ICOS Ecosystem Station Labelling Report

Station: SE-Nor (Norunda)

Viterbo (Italy), Antwerp (Belgium), Bordeaux (France), November 6th 2018

Description of the Labelling procedure

The Step2 procedure has the aims to organize the building the station in accordance with the ICOS Instructions, to establish the link with the ETC, and to validate all the data formats and submission. Furthermore, it involves also defining the additional steps needed after the labelling to complete the station construction according to the station Class. During the Step2 a number of steps are required and organized by the ETC in collaboration with the PI.

Preparation and start of the Step2

The station started the Step1 of the labelling on May 27th, 2016 and got the official approval on August 28th, 2016. The Step2 started officially on January 18th, 2017 with a specific WebEx between the ETC members and the station team members where the overall procedure was discussed and explained.

Team description

The station PI has to describe the station team and provide the basic information about the proposed station using the BADM system. The submission is done using a specific ICOS interface.

Sampling scheme implementation

The sampling scheme is the distribution of points in the ecosystem where a number of measurements must be done. It is composed by two different type of sampling locations: the Sparse Measurement Plots (SP) that are defined by the ETC following a stratified random distribution on the basis of information provided by the PI and the Continuous Measurement Plots (CP) where continuous measurements are performed.

Measurements implementation

The measurement of a set of variables must be implemented in the Step2 labelling phase. The compliance of each proposed sensor and method is checked by the ETC and discussed with the PI in order to find the optimal solution. In case for specific reasons it is not possible to follow the ICOS agreed protocols and Instructions an alternative solution, equally valid, is defined and discussed also with the MSA if needed.

Once the sensors and methods are agreed the station Team has to implement the measurements using calibrated sensors, submit the metadata to the ETC and start to submit data Near Real Time for the continuous measurement. Also vegetation samples must be collected and shipped to the ETC chemical laboratory in France. The list of variables to be implemented during Step2 is reported in Table 1. Adaptation of the table to specific ecosystem conditions are possible and always discussed with the PI and the MSA.

In addition to the variables reported in Table 1 there is an additional set of measurements that are requested and that must be implemented after the labelling in the following 1-2 years. For all these variables (in particular for the soil sampling) an expected date and specific method to be used is discussed and agreed before the end of the Step2 process.

Group	Variable
EC fluxes CO2-LE-H	Turbulent fluxes Storage fluxes
Radiations	SW incoming LW incoming SW outgoing LW outgoing PPFD incoming PPFD outgoing
Meteorological above ground	Air temperature Relative humidity Air pressure Total precipitation Snow depth Backup meteo station
Soil climate	Soil temperature profiles Soil water content profiles Soil heat flux density Groundwater level
Site characteristics	History of disturbances History of management Site description and characterization
Biometric measurement	Green Area Index Aboveground Biomass
Foliar sampling	Sample of leaves Leaf Mass to Area Ratio
Additional variables for Class1 stations	
Radiation	SW/PPFD diffuse
Meteorological	Precipitation (snow)
Biometric measurement	Litterfall

Table 1 – Variables requested for Step2

Data evaluation

Stations entering Step2 have been already analyzed during Step1 of the labelling but the optimal configuration and the possible presence of issues can be checked only looking to the first data measured. For this reason a number of tests will be performed on the data collected during the Step2 (NRT submissions, that can be integrated if needed by existing data) and the results discussed with the PI in order to find the best solution to ensure the maximum quality that is expected by ICOS stations. Four tests are performed:

Test 1 - Percentage of data removed

During the fluxes calculation the raw data are checked by a number of and some of them will lead to data exclusion and gaps. It is be calculated the number of half hours removed by these QAQC filters and the target value is to have less than 40% of data removed. If the test fails, an in depth analysis of the reasons is performed in order to find solutions and alternatives.

Test 2 – Footprint and Target Area

The Target Area is the area that we aim to monitor with the ICOS station. The test will analyze using a footprint model (Klijun et al. 2015) the estimated contribution area for each half hour and check how many records have a contribution coming mainly from the target area. The target is to have at least 70% of measurements that are coming mainly (70% of the contribution) from the Target Area. If the test fails, a discussion with the PI is started in order to find solutions and alternatives, in particular changing the measurement height or wind sectors to exclude.

Test 3 – Data Representativeness in the Target Area

The aim is to identify areas that are characterized by different species composition or different management (and consequently biomass and density) and analyze, using the same footprint model (Kljun et al. 2015), the amount of records coming from the different ecosystems, checking their representativeness in terms of day-night conditions and in the period analyzed. The target is to get, for the main ecosystem types, at least 20% of the data during night and during day and also distributed along the period analysed. If not reached, a discussion with the PI is started in order to find solutions and alternatives, in particular changing the measurement height or wind sectors to exclude.

Test 4 – CP Representativeness in the Target Area

The CPs must be as much as possible representative of the Target Area and this will be checked on the basis of the results of the site characterization, in particular in relation to species composition, biomass and management. The target is to have the percentage of the two main species and their biomass in the CP not more that 20% different respect to the measurements done in the SP plots. In case the CPs proposed do not represent a condition present in the Target Area they are relocated or one or more additional CPs can be added.

Station Description

The Norunda research station, with ICOS code SE-Nor, is located in the southern part of the boreal forest zone (the nearest town is Uppsala, about 25 km to the South), with the following coordinates in WGS84 system: Latitude 60.08649722 °N, Longitude 17.47950278 °E, at an elevation of 45 m above sea level, and having an offset equal to +01 respect to UTC. The area is flat with small-scale variations in altitude. The site is marked by the following climate characteristics: Mean Annual Temperature 5.65 °C, Mean Annual Precipitation 544.2 mm, Mean Annual Radiation 108 W m^{-2}. The site is dominated by Norway spruce and Scots pine with a small fraction of birch trees, and the shrub layer is dominated by blueberry, cranberry, moss, and flowers. The soils are sandy-loamy tills with high content of stones and blocks.

Figure 1 - The SE-Nor tower

Team description

The staff of the site has been defined and communicated in February 2017. It includes in addition to the PI, the Manager, and the technical-scientific staff. Below the summary table of the Team members is reported.

Table 2 - Description of team members roles at SE-Nor

MEMBER_NAME	MEMBER_INSTITUTION	MEMBER_ROLE	MEMBER_MAIN_EXPERT
Meelis Mölder	Lund University	PI	MICROMET
Irene Lehner	Lund University	MANAGER	MICROMET
Jutta Holst	Lund University	DATA	MICROMET
Anders Båth	Lund University	TEC	SOIL

Spatial sampling design

For the spatial sampling design at SE-Nor, the Station Team (ST) proposed, in addition to the Target Area (TA) and a number of area to be excluded from sampling (EA), 2 continuous measurement points (CP). Figure 2 shows the extent and position of such spatial features in relation to the actual site area in addition to the randomly sampled first order sparse measurement plots SP-I. Being a forest ecosystem, CP areas have been further subsampled to extract the coordinates of the 5+5 subplots for biomass sampling which were sent to ST. The field location of both SP-I and SP-II points correctly matched with the proposed design, and such coordinates are currently definitive and used for specific vegetation and soil samplings.

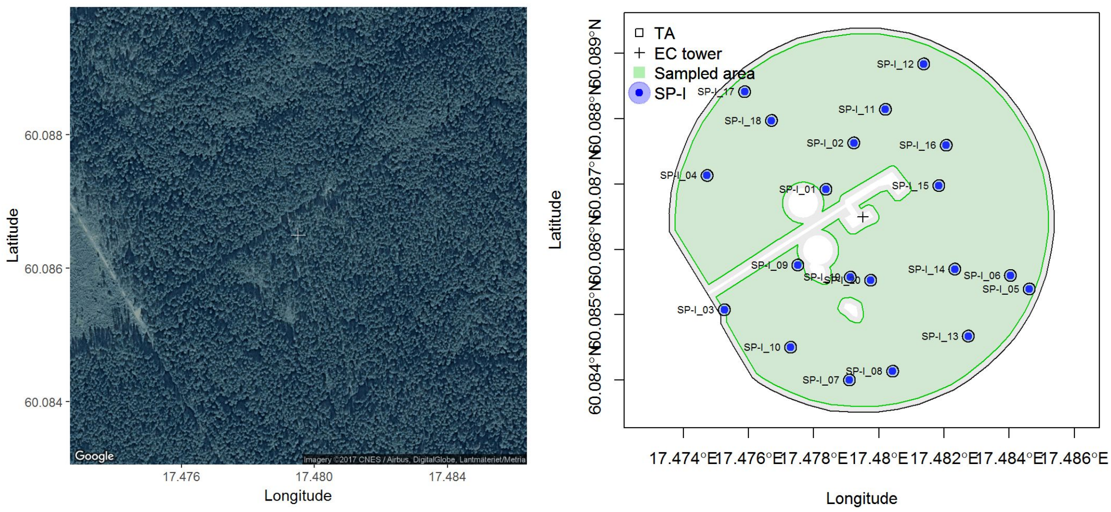


Figure 2: Aerial map of SE-Nor and proposed spatial features according to the reported target area, exclusion area and ICOS requirements. Note that also the CP areas have been excluded from the sampled area. The TA surface is 33.2 Ha, the total excluded area is of 0.46 Ha and the minimum distance between SP-I centers is 35.18 m.

Station implementation

Eddy covariance:

The present ICOS EC system is running since half 2017. According to the BADM group INST, both the sensor are factory calibrated or purchased from less than two years. The tower corner is the reference point of the station. The orientation of the SAT is 153 degrees from N as proposed and agreed during the Step1. Due to the geometry of the tower, the station team asked to extend the default wind exclusion sector (i.e. 323-343°) of 10° towards N (323-353°), and the ETC agreed. This info was correctly reported in the BADM system. Due to the type of fixture used, the head of the IRGA is placed 3 cm below the lower limit defined by the ETC: this exception is accepted by the ETC. Further details on EC setup are reported in Tab. 3.

