

Site biomass and growth characteristics of the research site Seehornwald Davos – facts and figures

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Roman Zweifel, Sophia Etzold, Käthi Liechti, Christian Hug, Flurin Sutter, Iris Feigenwinter, Susanne Burri, Lukas Hörtndl, Nina Buchmann

Overview

The Seehornwald Davos research site (CH-DAV) in the subalpine zone of the Swiss Alps is dedicated to forest ecosystem research and is one of the best-equipped forest monitoring sites in the world. The forest is an almost pure Norway spruce forest. Current projects deal with questions related to climate change, the carbon and water balance of the ecosystem, the ecophysiological understanding of tree growth, the effect and quantification of air pollutants and the general development of soil and forest over time.

The Seehornwald Davos site is operated jointly by the National Air Pollution Monitoring Network (EMPA/BAFU), the Swiss Federal Institute of Technology Zurich (ETH Zurich), and the Swiss Federal Research Institute WSL in Birmensdorf and Davos in collaboration with private forest owners and the forestry service of the municipality of Davos.

CH-DAV was established as a research station in the 1980s and has been continuously expanded since then, including the construction of a 35-meter-high measuring tower. In 1995 and 1996, continuous measurements of the soil and air microclimate, the CO₂ and H₂O vapor gas exchange of the forest with the atmosphere (eddy covariance, EC) were added. Complete EC data sets have been available since January 1997 and continuous measurements of the water balance and tree growth since 1998. Measurements of local climate variables started already in 1864 in a nearby weather station of [MeteoSwiss](#). The station is part of larger networks such as the Long-term Ecosystem Research [LWF](#), [TreeNet](#) – the biological drought and growth indicator network, the National Air Pollution Monitoring Network [NABEL](#), the International Co-operative Program on Assessment and Monitoring of Air Pollution Effects on Forest ([ICPForests](#), level II site since 2005), the Integrated European Long-term Ecosystem, Critical Zone and Socio-ecological Research ([eLTER](#)), the [Swiss FluxNet](#) and the Integrated Carbon Observation System Research Infrastructure [ICOS RI](#) (Class 1 Ecosystem station since 2019).

Facts and figures are presented below based on a variety of biomass and radial stem growth data from different measurement areas and analyses concepts. The site consists of a central area with all permanent measuring equipment, including a 35 m high EC tower and a cabin for logistics. This central area is divided into four polygon-shaped **CP plots** where the continuous (automatic) measurements are performed, according to the ICOS RI instructions (Fig. 1). A second sampling design of ICOS RI includes a larger area with 20 circular so-called sparse measurement plots (**SP plots**). SP plots are exclusively used for biomass and soil inventories every ten years. The SP plots cover a large part of the so-called footprint area of the EC method and partly overlap with the CP plots. The following facts and figures refer either to data from the CP plots, data from the SP plots or to data from both plot designs, whereby the measured site characteristics of each plot are weighted so that they correspond to the contribution of the footprint of this plot area to the EC signal (**FP-weighted**).

For more general site information visit:

www.wsl.ch/seehornwald

or one of the networks listed above.

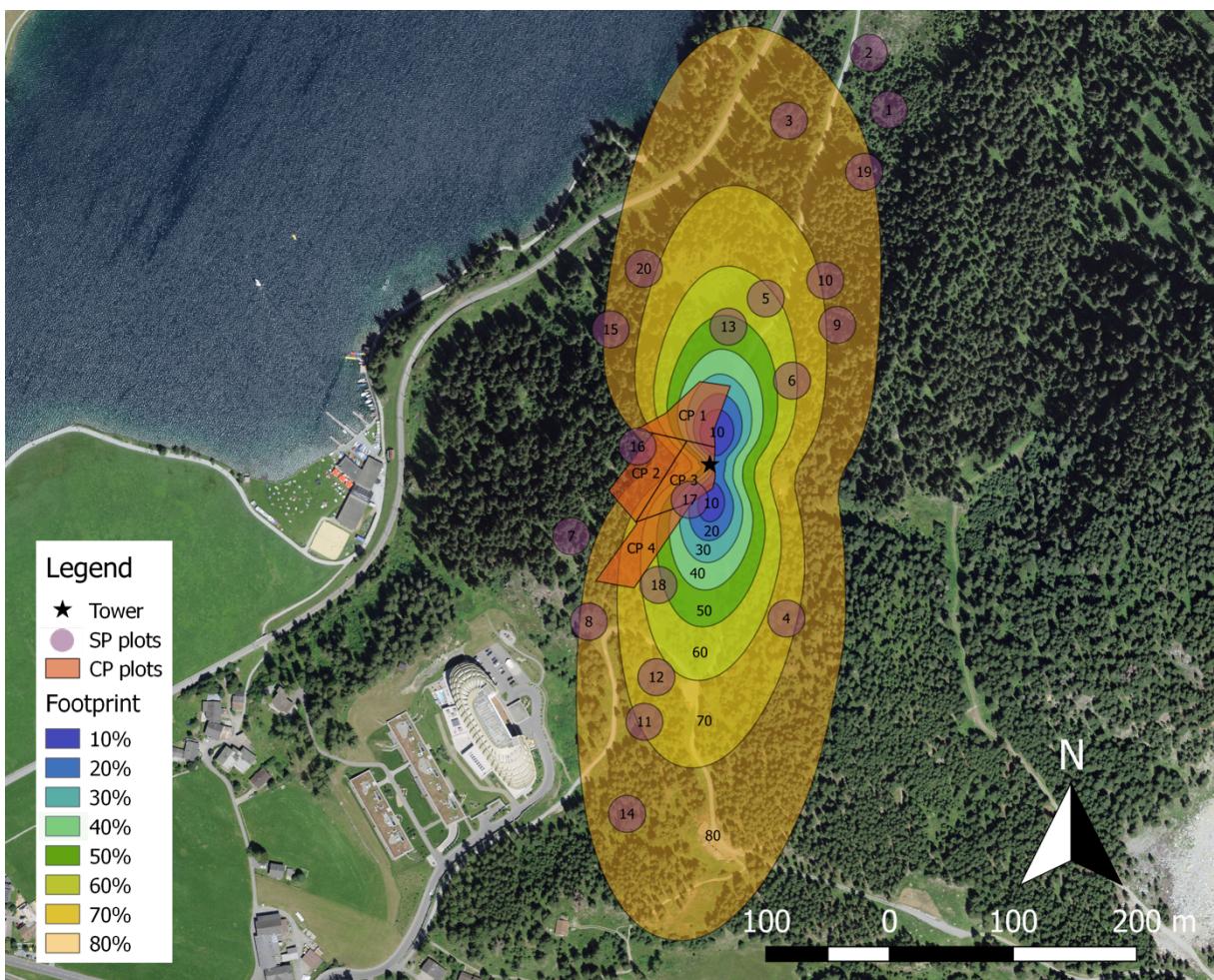


Fig. 1. Research site Seehornwald Davos (CH-DAV). The site consists of four continuous measurement plots (CP; orange polygons), 20 sparse measurement plots (SP; purple circles) and the eddy covariance-related footprint (FP) area. The coloured areas of the FP with the respective labels indicate the cumulative contribution of areas inside a specific isoline to the eddy covariance (EC) measurements at the top of the tower (black star), e.g., the net ecosystem exchange of carbon dioxide (NEE). The outermost isoline indicates the area that covers 80% of the EC signal. The orthophoto is from the Federal Office of Topography [swisstopo](#).

