ICOS Ecosystem Station Labelling Report

Station: DE-HoH (Hohes Holz)

Viterbo (Italy), Antwerp (Belgium), Bordeaux (France), January 17th 2019

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 September 16th 2016 and got the official approval on February 13th 2017. The Step2 started officially on March 13th 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 station Hohes Holz, with code (DE-HoH) is located at the northern border of the water catchment Bode. The site is an alluvional forest, with the following coordinates in WGS84 system: Latitude 52.08656 °N, Longitude 11.22235 °E, having an offset respect to the Coordinated Universal Time (UTC) equal to +01 and the elevation above sea level of 193 m. The site is marked by the following climate characteristics: Mean Annual Temperature 9.1 °C, Mean Annual Precipitation 563 mm. The dominant species of the forest are: *Fagus sylvatica L., Quercus petraea (Matt.) Liebl.* with *Betula pendula Roth*, *Carpinus betulus L.,* in afforestations *Picea abies (L.) H.Karst.* and *Larix decidua Mill*. The soils are Luvisoles.

Figure 1 - The DE-HoH tower

Team description

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

MEMBER_NAME	MEMBER_INSTITUTION	MEMBER_ROLE	MEMBER_MAIN_EXPERT
Corinna Rebmann	Helmholtz Centre for Env.Res. - UFZ	PI	MICROMET
Sebastian Gimper	Helmholtz Centre for Env.Res. - UFZ	CO-PI	LOGISTIC
Inmaculada García Quirós	Helmholtz Centre for Env.Res. - UFZ	SCI-ANC	PLANT
Laura Dienstbach	Helmholtz Centre for Env.Res. - UFZ	SCI-ANC	BIOMASS
Patrick Schmidt	Helmholtz Centre for Env.Res. - UFZ	TEC	SOIL

Table 2 - Description of team members roles at DE-HoH

Spatial sampling design

For the spatial sampling design at DE-HoH, the Station Team (ST) proposed in addition to the Target Area (TA), 6 areas to be excluded from sampling (EA). 4 continuous measurement points (CP) were submitted and after verifying their compliance, the respective areas were excluded from the surface available for sampling. 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.

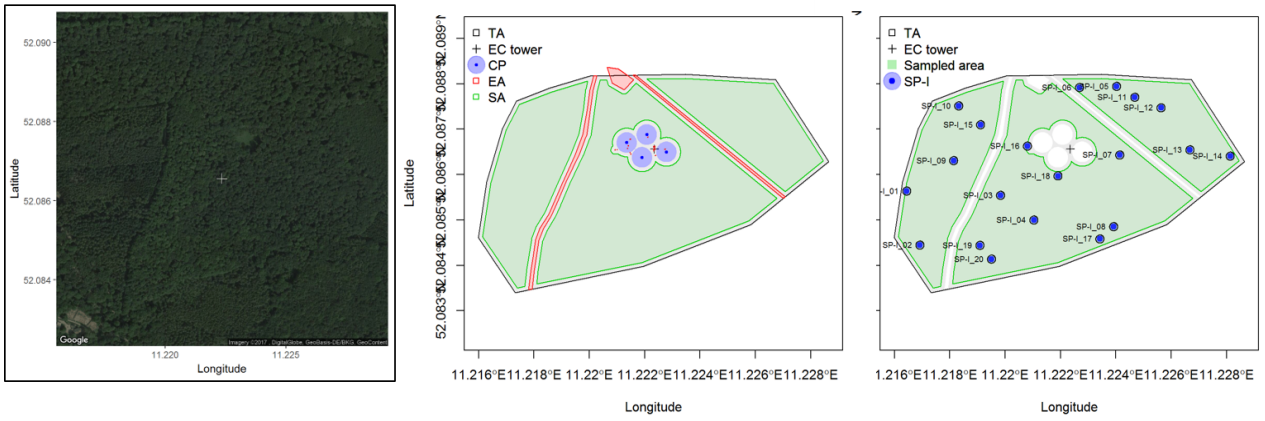


Figure 2: Aerial map of DE-HoH and proposed spatial features according to the reported target area (TA), exclusion areas (EA), continuous plots (CP) and ICOS requirements. Note that the CP areas have been excluded from the sampled area. The TA surface is 32.93 Ha, the total excluded area is of 0.91 Ha.

PI asked as exception to locate and mark the sampled SP-I and SP-II positions as precise as possible with a normal accuracy (3 m) D-GPS, start the soil sampling at these points, and then take back the locations more accurately by tachymetry. ETC, in consideration that the D-GPS accuracy was not negligible but also not critical (randomness was hold anyway) and to avoid delays in the labelling, decided to accept the proposal. Field points check has been done in several steps, according to

progressive feedbacks between ETC and the PI, which in addition proposed a list of reserve points to be used as replacements for sampled SP-II locations (Tab. 3).

A further exception concerned the field positioning of the SP-I_01. The PI, during the mapping of the points, realized this point felt within a fenced protected area (plantation) causing the determination of the coordinates as well as soil sampling within this area is not possible or even not allowed. ETC analyzed and discussed the point concluded that it would be still important to get all the biological information from this area (GAI, AGB, species etc.) that are part of the characterization protocol even if without the soil sampling. For this reason the ETC suggestion was to still locate the SP-I_01 center (if not not possible with the GPS, with other tools) and do all the characterization but not the soil sampling. The PI agreed and this solution was considered as definitive.

Table 3: list of replacement points proposed by DE-HoH PI.

sampled point	**replacement**	**motivation**
SP-II_02-01	SP-II_02-01-R	bad accessibility of the original point.
SP-II_04-03	SP-II_04-09-R	lower order points trees were preventing the correct measurement of the other points.
SP-II_15-05	SP-II_15-12-R	terrain there is very densely stocked by small trees and lower order points were not accessible for the instrumentation of the topographer
SP-II_19-01	SP-II_19-03-R	trees were preventing the correct measurement of the other points
SP-II_19-03	SP-II_19-04-R	trees were preventing the correct measurement of the other points
SP-II_20-02	SP-II_20-10-R	trees and large roots were preventing the correct measurement/soil sampling of the other points
SP-II_20-03	SP-II_20-11-R	this was already measured by the topographer and soil sampled before our previous discussion.

The last iteration for field points check, confirmed that they all were compliant (distance mismatches with sampled points always less than tolerance) and the current points locations are now definitive.

Station implementation

Eddy covariance:

EC System		
MODEL	GA_CP-LI-COR LI-7200	SA-Gill HS-50
SN	72H-0596	H154102

HEIGHT (m)	45	45
EASTWARD_DIST (m)	-3.94	-3.94
NORTHWARD_DIST (m)	-1.18	-1.18
SAMPLING_INT	0.05	0.05
LOGGER	99	99
FILE	1	1
GA_FLOW_RATE	15	-
GA_LICOR_FM_SN	FM1-0508	-
GA_LICOR_AIU_SN	AIU-1357	-
SA_OFFSET_N	-	235
SA_WIND_FORMAT	-	U, V, W
SA_GILL_ALIGN	-	Spar
ECSYS_SEP_VERT	0	
ECSYS_SEP_EASTWARD	0.22	
ECSYS_SEP_NORTHWARD	-0.01	
ECSYS_WIND_EXCL		
ECSYS_WIND_EXCL_RANGE		

The EC station in DE-HoH is provided with ICOS compliant sensors. Both sensors have been factory-calibrated more than 2 years ago; however, they are running from April 2016, so they need calibration. The PI planned to send them to the factory for calibration in March 2019. The sensors are in the agreed position and height. However, the station didn't pass the footprint test at the end of the Step2 (see corresponding section). For that reason, the ETC and the PI agreed in lowering the EC system to 45 m, which happened on Oct 25th 2018.

For the storage system at DE-HoH the sequential sampling scheme has been proposed and agreed. The IRGA LI-840A (*Li-Cor*) will be used for measuring concentrations and placed in a temperature controlled hut. Air temperature profile will be measured at 0.1, 0.4, 1, 2, 4, 8, 10, 16, 22, 28, 38 and 49 m by the 43347 Rtd Temperature Probe (*Campbell Sci*.). The sensors are housed with the 3502-L RM Young compact aspirated shields. Two additional ventilated thermohygrometers, a HMP155 and a HMP45C will be placed at 50 m and the at 38 m respectively. Flow rate at the inlets will be measured by the UD-34500-12 (*Cole-Parmer*, test phase), while the flow to the GA by the GE50 (*MKS*) mass flow controller. The air will be aspirated by an 815 KNE (KNF) pump. 3-way solenoid electro-valves 365B01G-Z031A-DN1 (*Sirai*) connected to a self-build connection node will control the air system. Because of technical limitations, the PI requested to to use 12 sampling levels instead of 13 as recommended by ICOS according to the EC system height (i.e. 49 m), distributed at 0.1, 0.4, 1, 2, 4, 8, 10, 14, 22, 28, 38 and 49 m. ETC accepted both the number and the vertical distribution of levels as are appropriate for the concerning ecosystem, though , suggested to lower the first level (# 1, originally at 50 m) at the same level of the EC system. The ETC request has been agreed by the PI. The lowest level will have 4 distributed inlets and the

second level 2 inlets, mixed in buffer volume. The air system is made by 4 mm inner diameter tubes with brass and PE joints, Swagelock and self-build inlets. Every length between inlet and MFC is 60 m. The actual system flow rate is 1 L min-1, each levels is sampled for 25 s and the full profile is thus sampled in 300 s. The PI originally proposed buffer volumes of 5 L which, assuming a line pressure of 1000 hPa, such volumes may be at the limit of compliance. After a discussion with ETC has been agreed to use volumes of 7.3 L.

