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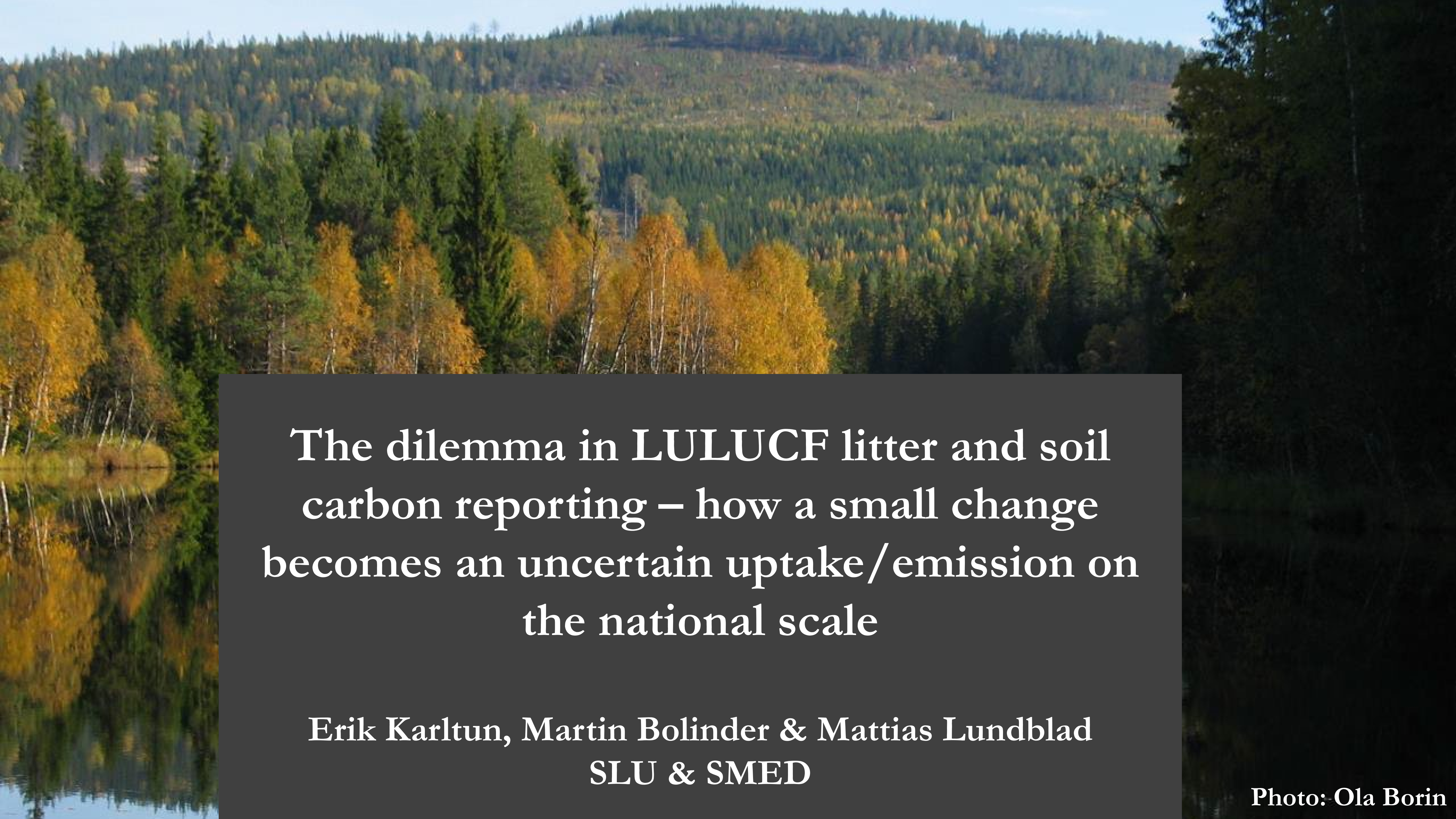
SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE



The dilemma in LULUCF litter and soil carbon reporting – how a small change becomes an uncertain uptake/emission on the national scale

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Photo: Ola Borin

Carbon stock changes in litter and mineral soils
Forest land remaining forest land


Photo: Ola Borin

Challenges in soil carbon change estimation

- Changes are normally slow - decades
- Expected changes are small in relation to stocks
- Sampling destructive - re-sampling at exact location not possible
- Spatial variation is high + many sources contributes to variation along the data generation chain

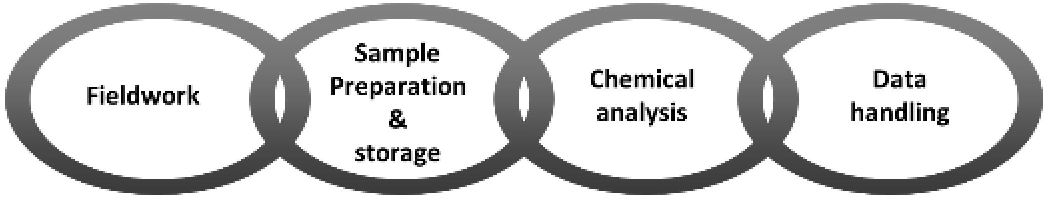
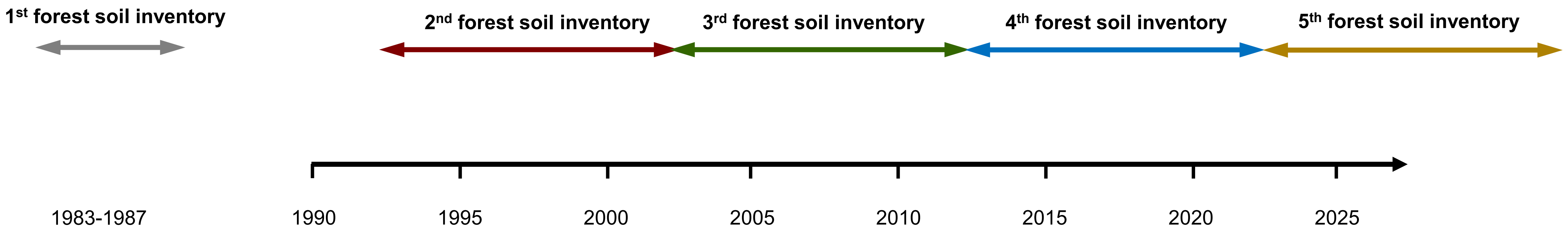