Data base

This work reports the site characteristics, i.e., the main data describing the forest in terms of biomass and growth. The underlying analyses are based on the WSL Sanasilva/LWF biomass inventory completed in October 2020, in accordance with the [ICOS instruction documents](#) to fulfil the needs of an ICOS RI Ecosystem Class 1 station. Radial stem growth characteristics are based on TreeNet data measured with automated point dendrometers at breast height from 1998 until the end of 2022 (Zweifel *et al.*, 2021a). The footprint area and the respective relative contributions of the plots refer to the calculations of Iris Feigenwinter in June 2023 (updating the footprint for the [Davos excursion guide](#)) and January 2024 (calculating CP and SP contributions).

Measured variables:

Tree coordinates, tree height, stem diameter at breast height (DBH), tree species, and health status were measured in SP and CP plots. Automated radial stem measurements with point dendrometers are obtained from selected trees in the CP plots (**radial stem growth**). SP- and CP plots refer to the [ICOS RI sampling scheme](#) in which the CP plots (four polygons, each about 2000 m² in size) are the home of all automated monitoring equipment and the SP plots (20 circles with 15 m in radius, each about 700 m² in size) are covering a larger spatial fraction of the so-called footprint area of the EC method (Tab. 1). Measurements in the SP plots are updated every 10 years. The footprint area was estimated with the footprint model of Kljun *et al.* (2015). The isolines show where on average a certain percentage of the EC signal measured at the central tower comes from (calculated for the year 2022).

Radial stem growth data (version 12.2022) were obtained from the TreeNet data base (Zweifel *et al.*, 2021a; Zweifel *et al.*, 2023) and analysed according to Knüsel *et al.* (2021) and Zweifel *et al.* (2021b)

Tree ages were estimated from a wood collection dataset containing tree ring widths and tree ages measured at CH-DAV by Stefan Klesse (WSL, 2013) and some corresponding measurements from the LWF.

The original biomass data are available as an Excel file: *DAV_Daten_SP_CP_2020_V2.xlsx*. It contains a detailed list of metadata of the measured and estimated variables.

Analyses and figures based on the above-mentioned Excel file were produced with the R-script: *DAV_Site_Char.R* (version April 2024).

Data extractions are stored as:

Site_Char_Data.Rda (df1): Full data set including trees in all 20 SP plots and 4 CP plots. This data set includes 76 trees that are double counted, once under the CP trees collection and once under the SP trees collection. Dead, fallen and formerly removed trees from the site were filtered out.

Site_Char_Data_nodouble.Rda (df2): Data set with double counted trees removed in the SP plots.

Site_Char_Data_double_trees.Rda: List of the double counted trees that belong to an SP and a CP plot.

Site_char_table.csv: Summary output of site characteristics

Site_GRO_table.csv: Summary output of growth characteristics

The shape files of the footprint can be found in the folder *fp_shapefiles_DAV_2022*.

Key numbers for biomass and growth

In terms of biomass characteristics, there are clear differences between SP and CP area (Table 1). The trees in the CP plots are taller, older and have a larger stem diameter. This fact is most likely due to the lack of forest management in the CP area for more than 30 years. The footprint-weighted (FP-weighted) data include a factor for each plot (CP and SP) that weights the biomass data according to each plot's contribution to the eddy covariance signal (Table 2). Two CP plots (CP1 and CP3) have a joint weight of about 60 % and therefore dominate the calculation of all FP-weighted variables listed in Tab. 1. In contrast to the data for the CP and SP plots, which describe the forest as it is, these footprint-weighted variables describe the site from the perspective of eddy covariance measurements.

Growth characteristics are measured in CP plots only and are compared to Norway spruce growth data across Switzerland.

Table 1. Biomass characteristics of the research site Seehornwald Davos (CH-DAV). Data refer to SP-, CP plots, or are scaled to the footprint area (80% isoline) with the weighted plot contributions to the eddy covariance signal (FP-weighted). For details see Tab. 2.

Name	VAR	Unit	SP plots	CP plots	FP-weighted
Number of plots	plots	n	20	4	NA
Total plot area	area	m ²	14'137	8'001	134'448
Elevation	elevation	m asl	1590 - 1682	1628 - 1657	1550 - 1690
Number of trees	<i>Picea_abies</i>	n	1'603	757	13'355
Number of trees	<i>Larix_decidua</i>	n	1	1	3
Number of trees	<i>Pinus_mugo</i>	n	9	0	13
Number of trees	<i>Abies_alba</i>	n	2	0	2
Number of trees	<i>Buxus_sempervirens</i>	n	1	0	3
Total number of trees	tree_total	n	1'616	758	13376
Double-counted trees	tree_double_count	n	76	76	0
Tree density per ha	tree_density (median/mean)	n per ha	1'061/1143	995/947	825
Tree basal area per ha	basal_area (median/mean)	m ² /ha	40.6/41.9	54.7/54.2	49.4
Diameter at breast height	dbh (median/mean)	cm	12.5/17.3	22.0/24.0	23.7/24.7
Diameter at breast height min	dbh_min	cm	5.0	5.1	5.0
Diameter at breast height max	dbh_max	cm	74.3	61.3	74.3
Tree height median	height (median/mean)	m	9.9/12.8	18.3/17.5	18.5/17.5
Tree height min	height_min	m	0.8	3.0	0.8
Tree height max	height_max	m	41.0	37.0	41.0
Tree age median	age (median/mean)	yr	60.3/83.6	106.1/115.6	113.9/118.5
Tree age min	age_min	yr	24.0	24.5	24.0
Tree age max	age_max	yr	356.7	294.2	356.7

Table 2. Calculated contributions of plots to the EC footprint (FP, 80% isoline). Listed are the relative contributions of each plot to the footprint area (%) and the respective values weighted to 100%. Coordinates in the format LV95 indicate the centre of the respective plots (x cor, y cor). The FP was resolved in pixels of one square meter. The last column indicates the number of pixels that was associated with each plot equalling the approximate plot area in m². To avoid double-counted trees, the plots SP16 and SP17 contain data for that fraction of the plot that is not overlapping with the respective CP plots.

