ICOS Ecosystem Station Labelling Report

Station: SE-Sto (Abisko-Stordalen Palsa Bog)

Italy, Belgium, France, April 18th 2022

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 April 15th 2016 and got the official approval on August 28th 2016. The Step2 started officially on December 07th, 2016 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 with 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 Abisko-Stordalen Palsa Bog station (with ICOS code SE-Sto) is located 10 Km east of the town of Abisko in the 1100 Ha nature reserve of Stordalen. The coordinates in WGS84 system are: Latitude 68.35594288 °N Longitude 19.04520892 °E. The elevation above sea level is 351.893 m and the offset respect to the Coordinated Universal Time (UTC) is equal to +01. The area is located at the 0 °C isotherm which causes the permafrost in the mire to be of sporadic and of very dynamic nature. As a result of recent years' warming in the area, permafrost has been observed to degrade in many parts of the mires. The site is marked by the following climate characteristics: Mean Annual Temperature -0.1 °C, Mean Annual Precipitation 332 mm. The site is a mixed palsa-mire underlayed by sporadic permafrost under rapid degradation. Vegetation in the mire consists of sedges and sphagnum mosses in the wet parts and lichens and dwarf birch in more elevated parts of the mire.

Figure 1 - The SE-Sto site

Team description

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

MEMBER_NAME	MEMBER_INSTITUTION	MEMBER_ROLE	MEMBER_MAIN_EXPERT
Erik Lundin	Swedish Polar Research Secretariat	PI	
Alexander Meire	Swedish Polar Research Secretariat	MANAGER	
Patrick Crill	Stockholm University	SCI	SOIL
Janne Rinne	Lund University	SCI	
Niklas Rakos	Swedish Polar Research Secretariat	SCI	
Håkan Grudd	Swedish Polar Research Secretariat	SCI-ANC	DATAPROC
Meelis Mölder	Lund University	SCI-FLX	MICROMET
Jutta Holst	Lund University	DATA	DATAPROC
Annika Kristoffersson	Swedish Polar Research Secretariat	TEC	LOGISTIC

Table 2 - Description of team members roles at SE-Sto

Spatial sampling design

For the spatial sampling design at SE-Sto, the Station Team proposed in addition to the Target Area (TA), 5 areas to be excluded from sampling (EA). Originally, 2 continuous measurement points (CP) were submitted, while according to the instruction a minimum of 5 CP were requested. As this did not prevent the random extraction of points, ETC decided to do the sampling anyway and send the results to the ST. After a discussion with ETC it has been agreed that, given that 3 plant community types can be distinguished within the TA, SE-Sto ST needs to install a total of 10 CPs in the TA and one soil meteorological station per plant community type.

The EA were excluded from the surface available for sampling, while the areas of the originally proposed 2 CP were not. Figure 2 shows the extent and position of such spatial features in relation to the actual site area.

In addition, the PI proposed a set of 12 pre-existing points to evaluate the possibility to use some of them as SP-I. ETC originally accepted the proposal and, after the 20 SP-I locations were randomly extracted according to the standard procedure, the proposed points that were at a distance of less than 20 m from a sampled position were identified and considered as an effective SP-I. In total 3 out of 12 proposed points were used as SP-I. However, after a discussion with ETC it has been agreed that, given that SE-Sto is an accessible mire, they will carry out the site characterization measurements at the SP-II-order points, while the SP-I will not be used for any measurements.

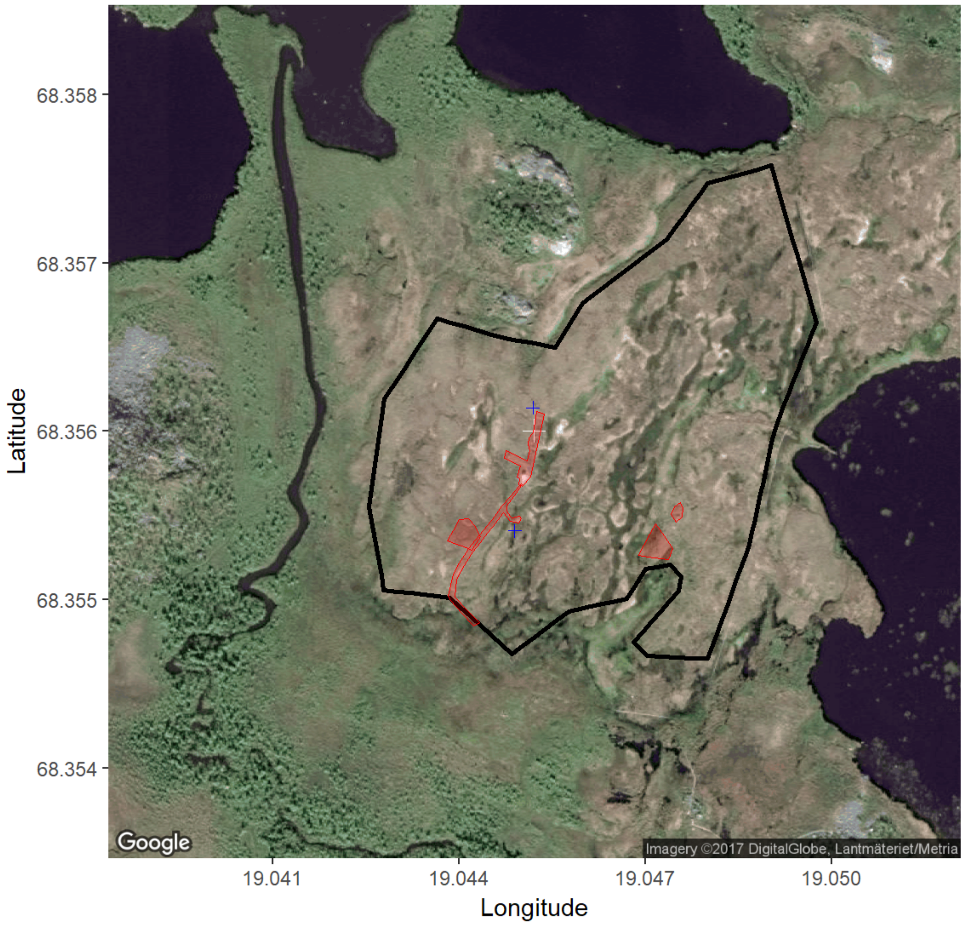


Figure 2: Aerial map of SE-Sto and proposed spatial features according to the reported target area (TA), exclusion areas (EA) and ICOS requirements. Note that the 2 originally proposed CP areas (now no more effective) have not been excluded from the sampled area. The TA surface is 5.84 Ha, the total excluded area is 0.14 Ha.

The field location of SP-II points (recorded field coordinates), have been reported to ETC, which ascertained that they almost perfectly matched with the randomly sampled positions, becoming thus definitive positions. The coordinates of 12 candidates CP points have been reported to ETC (Figure 2). It was agreed with ETC that the Station Team will use all 12 CPs for repeated ancillary measurements. The original CP_06 was replaced with a new CP_06 according to the representativity test results. The original CP_10 has been slightly moved toward West, close to a boardwalk, but it is still slightly outside from the TA (Figure 3). However, given the importance of this point as it represents a commonly occuring habitat type that is not represented in any of the other CP plots, ETC decided to accept the current location (see also Sect. “Ancillary plot representativeness”). The sampling design is achieved and current points locations are thus definitive.