Table 3 - Description of EC system at SE-Nor

EC System		
MODEL	GA_CP-LI-COR LI-7200	SA-Gill HS-50
SN	72H-0340	H162106
HEIGHT (m)	36	36
EASTWARD_DIST (m)	1.75	1.82
NORTHWARD_DIST (m)	-3.54	-3.56
SAMPLING_INT	0.05	0.05
LOGGER	6	6
FILE	1	1
GA_FLOW_RATE	12	-
GA_LICOR_FM_SN	FM1-0325	-
GA_LICOR_AIU_SN	AIU-0734	-
SA_OFFSET_N	-	153
SA_WIND_FORMAT	-	U, V, W
SA_GILL_ALIGN	-	Spar
ECSYS_SEP_VERT	-0.080	
ECSYS_SEP_EASTWARD	0.0658	
ECSYS_SEP_NORTHWARD	0.0187	
ECSYS_WIND_EXCL	343	
ECSYS_WIND_EXCL_RANGE	20	

Concerning the storage system, the PI proposes to use the sequential sampling scheme with a single gas analyser (LI-Cor LI-7200). This scheme is appropriate for the concerning ecosystem and was accepted. The system setup were agreed at the end of a fruitful discussion with the PI which proposed a setup as summarized in Tab. 4 and shown in Fig. 3 and 4. One of the main requested exception was the use of additional sampling levels above the EC system (because already installed and operative), without reporting them as ICOS variables. ETC decided to accept the sampling of further levels, in addition to the ones dedicated to ICOS measurements, in consideration of the scientific importance of such a rare setup. Then ETC raised some concerns with respect to 1) the number of the 'ICOS level' which was not compliant (currently 9 while it should be 11 considering the default value of 2/3 for the exponent *a* in the relevant formula of the instructions); 2) their vertical distribution which is also not compliant (suggesting to rearrange the levels according to an exponent *b* = 1.8); 3) the ramification of the two lowermost levels (not specified).

Table 4: characteristics of the proposed (by PI) storage sampling scheme for SE-Nor

Feature	*unit*	*value*
Tower height	(m)	100
Flux height	(m)	36.5
ICOS levels	(m)	0.8, 3.4, 8.6, 13.9, 19.9, 25.6, 28.7, 31.8, 37
Additional levels	(m)	43.8, 58.6, 73, 87.6, 100.9
Number of ICOS levels + 1		9+1
Number of additional levels		5
Flow rate	(L/min)	4.2
95% response for H2O change	(s)	15
Presently switched in steps of	(s)	30
Time for ICOS levels	(min)	5
Time for all levels	(min)	7.5

After the discussion, an agreement was found and the ETC decisions were 1) in consideration of the already long cycle time and that it is not feasible to add extra levels, the current levels number has been accepted; 2) considering that the current profile design is optimized to the local conditions and the current system do not allow for any modification, the current configuration was also accepted; 3) given that the ramification of the lowest two levels is confirmed, the design was accepted, with air inlets placed at about 25 meters far from the tower because the environment at the base of the tower is disturbed and not representative of the target ecosystem.

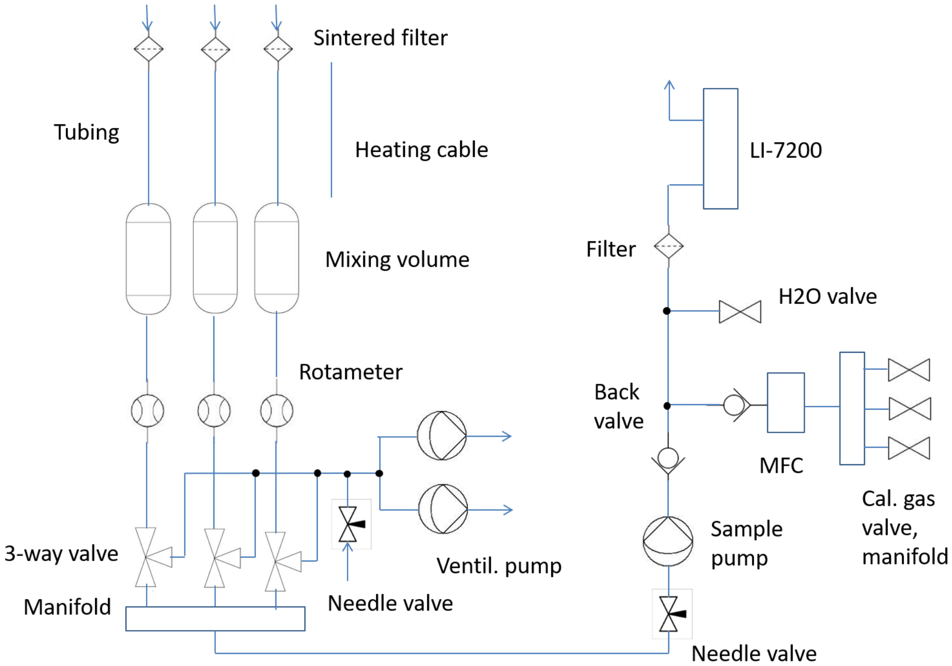


Figure 3: Storage system design at SE-Nor.

According to info in Tab. 4, the flow rate is 4.2 L/min, the switching between levels is done each 30 s. All 14 level sampling takes 7.5 minutes, while the 'ICOS levels' (10 considering the repetition of the lowermost level to allow for a good stabilization of concentration signals after switching from the highest to the lowest level) takes 5 minutes. This timing was accepted. The air system tubing is in high-density polyethylene, 4 mm inner diameter, ca 150 m long (tubes are of the same length and insulated). Buffer (mixing) volumes are of 8 L each. At the atmospheric pressure and with a flow rate 4.2 L/min, it results in a 1.9 min time constant. Since the tubes are long, the pressure in the system is lower (about 430 mb) resulting in an effective time constant of 0.82 min.

Figure 4: Storage system features at SE-Nor.

The first 0.8 m-level has 4 intakes. The distances between the adjacent intake points are 5.30 to 6.10 m, the diagonal distances are 7.80 and 8.10 m. The second 3.35 m-level has 2 intakes. The distance between them is 7.80 m (Fig. 5). The distance from the tower to the middle point of the intakes is 41 m. The estimate of the average canopy radius of dominant trees in the area around the intakes is 2.5 m.

Figure 5: Air inlets displacements of the 2 ramified levels of at SE-Nor.

Radiations:

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
RAD-4C-KZCNR4	120873	55	2.25	-3.9	SW_IN_1_2_1
					SW_OUT_1_1_1
					LW_IN_1_1_1
					LW_OUT_1_1_1
LI-COR LI-190R	Q105117	54.95	1.8	-3.12	PPFD_IN_1_1_1
LI-COR LI-190R	Q105116	55.05	1.8	-3.12	PPFD_OUT_1_1_1

For SW-LW radiations the *CNR-4* (Kipp & Zonen) pyranometer will be used in combination with the *CNF4* ventilation and heating unit while for the PPFD radiations the *LI190R-L* (Li-Cor) quantum sensor will be used. Concerning the diffuse radiation the Team proposed to use the *BF5* (Delta T) sensor, which is not fully ICOS compliant. ETC proposed to discuss its use as an exception if measured in parallel with another sensor used for the absolute value (and *BF5* used for the ratio diffuse/total). The PI agreed and installed a *CMP21* (Kipp & Zonen) pyranometer close to the BF5 to use as reference for the direct radiation.

Precipitation:

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
Geonor T-200BM	23812	1.8	48.48	63.83	P_1_1_1
Campbell SR50ATH	4571	1.9	45.52	63.73	D_SNOW_1_1_1

For total precipitation at SE-Nor will be used the *T200BM* (Genor) weighing gauge in combination with the Geonor Alter type windshield and an intake heating ring. Snow depth will be measured by the *SR50* (Campbell) sonic range sensor.

Air temperature, relative humidity and air pressure

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
Rotronic MP102H HC2-S3	61801692	36.8	-1.18	2.65	TA_1_1_1
					RH_1_1_1
Vaisala PTB210	H2220003	1.5	-15.23	-11.00	PA_1_1_1
TC Type T	TA_2_01_1	100.55	-1.63	3.65	TA_2_1_1
TC Type T	TA_2_02_1	87.4	-1.63	3.65	TA_2_2_1
TC Type T	TA_2_03_1	72.9	-1.63	3.65	TA_2_3_1
TC Type T	TA_2_04_1	58.45	-1.63	3.65	TA_2_4_1
TC Type T	TA_2_05_1	43.65	-1.63	3.65	TA_2_5_1
TC Type T	TA_2_06_1	36.8	-1.63	3.65	*TA_2_6_1*
TC Type T	TA_2_07_1	31.65	-1.63	3.65	TA_2_7_1
TC Type T	TA_2_08_1	28.5	-1.63	3.65	TA_2_8_1
TC Type T	TA_2_09_1	25.45	-1.63	3.65	TA_2_9_1
TC Type T	TA_2_10_1	19.65	-1.63	3.65	TA_2_10_1
TC Type T	TA_2_11_1	13.65	-1.63	3.65	TA_2_11_1
TC Type T	TA_2_12_1	8.4	-1.63	3.65	TA_2_12_1
TC Type T	TA_2_13_1	3.5	11.45	-35.94	TA_2_13_1
TC Type T	TA_2_14_1	0.85	11.45	-35.94	TA_2_14_1
SR50ATH	4571	1.9	45.52	63.73	TA_4_1_1

The sensors proposed for measurements of TA, RH and PA are ICOS compliant. The thermo-hygrometer is brand-new, while the calibration plan has been agreed and is discussed below. The station has also installed a vertical profile of temperature sensors for the measurement of the storage of CO_2. The ETC accepted the exception of using thermocouples (TC), given a sufficient accuracy. The thermocouples selected by the station team (type T) are accepted by the ETC, even if the model is unknown. After discussion with the station team, an agreement has been reached between the PI and the ETC on the calibration schedule of thermocouples and reference PT100. In spring 2019 the station team will calibrate 5 thermocouples out of nine (every second starting from the ground), and the remaining four will be calibrated around September 2019. In May also calibration of the reference PT100 will occur, using an additional Pt100 of class AA. Calibration will be carried out in a thermos with mixed water. Also, an issue was pointed out by the station in reporting the raw data of the thermocouples, i.e. the voltage produced by the temperature difference, as the logger uses a simplified version of the NIST (National Institute of Standards and Technology) polynomials, which are valid for all the sensor of a given type. An agreement has been reached between the PI and the ETC on how to report the equations and the coefficients using the BADM system.