Plot	Relative contribution to FP	Weighted contribution to FP	x cor	y cor	n of pixels [m ²]
Var	fp_rel_contrib	fp_scaled_contrib	xref_LV95	yref_LV95	nof_pixels
CP1	7.70%	40.41%	2784437.5	1187780.5	2002
CP2	0.36%	1.89%	2784408.0	1187729.5	2001
CP3	4.00%	21.02%	2784430.5	1187726.5	2004
CP4	1.58%	8.27%	2784405.0	1187675.0	1998
SP01	0.04%	0.20%	2784603.5	1188026.5	701
SP02	0.04%	0.19%	2784586.5	1188073.0	698
SP03	0.09%	0.45%	2784522.5	1188018.5	701
SP04	0.23%	1.20%	2784520.5	1187615.5	704
SP05	0.45%	2.35%	2784503.5	1187874.5	705
SP06	0.47%	2.49%	2784524.5	1187807.5	703
SP07	0.02%	0.11%	2784346.0	1187681.5	698
SP08	0.07%	0.38%	2784360.5	1187612.5	703
SP09	0.13%	0.70%	2784561.5	1187852.5	701
SP10	0.16%	0.82%	2784551.5	1187888.5	703
SP11	0.18%	0.96%	2784405.5	1187531.5	701
SP12	0.29%	1.54%	2784414.5	1187567.5	699
SP13	0.87%	4.54%	2784473.5	1187851.5	704
SP14	0.09%	0.46%	2784391.5	1187457.5	703
SP15	0.07%	0.36%	2784377.5	1187849.5	707
SP16	0.03%	0.14%	2784399.5	1187754.5	447
SP17	1.34%	7.06%	2784441.5	1187711.5	221
SP18	0.66%	3.48%	2784416.5	1187642.5	706
SP19	0.06%	0.31%	2784583.5	1187976.5	702
SP20	0.13%	0.66%	2784404.5	1187898.5	705
Total	19%	100%			21'317

Table 3. Stem growth characteristics of spruce trees at the forest research site CH-DAV. The data refer to radial stem size changes measured with automatic point dendrometers in the CP area. ‘Growth’ is defined here as irreversible radial increment of the stem including new wood and bark cells. Growth start = day of the year when stem radial growth reaches 5% of the annual increment; Growth max = day of the year when the growth rate was highest; Growth end = day of the year when 95% of the annual growth is reached. Growth rates are listed per hour (hr), per day (d), per week (we), per month (m) and per year (yr). Number of growth hours = annual sum of hours the trees were growing; Growth max 24hr = time of the day when growth was highest (time zone: UTC+1). Shown are medians and the 25 and 75 percentiles of the data, respectively.

VAR	Unit	Percentile 25	Median	Percentile 75
Growth start	DOY	152	158	161
Growth max	DOY	173	184	189
Growth end	DOY	238	268	275
Growth rate per hour	$\mu\text{m}/\text{hr}$	2.5	2.8	3.7
Growth rate per day	$\mu\text{m}/\text{day}$	22.1	23.6	29
Growth rate per week	$\mu\text{m}/\text{we}$	52.4	63.4	81.2
Growth rate per month	$\mu\text{m}/\text{m}$	82	131	172
Growth rate per year	$\mu\text{m}/\text{yr}$	1022	1168	1327
Number of growth hours	n/yr	165	220	274
Growth max 24hr	hour	5	6	6

Analyses and Figures

Location of trees:

