Master Agronomie, Environnement, Territoires, Paysage, Forêt (AETPF)

Forests and their Environment (FEN)

Axial and radial carbon dynamics in mature pine trees in response to an irrigation treatment – a $^{13}CO_2$ pulse-labelling experiment

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Context

- Carbon plays a vital role in tree functioning (Hartmann and Trumbore, 2016)
- Atmospheric CO_2 is assimilated during photosynthesis in leaves or needles.
- The assimilated C ("**assimilates**") is transported via the phloem in the form of low molecular carbohydrates;
- In the sink organs, the assimilates are either used for growth, to produce energy via respiration, for maintenance , or stored.
- Carbon allocation is influenced by drought.
  - Reduced C assimilation (McDowell, 2011)
  - Higher C residence time of assimilates in leaves (Ruehr et al., 2009)
  - Slower phloem transport (Ruehr et al., 2009)
  - Investment of assimilates in storage instead of growth (Galiano et al., 2017)

Context

- $^{13}CO_2$-pulse labelling allows the investigation of C allocation dynamics.
- Successfully applied to assess the distribution of new assimilates under drought (Epron et al., 2012)
- $^{13}CO_2$-pulse labelling experiments have been conducted mainly on young trees.
- $^{13}CO_2$-pulse labelling experiment conducted at the end of August 2017 in Pfynwald
- The aim of this study is to understand changes in carbon dynamics in mature trees in response to soil moisture

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Research paper

Effects of soil moisture, needle age and leaf morphology on carbon and oxygen uptake, incorporation and allocation: a dual labeling approach with $^{13}CO_2$ and $H_2{}^{18}O$ in foliage of a coniferous forest

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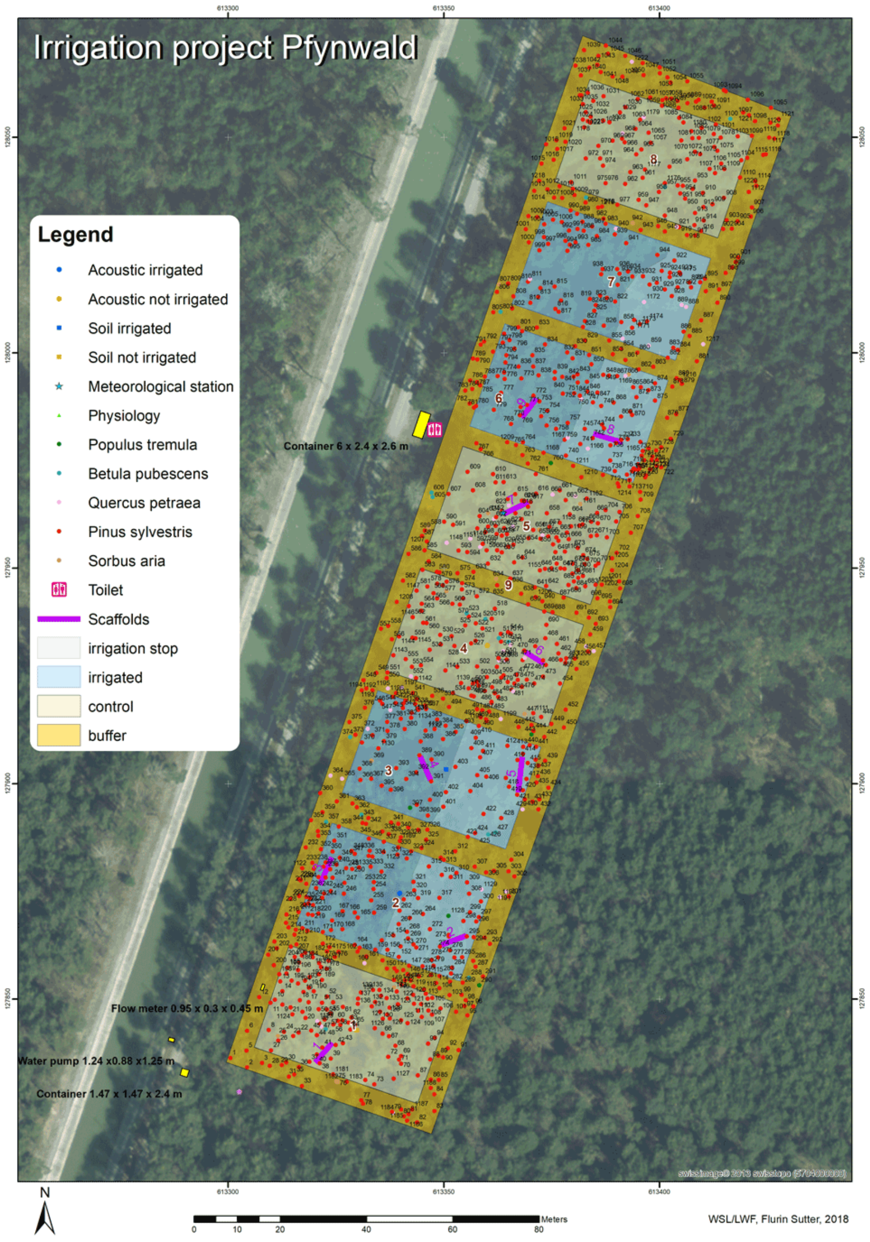
Objectives