In a later stage, it has been agreed to decrease the EC system height to 45 m. Consequently, the profile air inlet (together with the HMP155 humidity and temperature probe) at the tower top was also moved from 49 m to 45 m, while the others levels were kept at the original heights.

Radiations:

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
RAD-4C-KZCNR4	121102	49	1.75	-3.7	SW_IN_1_1_1
					SW_OUT_1_1_1
					LW_IN_1_1_1
					LW_OUT_1_1_1
LI-COR 190/R	Q106049	49	1.35	-3.4	PPFD_IN_1_1_1
LI-COR 190	Q43705	49	1.35	-3.4	PPFD_OUT_1_1_1
Delta-T BF5	70/09	49	1.3	-3.38	PPFD_IN_1_1_2
					PPFD_DIF_1_1_1
Delta-T SPN1	A1376	49	1.5	-3.1	SW_IN_1_1_2

For SW-LW radiations the CNR-4 (Kipp & Zonen) pyranometer will be used in combination with the CNF4 ventilation and heating unit. For PPFD radiations the *LI190R* (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 *SPN1* (Delta T) pyranometer to use as reference for the direct radiation.

Precipitation:

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
Thies Model 5.4032.35.008	7100067	50	1.13	0.15	P_1_1_1
MPS system sro TRwS215	1697	2	-19.60	35.43	P_2_2_1

Campbell SR50A	SR2090	2	-13.219831	-3.24268	D_SNOW_1_1_1

The PI requested an exception for the location of the pluviometer: the only possibility at the site is a clearing with a diameter of about 20 m, certified by pictures and local maps. While not compliant to ICOS requirements (e.g. surrounding trees are 17 to 30 m high), there are no other valuable locations to install the pluviometer. The PI sent some historical data collected by an heated rain gauge on top of the tower and by a tipping bucket installed in the clearing. After evaluating the dataset, ETC verified that the two series were statistically not different. Consequently, ETC decided to accept the installation of the pluviometer in this spot, asking the PI to optimize both the current position and the holding structure by:

- moving the pluviometer some meters toward ESE (about 5 m) so as to maximize the fetch according to the main wind direction (WNW)
- rising the height of the gauge so as to ensure that it is never covered by understorey vegetation
- installing the windshield

This changes to the proposed setup, while represent the best option, are likely still not enough to prevent some measurement errors, most of all, the accumulation of leaves and debris in the gauge. This must be avoided by regular and intensive manual cleanings. The PI was warned anyway that if the first rain data will not be compliant to ICOS standards, ETC could ask to find another solution.

Total precipitation will be measured with the weighing gauge TRwS215 (MPS system) coupled with its compliant (Alter type) windshield. Snow depth will be measured by the SR50AT (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
VAISALA HMP155	M0950041	49	1.25	-1.5	TA_1_1_1
					RH_1_1_1
SETRA 278	148.270/ 3766878	49	1.25	-1.5	PA_1_1_1
GILL Windsonic 4	16340053	49	1.3	-3	WS_1_1_1
					WD_1_1_1
Young 41342	TS18428	38	-1.5	-1.25	TA_1_2_1
Young 41342	TS15078	29	-1.5	-1.25	TA_1_3_1
Young 41342	TS18427	22	-1.5	-1.25	TA_1_4_1
Young 41342	TS15074	14.2	-1.5	-1.25	TA_1_5_1

Young 41342	TS15075	10	-1.5	-1.25	TA_1_6_1
Young 41342	TS18429	8	-1.5	-1.25	TA_1_7_1
Young 41342	TS26877	4	-1.5	-1.25	TA_1_8_1
Young 41342	TS28541	2	-1.5	-1.25	TA_1_9_1
Young 41342	TS28540	1	-1.5	-1.25	TA_1_10_1
Young 41342	TS15077	0.4	-1.5	-1.25	TA_1_11_1
Young 41342	TS15079	0.1	-1.5	-1.25	TA_1_12_1

The sensor proposed by the station team for measuring PA is ICOS compliant (SETRA 278, range 600-1100 hPa). The thermohygrometer to measure TA and RH (Vaisala HMP45AC) was instead not fully compliant for TA, as the T range started from -40 °C instead of -50 °C. Even if an exception was requested by the PI and accepted upon presentation of historical meteo data, showing that the lower TA ever measured at the station in the last 65 years was -24 °C, the PI decided to switch to a different sensor (Vaisala HMP155), fully ICOS compliant. A profile of TA sensors to be used for the storage calculation is also present. The model selected is not ICOS compliant, mainly because of a too long response time; however, it can be used for profile measurements. In addition to the sensors mandatory for the Step 2, the station team also reported a 2D sonic anemometer for measuring wind speed and wind direction. Even if not needed for the Step 2, the wind range of the Gill Windsonic sensor is shorter (0-60 m s-1) than ICOS requirements (0-75 m s-1). Like for other sensors, it could be accepted as exception in case a long dataset is available to show that the wind speed never get that high. However, as not required for completing the labelling procedure, this test can be also planned in the future activities.

Backup meteorological station

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
Hukseflux NR01	1123	37	-0.1	-4	SW_IN_2_1_1
					SW_OUT_2_1_1
					LW_IN_2_1_1
					LW_OUT_2_1_1
Thies 1.1005.54.000	171617	37	-1.5	-1.25	TA_2_1_1
					RH_2_1_1
Thies B-278-2T	7000553	37	-0.9	1.1	PA_2_1_1
Thies 5.4032.35.008	12160892	37	-0.6	-1.9	P_2_1_1
YOUNG Wind-Sentry 3002-5	WS-14845	37	-0.2	-3.2	WS_2_1_1
					WD_2_1_1

The sensor proposed for backup precipitation measurements is ICOS compliant (Thies 5.4032.35.008). The sensor for TA and RH, as well as the sensor for SW_IN, were instead accepted as exception. In addition to what requested by ICOS, the station team will have also a PA sensor at the backup station, and a vane and cup propeller anemometer, in addition to the main one. The PA sensor is accepted as additional, not requested, sensor. The anemometer is not compliant due to the range of WS (0-50 m s-1 instead of 0-75). However, as a backup sensor it could be accepted.

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

The station team has installed the full set of soil meteo sensors required for their Class 1 forest station. The sensors have been installed at locations in the target area that comply with the ICOS Instructions, i.e one soil plot near the centre of each of four installed Continuous Measurements Plot (CP_01 to CP_04; see Figure 3). *Note: As mentioned further in the report, a fifth CP has been installed by the station team upon request of the ETC, but this CP didn't have to include a soil plot.* The set-up of each soil plot, shown in Figure 4, is compliant with the ICOS Instructions in terms of sensor models, number of sensors, and sensor depths. Furthermore, the station team has submitted all requested metadata on the installed sensors.

The station is exempt from water table depth measurements, because data have shown that the groundwater table is located at a depth of more than 8 m. Measurements of water table depth are hence considered irrelevant.

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
Truebner SMT-100	UFZICOS-001-008	-0.03	-18.465	35.463	TS_11_1_1
Truebner SMT-100	UFZICOS-001-001	-0.05	-18.465	35.463	TS_11_2_1
					SWC_11_1_1
Truebner SMT-100	UFZICOS-001-002	-0.15	-18.465	35.463	TS_11_3_1
					SWC_11_2_1
Truebner SMT-100	UFZICOS-001-003	-0.25	-18.465	35.463	TS_11_4_1
					SWC_11_3_1
Truebner SMT-100	UFZICOS-001-004	-0.35	-18.465	35.463	TS_11_5_1
					SWC_11_4_1
Truebner SMT-100	UFZICOS-001-005	-0.5	-18.465	35.463	TS_11_6_1
					SWC_11_5_1
Truebner SMT-100	UFZICOS-001-006	-0.7	-18.465	35.463	TS_11_7_1
					SWC_11_6_1

Truebner SMT-100	UFZICOS-002-008	-0.03	31.779	-5.811	TS_12_1_1
Truebner SMT-100	UFZICOS-002-001	-0.05	31.779	-5.811	TS_12_2_1
					SWC_12_1_1
Truebner SMT-100	UFZICOS-002-002	-0.1	31.779	-5.811	TS_12_3_1
					SWC_12_2_1
Truebner SMT-100	UFZICOS-002-003	-0.2	31.779	-5.811	TS_12_4_1
					SWC_12_3_1
Truebner SMT-100	UFZICOS-002-004	-0.3	31.779	-5.811	TS_12_5_1
					SWC_12_4_1
Truebner SMT-100	UFZICOS-002-005	-0.5	31.779	-5.811	TS_12_6_1
					SWC_12_5_1
Truebner SMT-100	UFZICOS-002-006	-0.7	31.779	-5.811	TS_12_7_1
					SWC_12_6_1
Truebner SMT-100	UFZICOS-003-008	-0.03	-28.26	-22.783	TS_13_1_1
Truebner SMT-100	UFZICOS-003-001	-0.05	-28.26	-22.783	TS_13_2_1
					SWC_13_1_1
Truebner SMT-100	UFZICOS-003-002	-0.1	-28.26	-22.783	TS_13_3_1
					SWC_13_2_1
Truebner SMT-100	UFZICOS-003-003	-0.2	-28.26	-22.783	TS_13_4_1
					SWC_13_3_1
Truebner SMT-100	UFZICOS-003-004	-0.3	-28.26	-22.783	TS_13_5_1
					SWC_13_4_1
Truebner SMT-100	UFZICOS-003-005	-0.4	-28.26	-22.783	TS_13_6_1
					SWC_13_5_1
Truebner SMT-100	UFZICOS-003-006	-0.7	-28.26	-22.783	TS_13_7_1
					SWC_13_6_1
Truebner SMT-100	UFZICOS-004-008	-0.03	-67.3364	13.903	TS_14_1_1
Truebner SMT-100	UFZICOS-004-001	-0.05	-67.3364	13.903	TS_14_2_1
					SWC_14_1_1
Truebner SMT-100	UFZICOS-004-002	-0.1	-67.3364	13.903	TS_14_3_1
					SWC_14_2_1
Truebner SMT-100	UFZICOS-004-003	-0.2	-67.3364	13.903	TS_14_4_1
					SWC_14_3_1