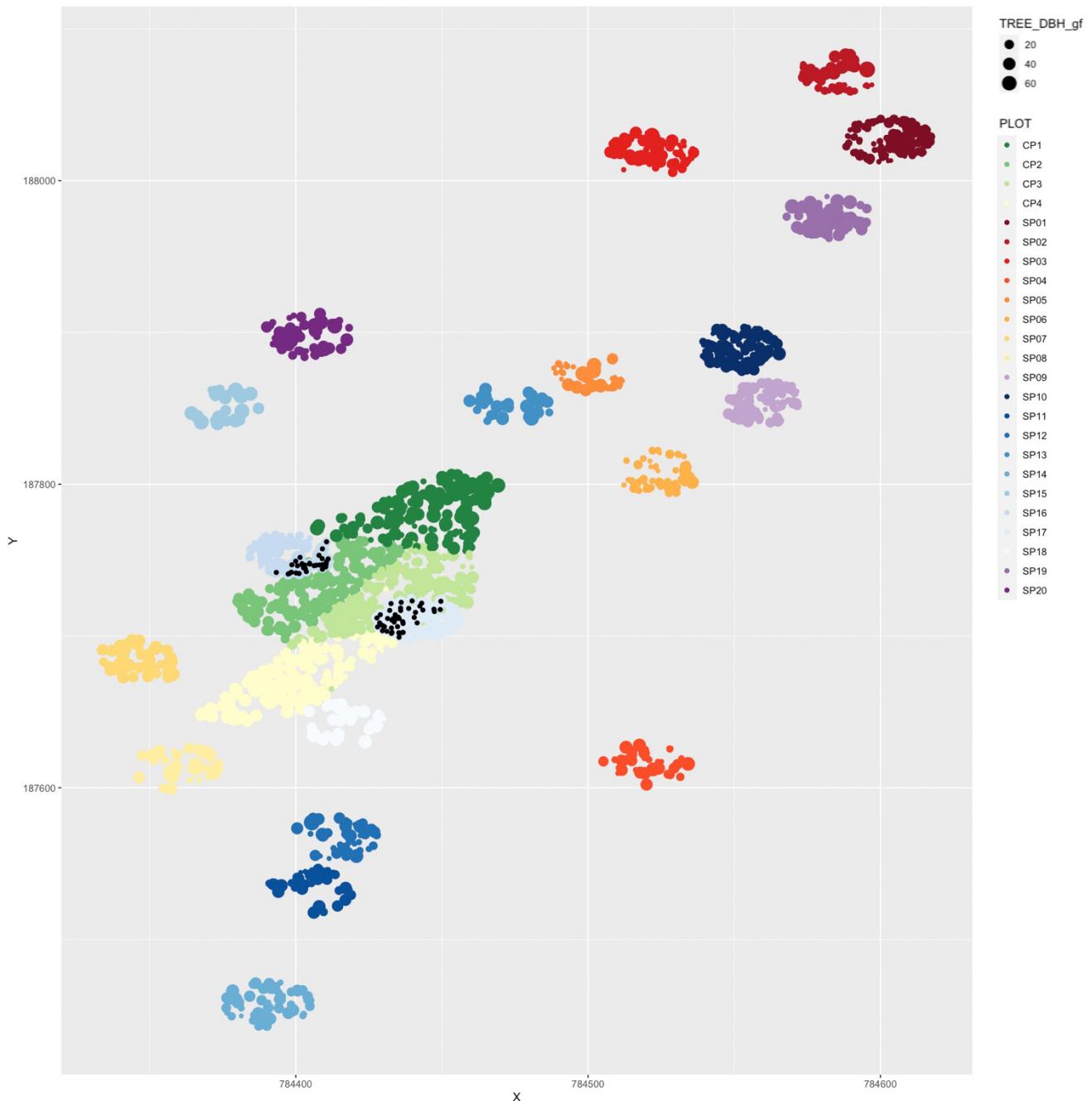


Figure 2. Location of trees of CH-DAV in the CH1903/LV03 coordinate system. The trees are color-coded according to their plot affiliation (4 CP plots and 20 SP plots). The circle size indicates the tree diameter at breast height (DBH in cm). Black dots highlight those 76 trees that belong to both a CP plot (1 and 3) and to a SP-plot (16 and 17).

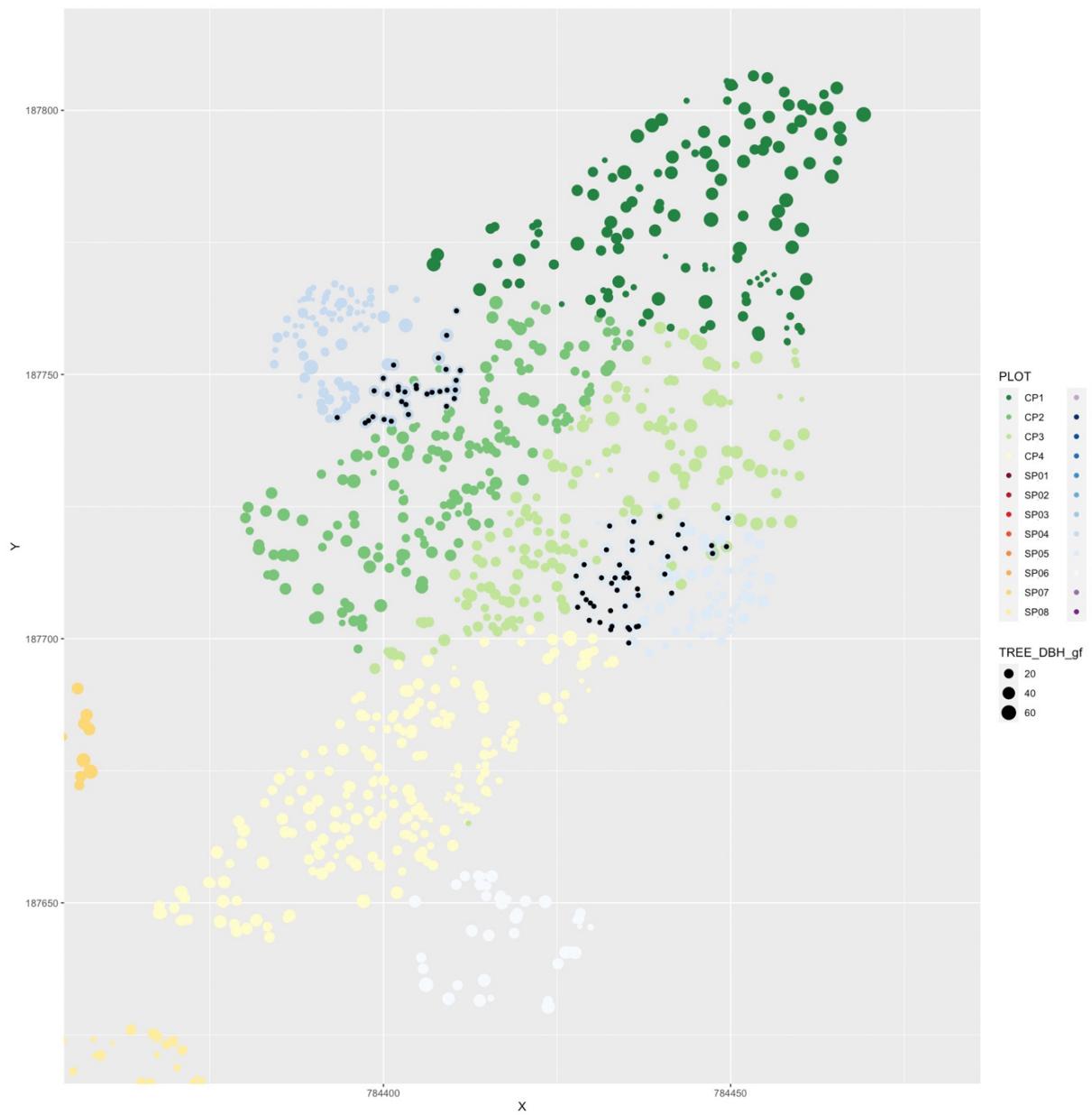


Figure 3. Map of CH-DAV trees in the four CP plots (greenish points) and some of the closest SP plots. The size of the circles indicates the tree diameter at breast height (DBH in cm). Black dots highlight those trees that belong to both a CP plot (2 and 3) and to a SP-plot (16 and 17).

Distribution of trees and species within the 24 plots:

