The storage of non-structural-carbon of the pines at SMEARII

Seasonal dynamics and connection to other carbon flows

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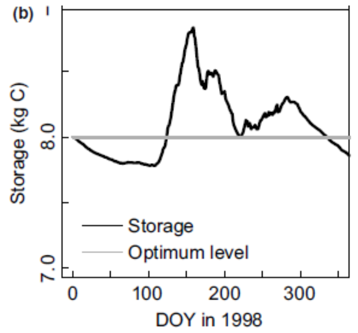
Motivation

- Estimates of the total NSC storage of a mature tree are rare.
- Aim was to estimate the total size of the storage and its annual dynamics as well as connection to the main carbon flows
- Hypotheses:
  1. Total storage increases in spring with photosynthesis, decreases during the most intensive growth period and increases again in autumn
  2. Labile sugar concentration stays stable whereas starch is more dynamic
  3. Root exudates are a notable sink of carbon



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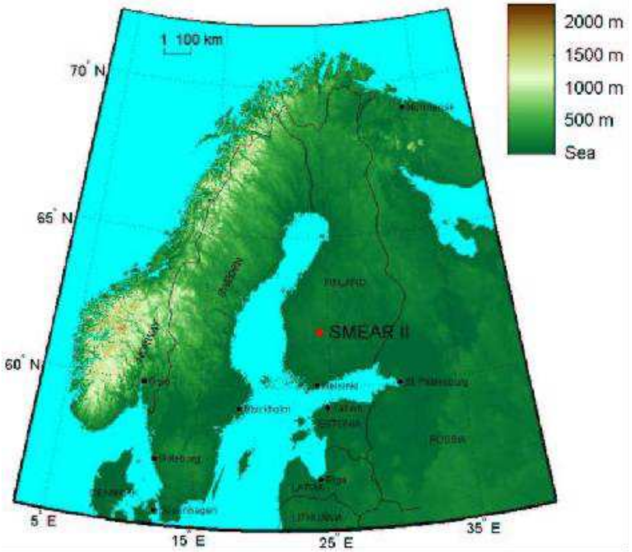
NSC sampling and analysis



- SMEARII, Scots pines ~50 years
  - 1-3 pines in 2015
- Needles, new needles, primary wood, new primary wood, (phloem,) xylem in upper trunk, xylem in lower trunk, big roots, small roots
- roots washed and separated from soil

→ -80 °C → freeze-drying → milling

- Analysis:
  - Soluble sugars with liquid chromatography
  - Starch enzymatically degraded to glucose with α-amylase (Total Starch Assay Kit)