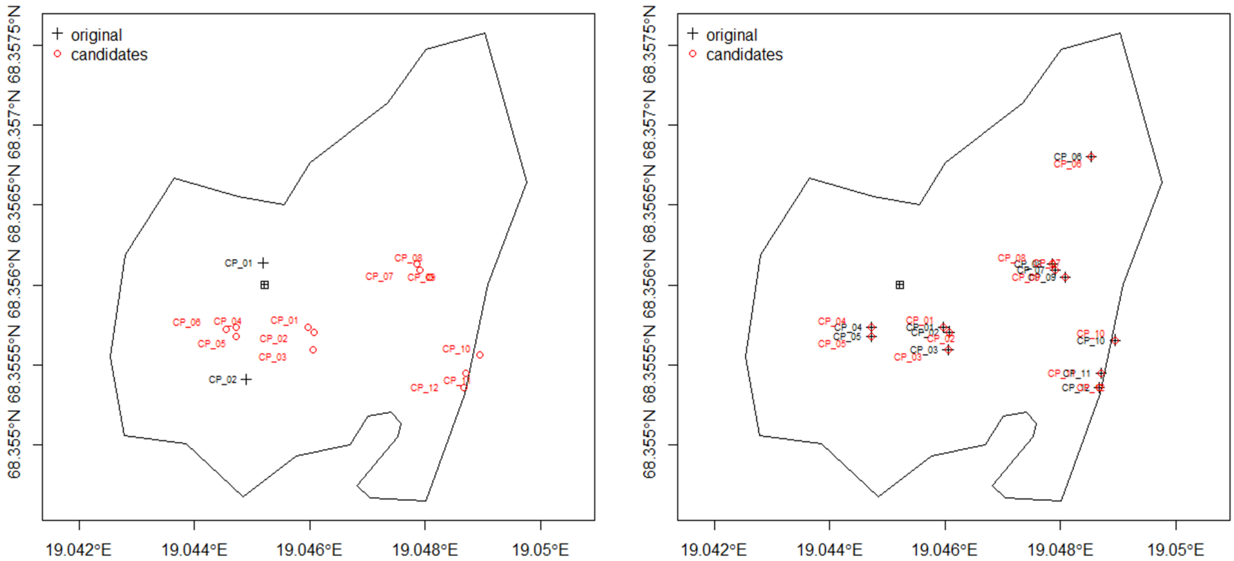


FIgure 3: *Left*: 12 candidates CP points (in red) as originally proposed by SE-Sto Station Team (the 2 CP in black represent the first proposal and are no more effective). *Right*: definitive CP locations as result of the field mapping check.

Station implementation

Eddy covariance:

EC System		
MODEL	GA_CP-LI-COR LI-7200	SA-Gill HS-50
SN	72H-0337	H162407
HEIGHT (m)	2.2	2.2
EASTWARD_DIST (m)	0.087	0.087
NORTHWARD_DIST (m)	1.1473	1.473
SAMPLING_INT	0.05	
LOGGER	1	1
FILE	2	2
GA_FLOW_RATE	12	-
GA_LICOR_FM_SN	FM1-0322	-
GA_LICOR_AIU_SN	AIU-0687	-
SA_OFFSET_N	-	2
SA_WIND_FORMAT	-	U, V, W
SA_GILL_ALIGN	-	Axis
ECSYS_SEP_VERT	0.01	
ECSYS_SEP_EASTWARD	-0.01	

ECSYS_SEP_NORTHWARD	-0.2
ECSYS_WIND_EXCL	
ECSYS_WIND_EXCL_RANGE	

The EC system in place at SE-Sto consists of a Gill HS sonic anemometer, and of a LICOR LI7200 IRGA: the calibrations of both will expire in 2023. The location, height and orientation of the sonic is in line with what was agreed during the step1 by the PI and the ETC. The firmware of the IRGA is up-to-date.

Storage. Given the EC height of 2.2 m, measuring the storage flux is not mandatory. However, the station team intends to update their storage system according to ICOS standard in the future. In this case, this will be discussed and agreed with the ETC.

Radiations:

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
RAD_4C-K&Z CNR4	120872	2.71	16.05	35.18	SW_IN_1_1_1
					LW_IN_1_1_1
					LW_OUT_1_1_1
					SW_OUT_1_1_1
RAD_PAR-LI-COR LI190R	Q111713	2.77	16.42	36.18	PPFD_IN_1_1_1
RAD_PAR-LI-COR LI190R	Q112586	2.67	16.42	36.18	PPFD_OUT_1_1_1
RAD_PAR-DeltaT BF5	44401	2.96	17.84	40.11	PPFD_DIF_1_1_1

For SW-LW radiation the CNR-4 (Kipp & Zonen) pyranometer will be used in combination with the CNF4 ventilation and heating unit, while a CMP21 (Kipp & Zonen) pyranometer will be used as back-up sensor. The tower structure has been modified (on 2018-08-31) and the CNR-4 boom is now pointing south, to avoid the shading of the sensor. For the PPFD radiation the LI190R (Li-Cor) quantum sensor will be used. Concerning the diffuse radiation the Team proposed to use the CMP21, which can be accepted for diffuse radiation if used in conjunction with a compliant tracker shading system (the optional CM121C shadow ring is not). BF5 sensor specifications do not meet ICOS requirements. It will work in parallel with the CMP21 which measures the absolute value and the BF5 will be used for the ratio diffuse/total.

Precipitation:

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
PREC-Geonor T200x	30012	1.85	100.31	-234.96	P_1_1_1
SNOW-Campbell SR50x	4767	1.51	19.46	41.91	D_SNOW_1_1_1

For total precipitation SE-Sto will use 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
RHTEMP-Rotronic HC2(A)-S	61199122	2.5	-0.8	-2.98	TA_1_1_1
					RH_1_1_1
PRES-Vaisala PTB210	H2220005	1.6	-6.53	-20.31	PA_1_1_1
TEMP-Campbell SR50 AT	4767	2.10	17.55	39.67	TA_2_1_1

The sensors installed for TA and RH measurements, as well as that for PA measurements, are ICOS compliant: Rotronic HC2(A)-S and Vaisala PTB210 respectively. The thermohygrometer is equipped with a ventilated shield as described in the ICOS Instructions, and the PA sensor is equipped with a pressure head as it will sample air with a tube.

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. For the thermohygrometer, the calibration expired in 2018: the station team plans to ship it for factory calibration soon, and will replace it with a brand new spare one.

The height and horizontal distance of these sensors from the EC system are compliant with the ICOS Instructions. No sensors for wind speed and direction measurements are present at the moment, or they were not reported yet. This is OK as for Class2 stations the anemometer is not mandatory, only suggested. An additional, non-ICOS compliant temperature is sent by the station that is associated with the snow depth sensor CS SR50. This additional variable will be regularly processed by the ETC.

Backup meteorological station

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
RHTEMP-Rotronic HC2(A)-S	20525449	3	-6.53	-20.31	TA_3_1_1
					RH_2_1_1
PREC-Lambrecht rainEH3	880215.0009	2	100.31	-230.96	P_2_1_1
RAD_SW-K&Z CMP21	120944	2.87	17.57	39.56	SW_IN_2_1_1

For the backup station the PI proposed a commercial precomposed station which is not ICOS compliant. ICOS-compliant sensors were for that reason purchased and installed by the station team: thermo-hygrometer Rotronic HC2-S3, pyranomenter Kipp&Zonen CMP21 and pluviometer Lambrecht rainEH3. The backup sensors are logged independently from the main sensors. However, the power source is shared. A different solution than the one recommended in ICOS was proposed by the station team, that is to use backup batteries for meteo sensors instead of a different power line. ETC accepted this exception together with the plan to install in the near future backup batteries also for the backup sensors, and a solar-panels system also for the backup sensors. The need for calibration of the backup sensors will be established by comparison with the main sensors

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

MODEL	SN	HEIGHT (m)	EASTWARD_DIST (m)	NORTHWARD_DIST (m)	VARIABLE_H_V_R
TEMP-MicroStep PT100	4440	0	-3.51	21.39	TS_1_1_1
SWCTEMP-Campbell SoilVUE10	2283_1	-0.05	-3.51	21.39	TS_1_2_1
					SWC_1_1_1
TEMP-MicroStep PT100	4434	-0.05	-3.51	21.39	TS_1_2_2
SWCTEMP-Campbell SoilVUE10	2283_2	-0.1	-3.51	21.39	TS_1_3_1
					SWC_1_2_1
SWCTEMP-Campbell SoilVUE10	2283_3	-0.2	-3.51	21.39	TS_1_4_1
					SWC_1_3_1
SWCTEMP-Campbell SoilVUE10	2283_4	-0.3	-3.51	21.39	TS_1_5_1
					SWC_1_4_1
SWCTEMP-Campbell SoilVUE10	2283_5	-0.4	-3.51	21.39	TS_1_6_1
					SWC_1_5_1