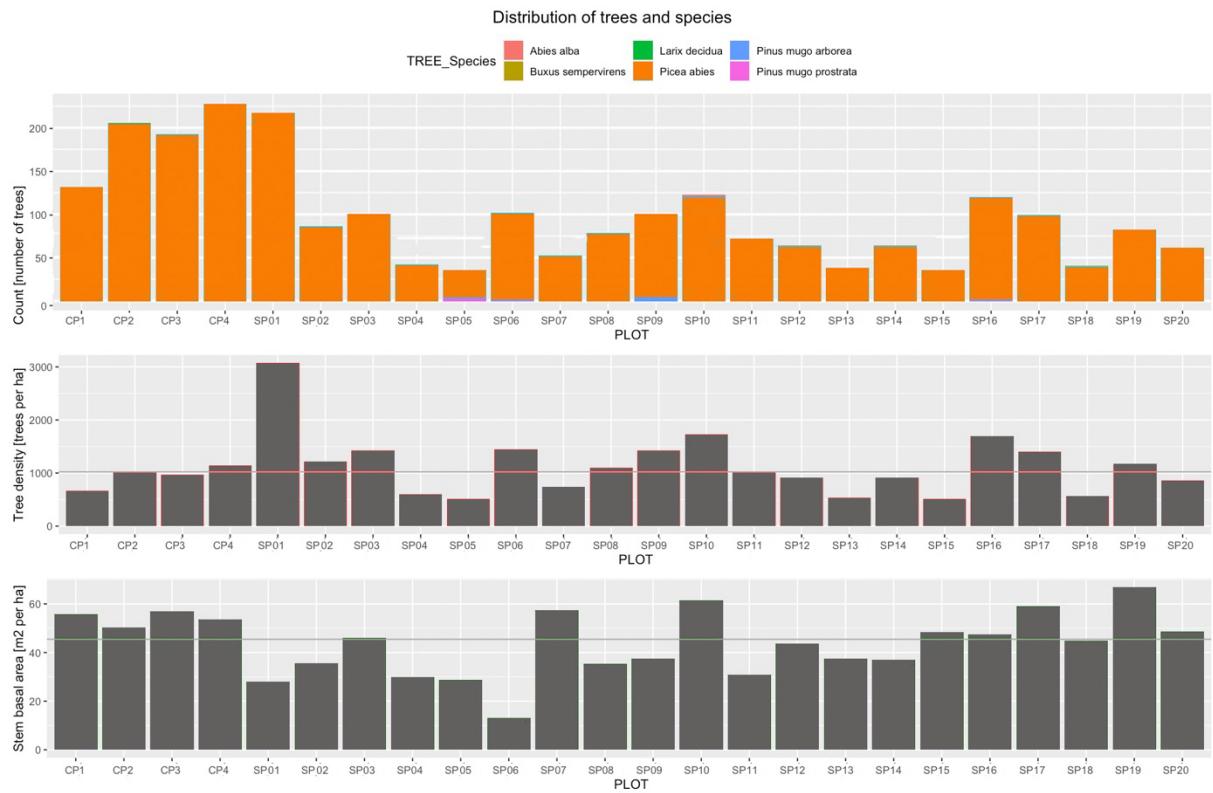


Figure 4. Distribution of trees and species across all plots. The upper panel shows the number of trees per plot with a diameter at breast height greater than 5 cm and the respective occurrence of species across the plots. The site is an almost pure subalpine (1640 m a.s.l.) spruce forest with only 14 out of 2298 trees belonging to another species (SP- and CP plots). The average tree density is about 1000 trees per ha across all plots. The median basal area is about 46 m^2 per ha (for details see Tab. 1)

Frequency distribution of tree heights

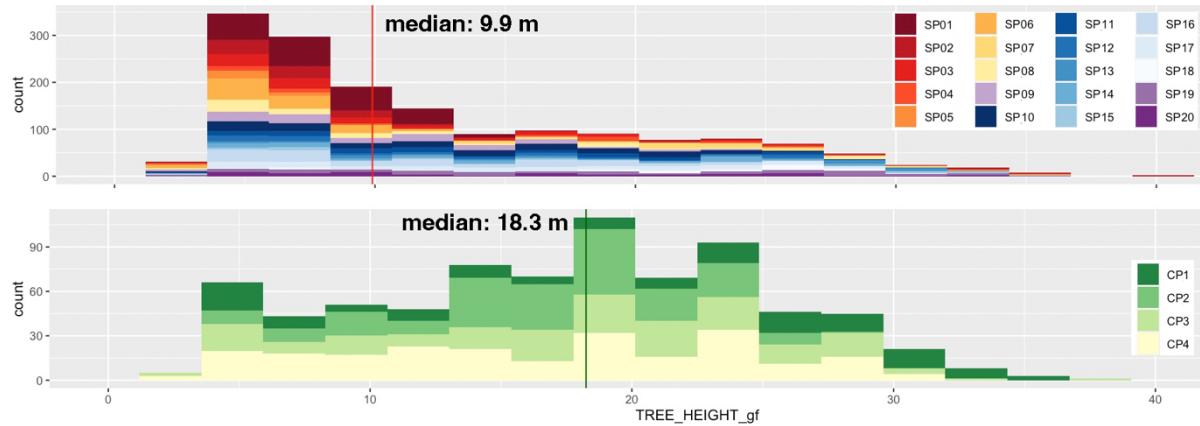


Figure 5. Distribution of tree heights separated for SP and CP plots. The median height of the CP trees is about twice as high as that of the SP trees.

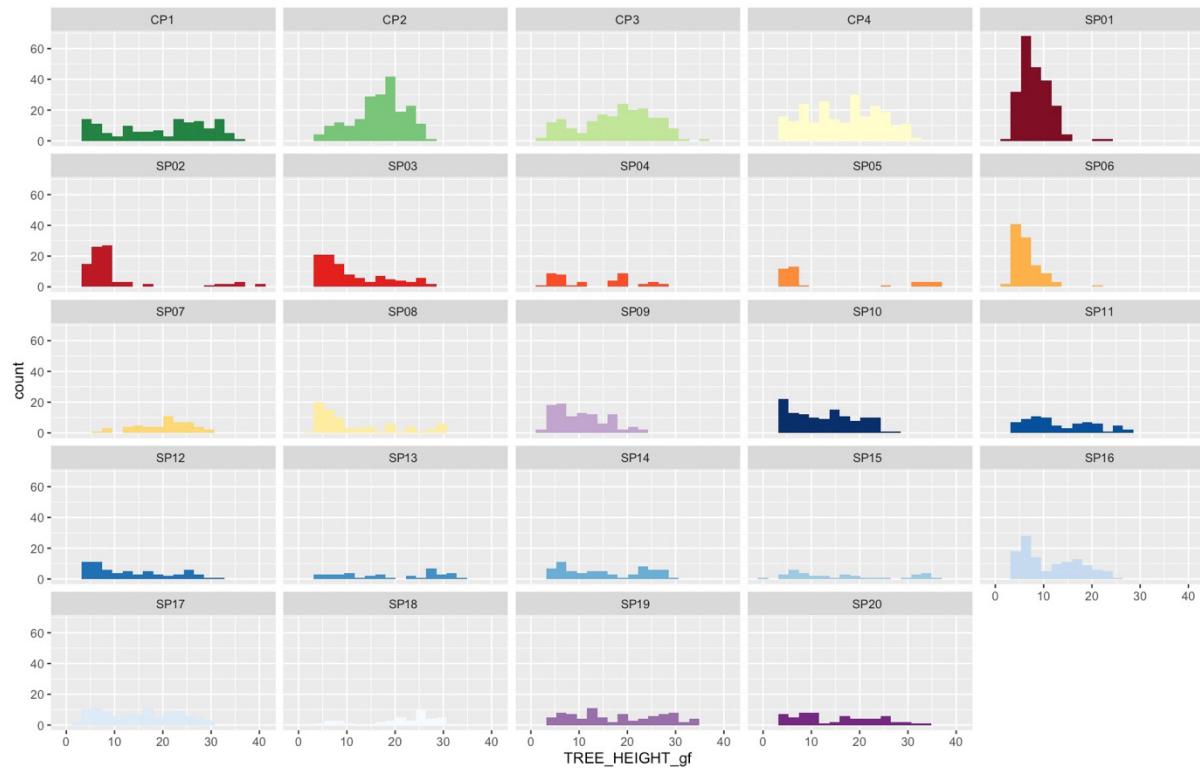


Figure 6. Distribution of tree heights separated by plots. CP plots have a larger proportion of tall trees compared to SP plots. SP01 and SP06 have the highest proportion of short trees.