Photo: Ola Borin

Repeated mesurements on permanent sample plots

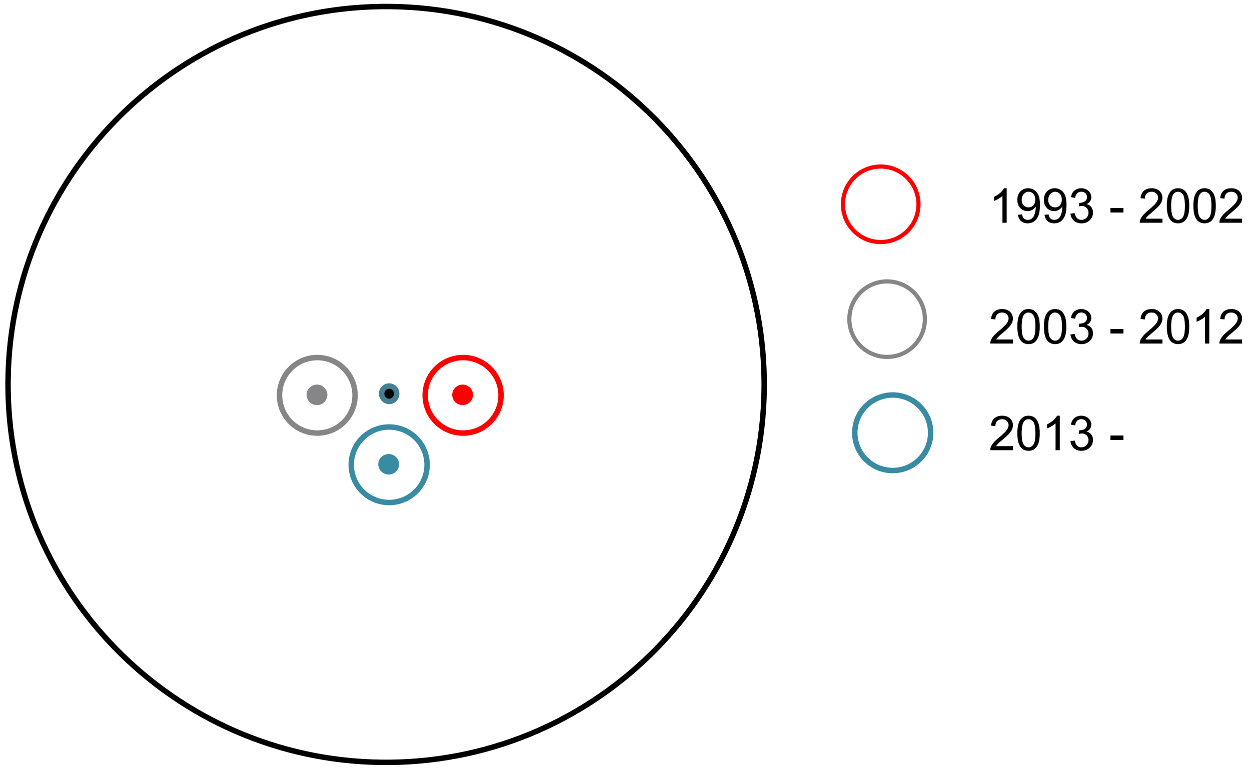
Forest Soil Inventory cycles

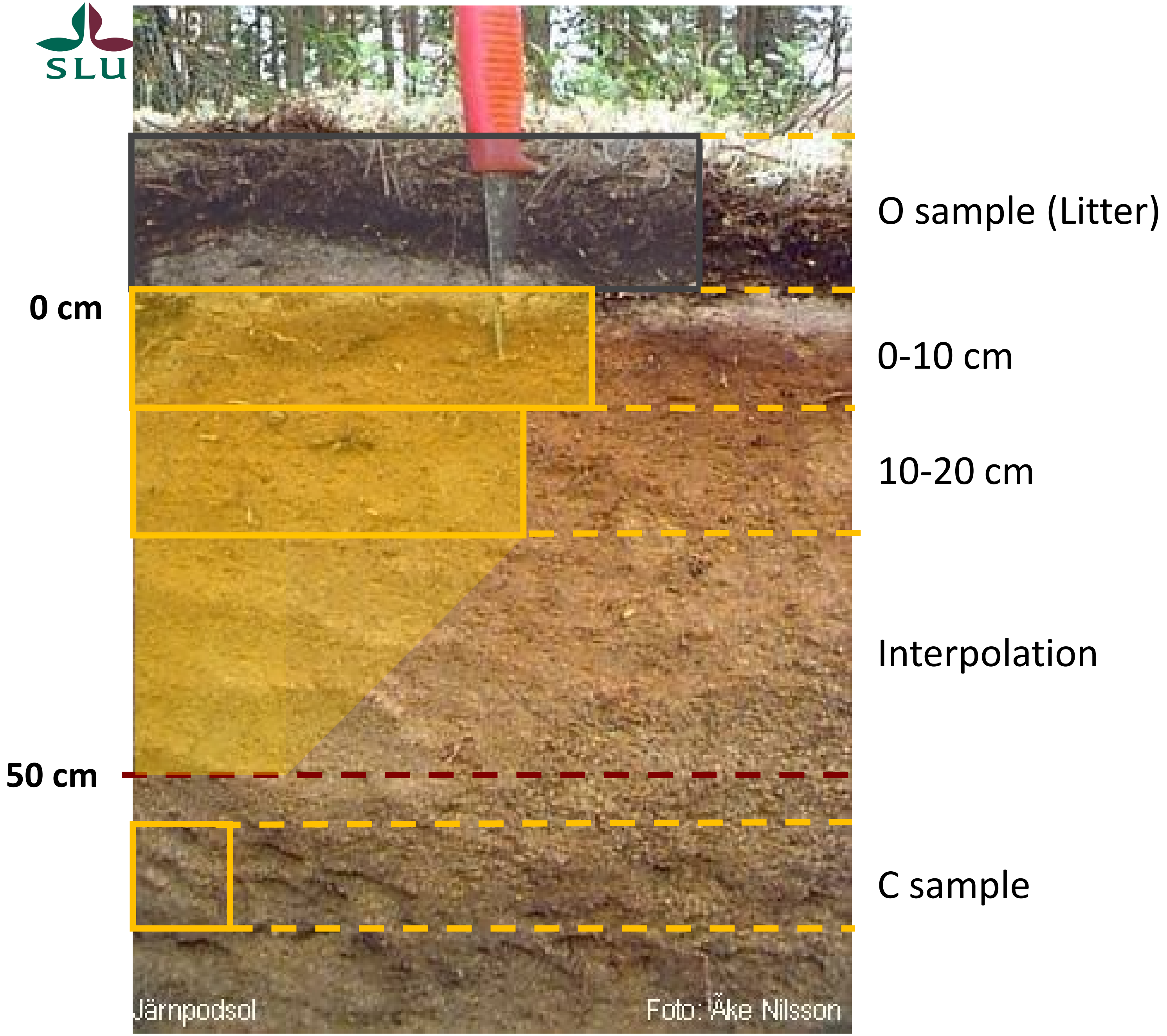


Inventory plots

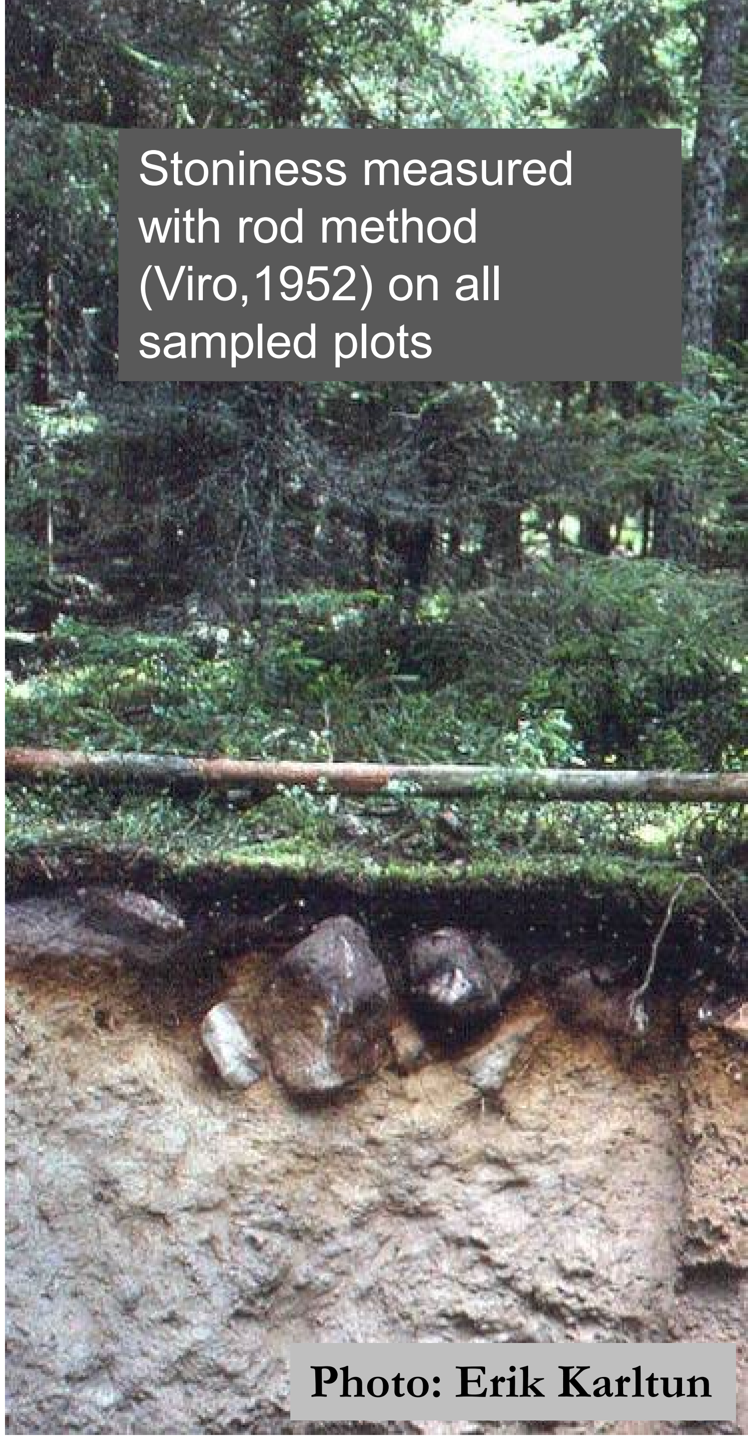
- 10 meter plot used in the SFSI
- Split plots in case of landuse borders
- Soil inventory on main subplot