Assess and understand the carbon allocation and the dynamics of plant assimilates in mature trees under different level of soil moisture availability (i.e. irrigation treatment)

- How is the ^{13}C partitioned into different tree tissues in axial direction and is there any difference between control and irrigated treatment?
- Is there any difference in mean residence time of assimilates between the tissues? Does it depend on the irrigation treatment?
- How are assimilates distributed in the radial axis of wood of stem and roots and is the radial allocation affected by the irrigation treatment?
- Are previous year assimilates remobilised for the construction of new tissues in the following year growing season ?

Site of experiment

Sutter 2018



Sutter 2018

Pfynwald : Driest part of the Swiss Rhone valley , 600 mm/year
Scot pine (*Pinus sylvestris L.*) **dominated forest** : 100 years old
Soil : shallow parendzina, very low water retention and high vertical drainage
Experiment site: 1.2 ha , 8 plots (25 m x 40 m)
Irrigation since 2003 from April- October, 700 mm per year
4 irrigated plots, 4 control plots

C. Hug

Pulse labelling experiment

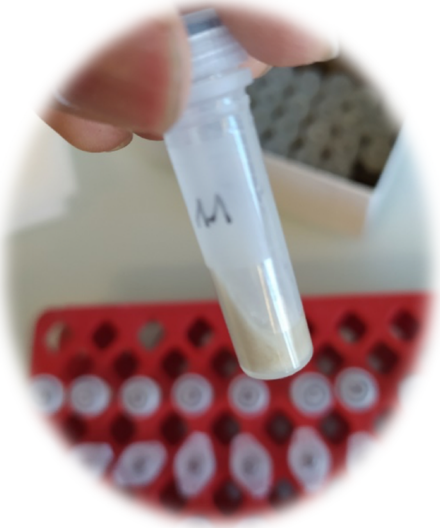
Ten mature scot pines : 5 Irrigated & 5 Control trees
Whole crown labelling experiment
two stages : - 3 pairs during dry period (29,30,31 August 2017)
- 2 pairs just after a short rain event (7,8 September 2017)

Sampling of plant material

Needles and branches : 1h before the labelling, 6h (days 0) , 8 days, 60 days and 1.5 years after the labelling

Stem and roots: 8 days , 60 days , 1.5 years after the labelling
3 segments of tree rings : 10 = 1-10, 20= 11-20, 30 = 21-30
(where 1: recent year tree ring from 2017 or 2018)

Samples of non-labelled trees to have a reference for natural isotope abundance at 8 days and 1.5 years after the labelling



Water soluble compounds (WSC) extraction

WSC = Sugars + organic and amino acids = plant assimilates
WSC extraction followed Lehmann et al., (2017), 100 mg DW, 1.5 ml H_2O, 85°C, 30 min

Cellulose extraction

For needles of 2018 only
Following standard protocols in dendro laboratories using $NaClO_2$, NaOH