Truebner SMT-100	UFZICOS-004-004	-0.3	-67.3364	13.903	TS_14_5_1
					SWC_14_4_1
Truebner SMT-100	UFZICOS-004-005	-0.5	-67.3364	13.903	TS_14_6_1
					SWC_14_5_1
Truebner SMT-100	UFZICOS-004-006	-0.7	-67.3364	13.903	TS_14_7_1
					SWC_14_6_1
Hukseflux HFP01	4840	-0.05	-18.265	35.463	G_11_1_1
Hukseflux HFP01	4841	-0.05	31.98	-5.911	G_12_1_1
Hukseflux HFP01	4803	-0.05	-28.06	-22.784	G_13_1_1
Hukseflux HFP01	4804	-0.05	-67.186	13.803	G_14_1_1

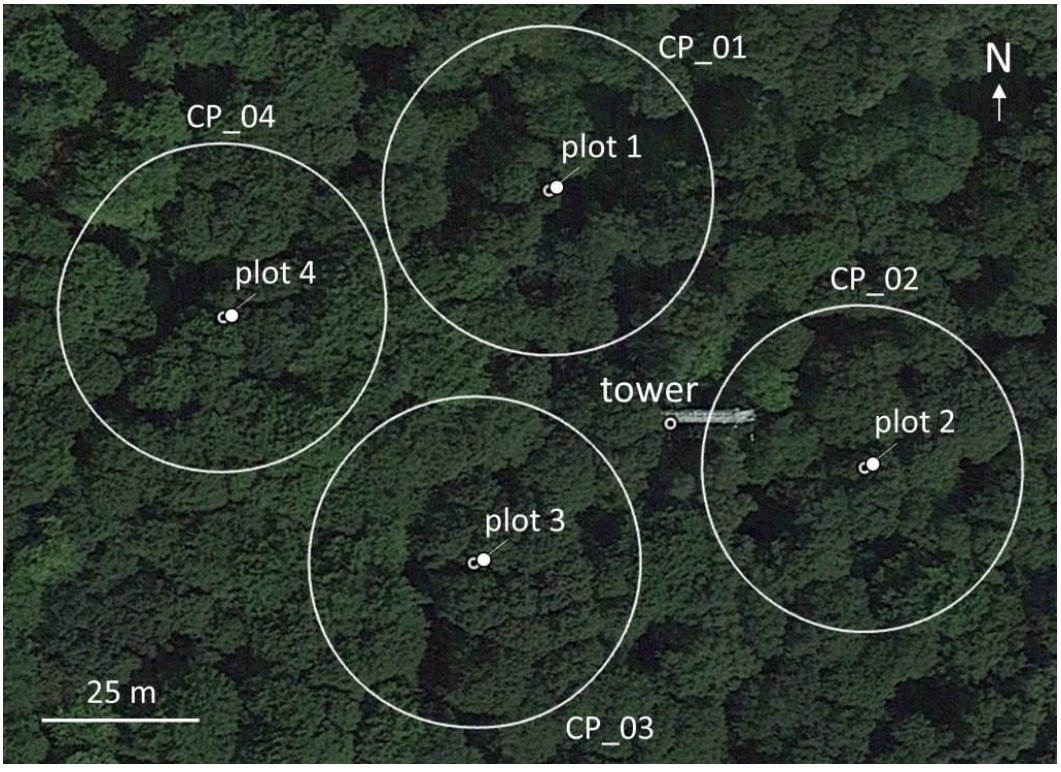


Figure 3: Location of the soil plots (plot 1 to 4) around the EC tower. CP = Continuous Measurements Plot.

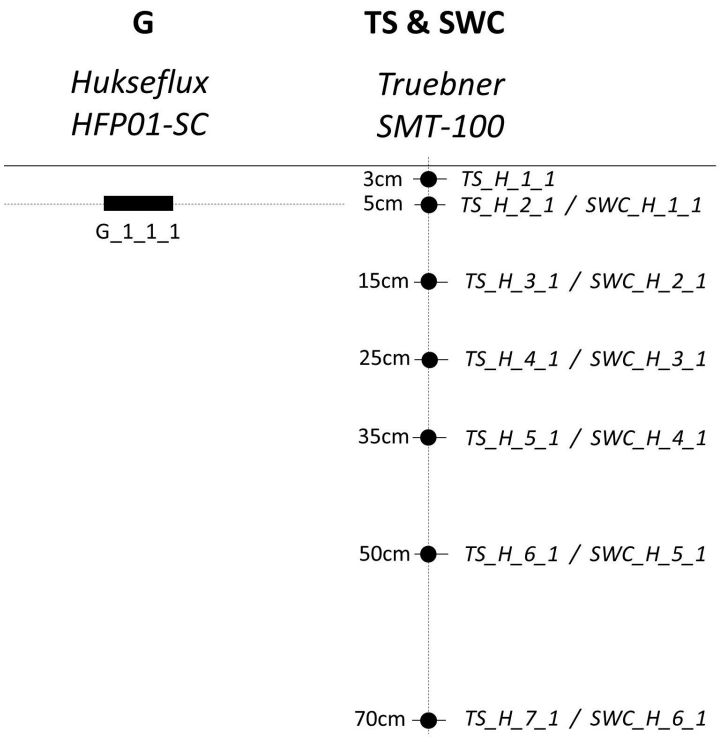


Figure 4: Set-up of the four soil plots. G = soil heat flux density, TS = soil temperature, and SWC = volumetric soil water content.

Spatial heterogeneity characterization

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. These data were submitted to ETC early May 2018. The ETC has quality-checked the data. Figures 4, 5 and 6 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 area that is distinguished in the target area (see Figure 8 and explanation further below). As can be seen in the figures, the target area is dominated by sessile oak (*Quercus petraea (Matt.) Liebl.*), common beech (*Fagus sylvatica L.*), and hornbeam (*Carpinus betulus L.*), with sparse occurrences of few other species such as European larch (*Larix decidua Mill.*) and Norway spruce (*Picea abies (L.) H.Karst.*).

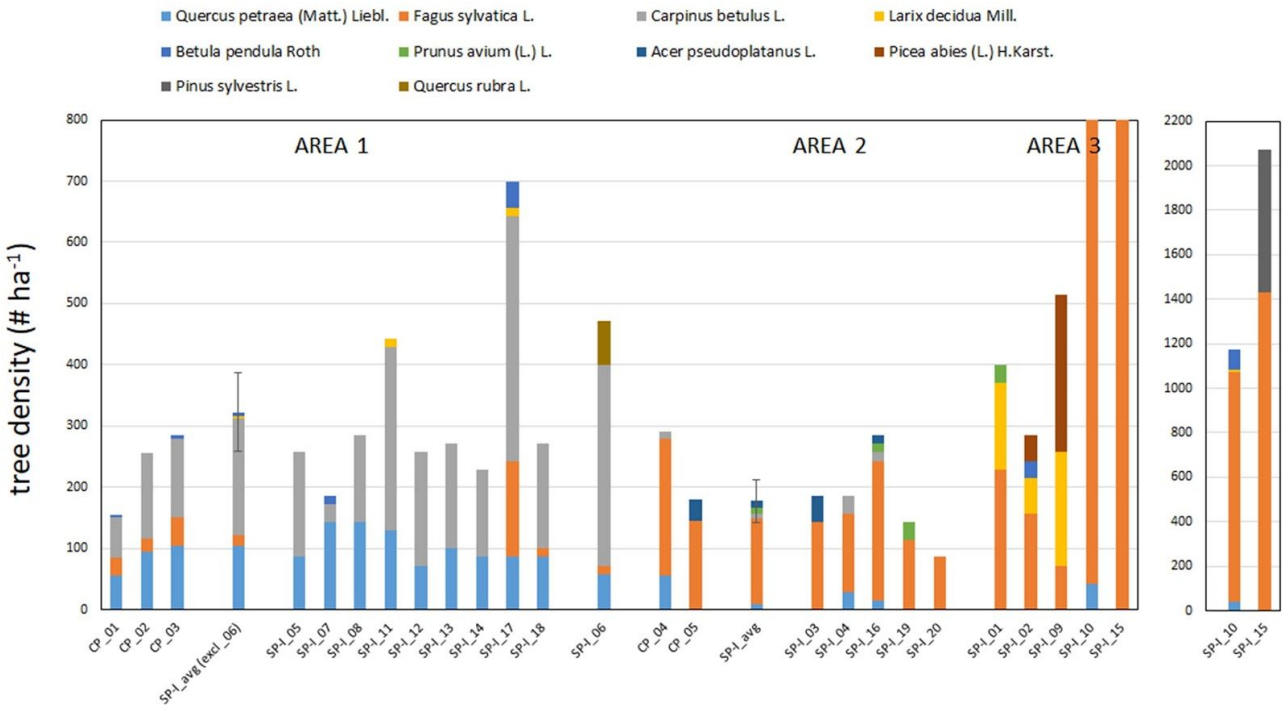


Figure 4: Tree density per species, shown for the 20 SP-I plots and the five CPs installed in the target area. The plots are grouped per area that is distinguished in the target area (see map Figure 8). Error bars on the two SP-I plot averages indicate +/-20% of the total plot value and are calculated for the representativeness checks of the CPs explained further in the report.