- Soil sampling circle (1 m radius) placed within each plot
  - Pre-determined positions for each inventory period
  - Information on old positions in field computers

Soil sampling in different inventories





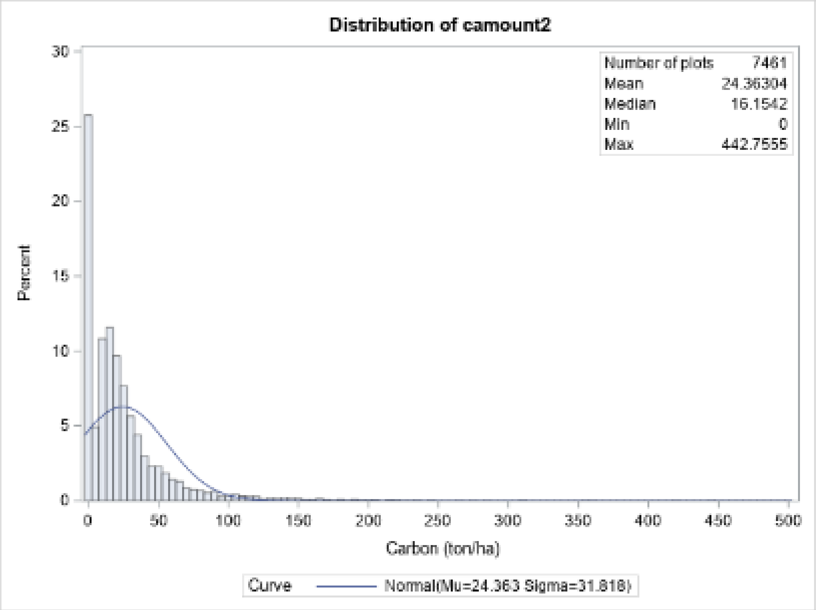
0 cm
50 cm
O sample (Litter)
0-10 cm
10-20 cm
Interpolation
C sample
Järnpodsol
Foto: Åke Nilsson