On the calibration of the PA sensor, it was agreed with the ETC for all the Swedish stations to have a spare sensor, factory calibrated every two years, to be sent from one station to the next for about a month every year. This will be used as a reference station to check the calibration of the main PA sensor: in case of important un-calibration, the main sensor will have to be sent to the factory for re-calibration.

The sensor installed for measuring D_SNOW (see Precipitation section) is provided with an air temperature sensor, reported in this section. As a temperature sensor it is not ICOS compliant, but it is accepted as companion of the snow depth sensor.

__Backup meteorological station__

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
Rotronic MP102H	61801693	28.6	-1.18	2.65	TA_1_2_1
					RH_1_2_1
Rotronic MP102H	61801693	28.6	-1.18	2.65	TA_1_2_2
Lambrecht 15189H	840902.0002	1.5	46.95	65.12	P_2_1_1
Kipp&Zonen CMP21	120922	101.5	0	0	SW_IN_1_1_1

The PI proposed as a backup meteo tower a precomposed commercial station. The sensor for RH was ICOS compliant, while the one for TA was not, and even if it could be accepted for the backup station, the PI decided to switch to a different, fully compliant sensor (Rotronic MP102H). The precipitation sensor was not compliant, and the PI proposed to use a different, brand new, compliant sensor (Lambrecht 15189H). The radiation sensor was not compliant, and the PI proposed an additional sensor which is fully ICOS compliant (Kipp&Zonen CMP21).

Soil temperature, soil water content, soil heat flux and water table depth

The station team has installed the full set of soil meteo sensors required for a Class 2 forest station (Table 5), except the water table depth sensors. The team has let know the ETC that monitoring holes for water table depth measurements have been drilled, but an unexpected delay in the delivery of the CS-451 pressure sensors prevents the team for completing the soil plots. As an exception, the ETC allows the station team to set up the water table depth measurements only after the labelling (yet as soon as the sensors are delivered, in autumn).

The soil meteo sensors have been installed at locations in the target area that comply with the ICOS Instructions: two soil plots each in the vicinity of the center of the two Continuous Measurements plots (CPs), plus two additional soil heat flux plates in the target area (see Figure 6). The set-up of each soil plot and each additional soil heat flux plate, shown in Figure 7, is compliant with the ICOS Instructions in terms of sensor models, number of sensors and sensor depths. The station team has furthermore submitted all requested metadata on the installed sensors.

The station team had mentioned in Action 5 that the auto-calibration of the soil heat flux plates is not possible at their site due to small soil heat fluxes and long "recovery periods" after the auto-calibration. It has sent ETC a dataset to demonstrate this. The ETC has checked the dataset and proposed a calibration frequency for the plates of one time per day. It can be evaluated later, when a sufficient amount of measurements have been collected, whether the self-calibration procedure can be omitted and replaced with a ‘fixed’ sensitivity factor that is function of the soil moisture level.

Table 5: List of the sensors employed at SE-Nor. *WTD sensors will be added later.*

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
Campbell Scientific CS107	ST1-1	-0.02	-77.28	-42.39	TS_1_1_1
Campbell Scientific CS107	ST1-2	-0.05	-77.28	-42.39	TS_1_2_1
Campbell Scientific CS107	ST1-3	-0.1	-77.28	-42.39	TS_1_3_1
Campbell Scientific CS107	ST1-4	-0.3	-77.28	-42.39	TS_1_4_1
Campbell Scientific CS107	ST1-5	-0.5	-77.28	-42.39	TS_1_5_1
Campbell Scientific CS107	ST2-1	-0.02	-74.44	-56.02	TS_2_1_1

Campbell Scientific CS107	ST2-2	-0.05	-74.44	-56.02	TS_2_2_1
Campbell Scientific CS107	ST2-3	-0.1	-74.44	-56.02	TS_2_3_1
Campbell Scientific CS107	ST2-4	-0.3	-74.44	-56.02	TS_2_4_1
Campbell Scientific CS107	ST2-5	-0.5	-74.44	-56.02	TS_2_5_1
Campbell Scientific CS107	ST3-1	-0.02	-109.89	-5.94	TS_3_1_1
Campbell Scientific CS107	ST3-2	-0.05	-109.89	-5.94	TS_3_2_1
Campbell Scientific CS107	ST3-3	-0.1	-109.89	-5.94	TS_3_3_1
Campbell Scientific CS107	ST3-4	-0.3	-109.89	-5.94	TS_3_4_1
Campbell Scientific CS107	ST3-5	-0.5	-109.89	-5.94	TS_3_5_1
Campbell Scientific CS107	ST4-1	-0.02	-103.63	17.96	TS_4_1_1
Campbell Scientific CS107	ST4-2	-0.05	-103.63	17.96	TS_4_2_1
Campbell Scientific CS107	ST4-3	-0.1	-103.63	17.96	TS_4_3_1
Campbell Scientific CS107	ST4-4	-0.3	-103.63	17.96	TS_4_4_1
Campbell Scientific CS107	ST4-5	-0.5	-103.63	17.96	TS_4_5_1
Delta-T Devices ML2x Thetaprobe	387/089	-0.05	-76.91	-42.51	SWC_1_1_1
Delta-T Devices ML2x Thetaprobe	387/086	-0.05	-74.12	-56.61	SWC_2_1_1
Delta-T Devices ML2x Thetaprobe	387/097	-0.1	-74.12	-56.61	SWC_2_2_1
Delta-T Devices ML2x Thetaprobe	387/075	-0.3	-74.12	-56.61	SWC_2_3_1
Delta-T Devices ML2x Thetaprobe	387/076	-0.5	-74.12	-56.61	SWC_2_4_1
Delta-T Devices ML2x Thetaprobe	387/083	-0.05	-109.86	-5.64	SWC_3_1_1
Delta-T Devices ML2x Thetaprobe	387/081	-0.05	-103.9	17.51	SWC_4_1_1
Delta-T Devices ML2x Thetaprobe	384/065	-0.1	-103.9	17.51	SWC_4_2_1

Delta-T Devices ML2x Thetaprobe	383/088	-0.3	-103.9	17.51	SWC_4_3_1
Delta-T Devices ML2x Thetaprobe	387/085	-0.5	-103.9	17.51	SWC_4_4_1
Hukseflux HFP01SC-05	2838	-0.05	-77.16	-42.88	G_1_1_1
Hukseflux HFP01SC-05	2839	-0.05	-74.56	-56.4	G_2_1_1
Hukseflux HFP01SC-05	2840	-0.05	-109.45	-6.46	G_3_1_1
Hukseflux HFP01SC-05	2805	-0.05	-104.01	18.1	G_4_1_1

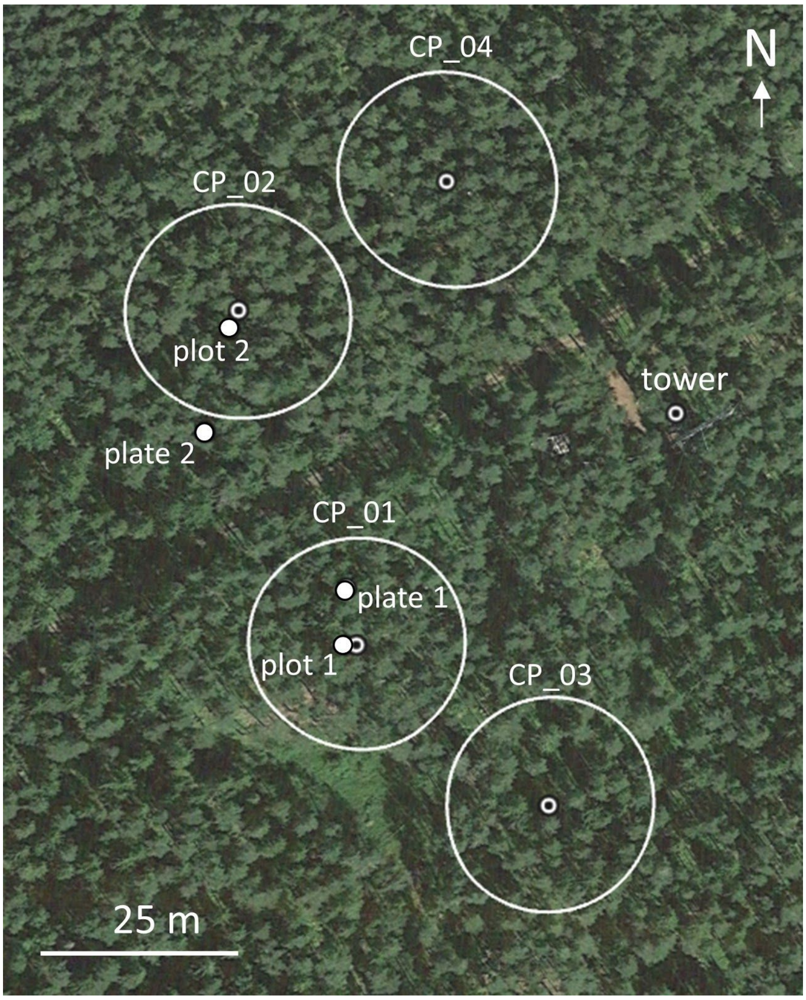


Figure 6: Location of the two soil plots (plots 1 & 2) and the two additional soil heat flux plates (plates 1 & 2) around the EC tower . CP = Continuous Measurements plot.