SWCTEMP-Campbell SoilVUE10	2283_6	-0.5	-3.51	21.39	TS_1_7_1 SWC_1_6_1
TEMP-MicroStep TPP	051_1	0	32.87	-31.96	TS_2_1_1
TEMP-MicroStep TPP	051_2	-0.05	32.87	-31.96	TS_2_2_1
TEMP-MicroStep TPP	051_3	-0.1	32.87	-31.96	TS_2_3_1
TEMP-MicroStep TPP	051_4	-0.2	32.87	-31.96	TS_2_4_1
TEMP-MicroStep TPP	051_5	-0.5	32.87	-31.96	TS_2_5_1
TEMP-MicroStep TPP	051_6	-1	32.87	-31.96	TS_2_6_1
TEMP-MicroStep TPP	052_1	0	-13.67	-60.09	TS_3_1_1
TEMP-MicroStep TPP	052_2	-0.05	-13.67	-60.09	TS_3_2_1
TEMP-MicroStep TPP	052_3	-0.1	-13.67	-60.09	TS_3_3_1
TEMP-MicroStep TPP	052_4	-0.2	-13.67	-60.09	TS_3_4_1
TEMP-MicroStep TPP	052_5	-0.5	-13.67	-60.09	TS_3_5_1
TEMP-MicroStep TPP	052_6	-1	-13.67	-60.09	TS_3_6_1
TEMP-MicroStep PT100	4437	0	-45.78	-15.42	TS_4_1_1
SWCTEMP-Campbell SoilVUE10	2280_1	-0.05	-45.78	-15.42	TS_4_2_1 SWC_4_1_1
TEMP-MicroStep PT100	4438	-0.05	-45.78	-15.42	TS_4_2_2
SWCTEMP-Campbell SoilVUE10	2280_2	-0.1	-45.78	-15.42	TS_4_3_1 SWC_4_2_1
SWCTEMP-Campbell SoilVUE10	2280_3	-0.2	-45.78	-15.42	TS_4_4_1 SWC_4_3_1
SWCTEMP-Campbell SoilVUE10	2280_4	-0.3	-45.78	-15.42	TS_4_5_1 SWC_4_4_1
SWCTEMP-Campbell SoilVUE10	2280_5	-0.4	-45.78	-15.42	TS_4_6_1 SWC_4_5_1
SWCTEMP-Campbell SoilVUE10	2280_6	-0.5	-45.78	-15.42	TS_4_7_1 SWC_4_6_1
SOIL_H-Hukseflux HFP01SC	2812	-0.05	-3.51	21.39	G_1_1_1
SOIL_H-Hukseflux HFP01SC	2823	-0.05	32.87	-31.96	G_2_1_1
SOIL_H-Hukseflux HFP01SC	2828	-0.05	-13.67	-60.09	G_3_1_1

SOIL_H-Hukseflux HFP01SC	2829	-0.05	-45.78	-15.42	G_4_1_1
WTD-Campbell CS45X	70010945	X	8.87	11.11	WTD_1_1_1
WTD-Campbell CS45X	70010947	X	31.81	-39.5	WTD_2_1_1
WTD-Campbell CS45X	70010949	X	-14.87	-63.18	WTD_3_1_1
WTD-Campbell CS45X	70010944	X	-37.78	-15.42	WTD_4_1_1

The station team has installed the full set of soil meteo sensors required for their Class 2 mire station. The sensors are installed in four soil plots at locations in the target area that comply with the ICOS Instructions and that are accepted by the ETC (Figure 4). The set-up of each soil plot, shown in Figure 5, 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.

Figure 4: Location of the four soil plots around the EC tower. The locations of the monitoring holes for WTD measurements are shown separately. The white line indicates the target area boundary. The light gray zones are exclusion areas.

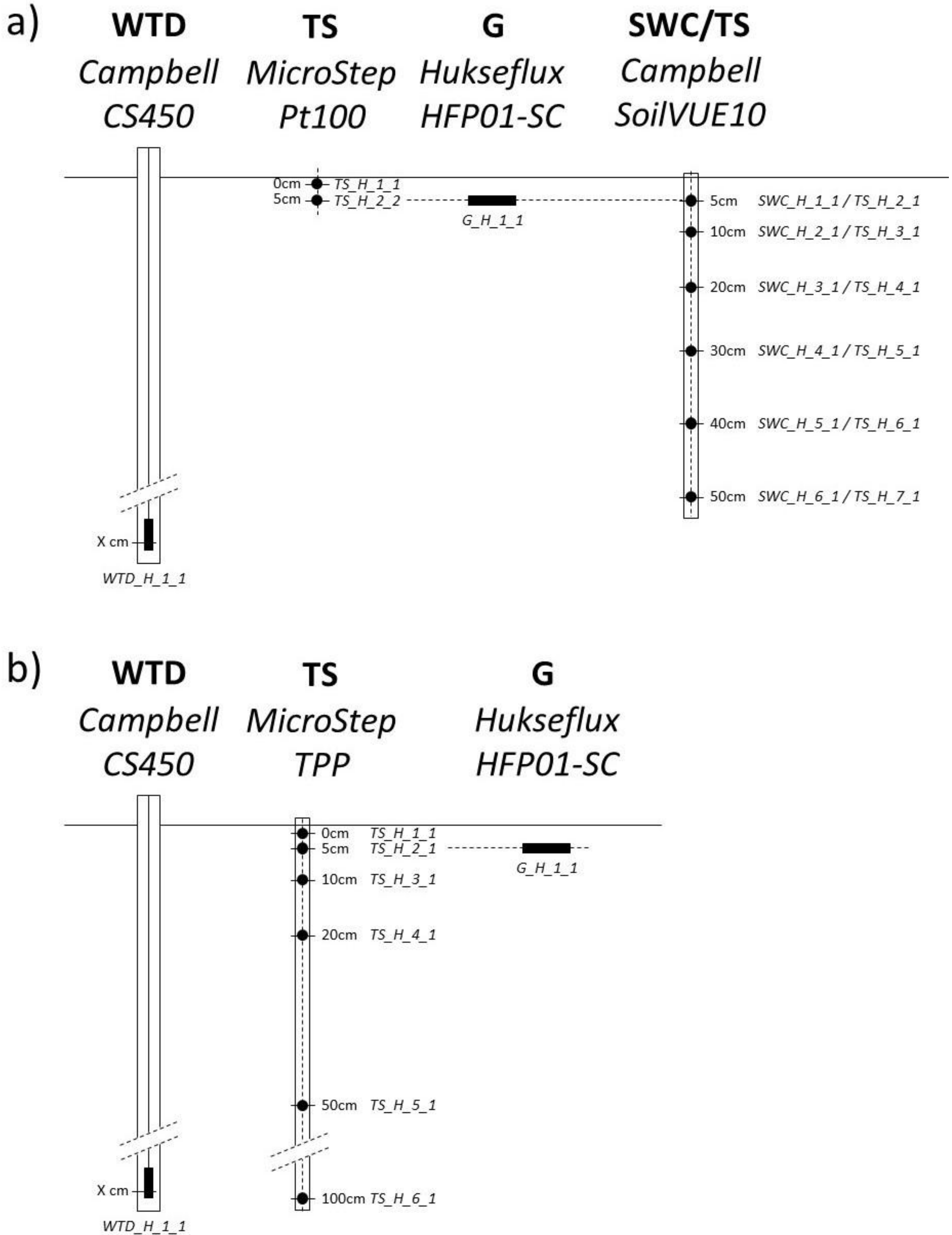


Figure 5: Set-up of the four soil plots. a) plots H = 1 and H = 4, b) plots H = 2 and H = 3. WTD = water table depth, TS = soil temperature, G = soil heat flux density, and SWC = soil water content,. Plots H = 2 and H = 3 are installed at permanently water-logged locations, i.e. where the soil is year-round saturated with water. For this reason the plots don't include SWC sensors. WTD sensor depths are indicated with X cm, because the sensors could not be installed yet at the time of submitting the sensor info; the station team has to wait until spring thaw for sensor installation.

Spatial heterogeneity characterization

The station team has collected all the measurements required for the site characterization in the summer of 2018. These measurements comprise species cover records at the 100 SP-II-order points (and at 12 candidate CPs). With the consent of the ETC, the measurements have been carried out in 60x60 cm square plots, which are identical in size and shape with the CPs, instead of in the standard 30 cm-diameter circular plots. The ETC has quality-checked the submitted data and has subsequently carried out a TWINSPAN cluster analysis of the data in order to classify the 100 SP-II-order plots into groups that correspond with the Plant Community Types (PCTs) that can be distinguished in the target area. The station team proposed to distinguish two PCTs at the site: a dry 'palsa' PCT and a wet 'bog' PCT. The two groups that were output by the TWINSPAN cluster analysis were each linked with a PCT based on the known environmental preferences of the main species in the groups. Figure 6 shows the average species composition per PCT. Figure 7 shows the distribution of the SP-II-order plots per PCT in the target area.