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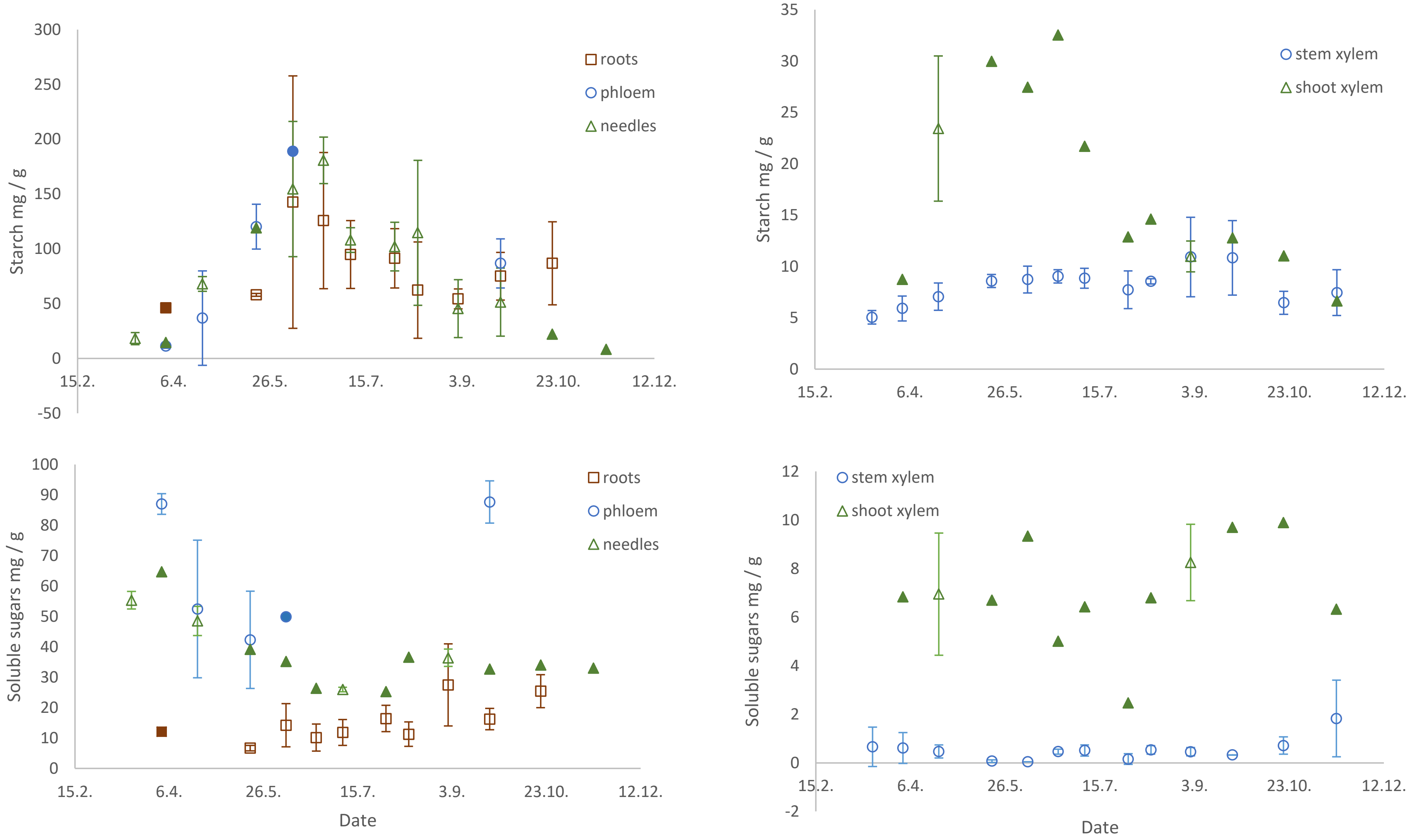
Concentrations



Starch and soluble sugar concentration in tree organs. Open symbols indicate dates when samples from three trees were analysed. Standard deviations of the sample values are shown with bars. Filled symbols represent values of one tree (tree number 2) on days when samples only from that tree were analysed.

Upscaling to whole tree level – sizes of tree organs

- Tree needle mass based on tree diameter and height (Repola 2009)
  - Assumed that during winter period (doy 285-150) needle mass is 2/3 of maximum
- Needle mass : fine root mass ratio 2:1 (Vanninen & Mäkelä 1999)
- Sap wood estimated to be 80 % of total xylem wood. Sap wood mass then divided to shoots (10 %) and stem and bigger branches (90 %)
- Phloem mass estimated roughly based on Hölttä et al. 2013 (10 % of sap wood mass)

Upscaling to whole tree level – amount of storages

We have samples of stem and shoot xylem and needles for every sampling date.

Fine root (< 2 mm) samples exist for the snowless period. Our root NSC concentration values show a similar yearly pattern as observed by Oleksyn et al. (2000) and thus, we filled in the missing winter time observations from our root NSC series based on those results.

We took a few phloem samples in the beginning of the growing season and one in autumn. We formed a series of phloem NSC data with our results and yearly pattern of phloem storage contents measured by Gruber et al. (2013) and Jyske et al. (2015).