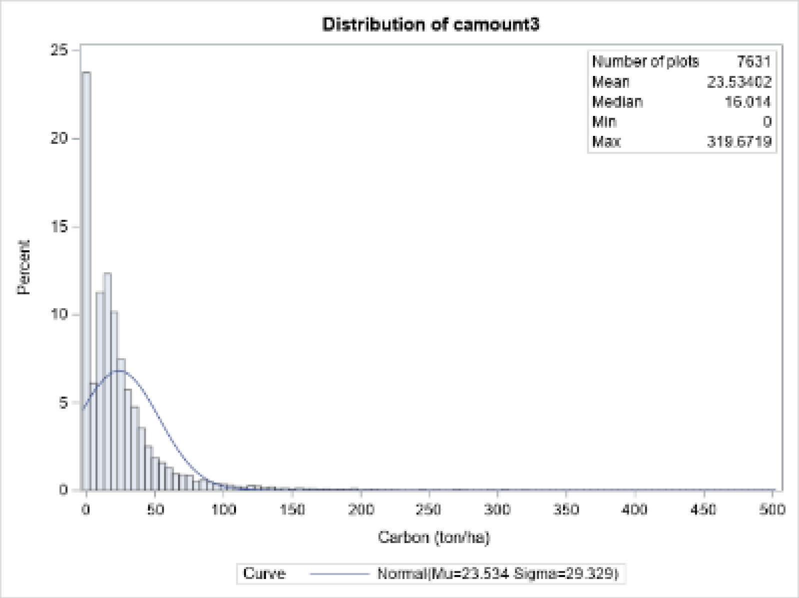
Stoniness measured with rod method (Viro,1952) on all sampled plots
Photo: Erik Karltun