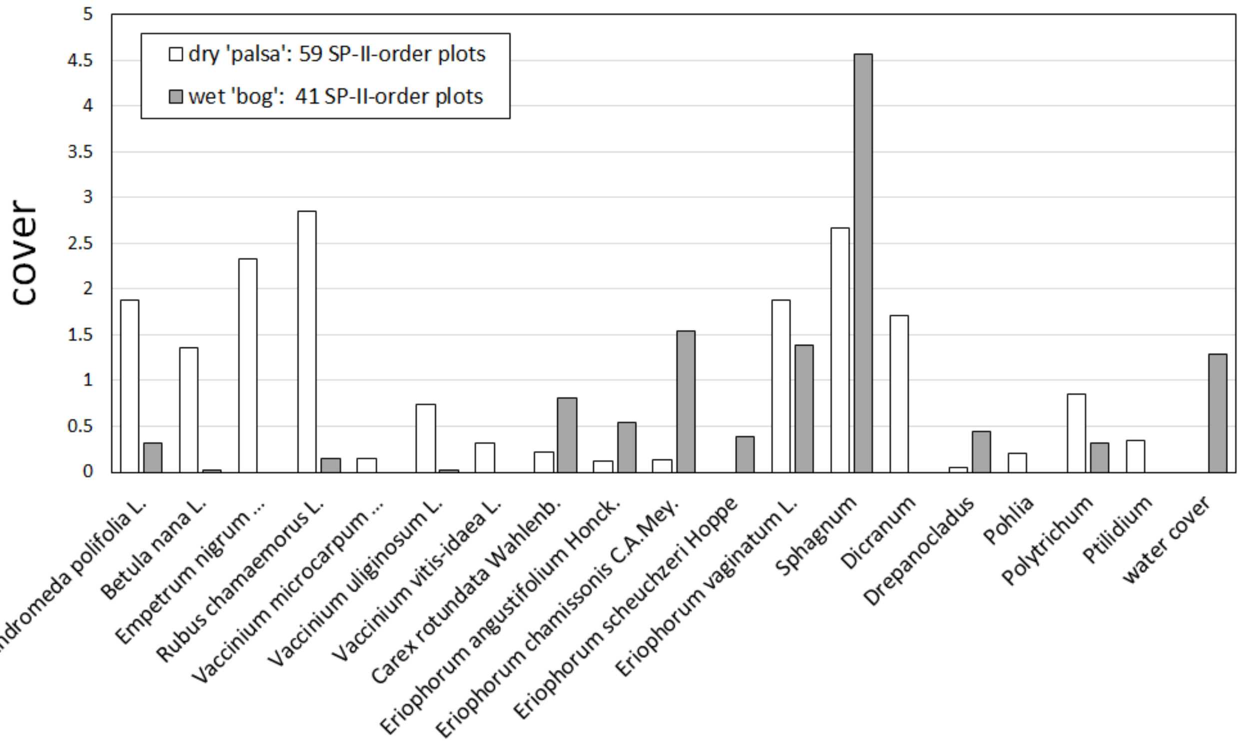


Figure 6: Species composition per plant community type (PCT): dry 'palsa' and wet 'bog'. Species presence is expressed in terms of average cover. For this, the measured percentages of cover in % were converted to a scale from 0 to 5 that corresponds with the cover classes used in the TWINSPAN cluster analysis: not present = 0, 0 - 2% = 1, 2-5% = 2, 5-10% = 3, 10-20% = 4, and 20-100% = 5. Species that were observed in less than four out of the 100 visited SP-II-order plots were excluded from the TWINSPAN analysis and are not shown in this graph.

Figure 7: Distribution of the 100 SP-II-order plots in the target area: white = dry 'palsa', gray = wet 'bog'. The white line indicates the target area boundary. The square shows the location of the EC tower. The white areas are exclusion areas.

Green Area Index

The station team has collected and submitted the two GAI datasets that are requested as part of the step 2 labelling requirements. Those sets of GAI data include measurements on herbaceous and dwarf shrub species in all 12 installed CPs with the modified Vascular Green Area method, done on 09/10 August 2018 and 1 August 2019, respectively. The ETC has quality-checked the data. As an example, Figure 8 shows the GAI measurements from 2018.

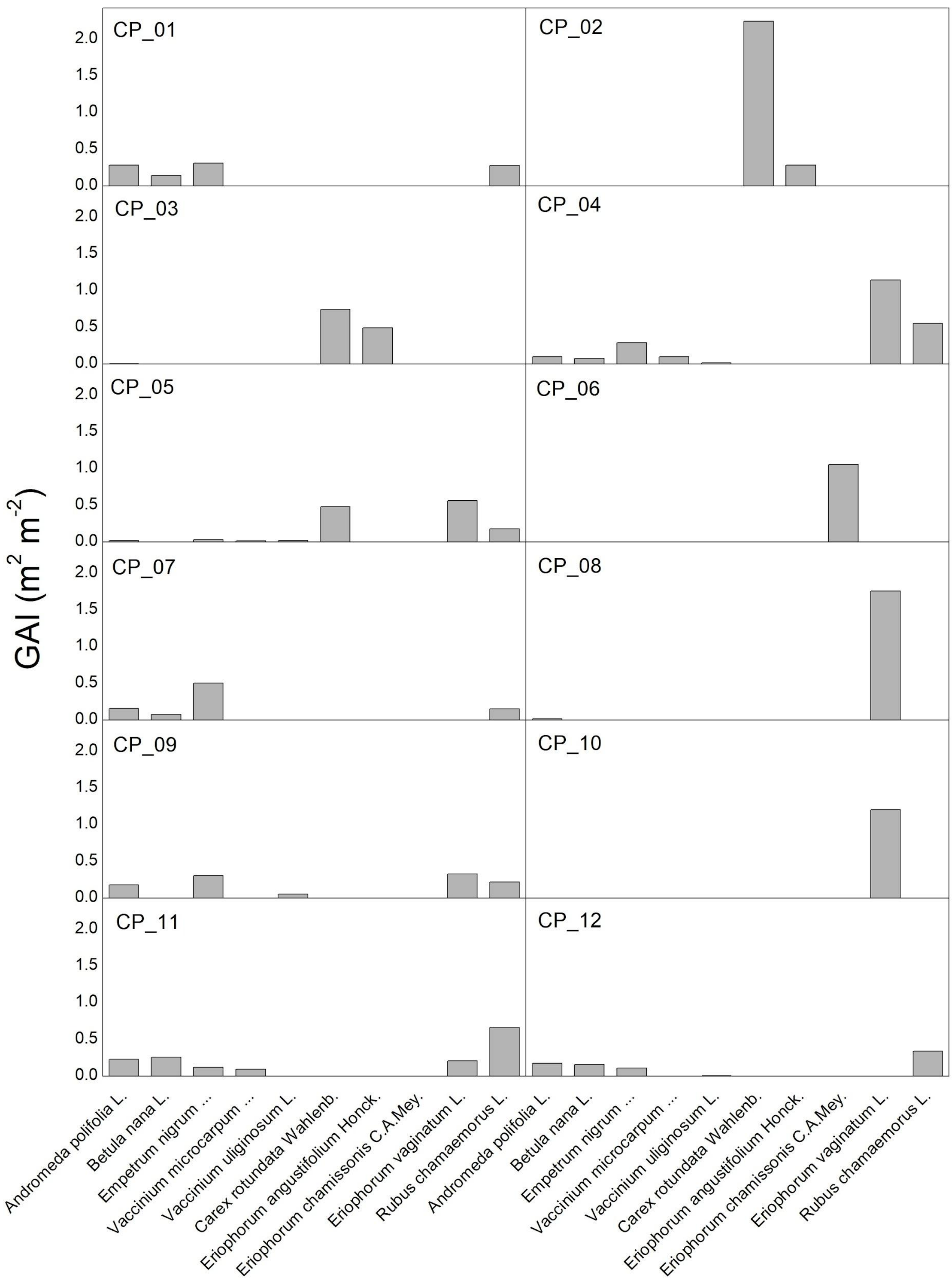
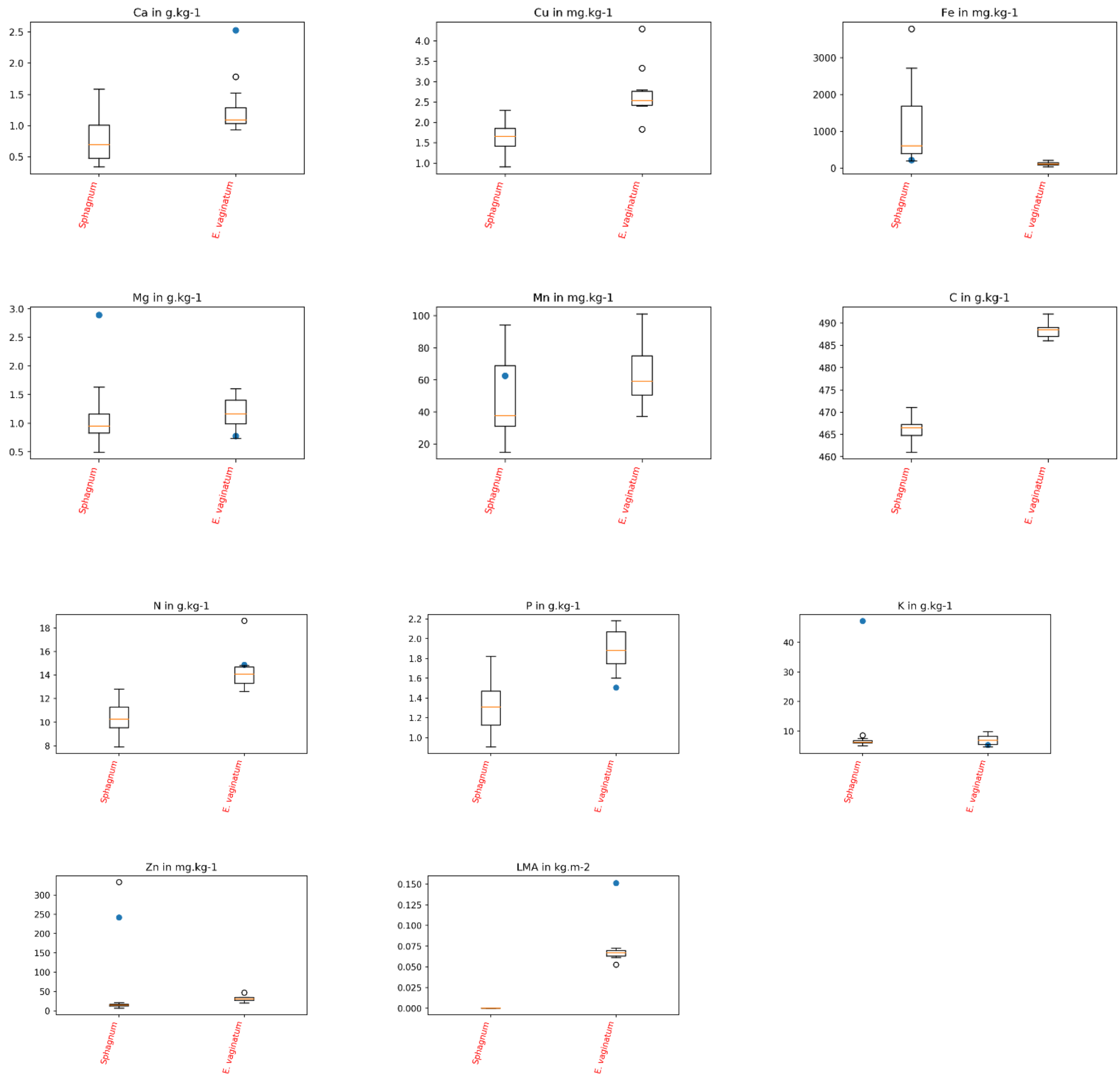