For each sampling day *i*, the total mass of carbon in soluble sugars W_{si} or starch W_{ti} of the measurement tree is

$W_{si} = \sum_k m_{ik} s_{ik}$ and $W_{ti} = \sum_k m_{ik} t_{ik}$

Where *m* is the mass of organ *k* (needles, shoot xylem, stem xylem, fine roots, phloem) and *s* and *t* are the soluble sugar and starch contents of the organ, respectively

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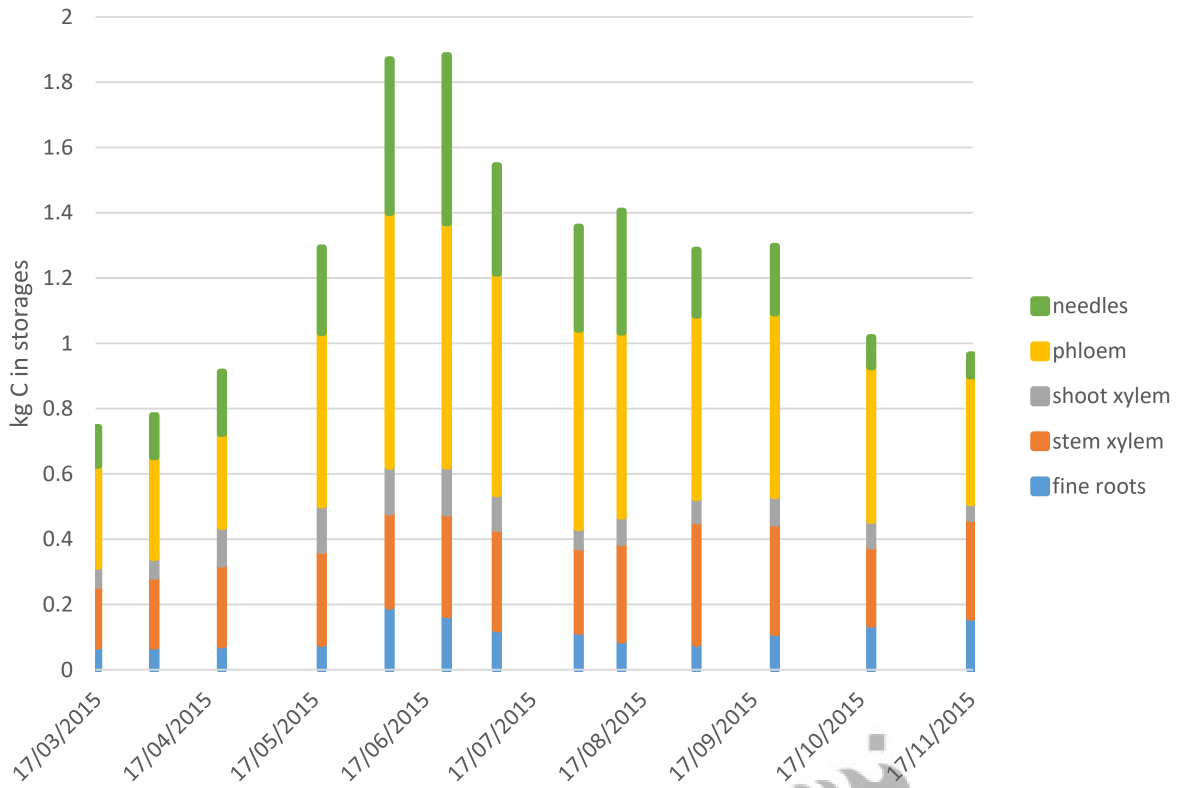
Upscaled storages



Total NSC in tree organs. Values for roots and phloem on missing sampling dates were constructed with our observations and previous work by Oleksyn et al. (2000), Gruber et al. (2013) and Jyske et al. (2015).