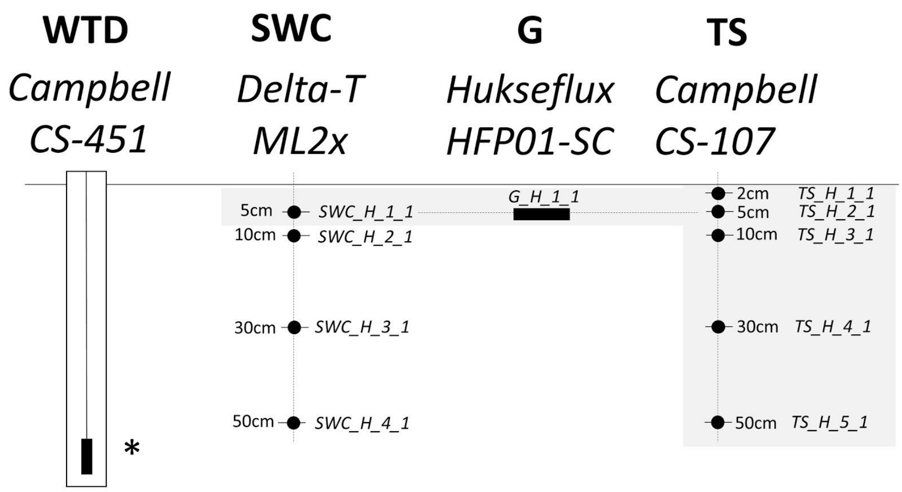


Figure 7: Set-up of the two soil meteo plots (all sensors) and the two soil heat flux plates with accessory SWC and TS sensors (sensors in grey). WTD = water table depth, SWC = soil water content, G = soil heat flux density, TS = soil temperature. * WTD sensors will be installed as soon as delivered.

<u>*Spatial heterogeneity characterization*</u>

Aboveground biomass: The station team has collected in the spring of 2018 the full set of tree data that is requested for the characterization of the target area and its spatial heterogeneity. This dataset comprises the species, DBH, height, and health status of all trees above the stem diameter threshold of 5 cm that are growing inside the 20 SP-I plots installed in the target area. The ETC has quality-checked and processed these data. Figures 8, 9 and 10 summarize the dataset, showing for each plot respectively the tree density per species, the basal area per species, and the percentage-wise species contribution to the total basal area of the plot. Basal area is used here as a proxy for Aboveground biomass. The plots are grouped per stand that is distinguished in the target area (thinned vs unthinned; explanation further below). As can be seen in the figures, the target area is dominated by Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H.Karst.), with sparse presence of downy birch (*Betula pubescens* Ehrh.), silver birch (*Betula pendula* Roth), and common alder (*Alnus glutinosa* (L.) Gaertn.).

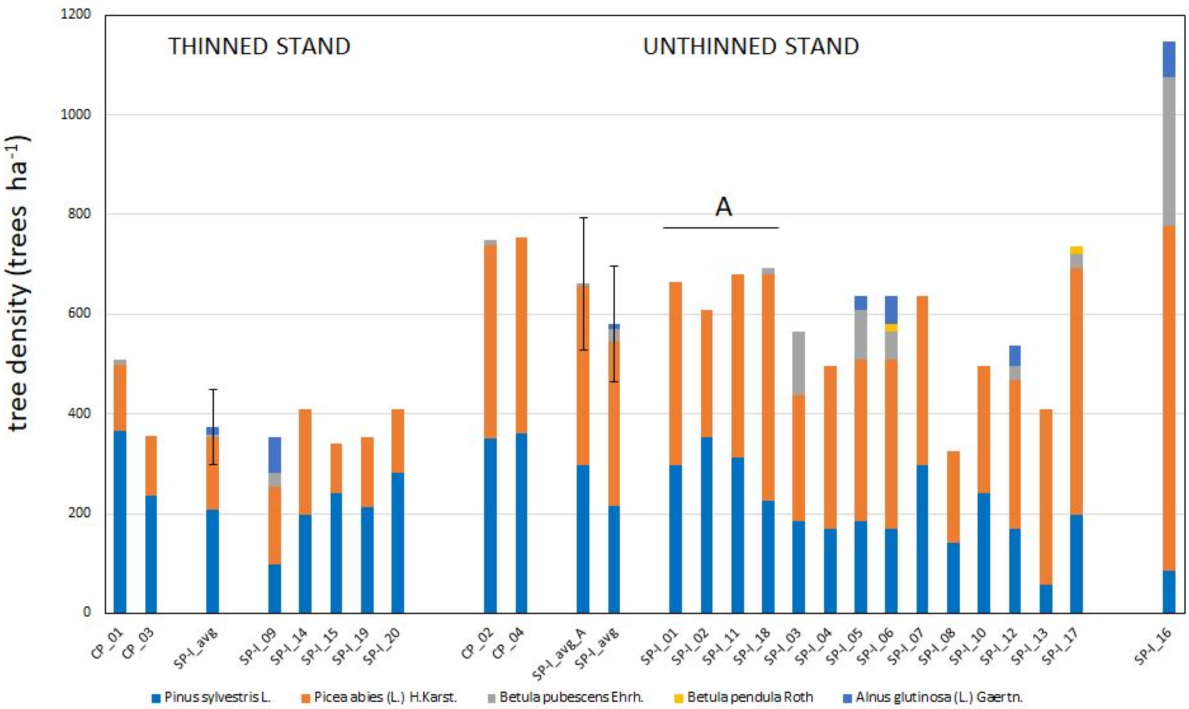


Figure 8: Tree density per species, shown for the twenty SP-I plots and the four CPs installed in the target area. The plots are grouped per stand that is distinguished in the target area (thinned vs unthinned stand, see also map Figure 11). Error bars on the SP-I plot averages indicate +/-20% of the total plot value and are calculated for the representativeness checks of the CPs explained further in the report.

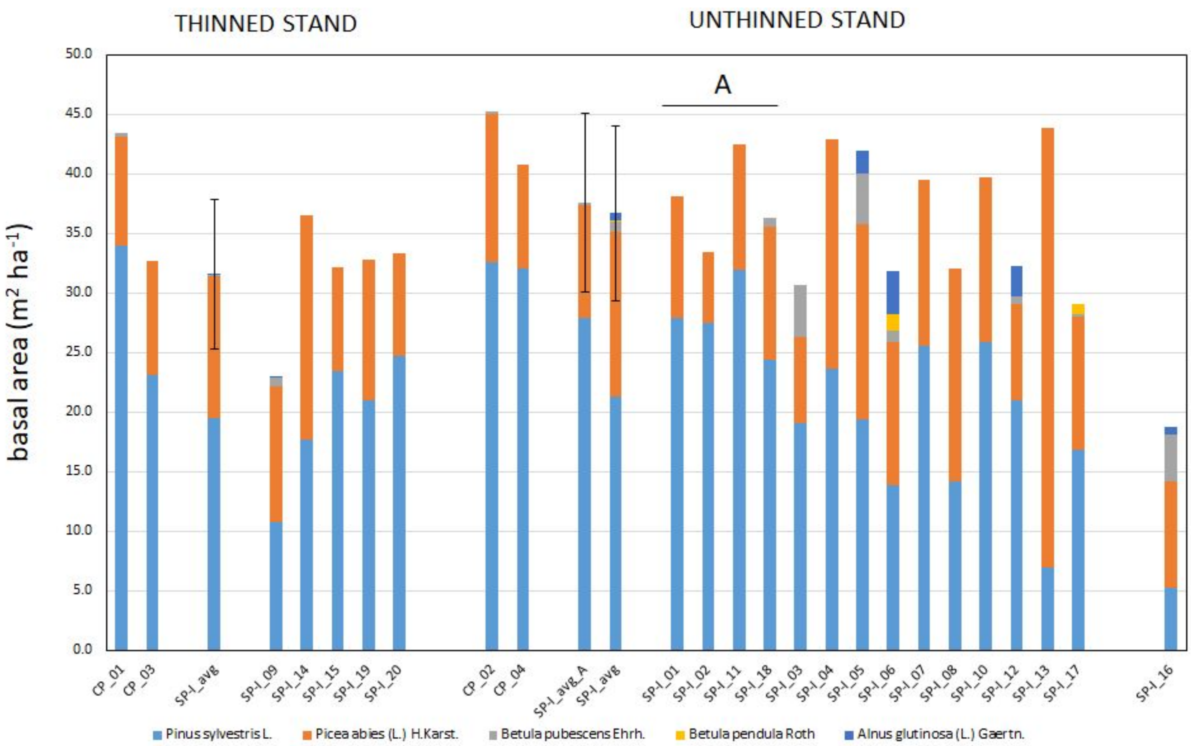


Figure 9: Basal area per species, shown for the twenty SP-I plots and the four CPs installed in the target area. The plots are grouped per stand that is distinguished in the target area (thinned vs unthinned stand,

see map Figure 11). Error bars on the SP-I plot averages indicate +/-20% of the total plot value and are calculated for the representativeness checks of the CPs explained further in the report.

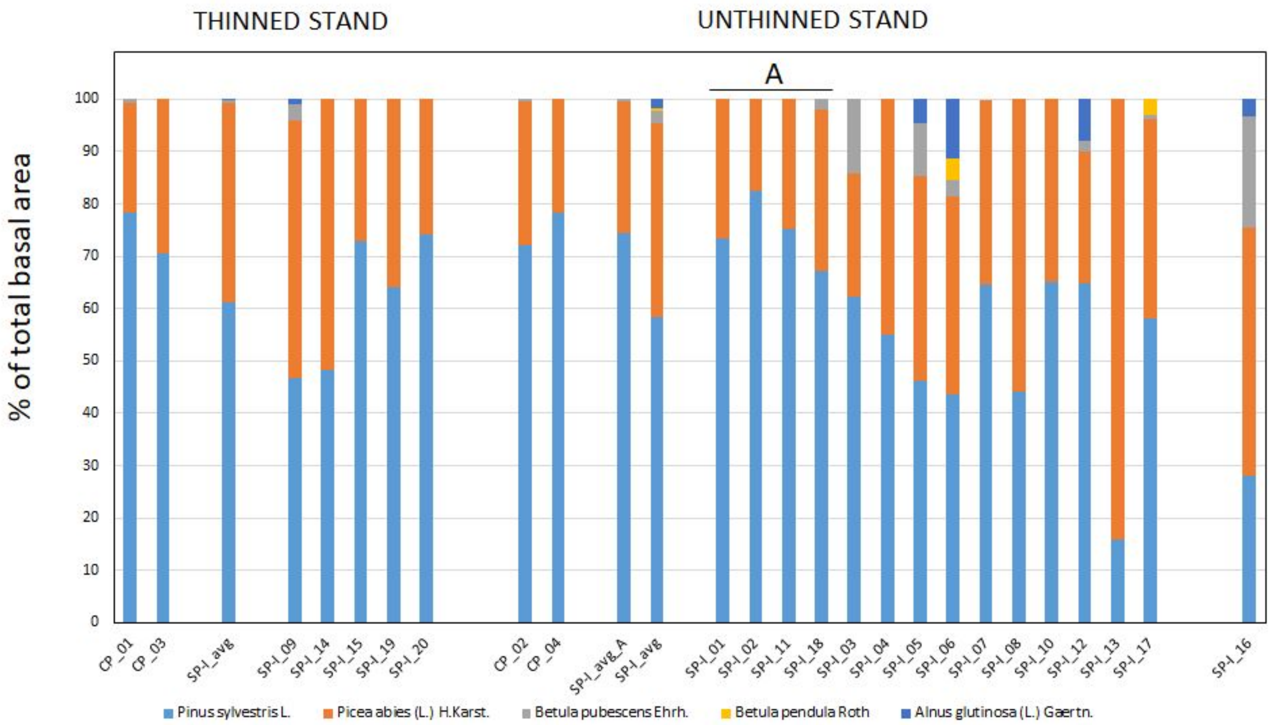


Figure 10: Percentage-wise contribution of each species to the total basal area of the plot, shown for the twenty SP-I plots and the four CPs installed in the target area. The plots are grouped per stand that is distinguished in the target area (thinned vs unthinned stand, see map Figure 11).