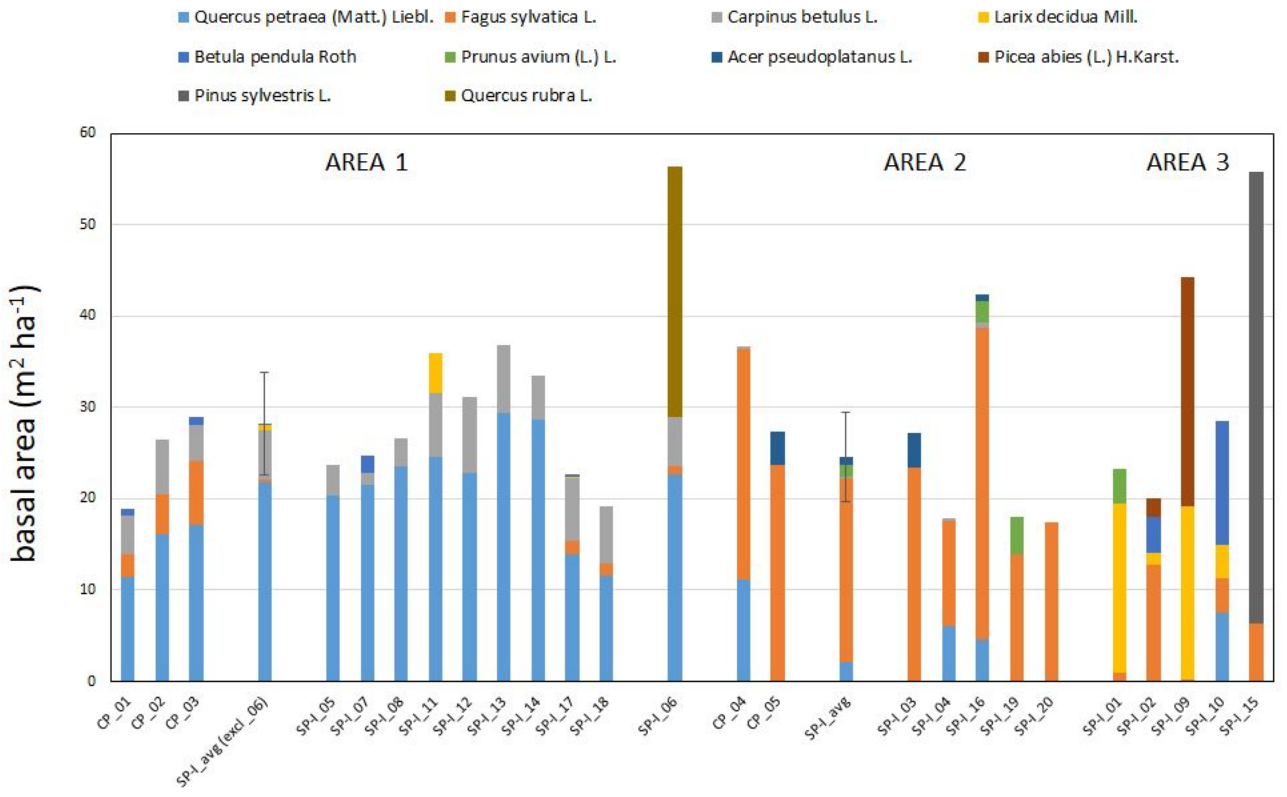


Figure 5: Basal area per species, shown for the 20 SP-I plots and the five CPs installed in the target area. The plots are grouped per area that is distinguished in the target area (see map Figure 8). Error bars on the two

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.

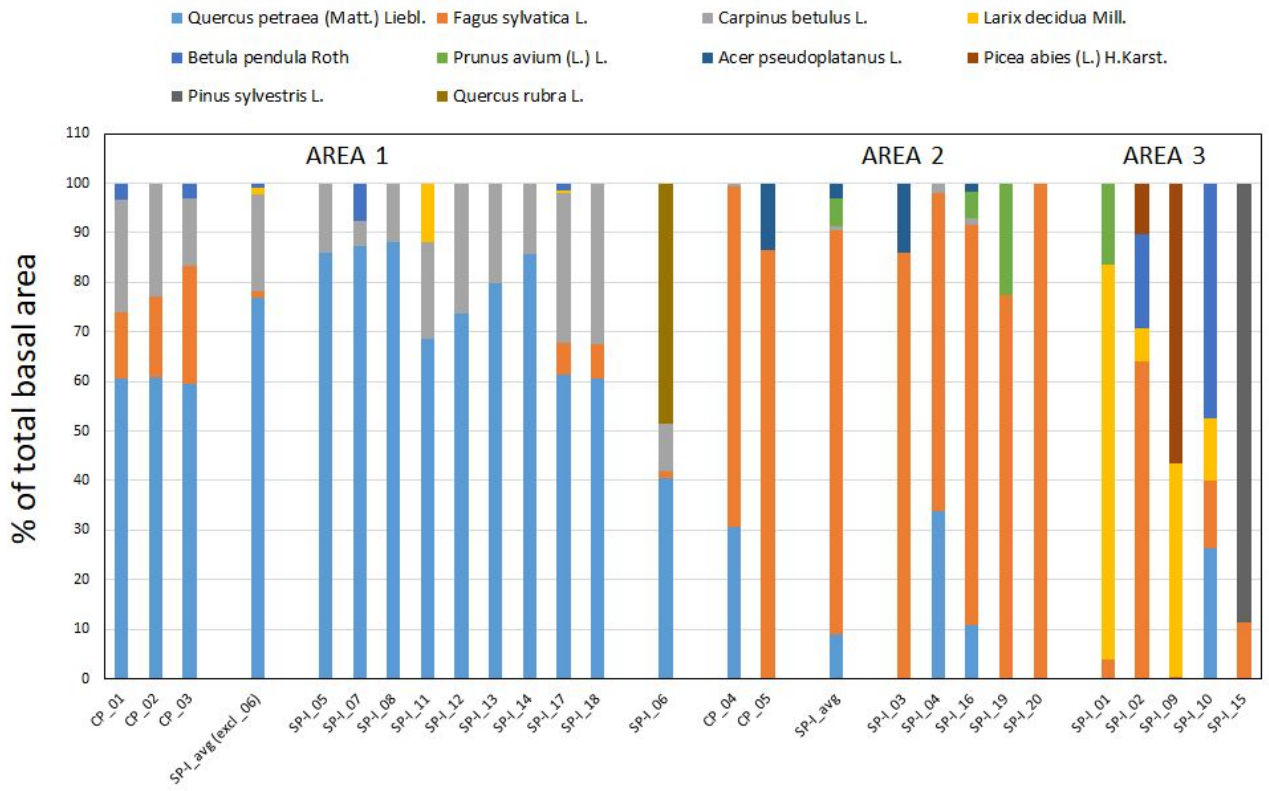


Figure 6: Percentage-wise contribution of each species to the total basal area of the plot, shown for the twenty SP-I plots and the five CPs installed in the target area. The plots are grouped per area that can be distinguished in the target area (see map Figure 8).

Green Area Index: The station team has collected the required GAI measurements in the 20 SP-I-order plots for the characterization of the target area and its spatial heterogeneity. These measurements have been collected on 15/16 August 2018 with the ceptometer. The station team had asked the ETC if it could use the ceptometer (due to time constraints), even though the ETC has decided that GAI must be measured with DHP. The ETC has accepted this request on the basis that the relative plot differences in GAI, which is what the ETC needs for the CP representativeness checks, should be equally well measured with the ceptometer as with DHP.