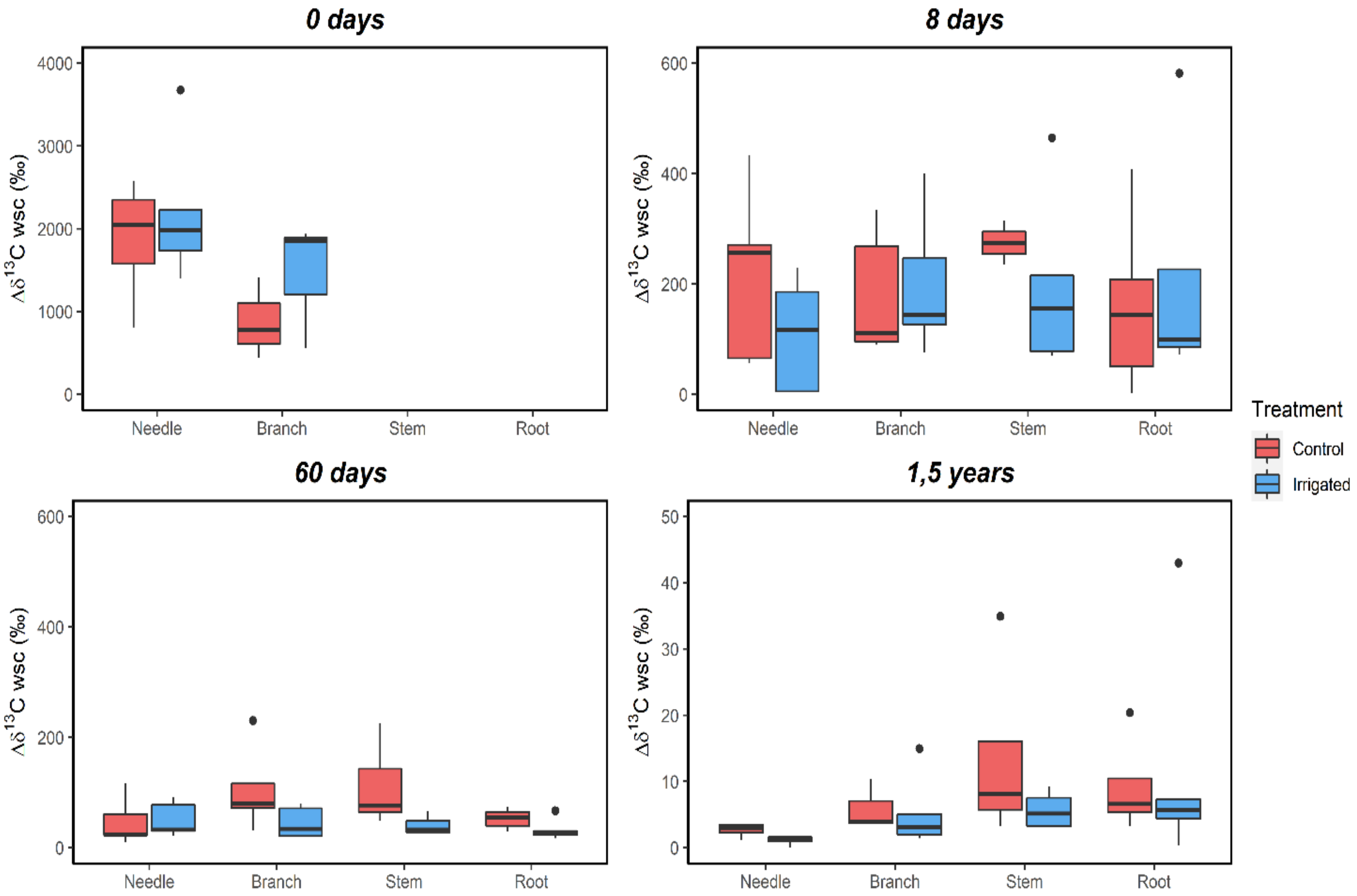
Measurement of $\delta^{13}C$ values

$\delta^{13}C$ values was measured in WSC, leaf cellulose and wood via a combustion method using an elemental analyser (EA 1110 CHN, CEInstruments, Milan, Italy) coupled with an isotope ratio mass spectrometer (IRMS: Delta XP^{Plus}, Finnigan MAT, Bremen, Germany)

Carbon mean residence time (MRT)

MRT was calculated by fitting an exponential model. MRT is the inverse of the decay constant (MRT= $1/\lambda$) of the model following Ruehr et al., (2009)

1. Carbon partitioning into different pine tissues under two soil moisture regimes



Δδ¹³C values of assimilates in the form of water-soluble compounds (WSC) for different pine tissues and soil moisture treatments