Green Area Index: The station team has carried out all the Green Area Index measurements in the 20 SP-I plots that are requested for the characterization of the target area and its spatial heterogeneity. The measurements have been done in the second part of May 2018 by means of Digital Hemispherical Photography. As prescribed in the ICOS Instructions, five hemispherical images were taken in each SP-I plot. The ETC has quality-checked and processed the images. A small number of images did not pass the quality check but these images have been successfully retaken by the station team in early June. Figure 11 shows the plot results.

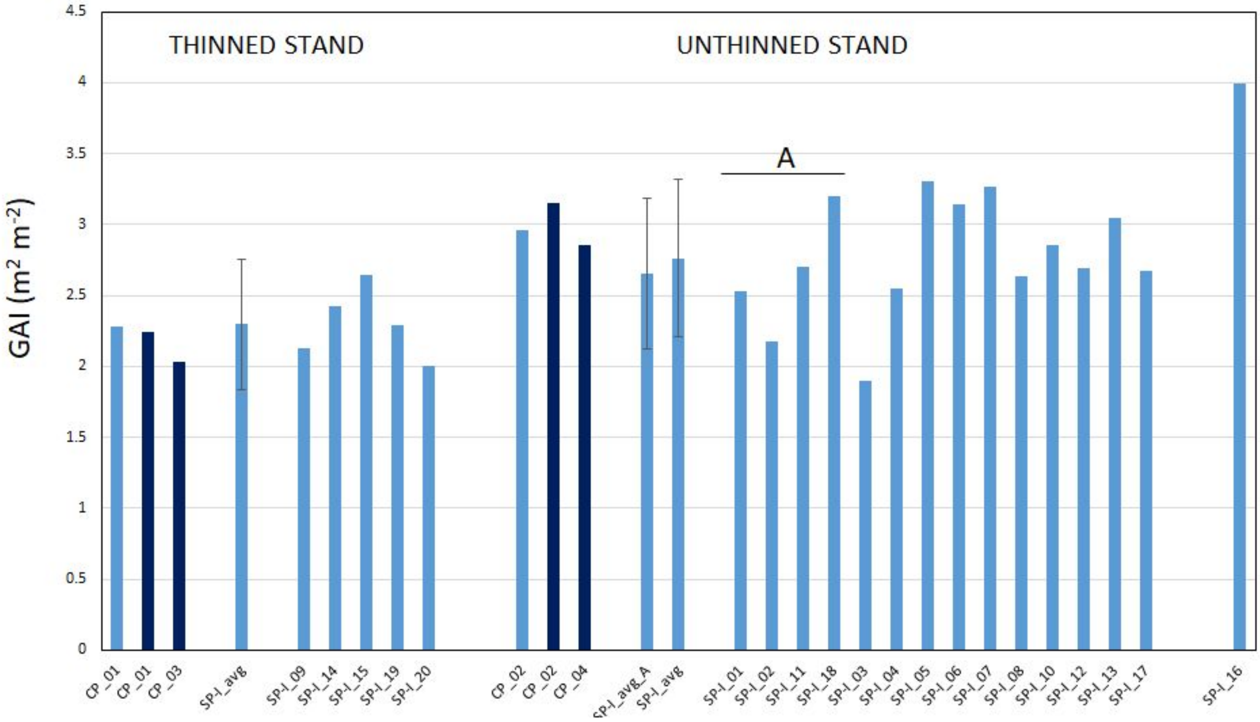


Figure 11: Green Area Index (GAI) for the twenty SP-I plots and the four CPs installed in the target area. The plots are grouped per stand that is distinguished in the target area (thinned vs unthinned stand, see also map Figure 12). Error bars on the SP-I plot averages indicate +/-20% of the total plot value and are calculated for the representativeness checks of the CPs explained further in the report. Light blue bars show measurements done in the second part of May 2018. Dark blue bars show measurements done in the four CPs on 10 July 2018.

The site characterization measurements revealed a large variability in tree density, basal area, and Green Area Index within the target area. Part of this variability can be explained by the fact that the target area includes two differently-thinned stands, as communicated by the station team. In 2008 a semi-circular area with a radius of 200 m around the EC tower was thinned, reducing tree density in this area from from 857 to 428 stems ha^{-1} and reducing basal area with 21%, while the rest of the target area remained untouched (see Figure 12). The average tree density in the thinned area is indeed much lower than in the unthinned area (370 vs 580 trees ha-1, Figure 8). The same is to a lesser extend true for basal area (31.6 vs 36.7 m2 ha-1, Figure 9). It must be noted that due to the removal of a significant amount of trees damaged by stormy weather in 2013, tree density and basal area are now lower than in 2008. As communicated by the stations, there can be further distinguished a square-shaped stand located within the unthinned stand NW from the EC tower (Figure 12, opaque polygon A). This stand has a higher tree density as compared to the unthinned stand (Figure 8) and includes more pine and less spruce as compared to the entire unthinned stand (Figure 10).

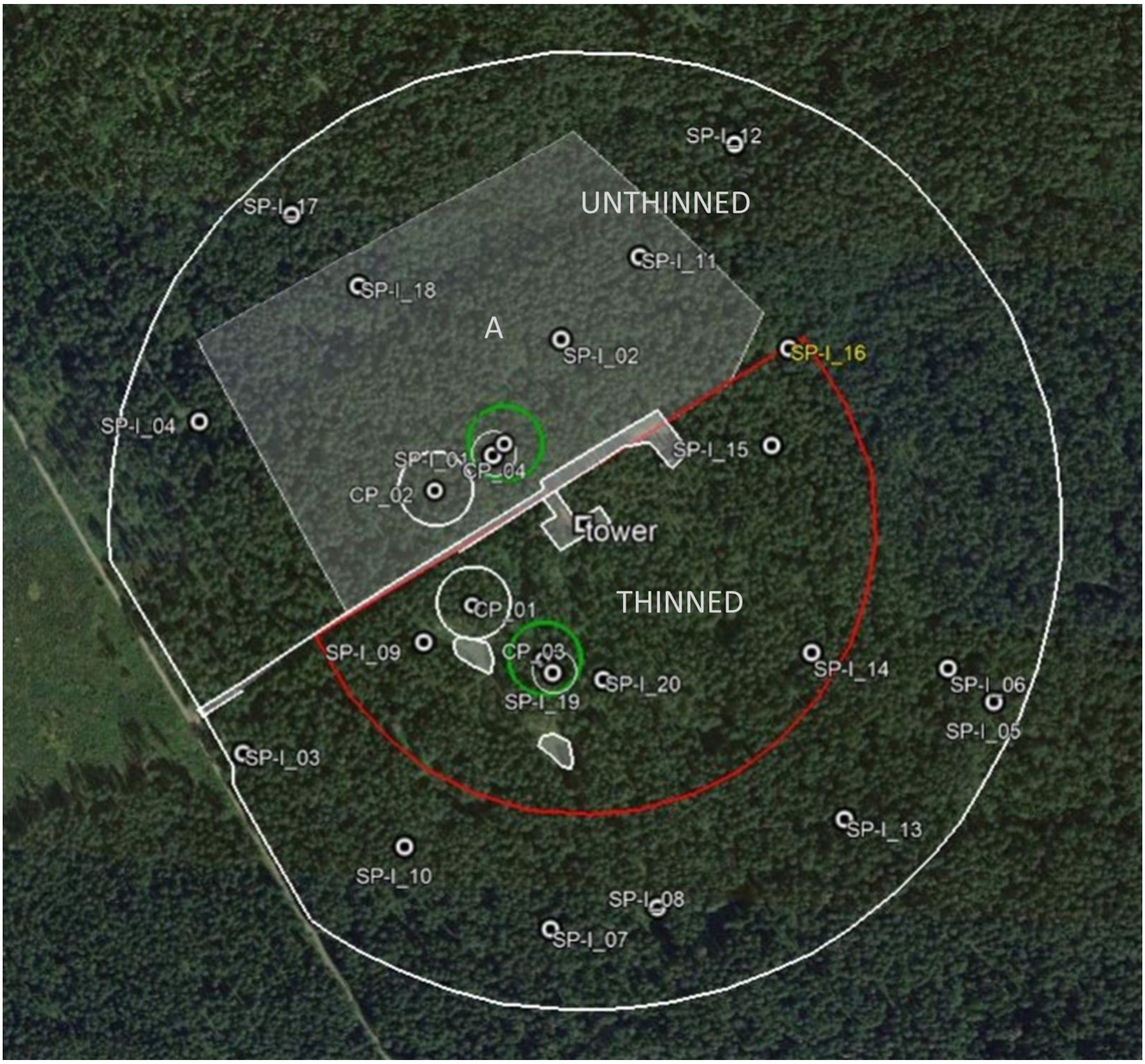


Figure 12: The target area with an indication of the thinned stand (red half circle), the unthinned stand, and a stand within the unthinned stand where the tree density and the pine-to-spruce ratio is higher as compared to the entire unthinned stand (opaque polygon A). Also shown are the locations of the twenty SP-I plots and the four CPs installed in the target area. The latter include two originally proposed CPs (CP_02 and CP_02; white circles) and two CPs that are additionally installed on request of the ETC (CP_03 and CP_04; green circles).