Litter carbon distribution

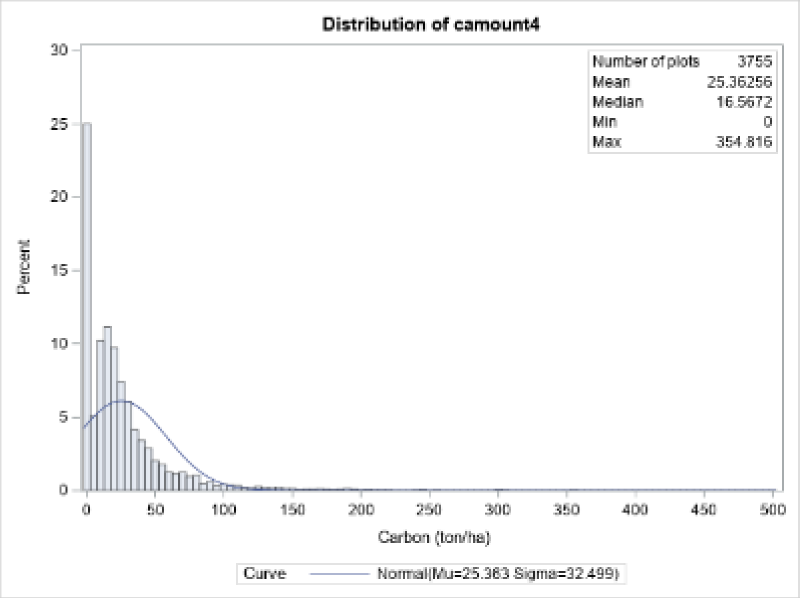
2nd inventory



3rd inventory

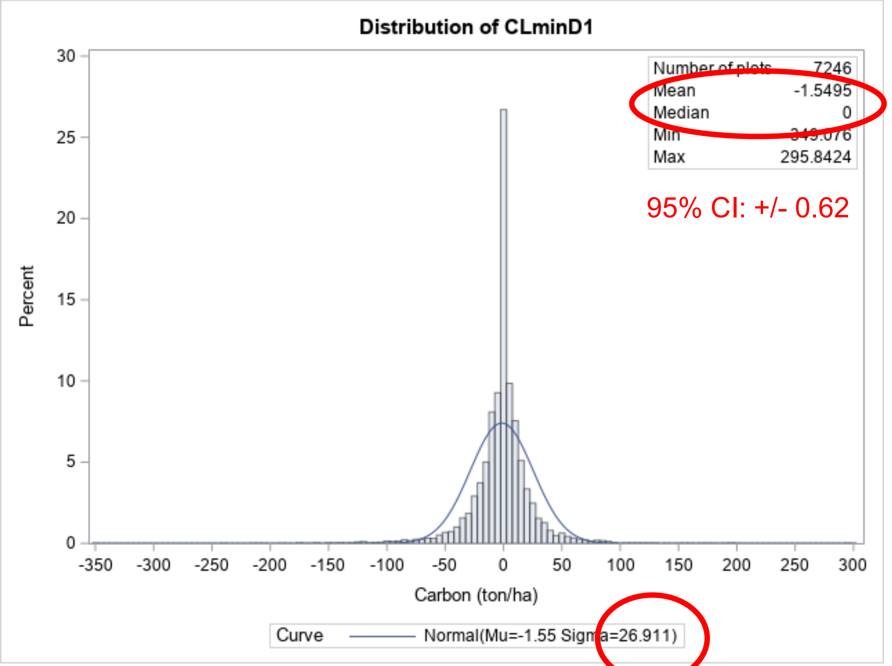


4th inventory

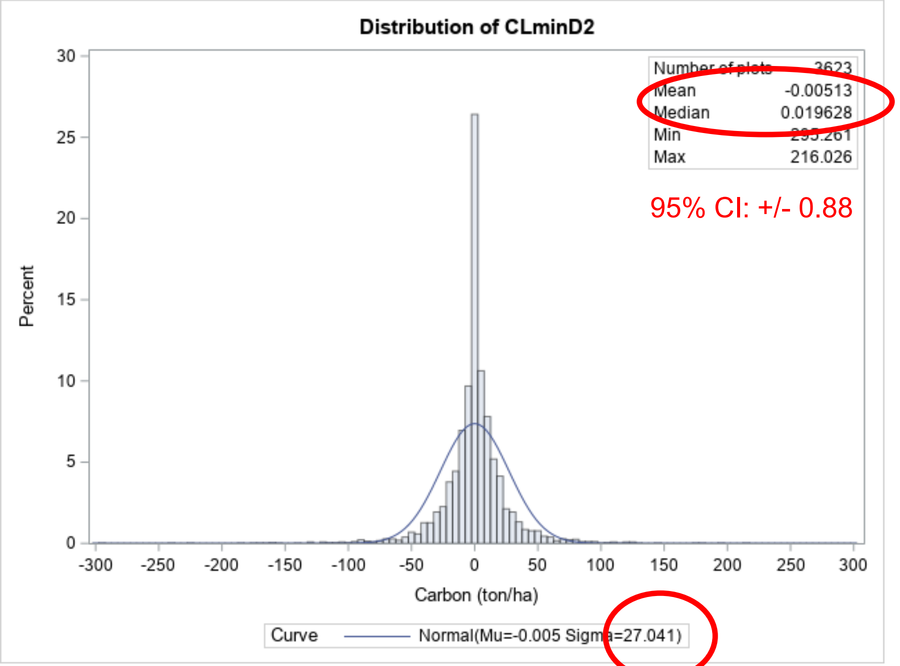


Litter carbon change distribution

2nd inventory to 3rd inventory

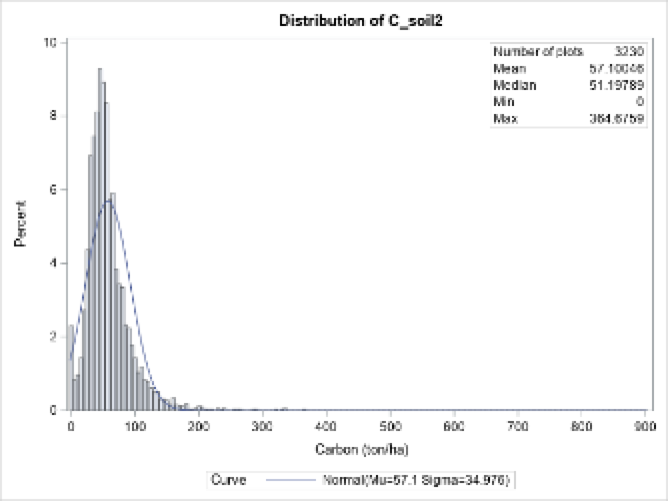


3rd inventory to 4th inventory

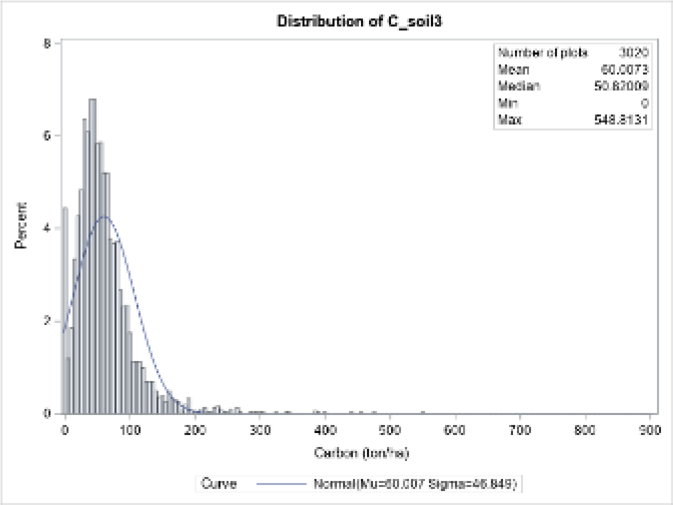


Soil carbon distribution

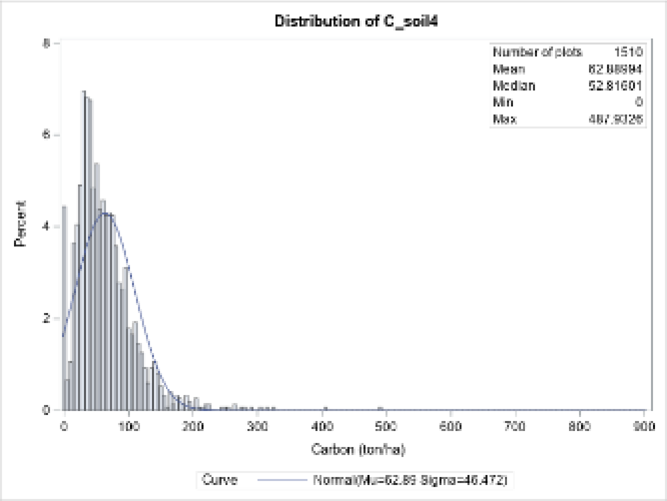