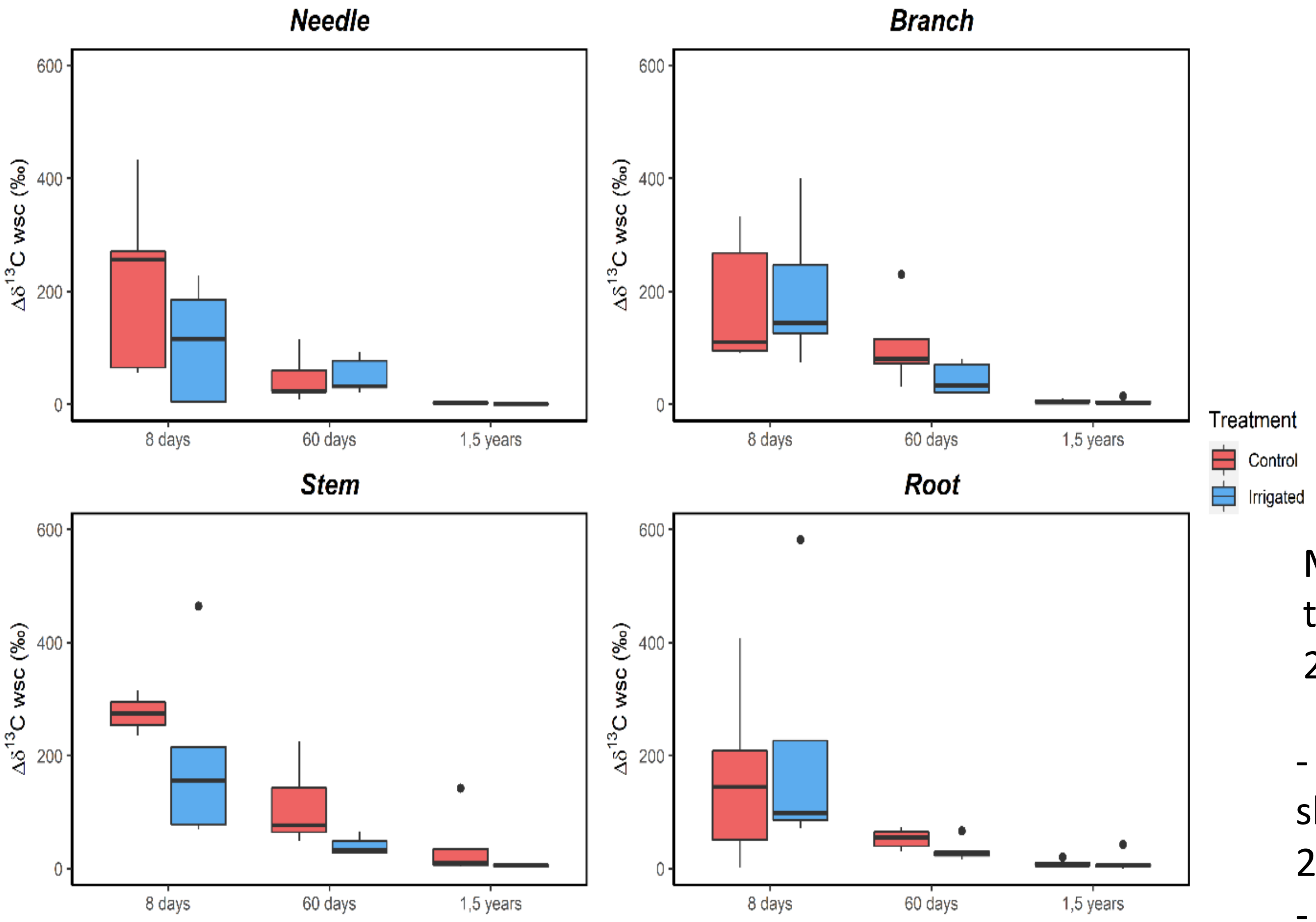
$\Delta\delta^{13}C$: $\delta^{13}C$ values of the labelled material corrected for natural isotopic variations

The control trees tend to have an overall higher $\Delta\delta^{13}C$ value

6 hours after the labelling (0 days) , there is a significant difference between needles and branches