<u>Green Area Index</u>

The station team has collected the minimum of two sets of GAI measurements that are requested for the step 2 labelling. As prescribed in the ICOS Instructions, GAI was measured by means of Digital Hemispherical Photography and at each measurement date nine hemispherical images were taken in each CP. The first set of measurements was collected on 22/23 May 2018 in two originally proposed CPs (CP_01 and CP_02) and this concomitantly with the GAI measurements in the SP-I plots. The ETC quality-checked and processed the images. A small number of images did not pass the quality check but these images were successfully retaken by the station team in early

June. The second set of measurements was collected on 10 July 2018 in four CPs, i.e. in the originally proposed CPs ánd in two other CPs (CP_03 and CP_04) that were additionally installed in the target area CPs on request of the ETC after the representativity tests of the originally proposed CPs. The ETC quality-checked and processed the images. A small number of images did not pass the quality check but these images were successfully retaken by the station team in mid July. Figure 11 shows the GAI results for each CP. The station team has furthermore submitted the DHP measurement locations for the four CPs.

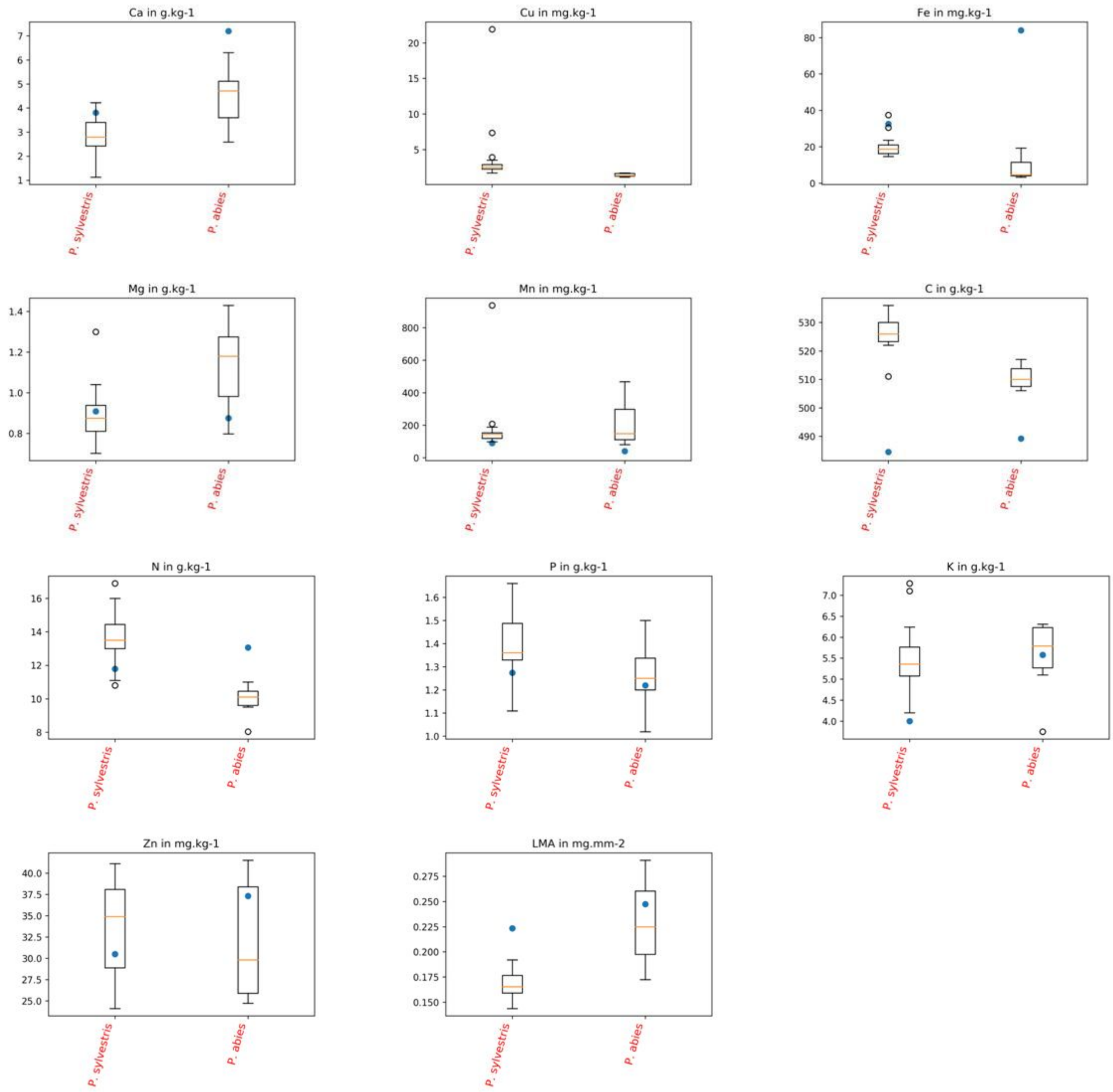
Aboveground biomass

The station team has collected in the spring of 2018 the tree data required for the Aboveground biomass assessment in the step 2 labelling phase. These data comprise the position, species, DBH, height, health status and dendrometer presence of all trees above the stem diameter threshold of 5 cm that are growing inside the two originally proposed CPs that the station team has installed (CP_01 and CP_02). The station has collected in early July also the same set of data in the two other CPs (CP_03 and CP_04), which were additionally installed in the target area upon request of the ETC after the representativity tests of the two originally proposed CPs. The ETC quality-checked and processed these data. Figures 8, 9 and 10 show for each of the four CPs respectively the tree density per species, the basal area per species, and the percentage-wise species contribution to the total basal area of the plot. Basal area is used here as a proxy for Aboveground biomass. As can be seen in the figures, the CPs are entirely dominated by Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) H.Karst.), with sparse presence of downy birch (*Betula pubescens* Ehrh.) in CP_01 and CP_02.

Vegetation sampling and analysis

The samples requested have been collected by the station team and sent to the ETC laboratory by February 2018. The mean and standard deviation values obtained for both the LMA and the needle nutrients mass ratio are as expected and seem typical of a healthy nutrient status for both species. After discussion with station team, it was agreed to keep the same sample design until the 2021/22 clearcut.

Foliar Analyses for station SE-Nor, 2018-03-02



Mean value of the ***Pinus sylvestris*** *and* ***Pices abies*** *from TRY-db Data when available.* (https://www.try-db.org/TryWeb/Home.php)

Data check and test

__Data quality analysis (Test 1)__

The quality control (QC) procedure aims to verify that at least 60% of half-hourly values in a given temporal window (e.g. 3 months) are of the highest quality possible. This means that the total percentage of missing and removed data after the QC filtering do not exceed the 40% threshold value.

On the basis of the current state of scientific knowledge, tests involved in the QC procedure aim at detecting (i) fluxes originating from wind sectors to exclude, (ii) instrument malfunction as provided by sonic anemometer (SA) and gas analyser (GA) diagnostics and by Vickers and Mahrt (1997) statistical tests; (iii) anomalous values of the spectral correction factor; (iv) lack of well developed turbulence regimes (Foken and Wichura, 1996) and (v) violation of stationary conditions (Mahrt, 1998).

By comparing each test statistic with two pre-specified threshold values, severe and moderate evidences of systematic error are provided (hereinafter denoted as SevEr and ModEr). Subsequently, the data rejection rule involves a two-stage procedure as described. In the first stage half-hourly fluxes affected by SevEr are directly discarded, whereas those affected by ModEr are removed only if they are also identified as outlying values.

Concerning SE-Nor site, the testing period involves raw data sampled in 2018 from July 1 to October 15. Of 5136 expected half-hourly files for NEE fluxes, 73.8% were retained after QC routines as illustrated in Figure 13. In particular, about 5.7% of raw-data files were missed, 23.7% of calculated half-hourly fluxes were discarded because affected by SevER, while an additional 2.5% of them were discarded because identified as outlier and affected by ModEr. Being the percentage of missing data equal to 26.2% and less than 40% threshold value, we conclude that SE-Nor site reaches the minimum requisite expected for the Step 2 of the labelling.