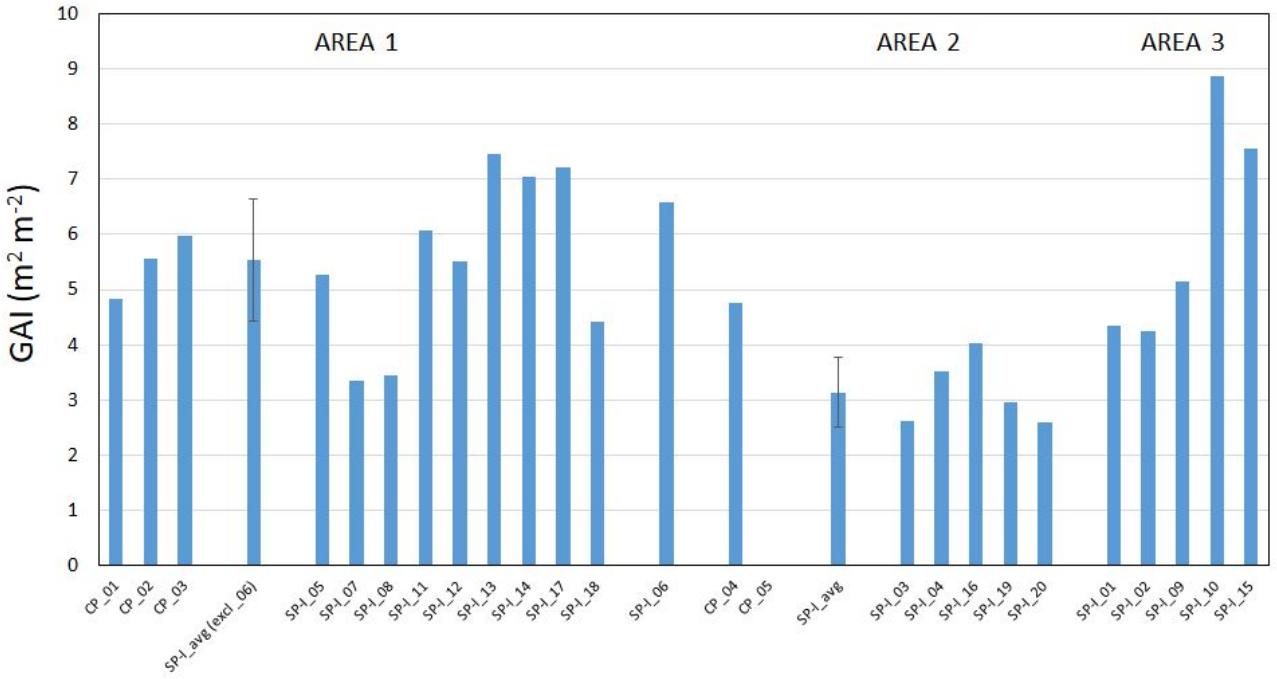


Figure 7: Green Area Index (GAI) measured in the 20 SP-I plots and the five CPs installed in the target area. Measurements were collected with the ceptometer on 18 July 2018 (CPs) and 15/16 August 2018 (SP-I plots). The plots are grouped per area that is distinguished in the target area (see map Figure 8). Error bars on the two 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. Data for plot CP_05, which was installed in the target area on request of the ETC only by the end of August, were not available.

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 three areas with distinct species composition and density: an oak/hornbeam dominated area (AREA 1), a beech-dominated area (AREA 2), and an area with patches of European larch (*Larix decidua Mill.*), Norway spruce (*Picea abies (L.) H.Karst*), and afforestation (AREA 3). In agreement with the ETC, the station team delineated these three areas as shown in Figure 8.

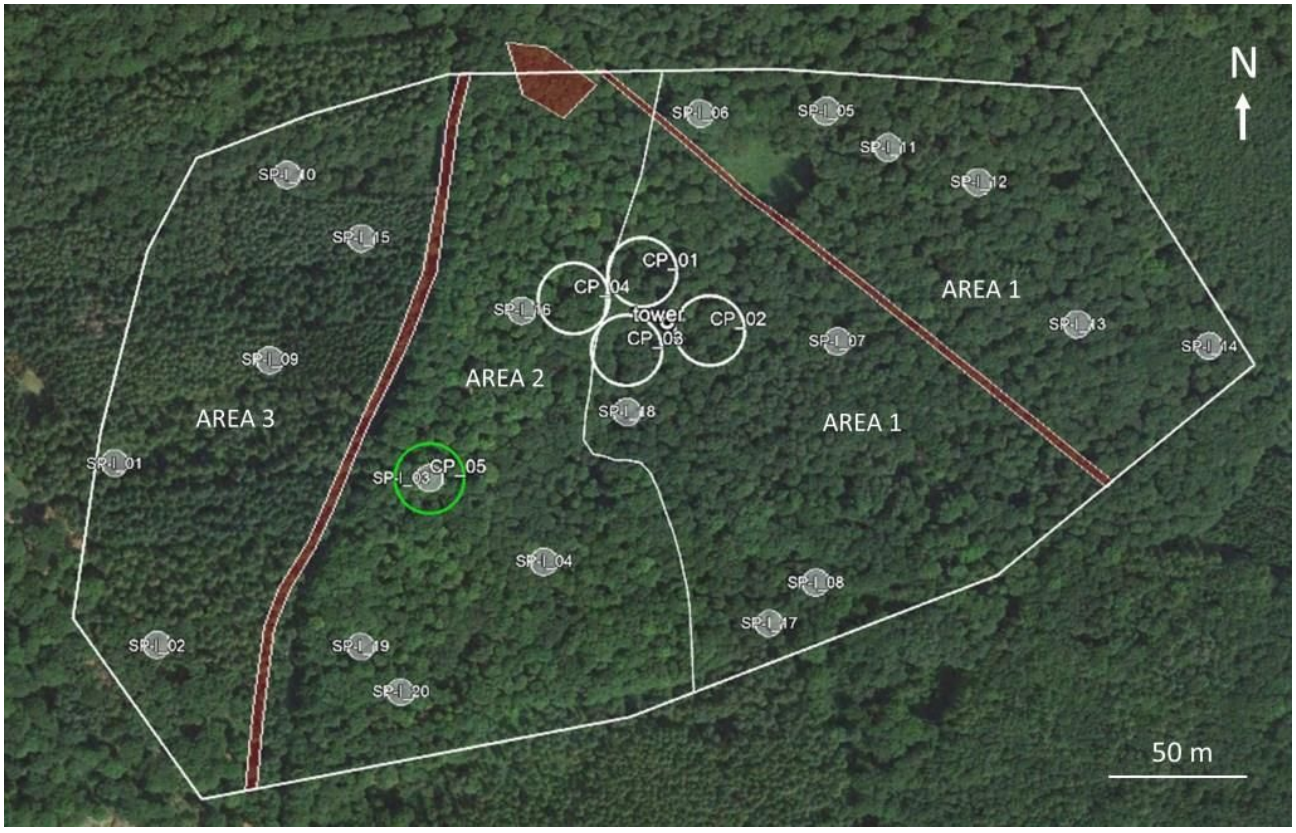


Figure 8: The target area with an indication of the three areas that are distinguished within: an oak/hornbeam-dominated area (AREA 1), a beech-dominated area (AREA 2), and an area with several patches of European larch, Norway spruce, and afforestation (AREA 3). Also shown are the locations of the twenty SP-I plots and the five CPs. The red areas are exclusion areas.

Green Area Index

The station team has collected the minimum required number of two sets of GAI measurements with Digital Hemispherical Photography (DHP) in the four initially installed CPs (CP_01 to CP_04), once on 18 July 2018 and once on 21 August 2018. GAI has not been measured in the fifth CP (CP_05), which the station team installed only end of August in AREA 2 upon request of the ETC after checking the representativity of the four initially installed CPs. All hemispherical pictures have been quality-checked and processed by ETC (Figure 9). Where needed, pictures have been retaken successfully by the station team. The station team has furthermore submitted the coordinates of all DHP measurement positions in the CPs.

It must be noted that the station team has, upon the request of ETC, put much effort in collecting GAI measurements with both the ceptometer and DHP during spring and summer 2018 and this with the aim to compare the methods and select one method (measurement results not shown). Based on the results and on an evaluation of the canopy structure, the ETC has decided to continue the GAI measurements with DHP.

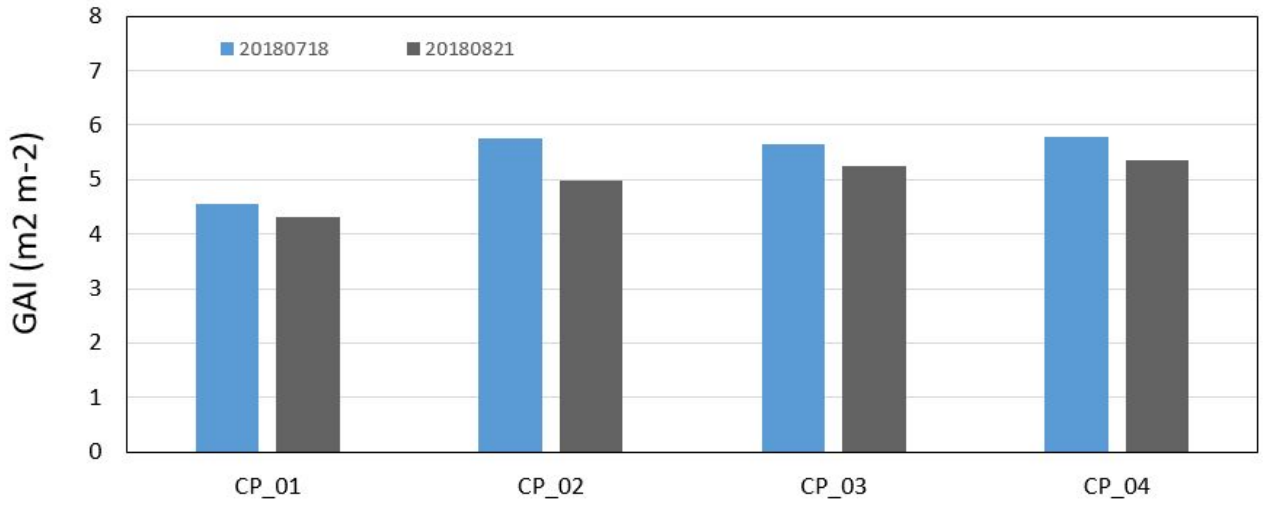


Figure 9: GAI measured with DHP in the four initially installed CPs on 18 July 2018 (blue) and 21 August 2018 (black).