Frequency distribution of tree stem diameters at breast height (DBH)

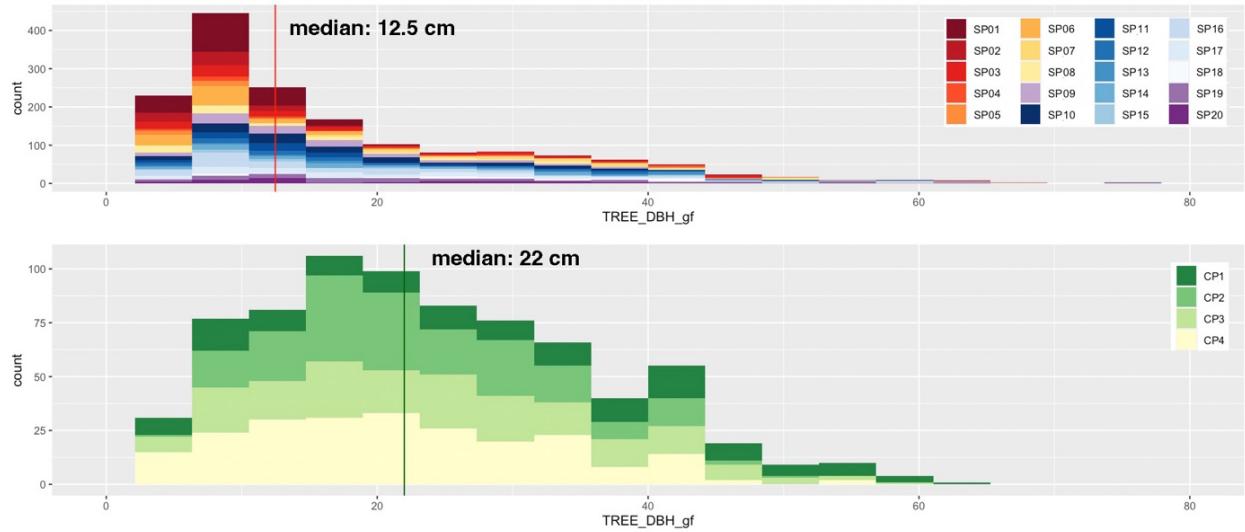


Figure 7. Distribution of DBH separated for SP- and CP plots. The median DBH for the CP plots is about 10 cm larger than that of the SP trees.

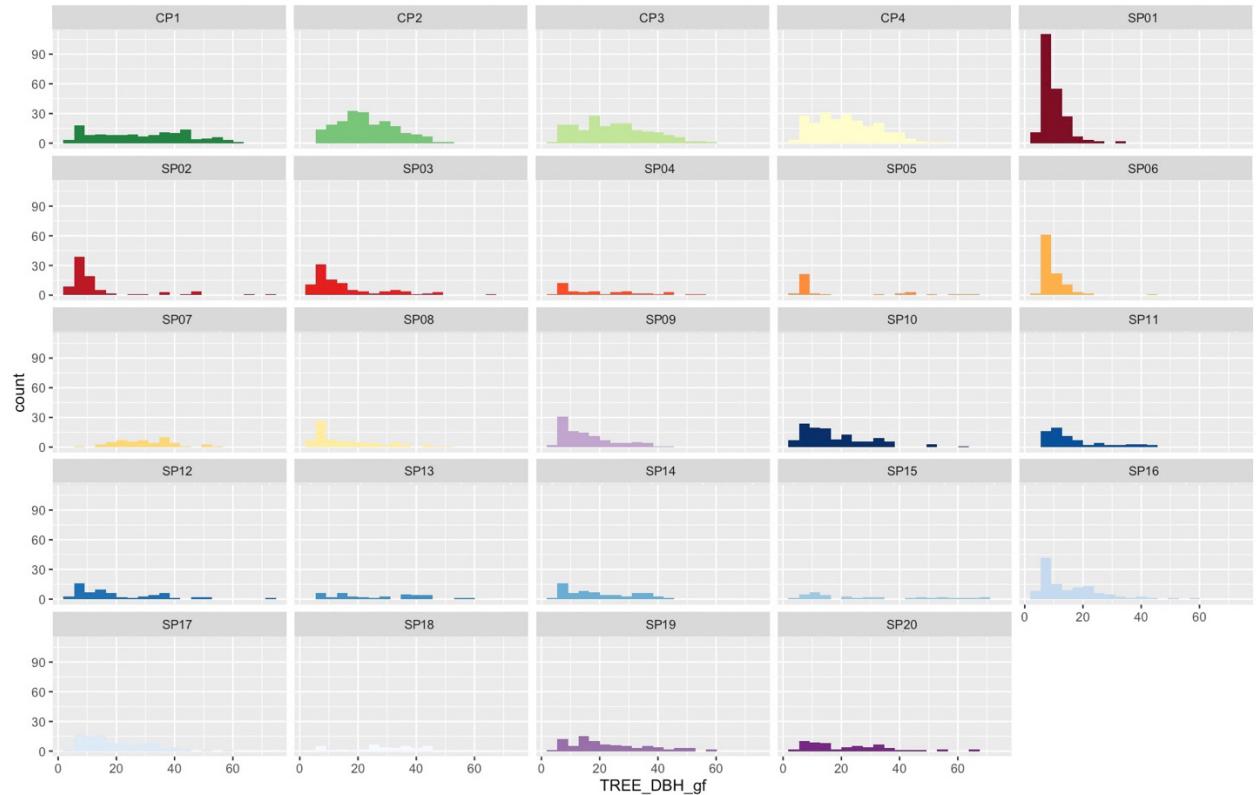


Figure 8. Distribution of DBH for each plot separately. The general pattern is like the one for tree height (see Fig. 7) since DBH is closely related to tree height (see Fig. 9).