Figure 8: Green Area Index (GAI) measured on 09/10 August 2018 on the herbaceous and dwarf shrubs species in the 12 CPs.

Vegetation sampling and analysis

The sampling plan at SE-Sto have been discussed with the station team and it was agreed to operate in 2018 a preliminary sampling campaign where chlorophyllic material from brushes and sphagnum have been collected. The protocol was validated after few changes in 2019 and applied again in August 2019. The foliar and moss samples have been received at the ETC laboratory, analysis are presented below.

Foliar Analyses for station SE-Sto, 2019-08-08



● *Mean value of the **Sphagnum, Eriophorum vaginatum L.** from TRY-db Data when available. (*https://www.try-db.org/TryWeb/Home.php*)*

Data check and test

Data quality analysis (Test 1)

The test aims at quantifying the availability of NEE half-hourly data after the application of the data cleaning procedure described in Vitale et al. (2020) and implemented in the RFlux R software package (Vitale et al., 2019). The requirement expected for the Step 2 of labelling is that the total percentage of missing and removed data does not exceed the 40% threshold value.

Tests involved in the procedure aim at detecting NEE flux estimates contaminated by the following sources of systematic error: (i) EC system malfunction occurring when fluxes originate from unrepresentative wind sectors or evidenced by diagnostics of sonic anemometer (SA) and gas analyzer (GA); instruments malfunction detected by (ii) low signal resolution and (iii) structural changes tests as described in Vitale et al. (2020); (iv) lack of well developed turbulence regimes (Foken and Wichura, 1996); (v) violation of the stationary conditions (Mahrt, 1998). By comparing each test statistic with two pre-specified threshold values, flux data are identified as affected by strong/severe (SevEr), weak/moderate (ModEr) or negligible (NoEr) evidences about the presence of specific sources of systematic error. Subsequently, the data rejection rule involves a two-stage procedure: in the first stage half-hourly fluxes affected by SevEr are directly discarded, whereas, in the second stage, those affected by ModEr are removed only if they are also identified as outliers."

The period under test was from 20210602 to 20210901, in which 4416 half hourly files were expected, and 4218 ICOS-compliant files were received, resulting in 198 files missing. For NEE, 72.3% valid data remained after the overall cleaning procedure. 733 files were discarded due to severe evidence of error, and 49 identified as outliers. This corresponds to 27.7% of data discarded and missing. This test is considered ***passed***, as the total is well below the established 40% threshold. However, the ETC recommends the PI to pay attention to avoid as much as possible gaps in the timeseries, in order to reduce at maximum the initial percentage of missing data, corresponding in this period to 10%. See Figure 9 below for more details.