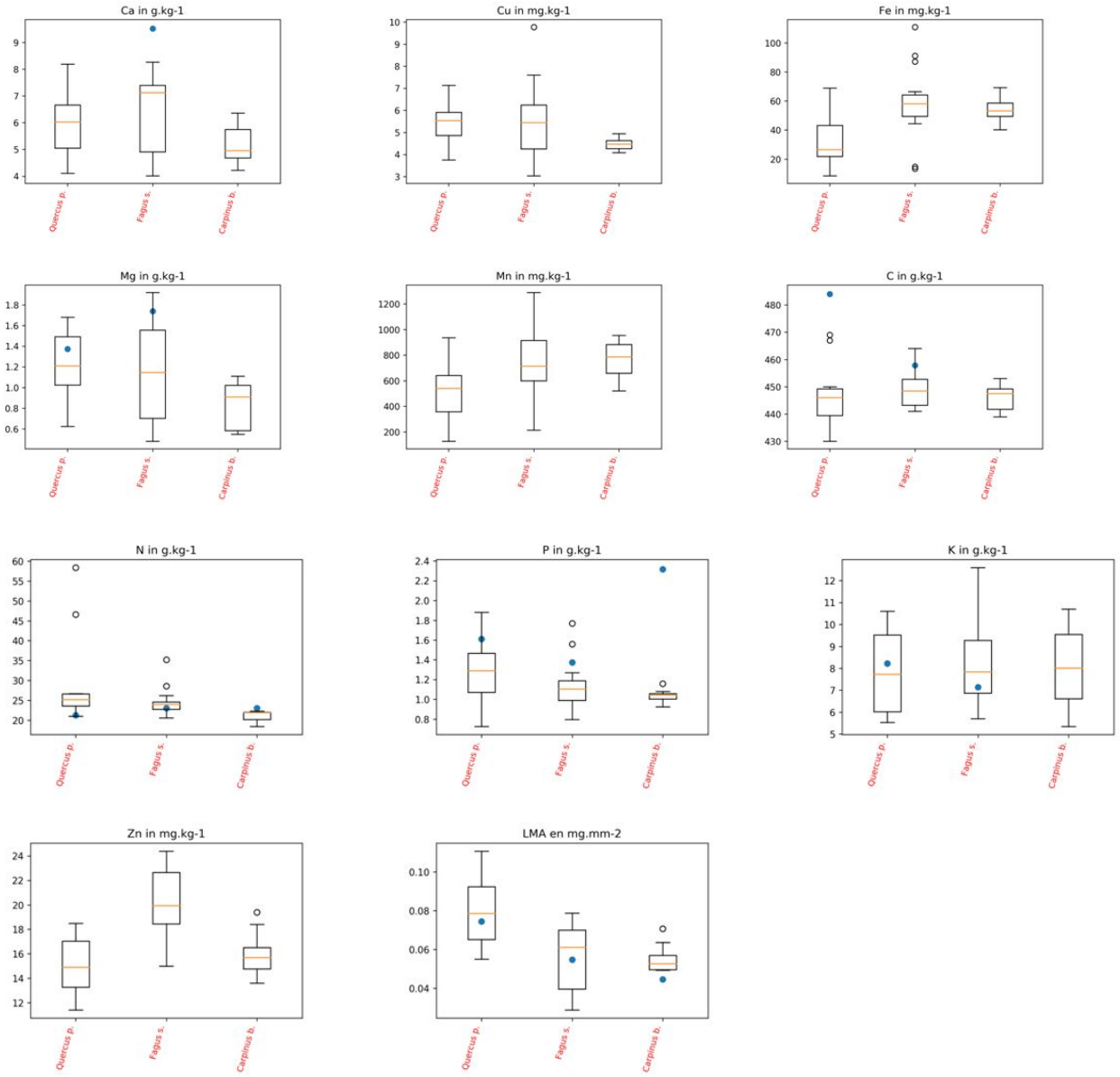
Aboveground biomass

The station team has collected in the first months of 2018 all 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 for all trees above the stem diameter threshold of 5 cm that are growing inside the four CPs that the station team had initially installed in the target area (CP_01 to CP_04; see map Figure 8). The same data have later also been collected in a fifth CP (CP_05), which the station team installed end of August in AREA 2 upon request of the ETC after checking the representativity of the first four CPs. The ETC has quality-checked and processed the tree data. Figures 4, 5 and 6 show for each of the five CPs the tree density per species, the basal area per species, and the percentage-wise species contribution to the total basal area of the plot, respectively. Basal area is used here as a proxy for Aboveground biomass. As can be seen in the figures, the CPs are dominated by sessile oak (*Quercus petraea (Matt.) Liebl.*), common beech (*Fagus sylvatica L.*), and hornbeam (*Carpinus betulus L.*).

Vegetation sampling and analysis

The site specific protocol was agreed by ETC and first set of leaf samples for NA has been sent and analysed in 2017 together with the data related to the LMA determinations. The report on data quality is below. There was no anomaly detected in the results both for the Leaf Mass to Area ratio and for the nutrient mass ratio. The 2018 samples have been collected and is being analysed. The 2018 LMA values have been collected and show a slight, non significant increase from 2017 to 2018 for all species (not shown).

Foliar Analyses for station DE-Hoh, 2017-09-13



Species: Quercus petraea, Fagus sylvatica L., Carpinus betulus L.

Mean value of the species 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 DE-HoH site, the testing period involves raw data sampled in 2018 from July 15 to September 19. Of 4608 expected half-hourly files for NEE fluxes, 71.3% were retained after QC routines as illustrated in Figure 10. In particular, about 9.7% of raw-data files were missed, 27.5% of calculated half-hourly fluxes were discarded because affected by SevEr, while an additional 1.2% of them were discarded because identified as outlier and affected by ModEr. Being the percentage of missing data equal to 28.7% and below the 40% threshold value, we conclude that DE-HoH site reaches the minimum requisite expected for the Step 2 of the labelling.

References

Foken T and Wichura B (1996) Tools for the quality assessment of surface-based flux measurements, Agric For Meterol, 78, 83-105

Mahrt L (1998) Flux sampling errors for aircraft and towers, J Atmosph Ocean Techn, 15, 416-429

Vickers D and Mahrt L (1997) Quality control and flux sampling problems for tower and aircraft data, J Atmosph Ocean Techn, 14(3), 512-526

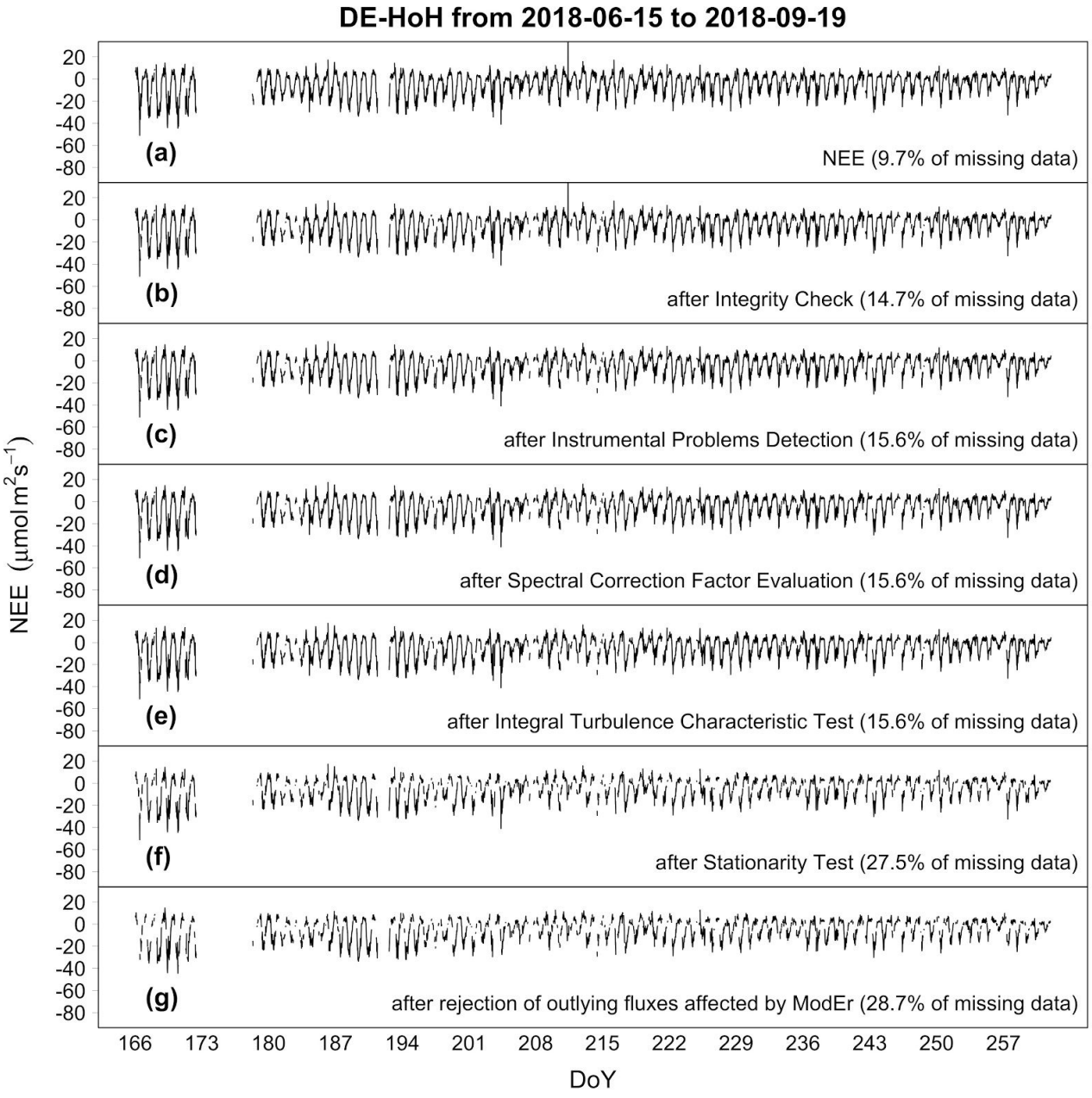


Figure 10: Summary of the quality control tests applied to the Net Ecosystem Exchange (NEE) of CO2 flux collected at DE-HoH site from 2018/06/15 to 2018/09/19. The original half-hourly flux time series is exhibited in the top panel. Panels b-f display the sequential removal of data affected by severe 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)

This test is based on the area that we aim to monitor with the ICOS station, namely the Target Area (TA, see the Sampling scheme implementation Sect.). By means of the footprint model by Klijun et al. (2015) it is estimated the source contribution area for each half hour and checked how

many records have a contribution coming mainly from the TA. The target value is to have at least a 70% of the data (only QC passed) with a cumulated contribution of at least 70% from the TA.