2nd inventory



3rd inventory

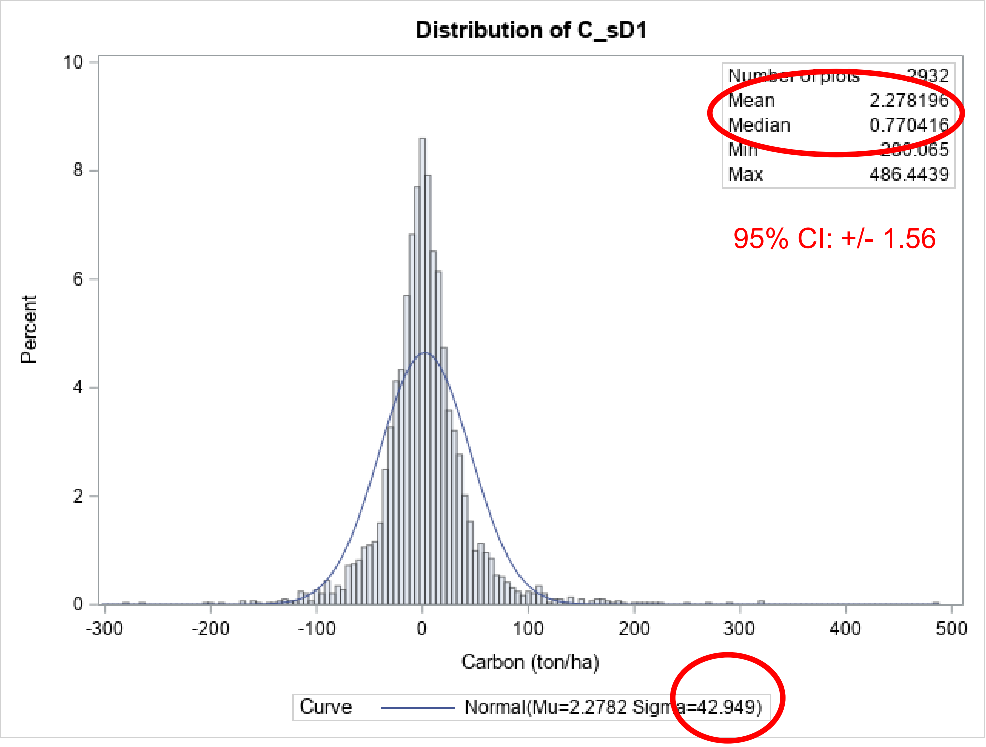


4th inventory

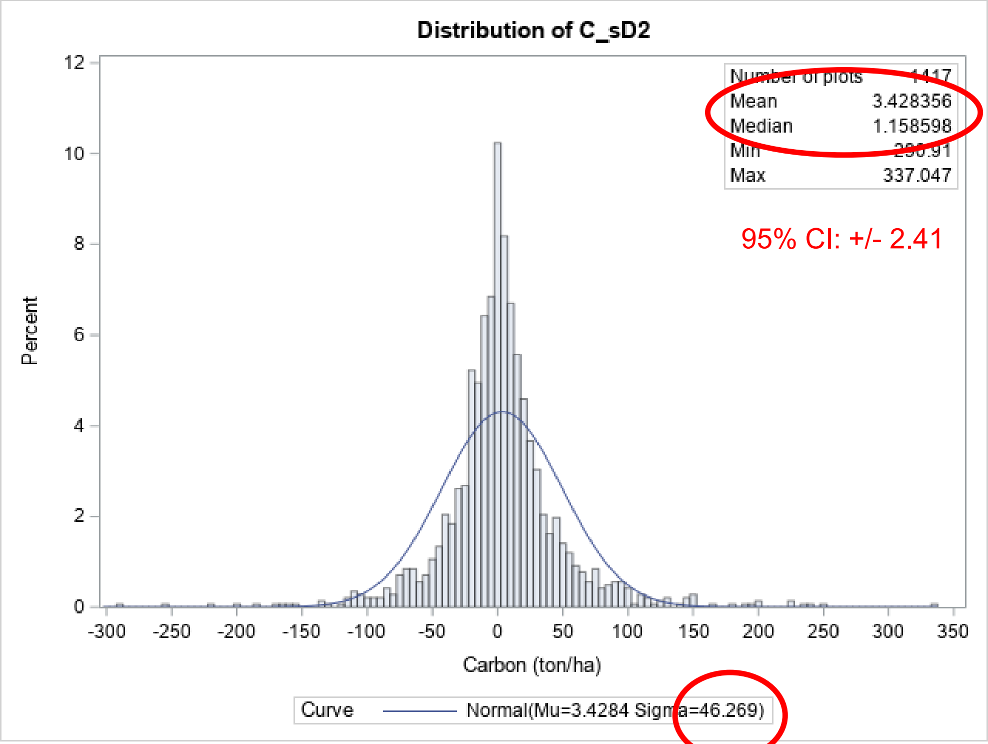


Soil carbon change distribution

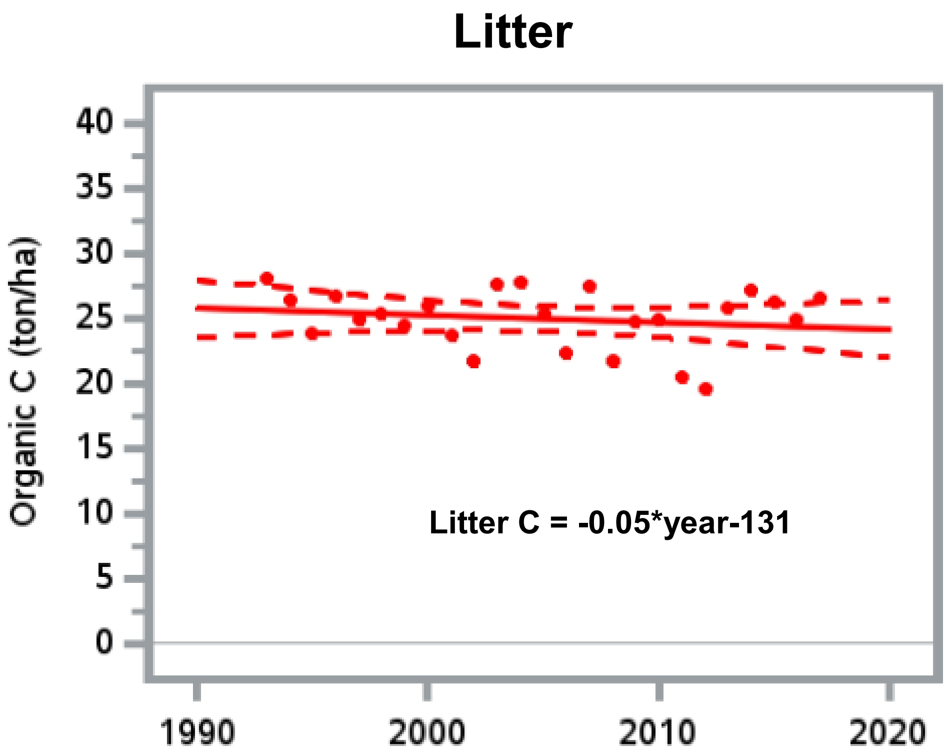
2nd inventory to 3rd inventory

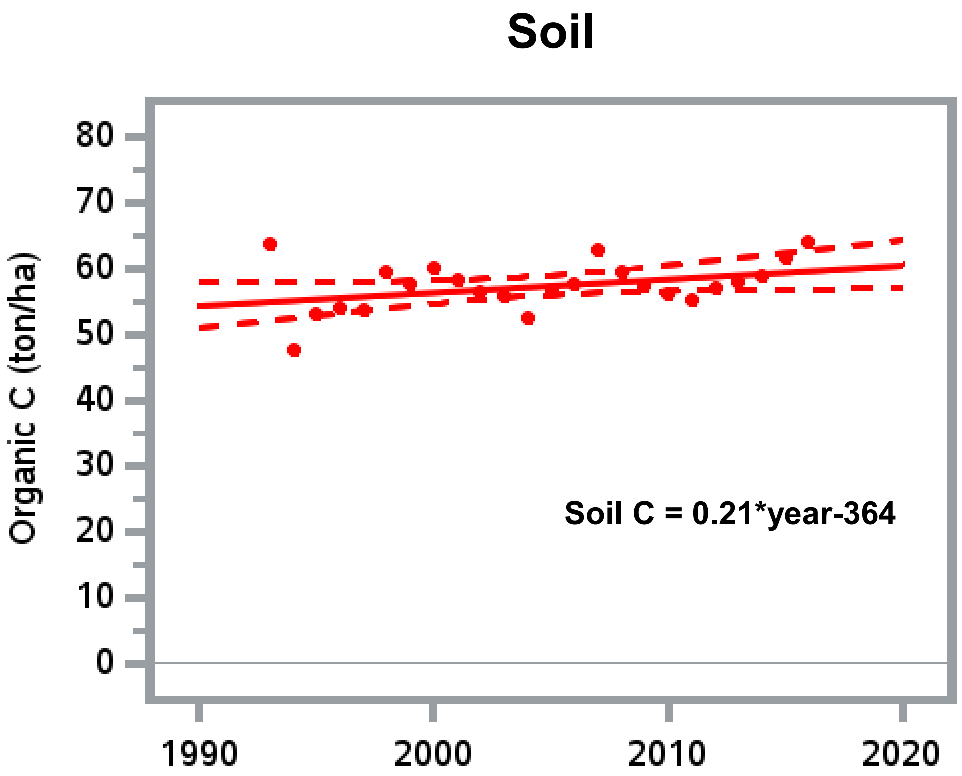


3rd inventory to 4th inventory



Forest soil carbon stock – time series

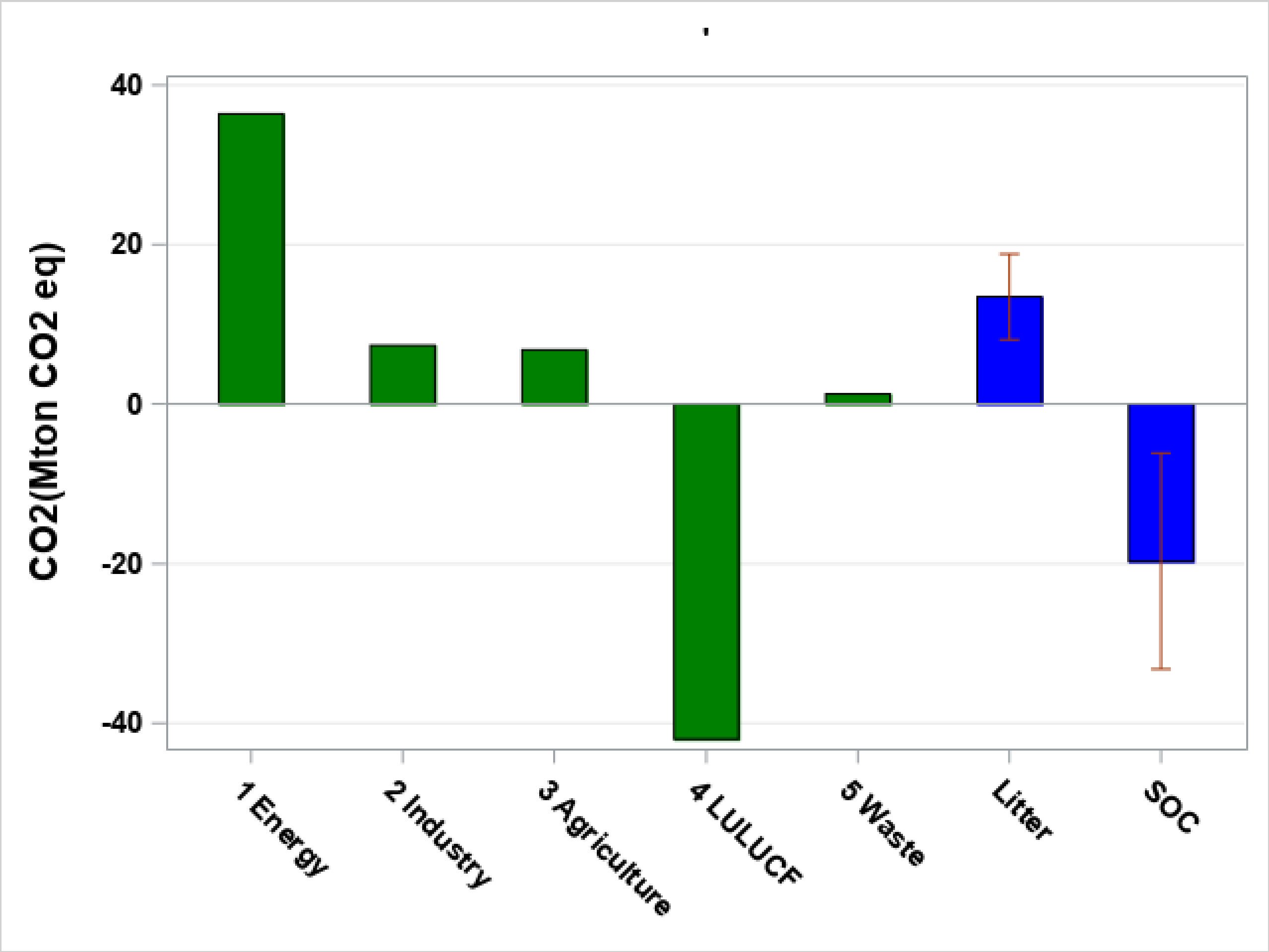




Stock size and change on Forest remaining Forest from in Sub2022

Variable	Litter	Soil
Stock (ton C ha^{-1})	25.8	57.8
Change ton C ha^{-1} yr^{-1}	-0.15	0.22
Change 95% CL	+/- 0.062	+/- 0.16
Change/Stock yr^{-1}	-6‰	4‰

Litter and soil carbon changes with statistical uncertainties (95% confidence limit) as compared to emissions/uptake in all reported sectors in Sweden



Carbon stock changes in mineral soils
Cropland remaining cropland

The ICBMregion concept.