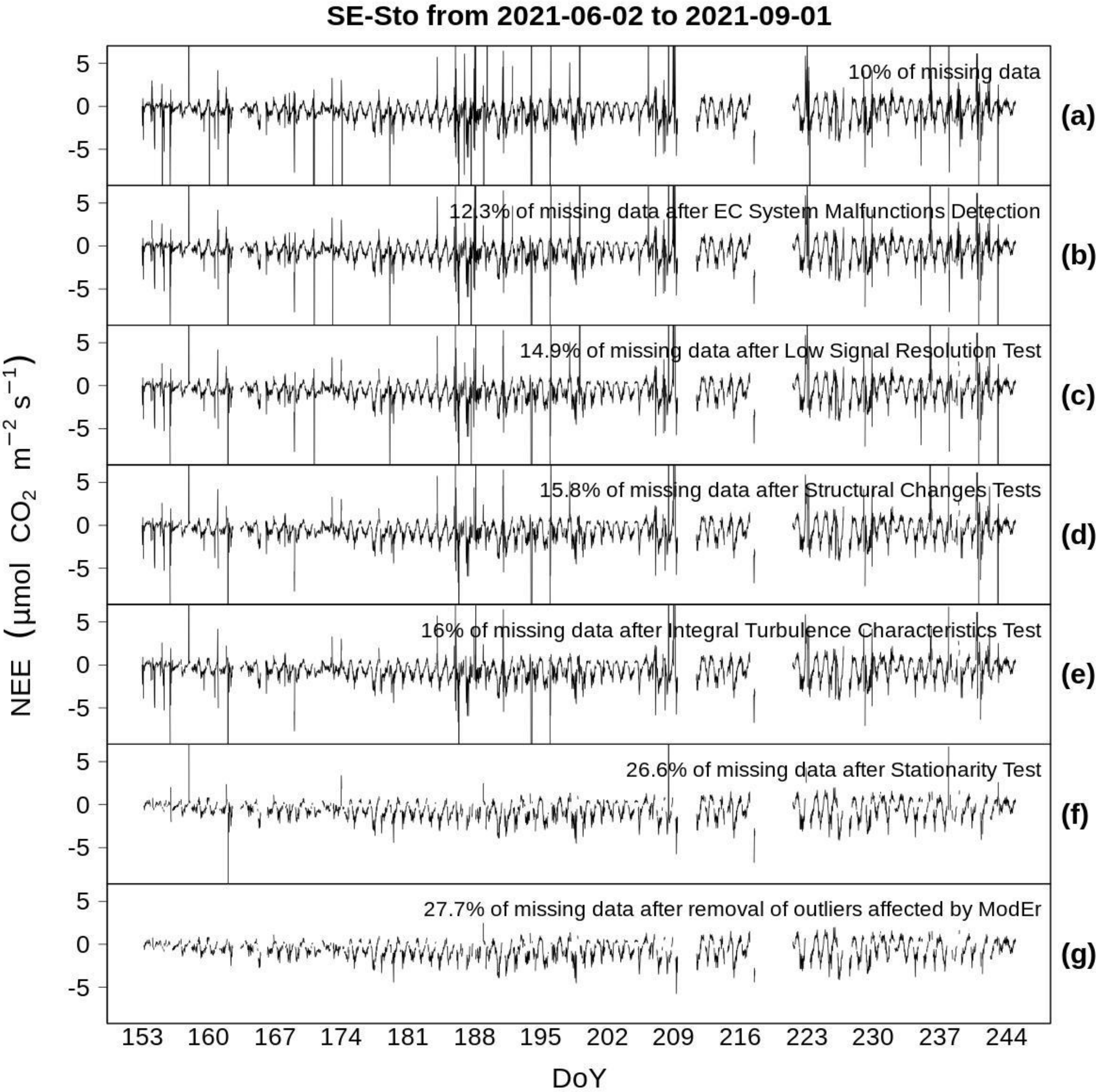


Figure 9: Summary of the data cleaning procedure applied to the Net Ecosystem Exchange (NEE) of CO2 flux collected at SE-Sto station from 20210602 to 20210901. The original half-hourly flux time series is exhibited in the top panel. Panels b-f display the sequential removal of data affected by severe 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-d) instrumental problems detection; (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 evidence of error.

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Softwares

LI-COR Biosciences: EddyPro 7.0.4: Help and User's Guide, LI-COR Biosciences, Lincoln, Nebraska USA, www.licor.com/EddyPro, 2019.
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Footprint analysis (Test 2)

The test aims to evaluate whether half-hourly flux values are sufficiently representative of the target area (TA) or not. For SE-Sto it was performed on 3 months (93 days) of QC filtered data (previous Section). The model by Klijun et al. (2015) was used to obtain the 2-dimensional flux footprint for each half-hour, which was compared to the TA spatial extent.

After the QC procedure and additional filtering according to footprint model requirements, 54% of the data was used for the test. Results showed that 100% of the data have a cumulative contribution of at least 70% from the TA (Figure 10, leftmost bars block), and this holds for daytime and nighttime periods too. The test was performed on 4 sub-periods of similar length and results confirmed the percentages obtained on the whole dataset (Figure 10).

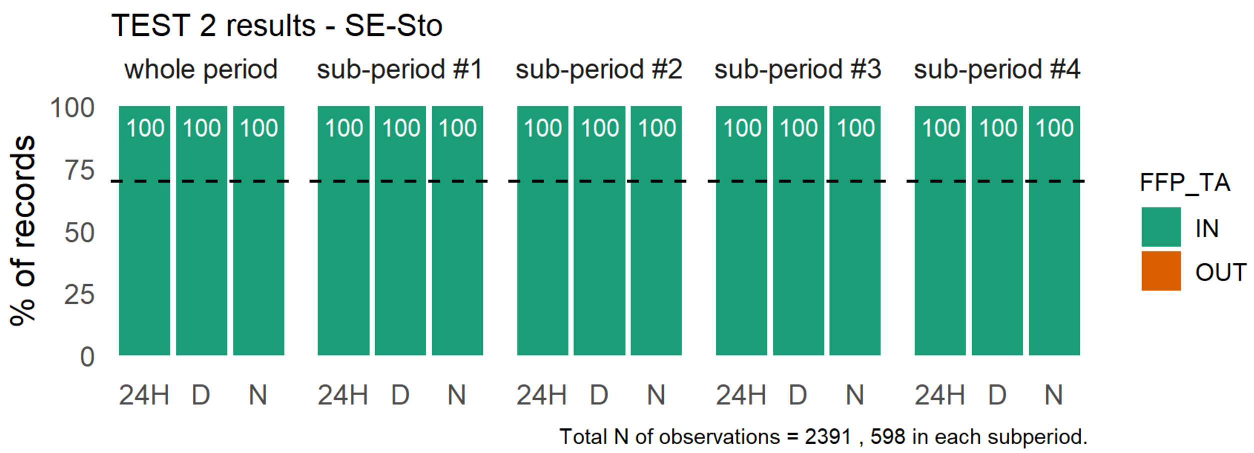

Figure 10: Test 2 results obtained over the whole period (leftmost block) and sub-periods, showing the percentage of half-hours with a footprint cumulative contribution of at least 70% from the target area. The target value (dashed horizontal line) is that 70% of data (half-hourly fluxes) must hold this condition. The analysis was done considering both the whole day ('24H') and daytime and nighttime separately ('D' and 'N' respectively).

The footprint climatology for SE-Sto, estimated over the period under consideration is reported in Figure 11, by which it is possible to notice that 70% footprint cumulative contribution (even 80% actually) is always included in the TA.

Given the particular wind direction distribution and that the EC tower is placed between two different land cover typologies (see next Section), the footprint climatology was calculated also for nighttime conditions to verify the consistency of flux sources over the 24 hours. Results confirmed both the percentages and the source areas distribution obtained over the 24 hours. According to these results, the test is passed.

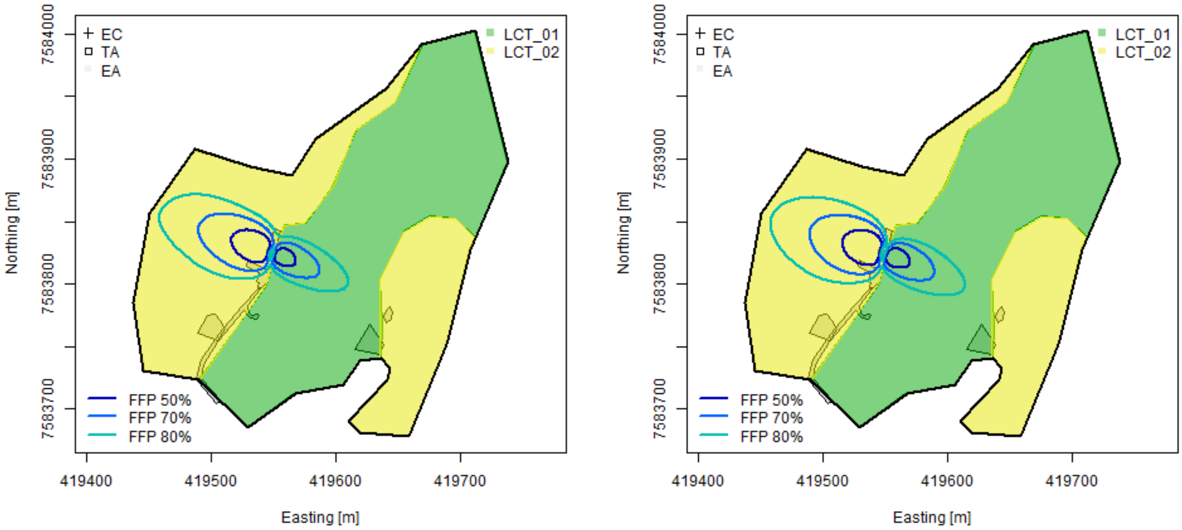

Figure 11: Footprint climatology at Se-Sto in relation to the TA, the EC tower (EC), and the excluded areas (EA, see the spatial sampling Section). Right panel: 24 hours result; left panel: nighttime conditions only. The 50, 70 and 80 % cumulative contribution isopleths are reported.

Data representativeness analysis (Test 3)

This test aims to evaluate the representativeness of the different land cover tipologies (LCT) inside the Target area (TA). It is run on LCT which contributes at least with 70% of the fluxes in at least 20% of the data (good data after filtering for QA/QC). For such LCTs the number of records collected during daytime, nighttime and for each of two periods obtained dividing the dataset in two parts, must be the 20% of data at least. According to the spatial heterogeneity characterization and the ancillary plot representativeness (see the Spatial heterogeneity characterization Section) at SE-Sto were defined 2 LCT according to the wetness degree of soil (LCT01 is a wetter area, LCT02 is a drier area). Illustrative half-hourly footprints in relation to the TA and the different land cover typologies are reported in Figure 12.