8 days, 60 days , 1.5 years :
No tissues or treatment effect

2. Carbon mean residence time in different pine tissues under two soil moisture regimes



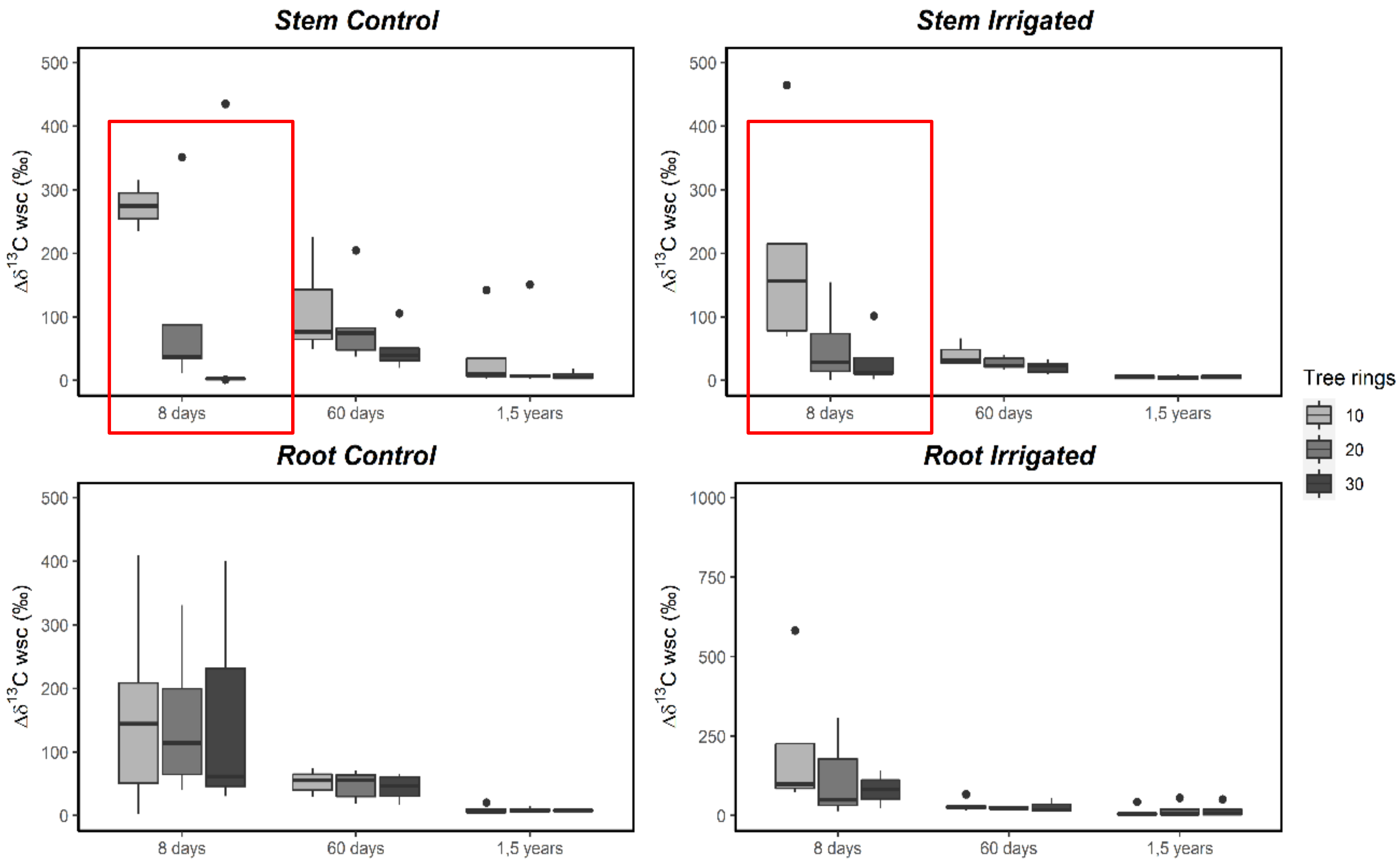
Temporal dynamic of $\Delta\delta^{13}C$ values of plant assimilates in form of WSC in different tissues

Tissues	Treatment	MRT (days)
Needle	Control	3.38
	Irrigated	2.65
Branch	Control	5.03
	Irrigated	4.02
Stem	Control	57.80
	Irrigated	32.94
Root	Control	46.15
	Irrigated	27.89