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New Phytologist
Research

CASSIA – a dynamic model for predicting intra-annual sink demand and interannual growth variation in Scots pine

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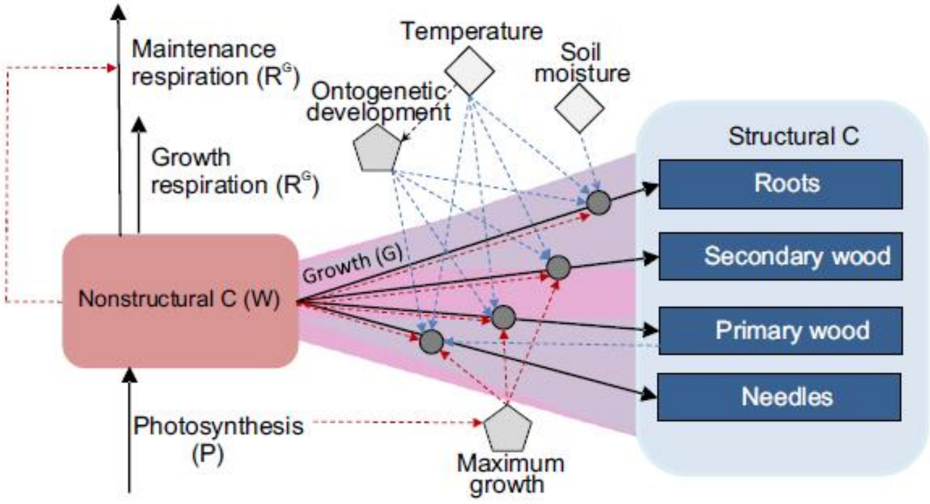


- Time step is one day
- The modelling unit is one tree (our sampling tree)

- GPP is a sum of trees of all size + ground vegetation

→ Photosynthesis by SPP
    - Parameterized at SMEAR II
    - Daily photosynthesis per tree in the particular size class (dbh 15-20 cm)

Daily growth, *G*, of xylem (length, diameter), needles and roots is determined as

$$G = k(t)g(T)f(s)L$$

Where *k(t)* is the decreasing effect of storage, *g* is a direct temperature effect, *f(s)* is a phenology factor, dependent on temperature sum, and *L* is a maximum growth parameter. $f(W), g(T), f(s) \in [0,1]$

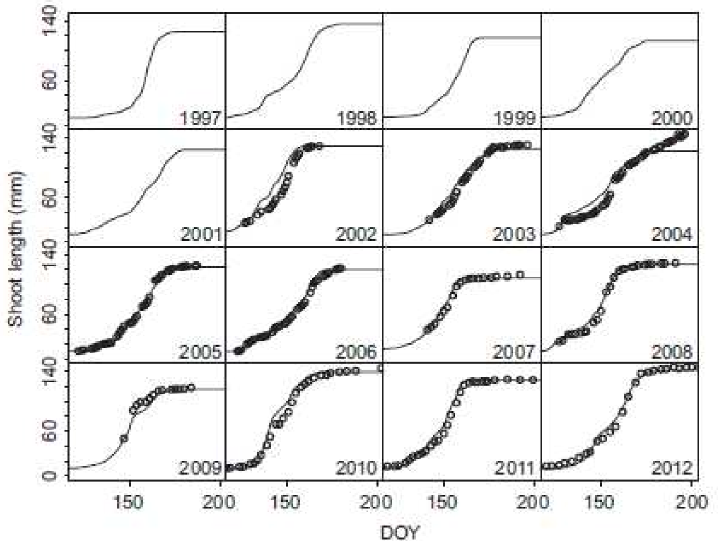
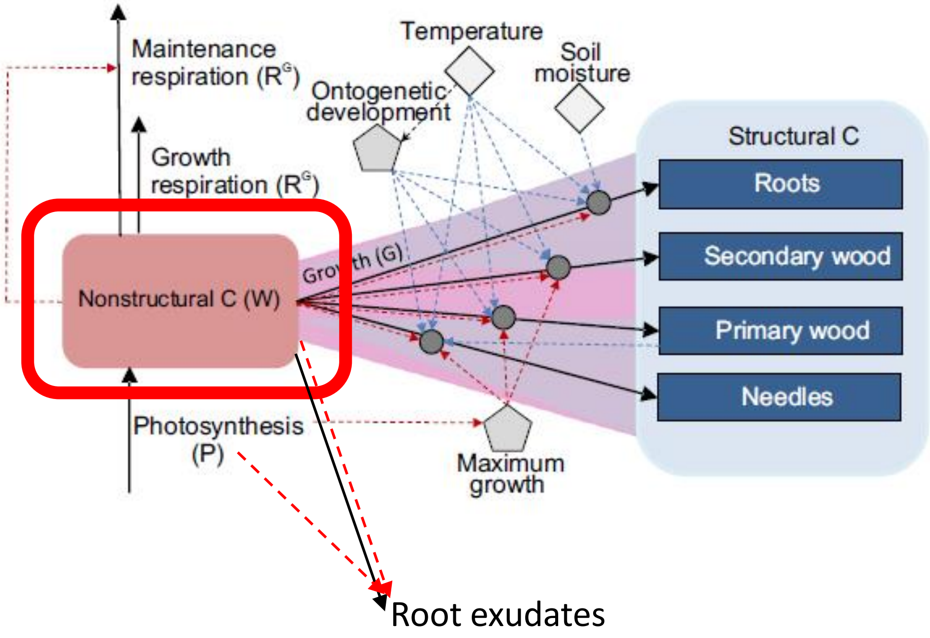