At DE-HoH the test was originally made using 3 months of EC data collected at an height of 49 m. This height, in relation to a canopy height of 33 m, frequently caused the footprint to elongate far outside the TA boundaries, causing the test to fail.

After a discussion with the PI, it was agreed to lower the EC measurement height to 45 m. After this system modification, a month of data have been collected and the test was repeated.

The test was passed as that the 84% of data have a cumulative contribution of at least 70% from the TA, and this hold also when considering day and night time separately (Figure 11).

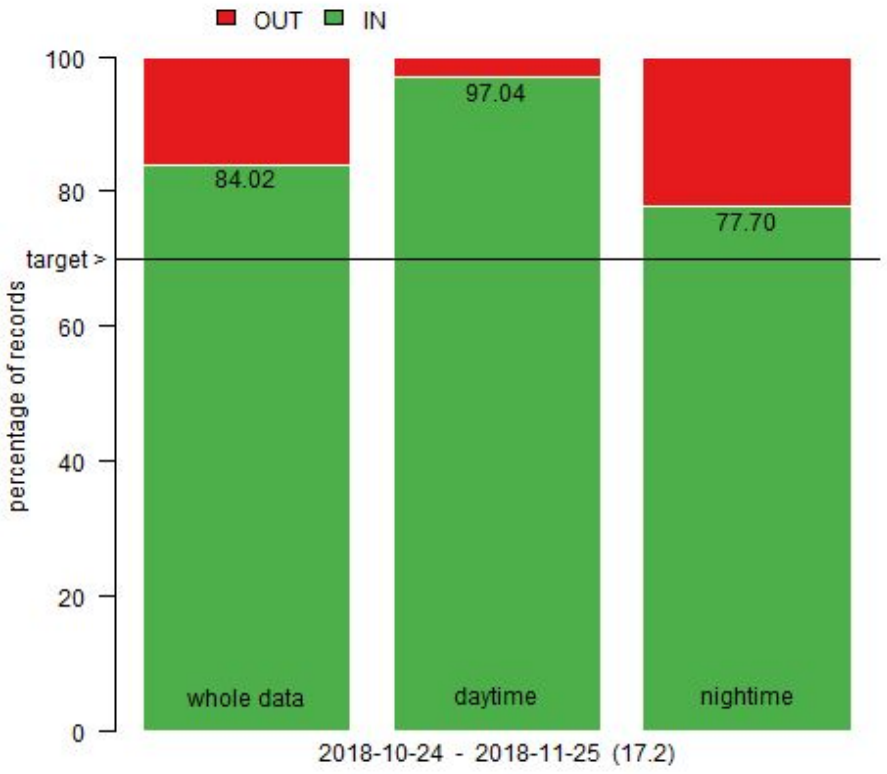


Figure 11: Barplot showing the actual percentage of data (records) with at least 70% contribution from the target area. Results are shown for the whole QC controlled dataset, and for day and night time separately.

The footprint climatology over the whole analyzed period is reported in Figure 12 in relation to the actual TA extension. The 70% contribution isopleth (medium blue) is completely inside the TA.

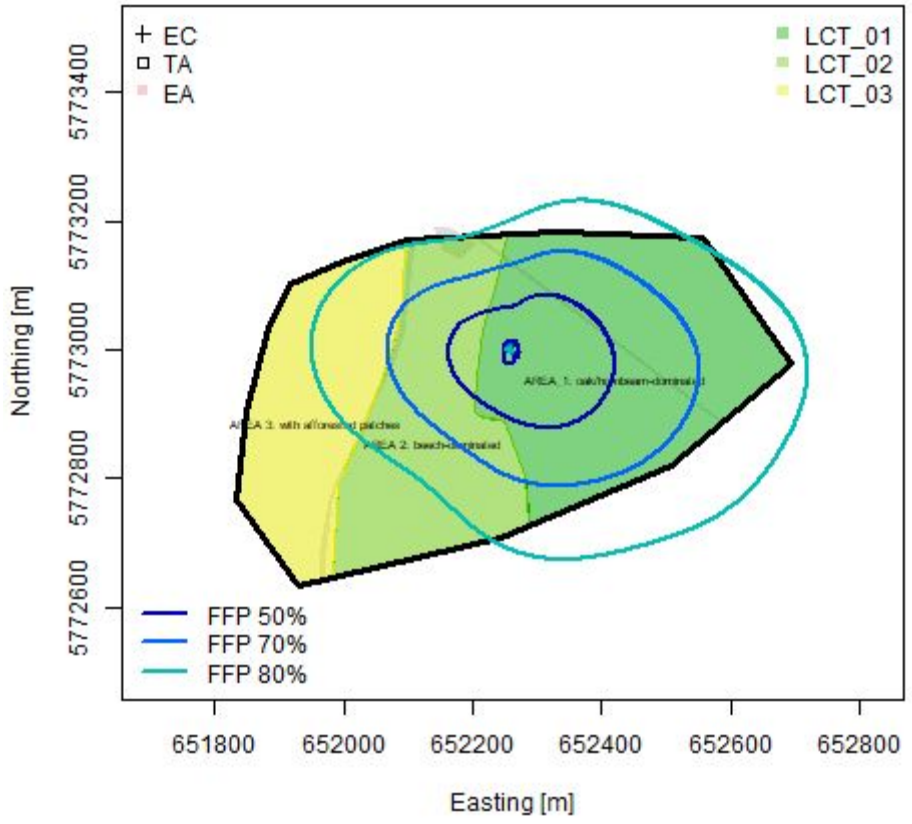


Figure 12: Footprint climatology at DE-HoH with isopleths showing the 50%, 70% and 80% cumulative contribution. The TA (black line) the exclusion areas (light red) and the land cover typologies (polygons in green scale, see next Sect.) are reported as comparison.

Data representativeness analysis (Test 3)

This test is based on possible areas, within the TA, characterized by different species composition or different management (and consequently biomass and density). These areas have been defined as reported in the Spatial heterogeneity characterization Section.

By means of the footprint model by Klijun et al. (2015) it is estimated the source contribution area for each half hour and checked how many records actually come from the different ecosystem patches (here named Land Cover Typologies, LCT) and check their representativeness in terms of day-night conditions and in the period analyzed. The analysis is focused on the LCT from which a cumulative contribution of at least 70% originates from. It is calculated the number of half-hourly measurements 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 (only QC passed).

3 LCT were identified. The test revealed that only one (LCT_01, oak/hornbeam dominated) sensibly contributes to fluxes, while for the other two (beech-dominated and afforested patches) the threshold of 70% contribution in the 20% of data is not reached. In Figure 13 the intersections between the footprint and the LCT are shown for two exemplary half-hour.

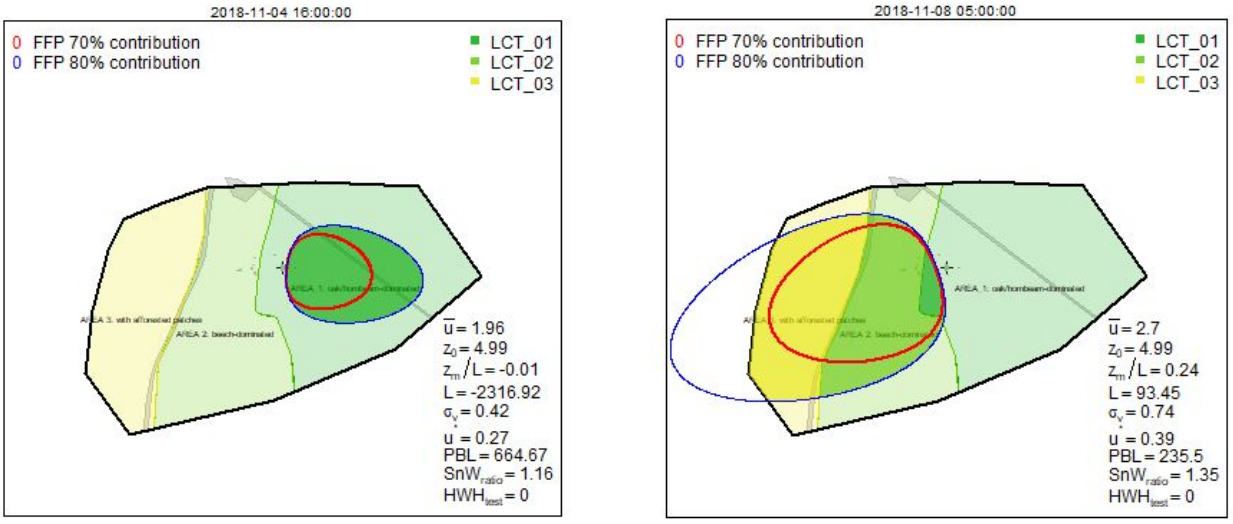


Figure 13: Exemplary footprint predictions and their intersections with the land cover typologies identified at DE-HoH.