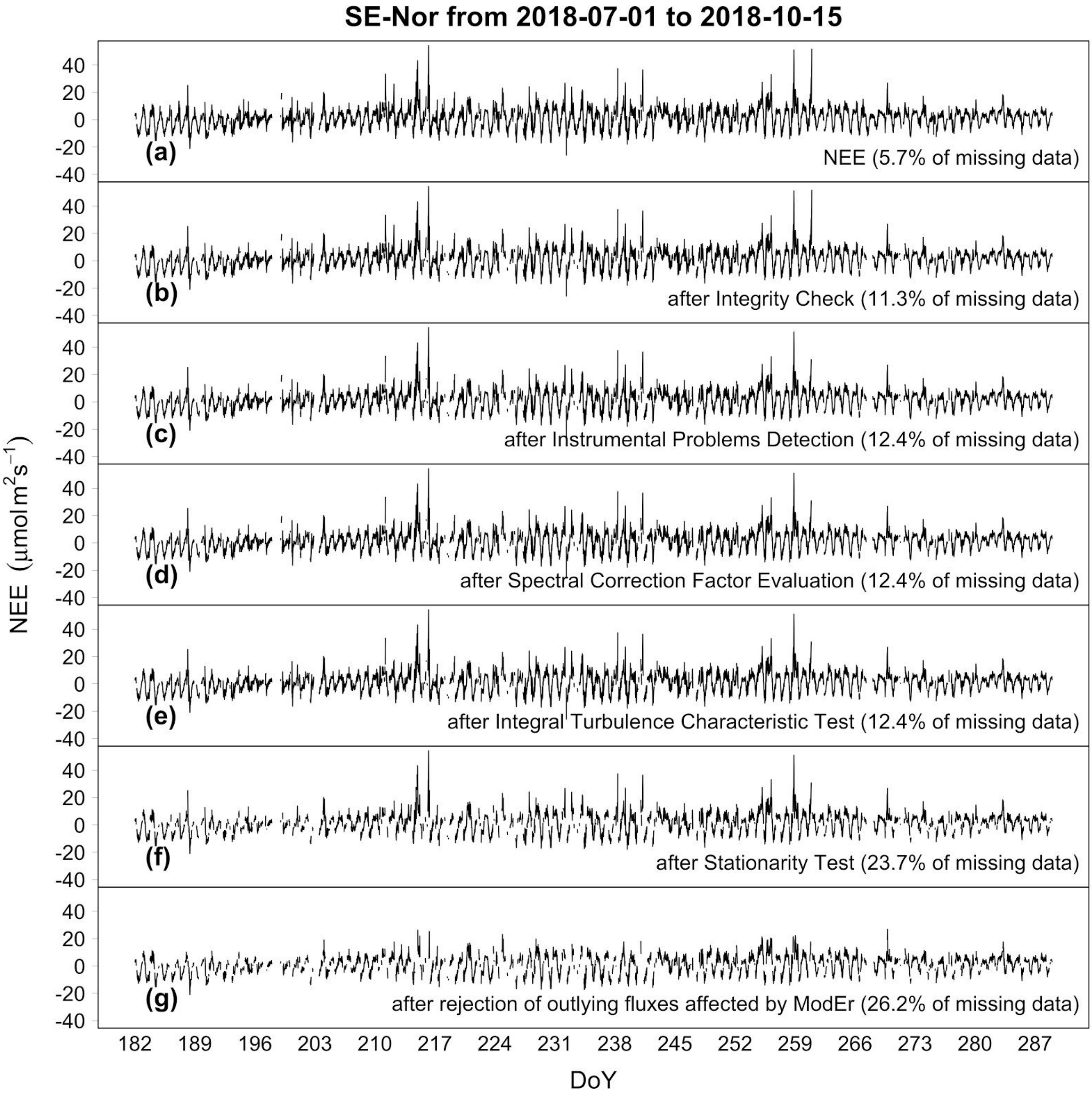


Figure 13: Summary of the quality control tests applied to the Net Ecosystem Exchange (NEE) of CO2 flux collected at SE-Nor site from 2018/07/01 to 2018/10/15. The original half-hourly flux time series is exhibited in the top panel. Panels b-f display the sequential removal of data affected by severe evidences of error according to the following criteria: (b) wind sectors to exclude and diagnostics provided by sonic anemometer (SA) and gas analyser (GA); (c) instrumental problems detection; (d) anomalous spectral correction factor (SCF) check; (e) integral turbulence characteristics test (ITC, Foken and Wichura, 1996); (f) stationarity test by Mahrt (1998). Bottom panel displays the time series of retained high-quality NEE after the additional removal of outlying fluxes affected by moderate evidences of error.

Footprint analysis (Test 2)

The test aims to evaluate whether half-hourly flux values are sufficiently representative of the target area (TA) or not. It was performed on 3 months of data, after QA/QC filtering procedure (previous Section) has been achieved. The model of Klijun et al. (2015) has been used to obtain the 2-dimensional flux footprint for each half-hour which was compared to the TA spatial extent. After the QA/QC procedure and additional filtering according to footprint model requirements, the 70% of the test data was used for the test. Results showed that the the very majority of the whole data have a cumulative contribution of at least 70 % from the TA (Fig. 14, left panel, first bar on the left), and this holds also for daytime and nighttime conditions (Fig. 14, left panel). In addition, the test was performed on 4 sub-periods and results were confirmed (Fig. 14, right panels).

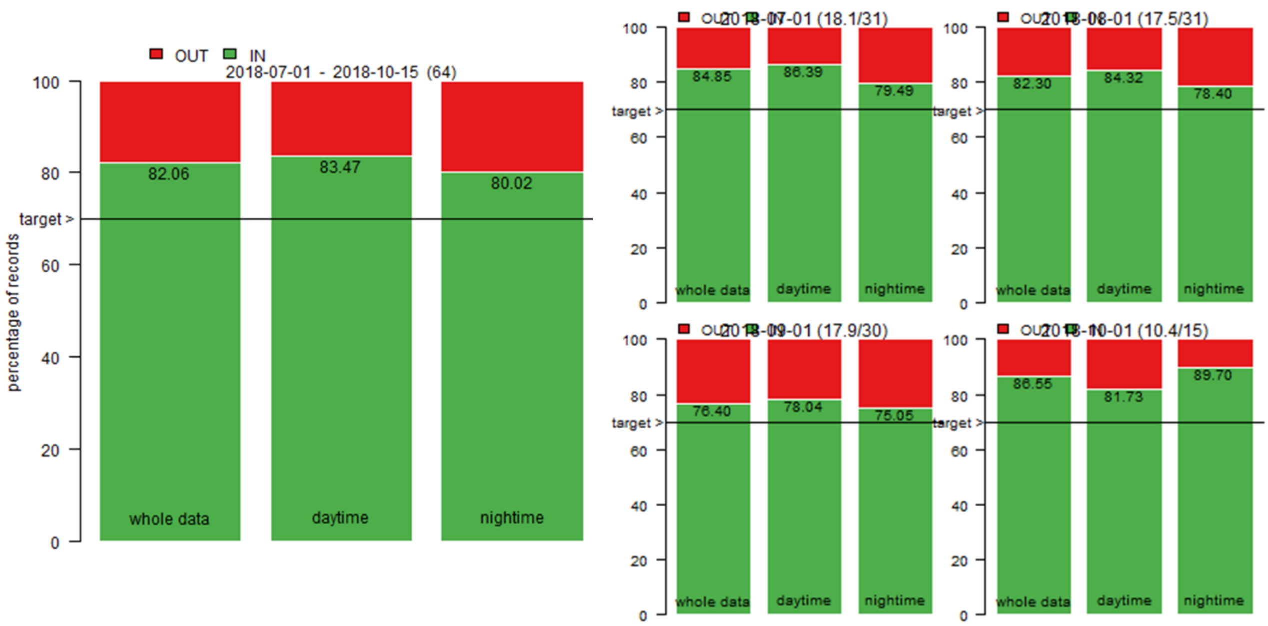


Figure 14: Test results showing the percentage of half-hours with a footprint cumulative contribution of at least 70% from the target area. The test target value is that the 70% of data must hold this condition in each considered period. Right panel: whole analyzed period; left panels: monthly sub-periods.

The footprint climatology for SE-Nor, for the period under consideration is reported in Fig. 15, by which it is possible to noticed that the footprint 70% contribution is generally included in the TA.

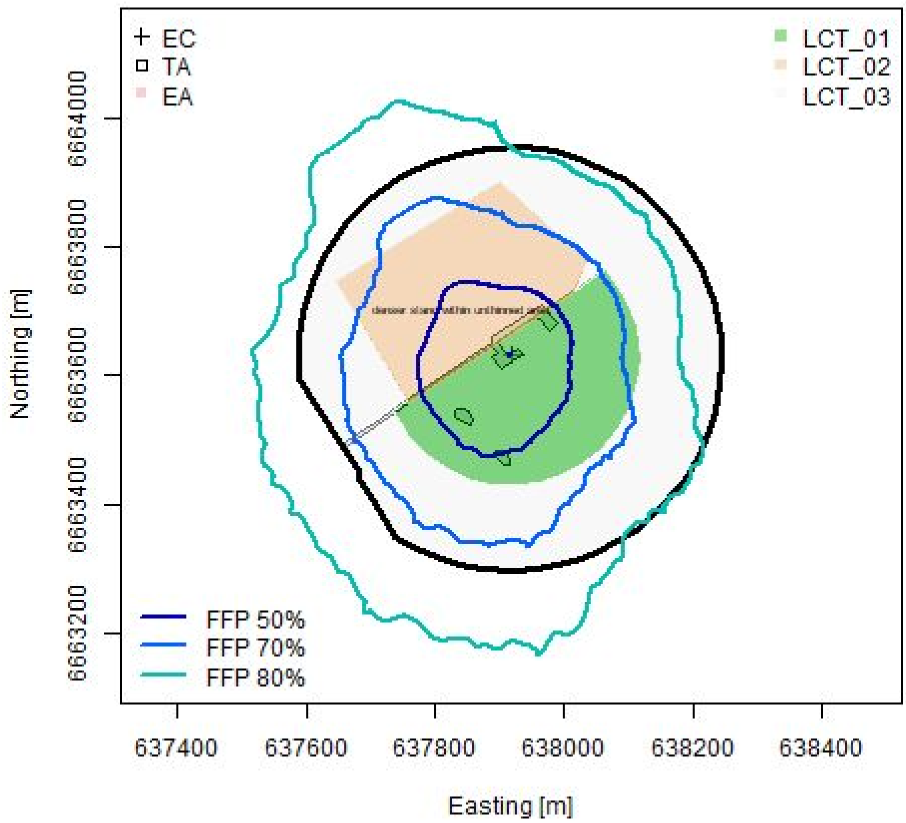


Figure 15: Footprint climatology at SE-Nor in relation to the TA, the different land cover typologies (LCT), the EC tower (EC), and the excluded areas (EA, see the spatial sampling Section). The 50, 70 and 80 % cumulative distribution isopleths are reported.

According to the results, the test is considered as passed.

Data representativeness analysis (Test 3)

The test aims to quantify, for possible ecosystem patches in the TA which contribute with at least 70% of the fluxes in at least 20% of the data (good data after filtering for QA/QC), the number of records collected during daytime, nighttime and for each of two periods obtained dividing the dataset in two parts. The target values is that each group includes at least 20% of data.

According to the spatial heterogeneity characterization (see the respective Section above, and the *Test 4* results) at SE-Nor were defined 3 land cover typologies, a thinned stand , an unthinned stand, and a stand within the unthinned stand where the tree density and the pine-to-spruce ratio is higher as compared to the entire unthinned stand, here named as LCT_01, LCT_03 and LCT_02 respectively. Exemplary half-hourly footprints at SE-Nor in relation to the TA and the different land cover typologies are reported in Fig. 16.

