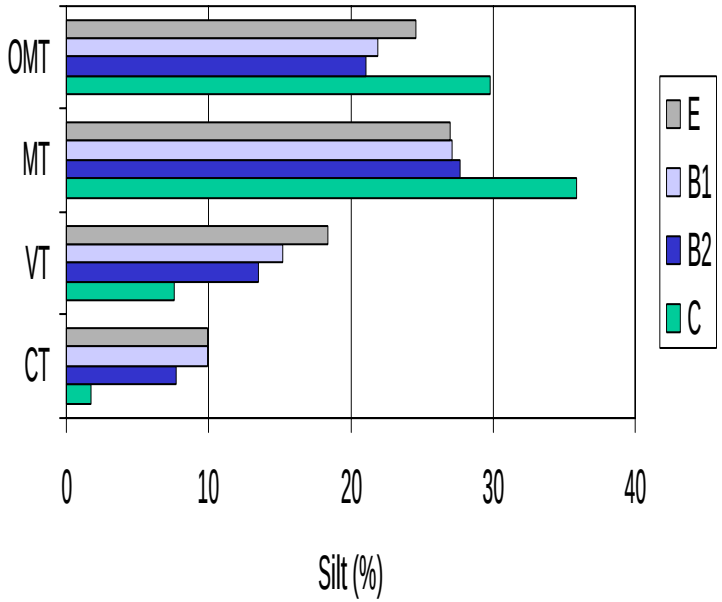
- Soil carbon stock estimates uncertain by nature
  - Dependent on the uncertain humus parameter values
- Soil carbon change estimates more reliable
  - Depend on the other, less uncertain parameter values

Soil texture effects

- Fine particles stabilize soil organic matter by slowing down decomposition

Soil carbon stocks in different forests: model estimates vs. measurements





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Liski et al. 2005. Ecological Modelling 189., Liski & Westman 1997. Biogeochemistry 36.

Soil texture effects: Discussion

- Effects of soil texture on productivity far more important than those on decomposition in these forest soils
- Variability in texture between soil horizons makes modelling of the texture effects on decomposition difficult

Mapping soil carbon stocks in Finland

- Background
  - No estimates for soil carbon stock in Finland's forests in the mid-1990s
  - Limited resources in a research project to come up with the estimates
  - Most important affecting factors: site productivity and temperature
- Material and method
  - Soil carbon measurements at 60 sites (30 site productivity effects, 30 temperature effects)
  - Statistical models for soil carbon density: organic layer = f(site productivity), 0-1 m mineral soil = f(site productivity, temperature)
  - Estimates for NFI sites (n=46 000)
  - Interpolation over the entire country

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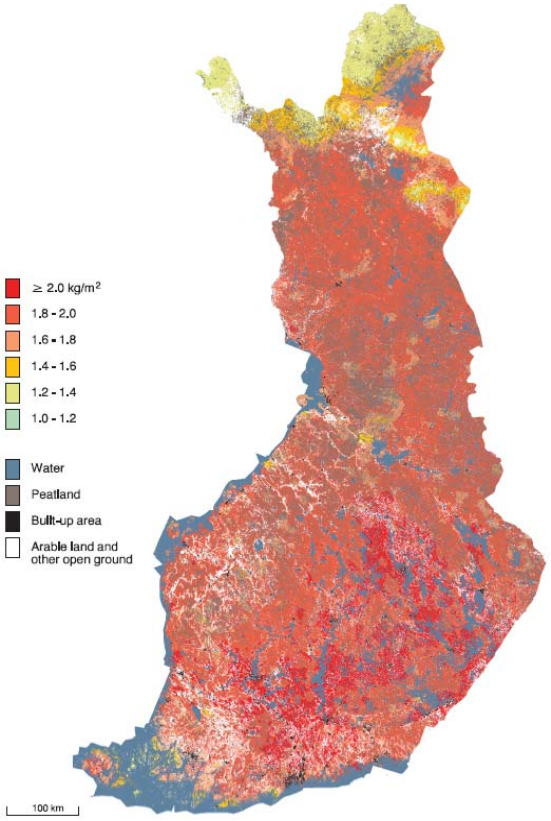
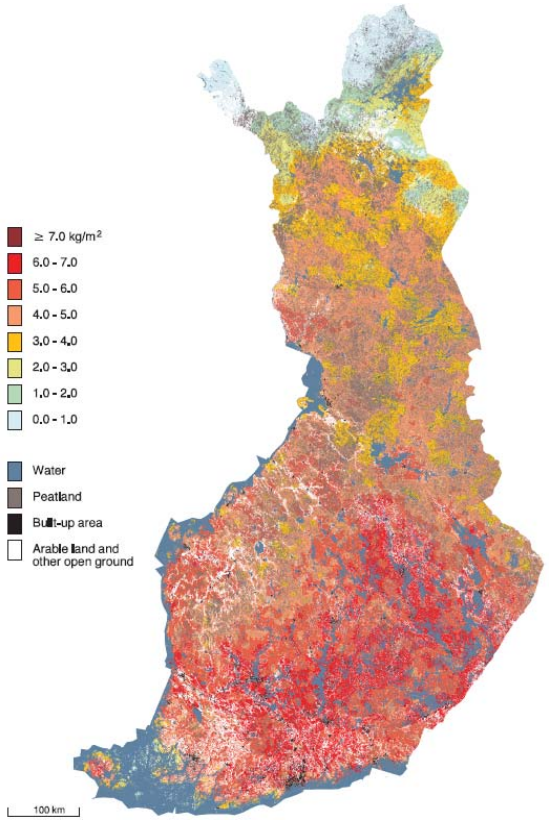
Liski & Westman 1997. Biogeochemistry 36.

Soil carbon in Finland's upland forests

Organic layer



0-1 m mineral soil layer



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Soil carbon in Finland's upland forests

Soil layer	Areal weighting estimate		Interpolated blocks estimate	
	Tg	%	Tg	%
Organic	315	28	370	28
Mineral soil 0–1 m	754	68	905	69
Mineral soil below 1 m	40	4	40	3
Total	1109	100	1315	100

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Potential error in the estimates of soil carbon stock

Error source	Organic layer	Mineral soil layer
Stoniness of soil	0	−21
Shallowness of soil	0	−7
Dominance of broadleaved trees	−3	−3
Forest harvesting	−16	0
Slash and burn cultivation	0	−4
Drainage properties of soil	+6	+6

Liski & Westman 1997. Biogeochemistry 36.

Summary: Modelling soil carbon balance at large scales

- Questions asked
  - Soil carbon stock
  - Soil carbon changes
  - Effects of different factors on soil carbon (changes)
- Choice of model
  - Statistical vs. dynamic
  - Simple vs. complicated
- Requirements for soil carbon modelling
  - Reliability
  - Relevance
  - Feasibility

Evaluation of different modelling approaches

		Reliability		Relevance	Feasibility	Overall
		Structure	Param.			
Stock	Stats.	+	+	+	+	+
	Dyn.	+	-	+	+	-
Δstock	Stats.	-	+	-	+	-
	Dyn.	+	+	+	+	+
	Simple	?	+	?	+	?
	Complex	+	?	+	?	?

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