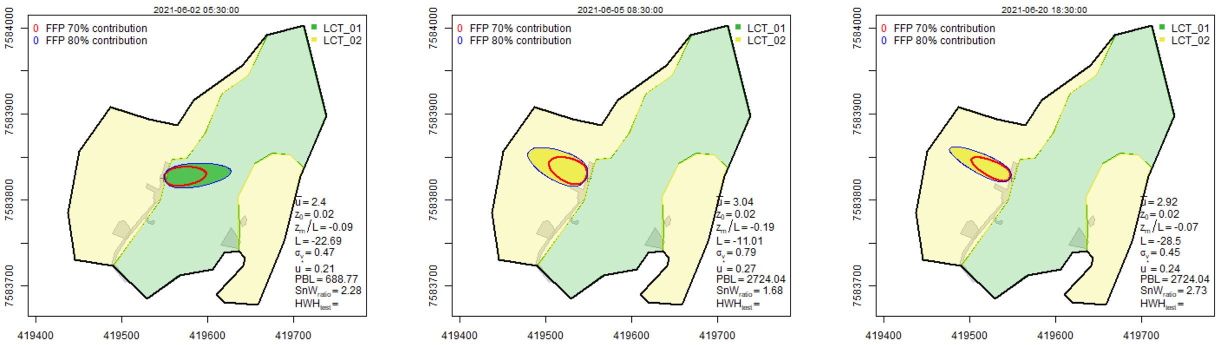

Figure 12: Illustrative 2D half-hourly footprints at SE-Sto In relation to the LCTs. The footprint 70% and 80% cumulative contribution isopleths are reported in red and blue respectively.

The test showed that both LCTs contribute with more than 70% to the fluxes in more than 20% of the data (Figure 13).

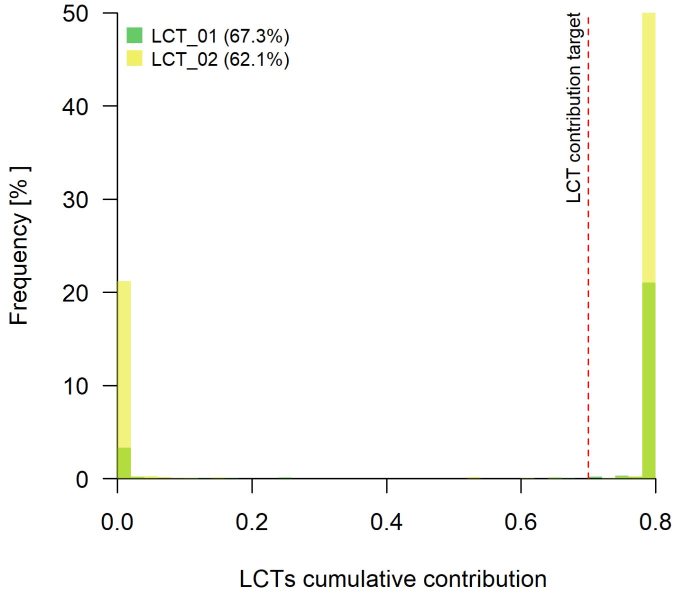

Figure 13: Histogram of half-hourly footprint cumulative contributions from the envisaged land cover typologies (LCT) at SE-Sto. Values reported in brackets are the LCT average cumulative contributions.

Additional analyses were performed in order to verify the consistency of the contributions among daytime and nighttime. Results show that, despite a generally larger contribution of LCT02, both LCT are evenly sampled during daytime and nighttime (similar percentages of data with at least 70% of contribution), and this holds for both of the considered subperiods (Figure 14). According to these results, test 3 is passed.

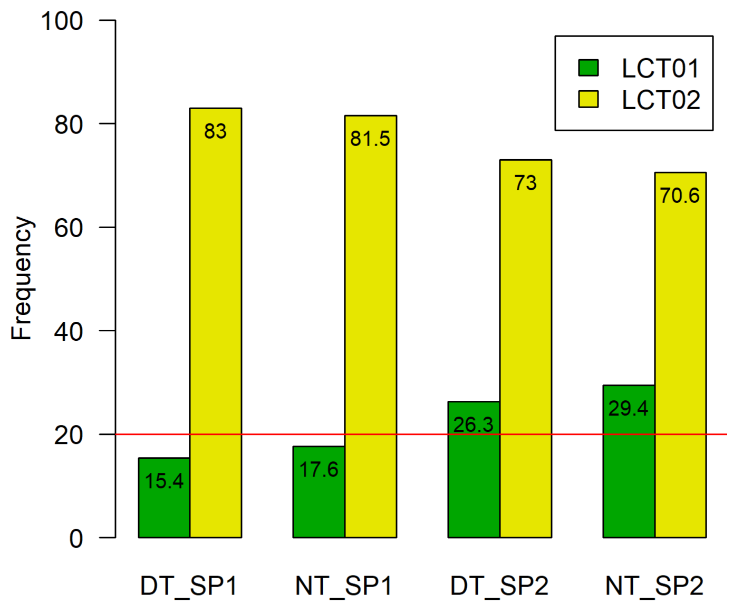

Figure 14: Frequency of records with a cumulative contribution of at least 70% from the LCTs. Data were analyzed for daytime and nighttime (DT and NT respectively) and for 2 subperiods (first and second halves of the concerned period, SP1 and SP2 respectively).

<u>Ancillary plot representativeness (Test 4)</u>

The station team has collected all the measurements needed for the ancillary plot representativity test in the summer of 2018. These measurements comprise species cover records at 12 candidate Continuous Measurements Plots (CPs), as well as at the 100 SP-II-order points for site characterization. For mire stations such as SE-Sto, it is not the standard test described in the Introductory section of this report that is applied here. Instead, each candidate CP is checked by running the same TWINSPAN cluster analysis as ran for the classification of the 100 SP-II-order points into groups corresponding with PCTs, but now with the candidate CP included in the input data set. It is then checked if the TWINSPAN algorithm assigns the CP to the PCT it is meant to represent. Borderline cases are discussed with the station team. The outcome of the test was positive for all CPs. The two PCTs are each represented by six CPs:

- dry 'palsa': CP_01, CP_04, CP_07, CP_09, CP_11, CP_12
- wet 'bog': CP_02, CP_03, CP_05, CP_06, CP_08, CP_10

Figure 15 shows the locations of the CPs in the target area. Figures 16 and 17 show the species composition of the CPs representing dry 'palsa' and wet 'bog', respectively. Figure 18 shows one 'palsa' CP and one 'bog' CP.

Figure 15: Locations of the 12 CPs in the target area: white = dry ‘palsa’, gray = wet ‘bog’. The white line indicates the target area boundary. The square shows the location of the EC tower. The white areas are exclusion areas.