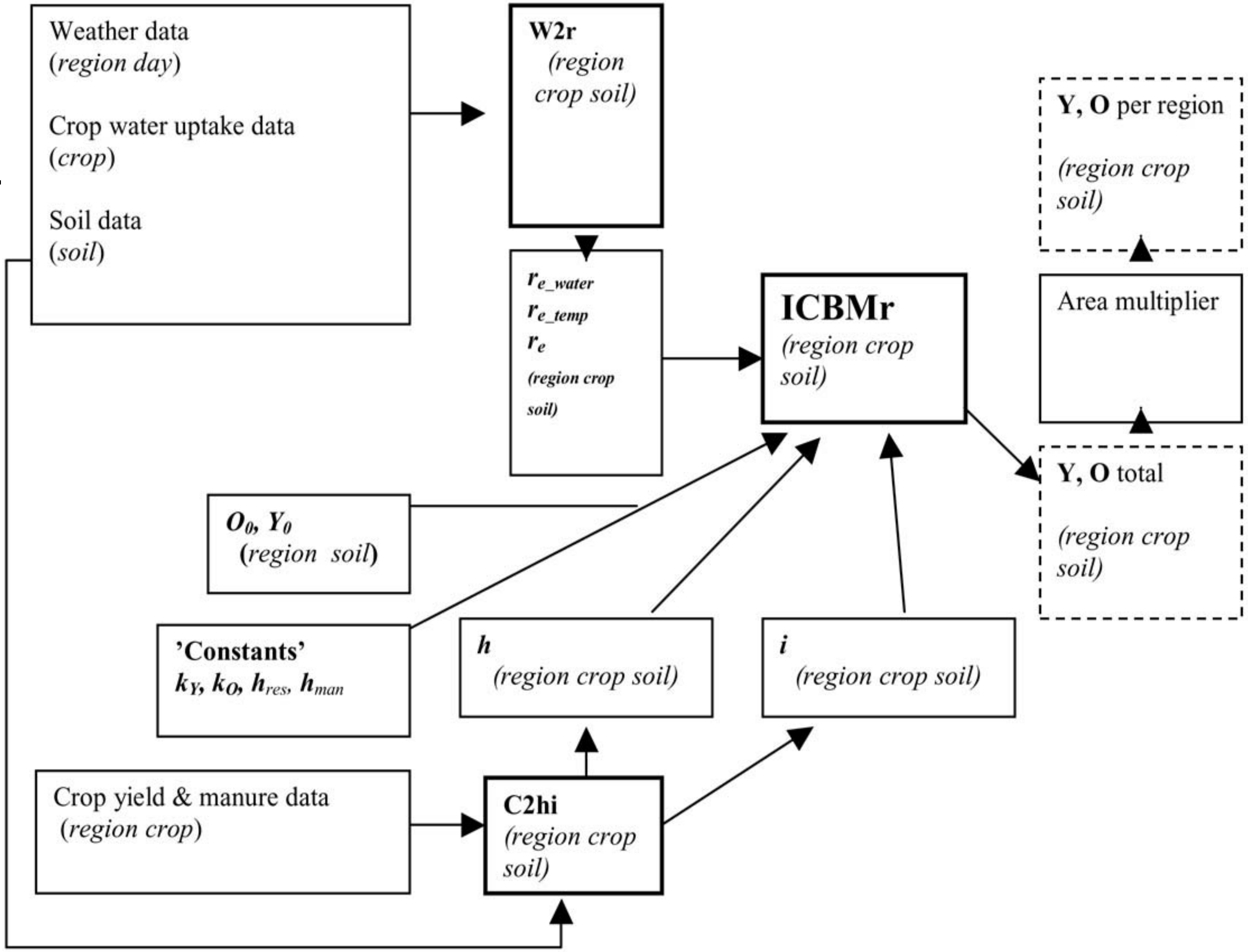
Crop, weather, and soil data for eight regions are used in the weather-to-re module W2r, calculating soil climate, re, for each region, crop and soil (top left).

The initial carbon mass values O_0, Y_0 are taken from soil inventory data.

Parameters k_Y, k_O, h_{res}, h_{man} are regarded as constants, and the indices *res* and *man* indicate crop residues and manure, respectively.

Crop yield and manure input data are used to calculate carbon input to soil *i*, as well as a weighted h, estimated by the allometric functions in the C2hi module.

The two initial values O_0, Y_0 and the five parameters re, k_Y, k_O, *h* and i are then used for calculating total young (Y) and old (O) carbon [kg ha $^{-1}$]



These values are then multiplied by the actual area to obtain totals for, e.g. a region

Some Tier III related challenges using SOC-models (I)

Estimation of C inputs to soil from crops

- Most important driving variable in many soil C models used for national reporting
  ICBM, C-TOOL (Denmark), Yasso07 (Finland), RothC (Switzerland)

- Very high uncertainty, in particular for root-derived C (e.g., Keel et al. 2017)

- Estimated from crop types and crop yields using various allometric functions
  ICBM; Andrén et al. (2004) and Bolinder et al. (2007; 2012; 2015)

- Is a central research topic within current modeling groups and projects (in which SLU are participating), e.g., **EJP SOIL: CarboSeq, MaxRoot-C, SIMPLE**

Some Tier III related challenges using SOC-models (II)

Calibration and validation of C models

- Data from long-term (>10 years) field experiments are essential!

- Approximately 600 long-term (10–100 years) field experiments in the world, most of them in Europe (Debreczeni & Körschens, 2003)
  Sweden is well supplied with experiments >60 years old (Bergkvist & Öborn, 2011)

- Use of long-term (especially the oldest) field experiments also present several difficulties (Kätterer & Bolinder, 2022 and references cited therein), for example:
  - They often not cover all the national geographical variation in soil properties and regional climatic conditions
  - They does not necessarily match all common agricultural practices in a country
    - New crop types and varieties, cover crops, fertilization rates, etc.
  - Variation in ploughing depth over time may create a dilution of C in the arable layer
    - Can result in a distortion of the time series of soil C

Some Tier III related challenges using SOC-models (III)

Activity data used for running the models, examples of potential difficulties

- Changes through time in how national data are collected and reported can be problematic
  - Example: Yield data for forage crops in Sweden

- Changes relating to national data on manures
  - Increasing use of milk robots and washing robots (swine) implies more water in manures, can create difficulties depending on the method used for estimating C from manures
  - Increasing use of manures for biogas production creates a new source of C ("biofertilizer") distributed on arable lands, which has new characteristics that needs to be accounted for in C models

- Changes in agricultural practices not necessarily included in national official statistics and difficult to estimate
  - Use of cover crops changes through time, partly depending on subsidies programs
    - Need to know both the actual area and productivity of cover crops
    - Need to develop allometric functions to estimate C inputs to soil

Continuous improvement of ICBM – some examples

Calibration

- Include more of long-term field experiments in a multi-site calibration approach

  Some of the Swedish long-term field experiments are meta-replicated, i.e., the same experiment is replicated at different geographical locations and should thereby permit at least a certain level of better generalization

Validation

- The Swedish soil-monitoring program can be used not only for initializing ICBM but also offers a possibility for validation, at least at the national level
- The last three inventories use identical coordinates, and cover a change in C over two decades (Inv. II (2001-2007), Inv. III (2011-2017) and Inv. IV ongoing (2021-2027)
  - One sampling point per 1300 ha arable land
  - Small differences in soil C concentrations over time, the variability is high and statistical inference is challenging. **A difference of only 0.04 percentage units in soil C concentrations is representing a soil C stock of 1 Mg C ha^{-1}**

Work related to activity data

- Quality assessment for calculations of C inputs from manures
- Development of a crop growth model for cover crops and associated allometric functions

The dilemma

Expectations from society regarding monitoring and mapping soil carbon stock changes increases

Small changes - a few ‰/yr - in litter and soil carbon stocks results in huge sink or sources on the national scale

The determination of the changes are uncertain and vulnerable to small systematic errors – which will inevitably be large errors in the national GHG budget

This problem is not limitied to inventories - all Tier 3 methodologies have challenges with precise and accurate estimation of litter and soil carbon changes