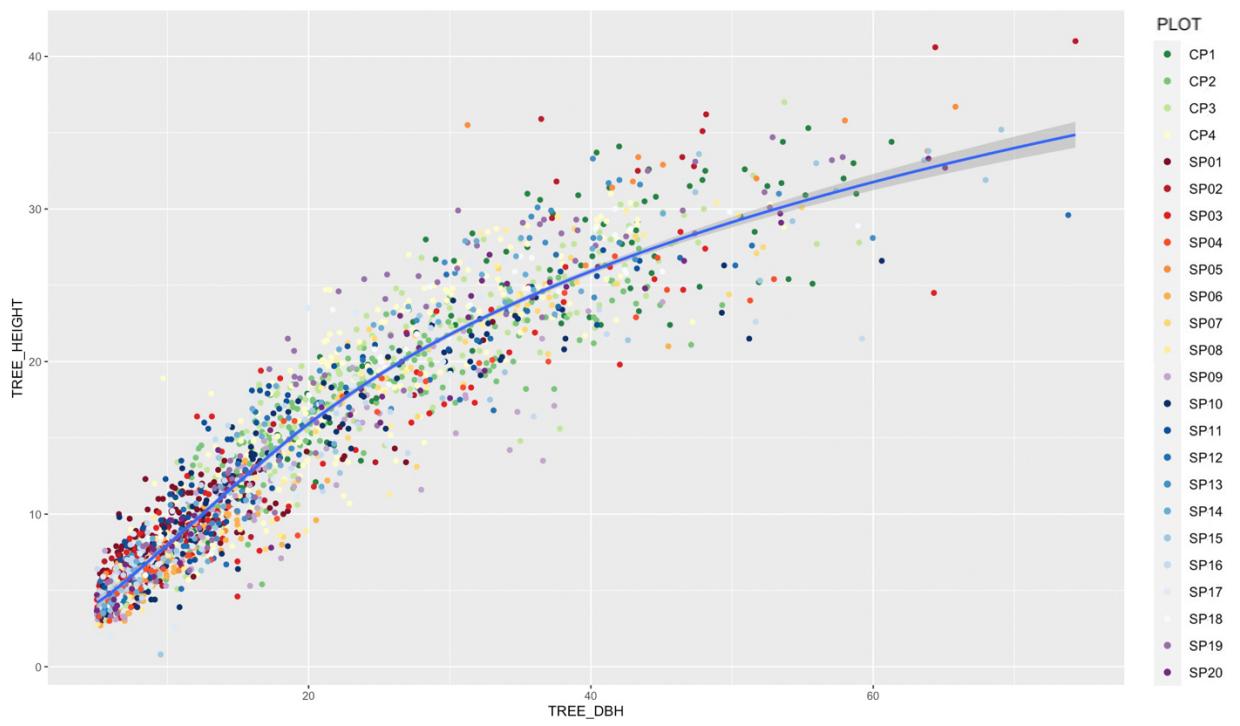


Figure 9. Logarithmic relationship between DBH and tree height. The formula fitted is $\text{TREE_HEIGHT} = 11.43707 * \log(\text{TREE_DBH}) - 17.33482$. The R^2 value is 0.88.

Frequency distribution of tree age

The age of trees is estimated from DBH of stems using a linear function (Klesse, S. *et al.*, 2018; Klesse, Stefan *et al.*, 2018). The linear function used is:

$$\text{Age} = 4.79965966 * \text{DBH}$$

Accordingly, the age distribution appears like the DBH distribution.

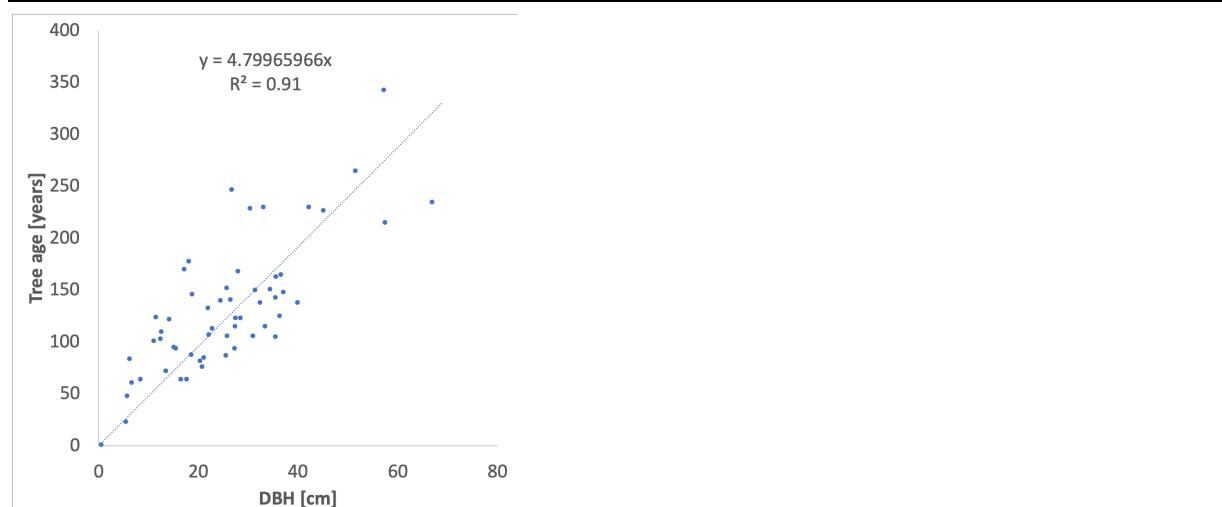


Figure 10. Relationship between DBH and tree age.