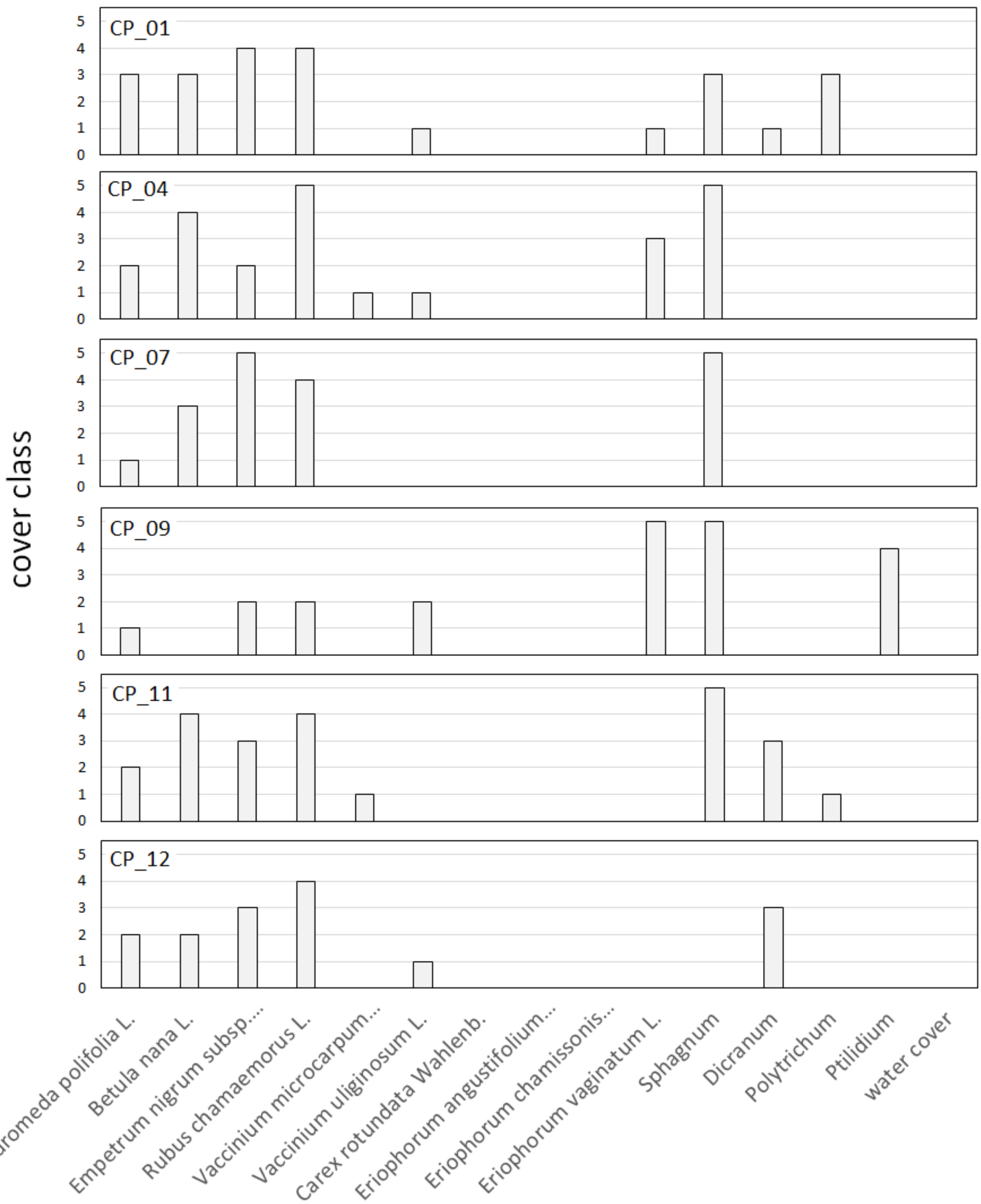

Figure 16: Species composition of the six CPs that represent dry ‘palsa’. Species presence is expressed in terms of the six cover classes used in the TWINSPAN cluster analysis: not present = 0, 0 - 2% = 1, 2-5% = 2, 5-10% = 3, 10-20% = 4, and 20-100% = 5.

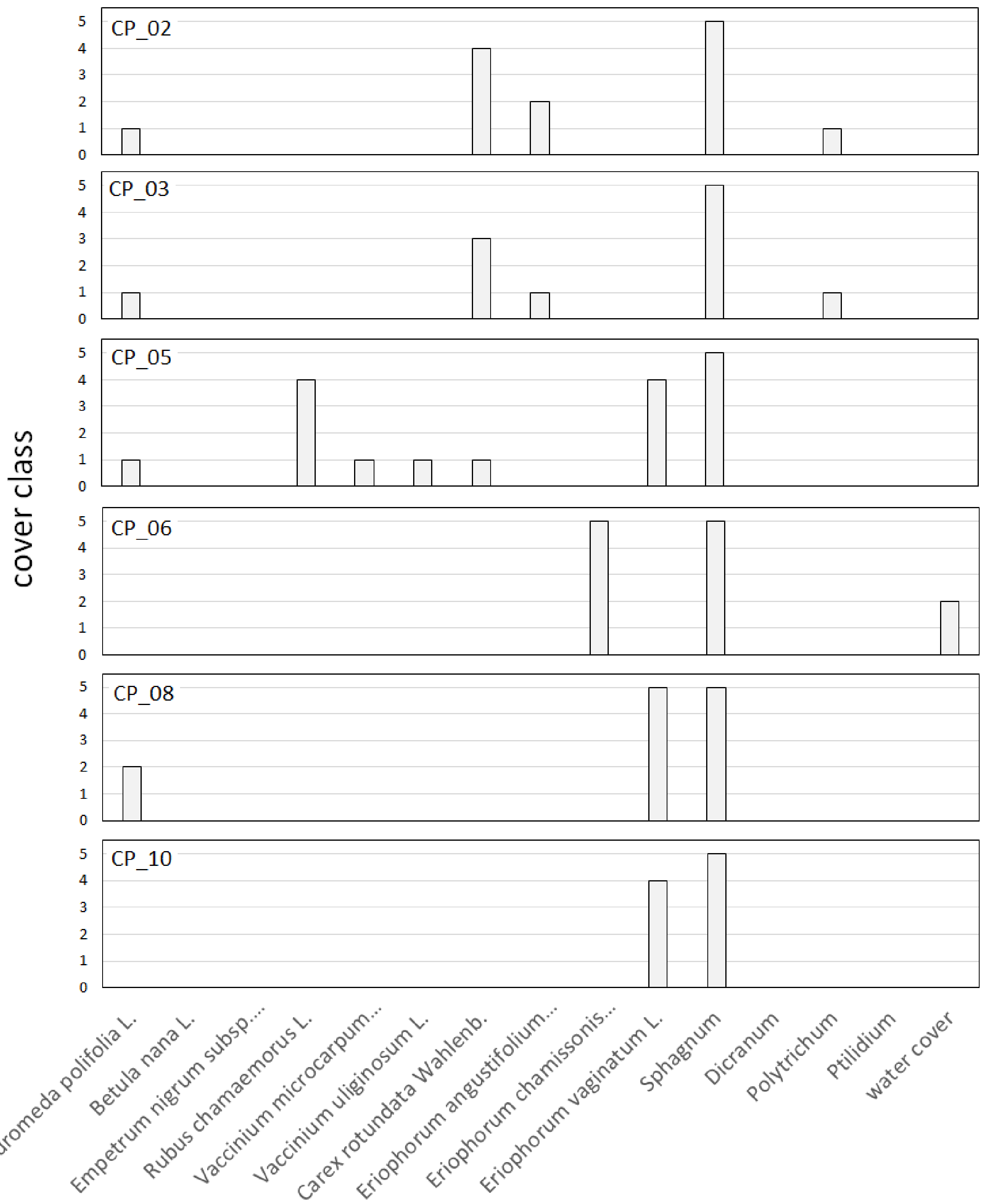

Figure 17: Species composition of the six CPs that represent wet 'bog'. Species presence is expressed in terms of the six cover classes used in the TWINSPAN cluster analysis: not present = 0, 0 - 2% = 1, 2-5% = 2, 5-10% = 3, 10-20% = 4, and 20-100% = 5.

Figure 18: Example of a CP representing dry ‘palsa’ (CP_01) and a CP representing wet ‘bog’ (CP_06). The square frame marks the CP and is the frame used for the species cover estimations. Pictures were taken in summer 2018.

Near Real Time data transmission

EC file L01_F02 got the green light on 20210601 and started flowing to the CP right after. They are collected on a Campbell Scientific CR6, issuing ASCII files. The station team is using the same script to collect the files on the logger as all the SE stations that already passed the sync test: for that reason the ETC deems the sync test not necessary.

Loggers used for BM collection are Campbell Scientific CR1000, CR3000 and CR310. BM files are all in ASCII format. BM file L02_F01 got the green light on 20211125. BM files L03_F02 and L03_F03 got the green light on 20220301, file L02_F02 and L06_F01 on 20220303, file L06_F02 on 20220329.

Plan for remaining variables

Soil sampling

The ETC agreed with the station PI and managers that the soil sampling will be discussed in depth to avoid any disturbance of this particularly fragile ecosystem and provide most useful information on soil carbon and nitrogen content. The foreseen sampling date is september 2023.

Other

Backup station: the station team will install in the near future backup batteries for the backup sensors, and a solar-panels system to ensure continuous powering of the sensors even in case of black-out.

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 Abisko-Stordalen Palsa Bog (SE-Sto) is labelled as ICOS Class 2 Ecosystem station.

Dario Papale, ETC Director

Viterbo, April 18th 2022