Fig. 4 Simulated (line) and measured average (dots) of relative shoot length of Scots pine (*Pinus sylvestris*). The measurement is rescaled using a linear relationship between the observation and prediction on the first day of measurements and on the one closest to day of year (DOY) 175. The model is parameterized using the measurements in 2008.

For this study…



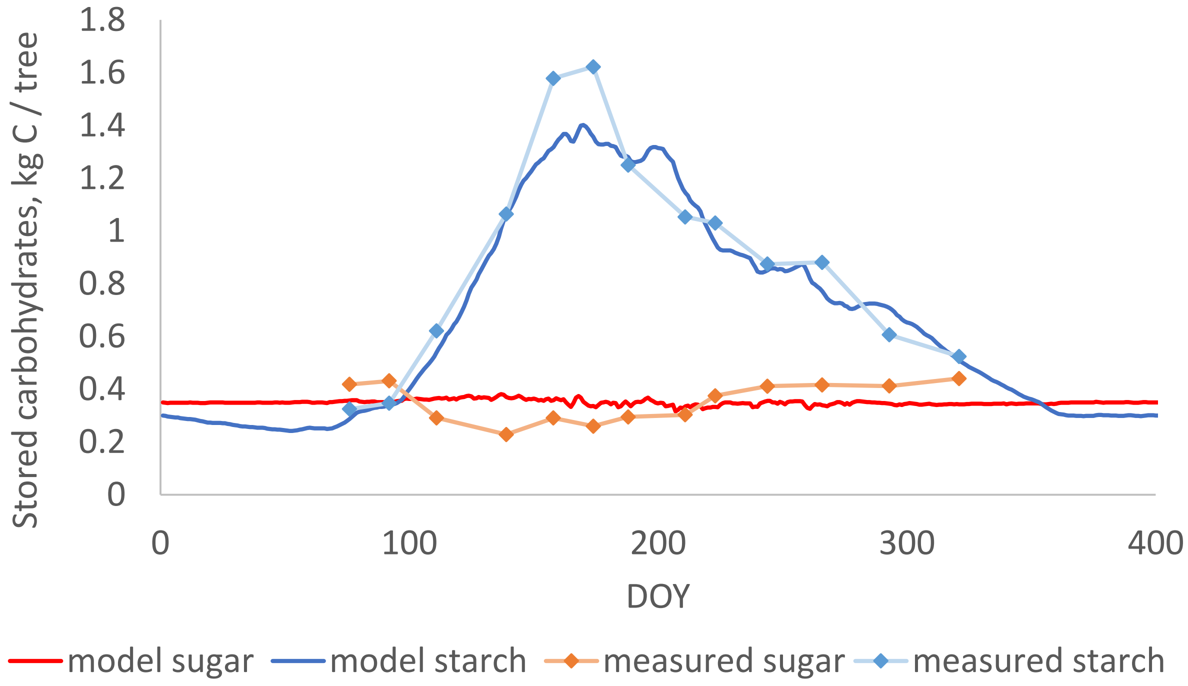
Total growth based on measurement data to reliably quantify the use of carbon to growth