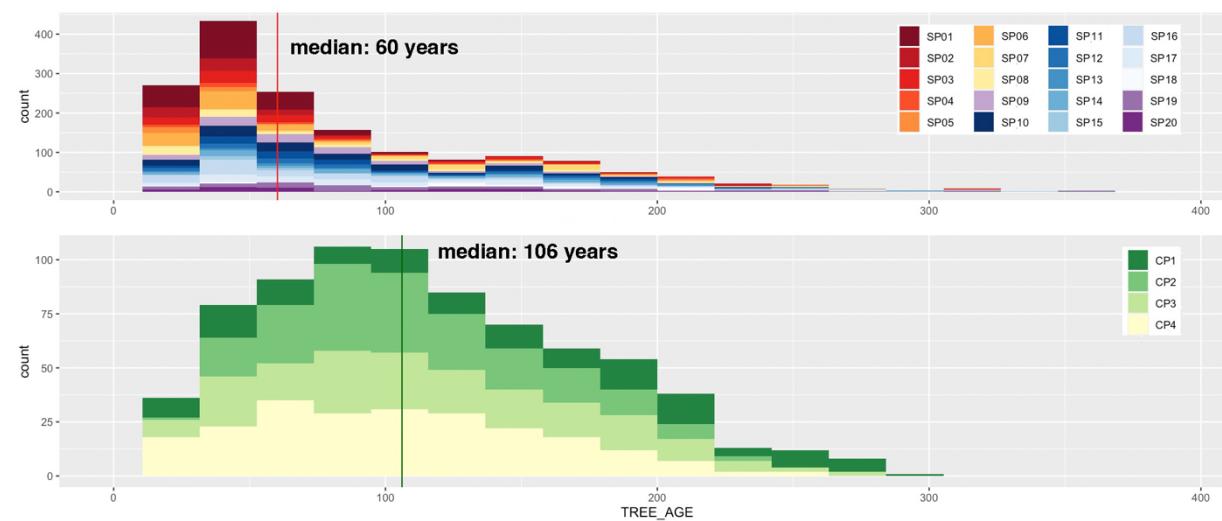


Figure 11. Distribution of tree age separated for SP- and CP plots. The average age of the trees on the CP plots is almost twice as high as that of the trees on the SP plots.

Growth characteristics of Norway spruce trees at CH-DAV

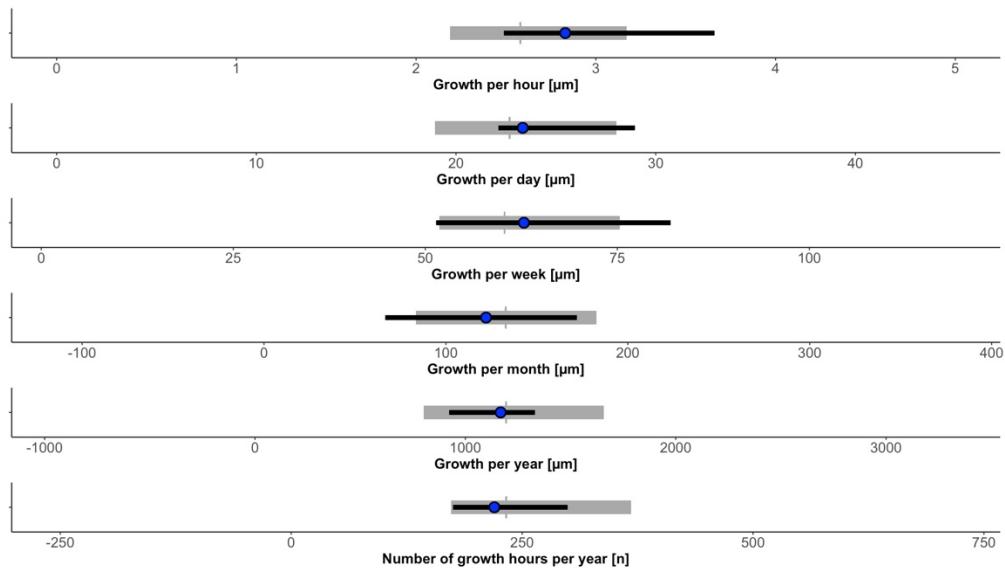


Figure 12. Radial stem growth of spruce in CH-DAV (blue dots (median) with black line; 25-75% percentile, 1998-2022) compared to all measured individuals of the same species in Switzerland (grey bars with a tick for the median; 136 trees from 20 TreeNet sites, 2012-2022). Compared to all measured spruce trees in TreeNet Switzerland, the trees in Davos grow slightly more per hour and day, but slightly less hours over the growing season. Consequently, the median growth rate per year is also very close to the Swiss average at around 1.17 mm/yr (see also Table 3).

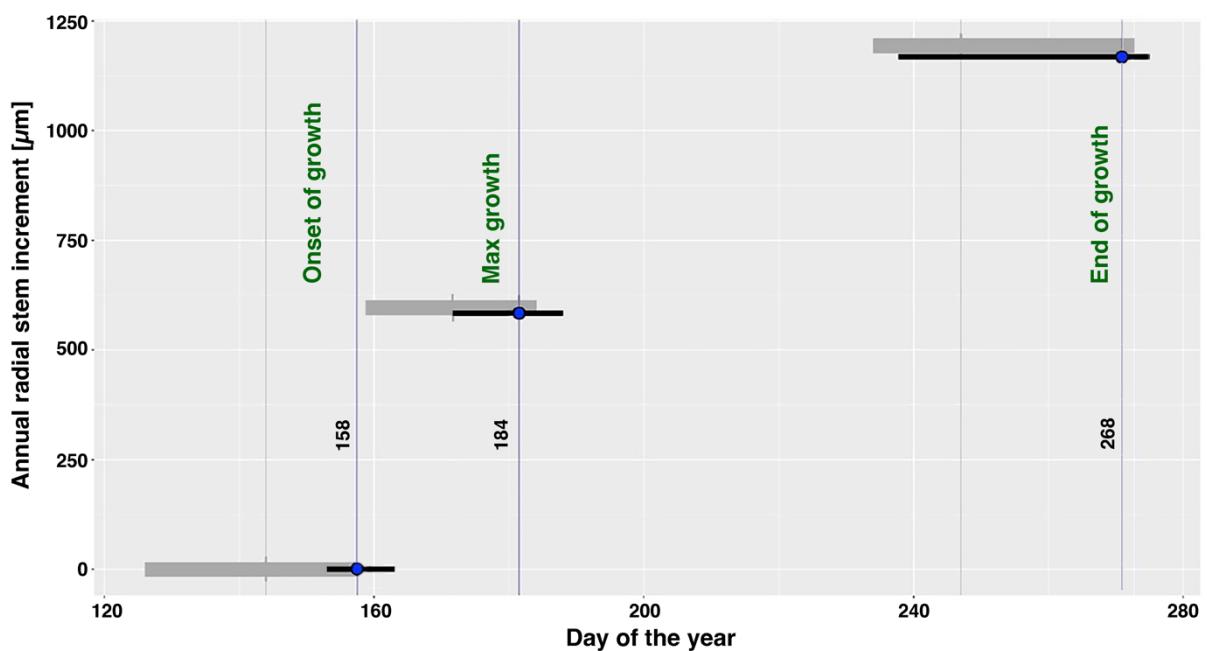


Figure 13. Timing of radial stem growth. Growth begins in CH-DAV approximately 2 weeks after the median onset of all spruce trees in TreeNet on day of the year 158 (June 7). On day of the year 184 (July 2), the maximum growth rate in the season is reached, about 10 days after the date of the TreeNet spruce trees all over Switzerland. The radial stem growth in Davos ends on day 268 (September 25), about 20 days after the median stop date for all spruce trees in Switzerland. Same data set and same symbols as in Fig. 12.

References

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