MRT was longer in the control compared to irrigated trees, especially in stem and roots (Blessing et al., 2015; Hesse et al., 2019; Ruehr et al., 2009)

- C transport rate and phloem transport velocity were slower in trees under drought stress (Ruehr et al. 2009)
- Respiration rate was slower in control trees compared to irrigated trees (WSL, not published data)

3. Radial carbon dynamics of assimilates in stem and root



Radial distribution of the ^{13}C-label over time. $\Delta\delta^{13}C$ values of plant assimilates in form of water-soluble compounds (WSC) in stem and root tree-rings

New assimilates are mixed into old C reserves

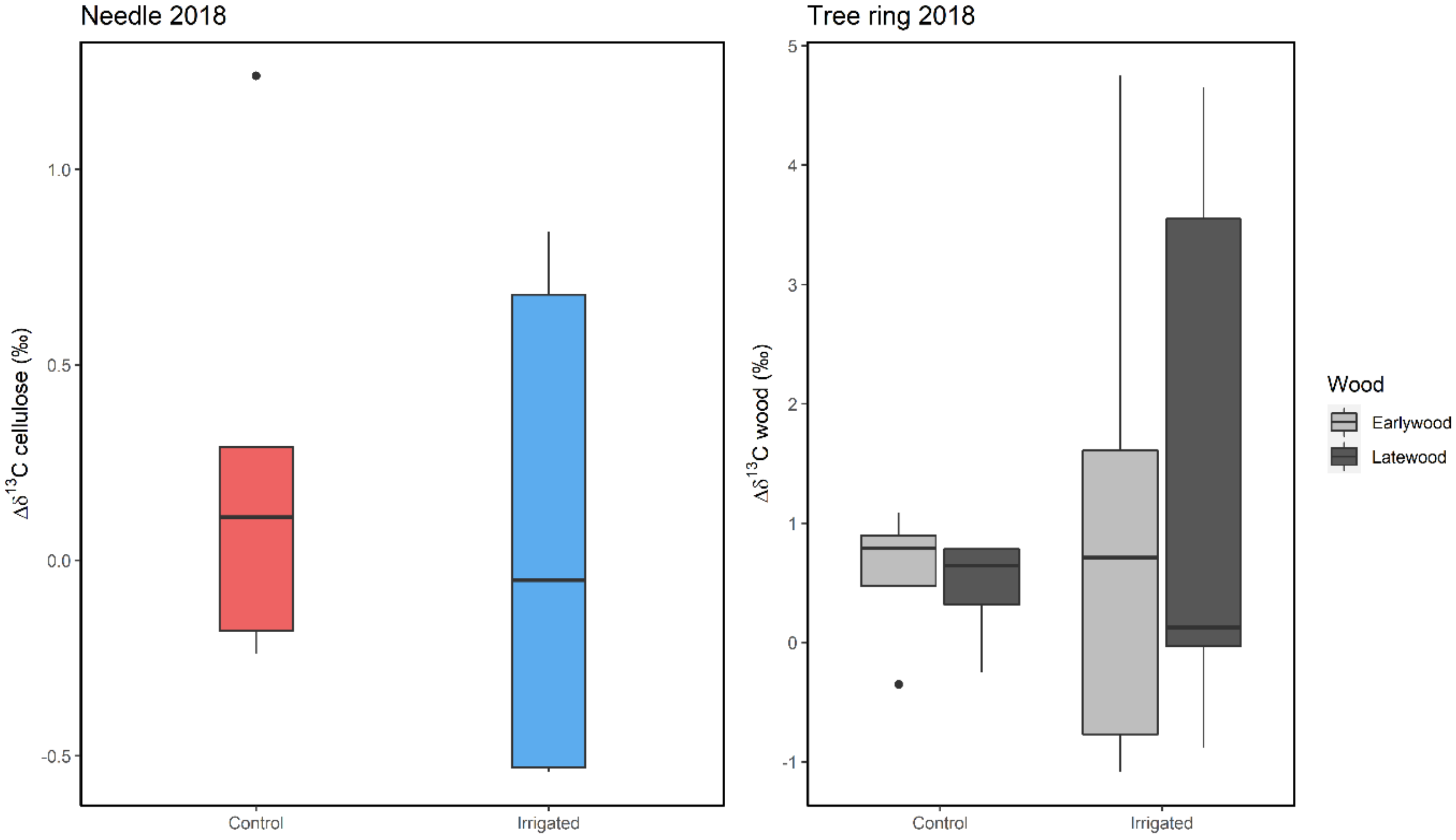
Stem : a tree rings age and time interaction effect on $\Delta\delta^{13}C$ value