Root exudates

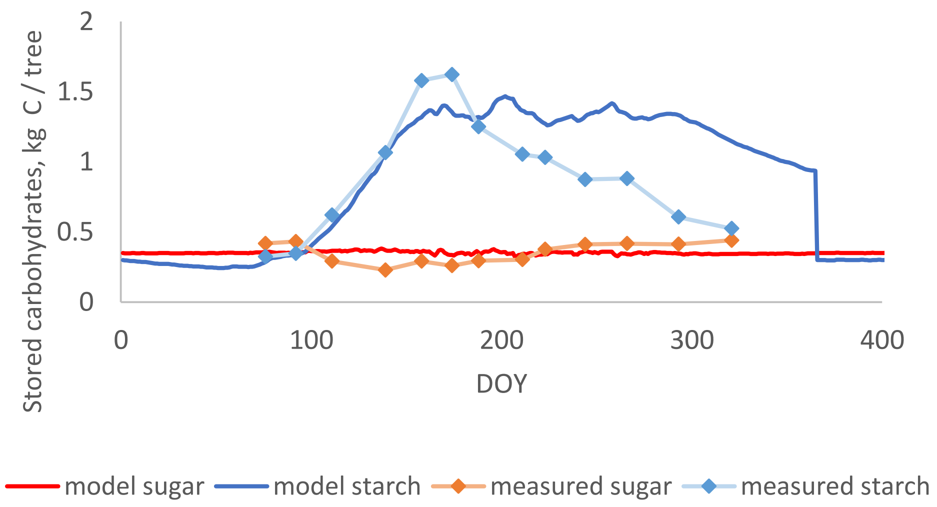
- A new part of the model
- After the shoot growth has finished, 10 % of daily photosynthesis P (kg C day^{-1}) is allocated below ground as root exudates (A_{ex}) if total storage level is higher than threshold W_{ex} (kg C)
- $A_{ex} = \begin{cases} 0.1P, & if\ s > s_s^c\ and\ W > W_{ex} \\ 0, & otherwise \end{cases}$
- $W_{ex} = W_{crit} + e$

where W_{crit} is the level of storage (kg) under which growth decreases and e is the average amount of carbon that was used for respiration during October-December during years 1997-2012.