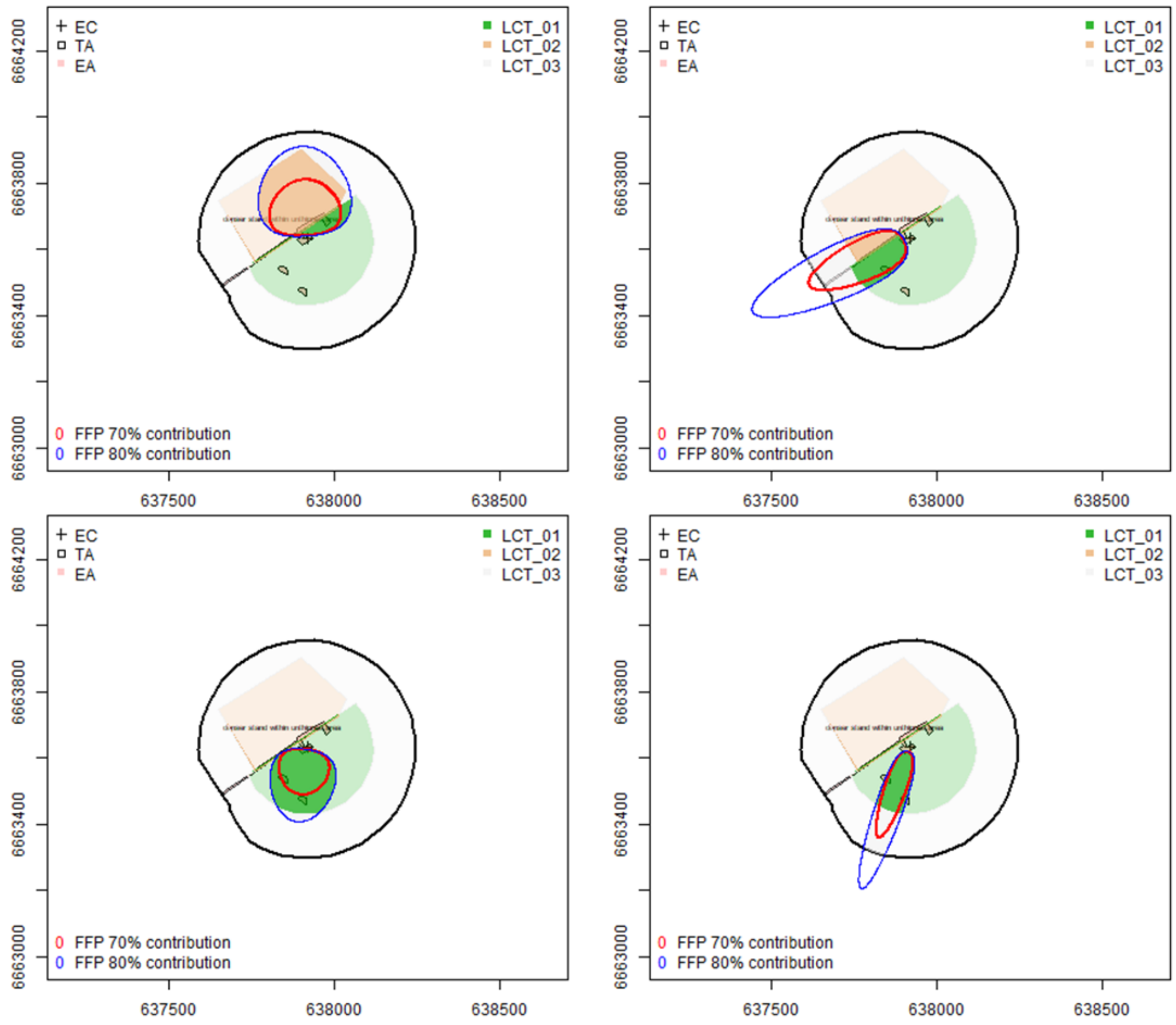


Figure 16: exemplary 2D half-hourly footprints at SE-Nor are related to the TA. The footprint 70 and 80% cumulative distribution isopleths are reported in red and blue respectively.

The test showed that, except for the LCT_03 which is rarely sampled, neither LCT_01 and LCT_02 contributes for more than 70% in more than the 20% of records (LCT_01 only reaches the 18% of data with more than 70% of contribution). Rather, they are sufficiently and proportionally sampled, with LCT_01 providing the major contribution.

Give this results, additional analysis were not achieved and the test considered as passed.

Ancillary plot representativeness (Test 4)

The representativeness of the CPs was evaluated by comparing each CP with the SP-I-order plots in terms of (i) standing biomass, i.e. the tree density and the basal area of the plot, (ii) species composition, i.e the percentage basal area of the main species, and (iii) Green Area Index. As explained in the introductory section of this report, a CP is deemed representative when values are less than 20% different with respect to the target area's average, i.e. the average of the 20 SP-I-order plots.

The station team originally proposed two CPs for their Class 2 station: CP_01 and CP_02. Because CP_01 and CP_02 were deliberately located to represent the thinned and unthinned part of the target area, respectively, each CP was compared against the average of the SP-I plots located in the respective part. Figure 12 shows the distribution of the plots. It must be noted that SP-I_16 was excluded from the comparison, because this plot is located in a small, swampy area with a very high density of small trees that is entirely different from the rest of the target area. On the basis of the comparison, the ETC decided that the two CPs are not representative (enough) for the thinned and unthinned stand: although GAI doesn't differ significantly between the CPs and the SP-I plots (Figure 11), the tree density and basal area of the CPs are more than 20% higher as compared with the average of the SP-I plots (SP-I_avg; Figures 8 and 9). Also, the CPs differ too much from the SP-I plots in terms of species composition: they contain much more pine and less spruce than the SP-I plots on average (SP-I_avg; Figure 10). The station team ascribed the basal area differences between the CPs and the SP-I plots partially to different methods of removal of trees damaged during stormy weather in 2013 that were used inside the CPs (manually, to protect equipment) and outside the CPs (with a harvester, felling a number of trees on its path).

Since the station team has let know the ETC that the target area will be clearcut in 2021/22, the ETC and the station team then agreed to install one additional, temporary CP in the thinned stand and one such temporary CP in the unthinned stand and this by converting one representative SP-I plot from each stand into a CP (green circles in Figure 12). In the thinned stand, SP-I_19 was converted to CP_03 and in the unthinned stand SP-I_1 was converted to CP_04. The representativity of these two new CPs was then assessed using tree data and GAI measurements that station team newly collected in these CPs. After comparison with the SP-I plots, the ETC decided that CP_03 is representative for the thinned stand: the tree density and basal area of this CP are close to the SP-I average (Figures 8 and 9), and GAI in this CP doesn't differ significantly from the SP-I average (Figure 11). Even though CP_03 contains more pine and less spruce than the SP-I plots on average, the difference in species composition is deemed acceptable (Figure 10). As regards CP_04, this CP was not only compared against the SP-I plots located in the entire unthinned stand, but also against the subset of SP-I plots located in the same distinguishable, square-shaped stand as the CP (opaque polygon A in Figure 12). Tree density and basal area of CP_04 fall within the accepted range of deviation from the average of the subset of SP-I plots (SP-I_avg_A; Figures 8 and 9), but this is not true for tree density when compared with all SP-I plots in the unthinned stand (SP-I_avg, Figure SHC1). In terms of species composition, CP_04 agrees well with the subset of SP-I plots (SP-I_avg_A; Figure 10), but less with the average of all SP-I plots in the unthinned stand. Furthermore, GAI doesn't differ significantly between CP_04 and the subset of SP-I plots or all SP-I plots in the unthinned area. In conclusion, CP_04 is representative for the smaller stand A in which it is located but less so for the unthinned stand as a whole. The ETC decided to accept CP_04, because the smaller stand is located NW and near the EC tower and thus expected to often be a source area of sensed fluxes, at least much more than the part of the unthinned stand that is represented less by CP_04 and lies further away from the EC tower.

The ETC and the station team agreed that repeated ancillary vegetation measurements will be carried out in the four CPs until the clearcut, after which CP_03 and CP_04 may cease to exist.

Near Real Time data transmission

NRT data submission started on July 18th. The ETC asked the station team to change the file number, because there was a change in the acquisition script (the files were firstly shifted of 30 steps). The station is in a special situation: as they are using Campbell logger to record EC data, the files are not fully ICOS compliant at the beginning of the submission (variable TIMESTAMP is called instead timestamps, and the sonic diagnostic is between double quotes). In addition, the station team communicated that the time-series were artificially shifted of 30 steps to correct an expected time lag. This approach is not accepted in ICOS, and creates problems with the processing: for that the ETC asked to remove this shift on September 4th. The ETC then asked on September 18th to use uppercase letters for the labels of TIMESTAMP: both these changes were made without changing the file name. Then, on September 20th the ETC, to reduce the inconsistencies in the files sent to the CP, asked CS users to make almost-fully compliant files either by removing the internal header, or by creating binary files. The station decided to remove the header (planning to do it within Nov 10th).

Plan for remaining variables

Soil sampling

A discussion with station PIs was started since the soil in this station is extremely stony, making the ICOS sampling scheme not applicable. Soil sampling in Norunda will be operated in 2019 or 2020 and sampling will be adapted.

EC data synchronization

The EC data are collected with a logger and a code where the synchronization of the two data streams from Sonic and IRGA are not evaluated yet. The station team agreed to do a specific test in collaboration with the ETC but data have not been sent yet. The station team will have to setup the experiment for the sync test before end of March 2019 and the data will be analysed by the ETC to verify the correct synchronisation.

Other

Due to unexpected delay in the delivery of the CS-451 pressure transducers, setting up the water table depth measurements may be postponed to after the step labelling phase (but it must however be done as soon as the sensors are delivered, in autumn).

Some PIs from northern climates reported issues in the quality of SAT data and on T_SONIC time-series in case of snow/rain/dew/cold. Discussion with Gill was started to check and solve the issue.

Labelling summary and proposal

On the basis of the activities performed and data submitted and after the evaluation of the station characteristics, the quality of the data and setup, the compliance of the sensors and installations and the team capacity to follow the ICOS requirements for ICOS Ecosystem Stations we recommend that the station Norunda (SE-Nor) is labelled as ICOS Class 2 Ecosystem station.

Dario Papale, ETC Director

November 6th 2018