Radial gradient is only significant at 8 days after the labelling

→ Fast remobilisation of the C in the outermost tree rings (von Arx et al., 2017)

Roots : No tree ring age tendency and effect in $\Delta\delta^{13}C$ values was observed (Richardson et al., 2015)

4. ^{13}C-label in leaf cellulose and wood structure in 2018



Remobilization of ^{13}C-label in the following growing season (2008). $\Delta\delta^{13}C$ values in needle cellulose and early- and latewood of tree-rings

In needle cellulose of 2018, no trace of labelled C

In wood structure of 2018, no trace of labelled C

In coniferous trees, the new needles are mainly built with recent assimilates (Hansen and Beck, 1994)

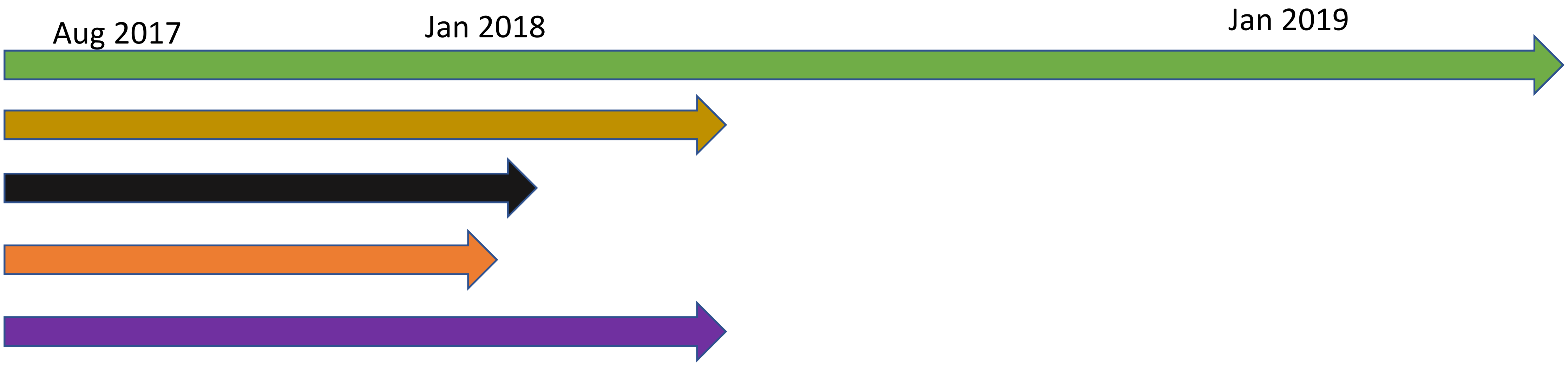
Stem wood is built from previous year C (Carbone et al. 2013) ➡ label strength of the previous year assimilates was already quite low during the 2018 growing season

Conclusion

- The ^{13}C-label was allocated along the axial axis to all tissues quite equally under both soil moisture conditions.
- The mean residence time was higher in control compared to irrigated trees (No SD!)
- There was a radial mixing of new assimilates with old carbon reserves in stem and roots
- Radial gradient of assimilates was observed in stem but not in roots.
- No investment of the previous year C into leaf cellulose and wood of the next growing season, independent of the soil moisture treatment
- **Still preliminary data - > further analysis needed!!**

Potential for a Synthesis – paper based on the $^{13}CO_2$-pulse labelling experiment

- C allocation in trees 1 (assimilates, storage, respiration -> short-term response in PNAS (30 days))
- C allocation in trees 2 (assimilates, growth, storage!) -> long-term response (1.5 years))
- C allocation in mistletoes (Light, Girdling, Needle removal)
- C allocation in soils (respiration, SOM? microbial biomass?)
- C allocation in fungi (ectomycorrhizae?, sporocarps?)
- C allocation in VOC and resin



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Thanks for your attention!

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