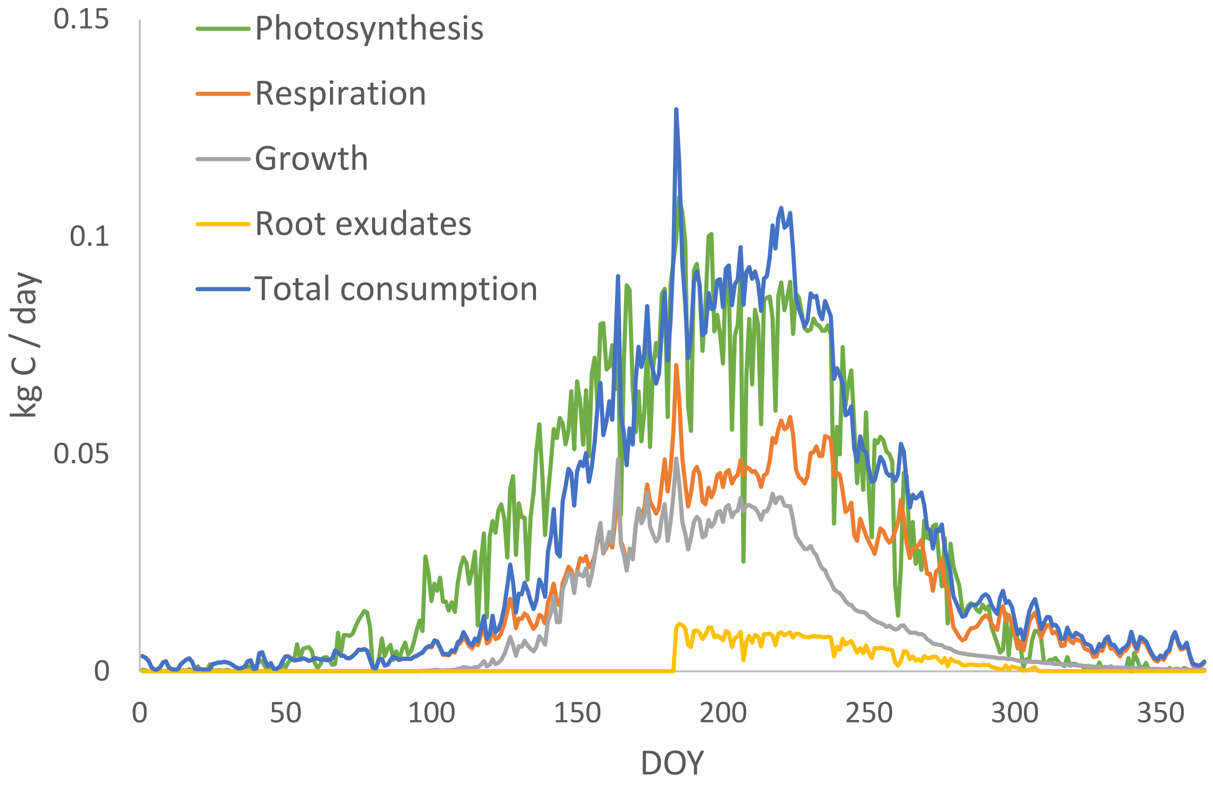
Storage – measured vs modelled



Without root exudates



Modelled carbon balance



Of the yearly photosynthesis

- 48 % to maintenance respiration
- 11 % to growth respiration
- 35 % to growth
- 6 % to root exudates