The representativeness analysis achieved on the most represented LCT revealed that the 20% threshold is reached in each subperiod, both during daytime and night time, so the test is as passed.

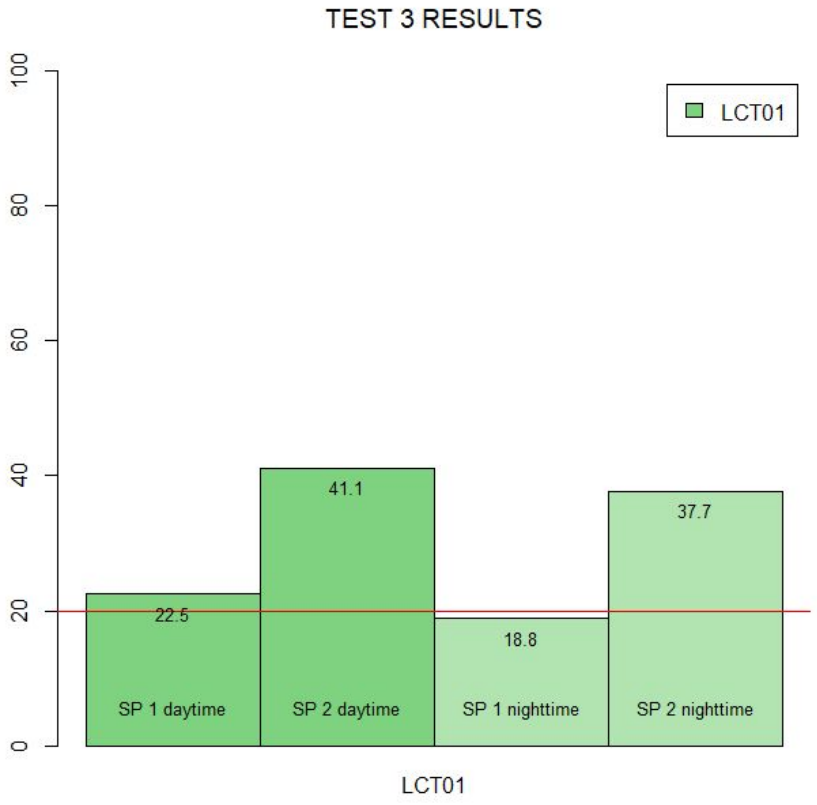


Figure 14: Test 3 results achieved on the LCT_01 (oak/hornbeam dominated patch). The results are shown for each subperiod (SP1 and SP2) and for day and night time hours. Note that during nighttime on the first subperiod the percentage is almost 19 % but it was considered to be enough.

Ancillary plot representativeness (Test 4)

The representativeness of the CPs has been evaluated by comparing each CP with the SP-I plots from the same area and this in terms of (i) basal area of the plot, (ii) species composition, i.e. the percentage basal area of the two 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 area's average, i.e. the average of the SP-I plots. Table 4 summarizes the test results.

Table 4: Results of the CP representativeness tests. Green and red numbers indicate passed and failed tests, respectively. BA = basal area, GAI = Green Area Index.

AREA 1						**AREA 2**			
		CP_01	**CP_02**	**CP_03**	**SP-I avg (-20% ; +20%)**		**CP_04**	**CP_05**	**SP-I avg (-20% ; +20%)**
(i) BA (m^2 ha^{-1}):		18.84	26.54	28.94	28.26 (22.6 ; 33.91)		36.61	27.4	24.58 (19.66 ; 29.5)
(ii) species BA (%):	*sum*	83.2	83.7	73.1	96.1 (76.9 ; 100)	*sum*	99.4	86.6	90.6 (72.5 ; 100)
	Q. petraea	*60.5*	*60.9*	*59.5*	*76.7*	*F. sylvatica*	*68.9*	*86.6*	*81.7*
	C. betulus	*22.7*	*22.8*	*13.6*	*19.4*	*Q. petraea*	*30.5*	*0*	*8.9*
(iii) GAI (m^2 m^{-2}):		4.82	5.57	5.97	5.53 (4.43 - 6.64)		4.76	/	3.14 (2.51 ; 3.77)

1) Plot CP_01 didn't pass the representativeness test because it contains too little basal area compared to the SP-I average in AREA 1. The ETC nevertheless accepts this CP on the ground that for areas where the variability in basal area between SP-I plots is as large as in AREA 1 (see Figure 15 below), the most important is not that the basal area of each CP lies close to the SP-I plot average but rather that the range of basal area is more-or-less covered by the CPs. Figure 15 shows that this is the case for AREA_1, with CP_01 representing the lower range and CP_02 and CP_03 representing the middle-to-higher range. This figure also shows that the CPs do not cover the highest end of the range. However, the four SP-I plots with the highest basal area (SP-I_11, _12, _13, and _14) are all are located further away from the EC tower in the eastern part of AREA 1 (see Fig_SHC5). This part is out of the main wind direction and likely less often sensed with the EC system than the part closer the the tower in the main wind direction where basal area is less high and which can be assumed to be sufficiently well represented by the three CPs.

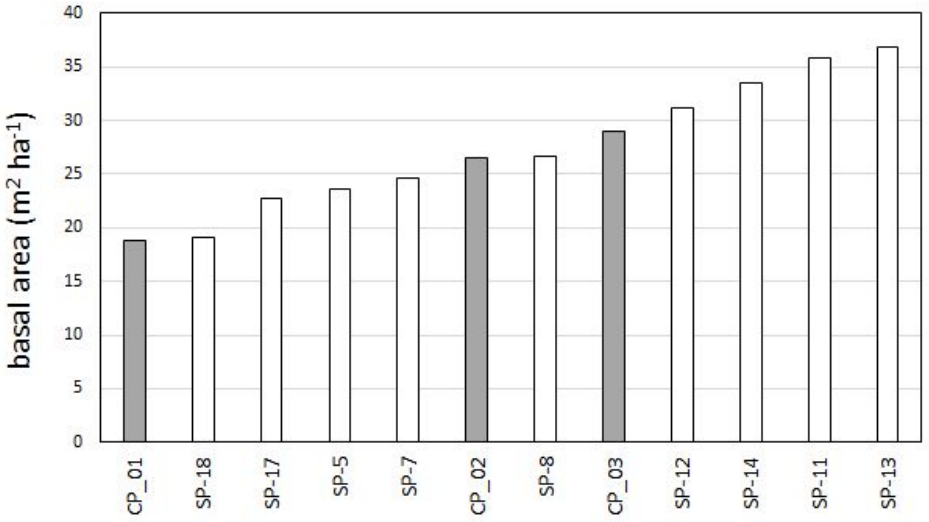


Figure 15: CPs and SP-I plots in AREA 1, ranked in ascending order of basal area.

2) Plot CP_03 didn't pass the representativeness test because the contribution of the two dominant species to the plot basal area (73.1%) is slightly less than 80% of the SP-I plot average in AREA 1 (76.9%). The ETC nevertheless accepts this CP.
3) CP_04 didn't pass the representativeness test because both basal area and Green Area Index are much higher than the SP-I plot average in AREA 2 and well above the average+20% threshold for accepting the CP. The station team confirmed that CP_04 is denser than AREA 2 and explained that this is due to a thinning that took place in winter 2016/2017 from which CP_04 was excluded. The station team has suggested as a solution on the long-term to remove trees from inside the fenced area at the next scheduled thinning to bring the tree density / basal area in agreement with AREA_2. The ETC agreed with this and, as a solution on the short term, it instructed the station team to install an extra, representative CP in AREA_2 by converting plot SP-I_03 into a CP. Until the next thinning, the same repeated ancillary measurements must be carried out in this CP as in the other four CPs. After the thinning, that CP may cease to exist. The station team installed this CP (CP_05) end of August and collected the necessary tree measurements in this CP soon after. The CP passed the representativity test (LAI not tested).

Note: AREA 3 doesn't include any CPs. It has been agreed with the station team that - if footprint analyses show that AREA 3 contributes significantly to the fluxes -, it must be considered to perform repeated ancillary vegetation measurements in one or more of the SP-I plots installed in AREA 3.

Near Real Time data transmission

One EC example file sent and correct, after firmware update of the logger. Then the NRT transmission to the CP started on May 30th, after fixing some issues in BADM and metadata harvesting. The first BM file sent had some inconsistencies in the labels and data type. A second file was sent based on the CS code, but some inconsistencies still remained. The PI suggested to

send the data to the CP anyway, as this should solve all of the issues. The ETC agreed, and even if some inconsistencies remained in the file sent, all of them were solved, and the station got the green light for the submission of BM file L01_F01 on October 1st.

An issue with a soil multisensor led to the need of renaming a variable (SWC) in some BM files into non-ICOS names. The solution is accepted by the ETC, even if the ideal solution would be to keep the ICOS name and avoiding mapping it into the BADM to not process it, or mapping it and then exclude from the variables to be averaged together. For these soil files the green light was given on 20181115. Due to a misunderstanding with the ETC, few EC files were sent to the CP with a wrong file ID in the file name: the issue will be fixed from the ETC side.

Plan for remaining variables

Soil sampling updated 2018/11/23.

The site specific protocol was agreed by ETC and the first set of soil samples for organic carbon and nitrogen stock determinations has been collected in Aug-Sept 2017. The soil samples are being processed by the station team.

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 Hohes Holz (DE-HoH) is labelled as ICOS Class 1 Ecosystem station.

Dario Papale, ETC Director

January 17th 2019