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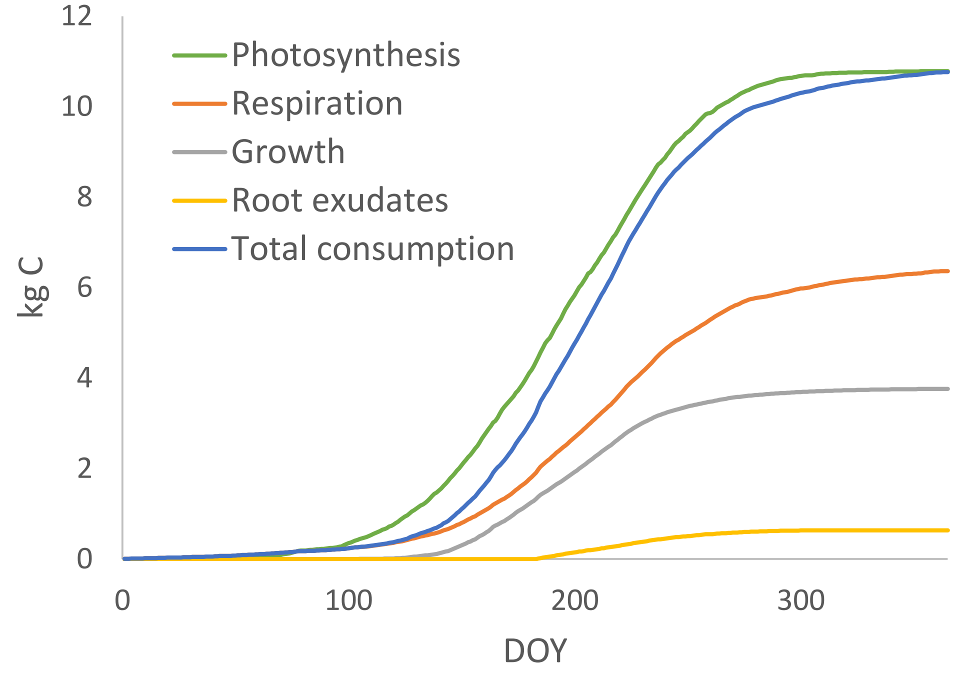
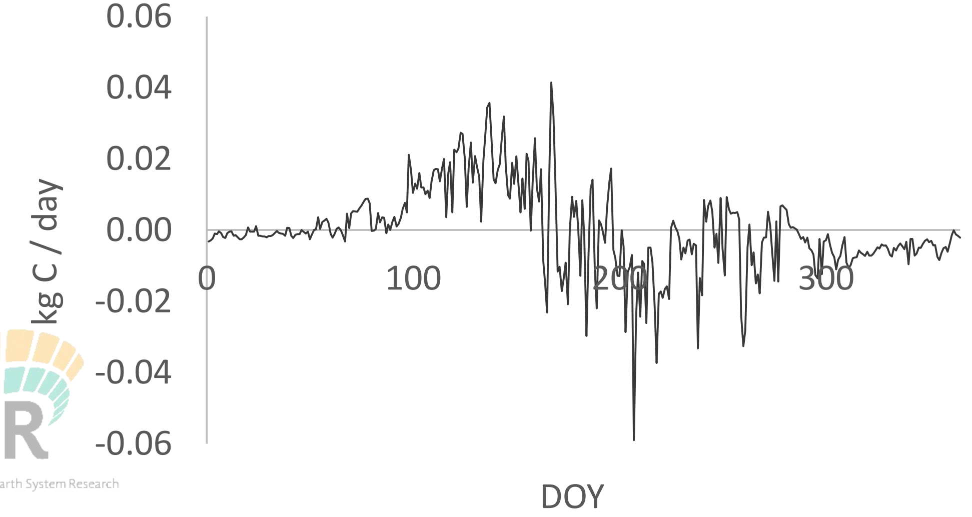
Cumulative carbon fluxes



Photosynthesis – total consumption



Conclusions

1. **Hypothesis 1:** Total storage increases in spring with photosynthesis, decreases during the most intensive growth period and increases again in autumn
   - Not exactly
   - Total level was way off (~ 8 kg vs. ~1 kg), annual variation ~ok

2. **Hypothesis 2:** Labile sugar concentration stays stable whereas starch is more dynamic
   - Yes but not exactly

3. **Hypothesis 3:** Root exudates are a notable sink of carbon
   - 6% of annual photosynthesis

Conclusions

Focus of Research

- The focus of our research is to increase knowledge on boreal tree carbon processes and flows, which is critical for understanding how forests interact with current and future climate. Connecting whole-tree carbon balance with environmental factors allows us to estimate how changing environment affects carbon flows between forest and atmosphere.

Key Challenges

- Studies on the survival of northern conifers have indicated that boreal Scots pine will benefit from the expected changes in the climate. However, the estimation of tree growth and their ability to sequester atmospheric carbon under future climate requires an all-inclusive view on whole-tree behavior, which is yet lacking.

Suggestion to Address these Challenges

- We need more research on whole-tree carbon budjet and its dependence on environmental variations. Specifically, we need to know how the responses of carbon uptake and carbon use for growth and other consumption to environmental factors differ.

THANK YOU!

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