

INSTRUCTIONS FOR

ANCILLARY VEGETATION

MEASUREMENTS

in

FOREST

GREEN AREA INDEX

ABOVEGROUND BIOMASS

LITTER BIOMASS

Version	Release date	Summary of changes
20170902	20170902	Clarified the calculation of LMA ratio in non-woody litter biomass and changed to one litter trap per CP (instead of subsamples).
20170911	20170911	Clarified the reporting of species composition for AGB of the understorey, clarification of true North instead of Magnetic North, clarification of Health status
20180131	20180131	Added that the real location of DHP, ceptometer and litter trap must be measured and reported (added Appendix C). Litter section reorganized and measurements simplified. Added information about the Submission of BADM variables.
20191123	20191123	Added clarification in DHP measurement and calibration section. Updated calculation of maximum radius. Added details for rounding calculated numbers in AGB. Added clarification on

		sampling design for understorey AGB measurements. Added brush wire method for mosses. Updated temporal sampling design for litter. Clarified section on AGB reporting of saplings and shrubs. Added section on allometric relations
20200316	20200316	Clarified section on DHP sky and light requirements. Updated figure 2 for temporal sampling. Changed understorey AGB plant type from 'flowering herb' to 'herb'. Changed requirement for shrub AGB measurement to destructive. Added line on measuring slope of plot. Remark on yearly litter area measurement. Note on how to report coarse litter transect angle. Clarified that litter values must be reported per square meter. Updated reference to DHP optical center tool. Changed minimum timing requirements for collecting data to fixed timing requirements.
20200330	20200330	Correction of litter trap location in Appendix C and clarification on reporting locations.
20211109	20211109	Clarification on AGB understorey destructive collection and on allometry of saplings. Removal of automatic dendrometer where a specific Instruction is under preparation. Added clarifications in different parts.

The ICOS protocols and the derived Instructions documents can be changed and amended in time, because new methods become available or to improve their clearness. For this reason, it is crucial to keep track of the versions and differences.

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SUMMARY

This document describes the measurement of ancillary vegetation variables at ICOS ecosystem stations in forests. These variables are Green Area Index (GAI), Aboveground Biomass (AGB), and litter biomass. In summary, they are measured for the following aims and with the following methods:

- GAI is measured to explain seasonal variation in ecosystem-atmosphere fluxes and is measured indirectly with Digital Hemispherical Photography (DHP) or a linear ceptometer. The choice of method depends on the GAI (seasonal max $GAI < 6 \text{ m}^2 \text{ m}^{-2}$ requires DHP, seasonal max $GAI > 6 \text{ m}^2 \text{ m}^{-2}$ requires ceptometer), however the choice of method should be discussed between the station PI and the ETC. The sensor type should be kept constant over time.
- AGB is measured to estimate Aboveground Net Primary Productivity (ANPP) and lateral carbon flow through harvest. AGB is measured by measuring diameter at breast height (DBH), stem height and allometric relations for overstorey vegetation and understorey saplings and destructive measurements for other understorey vegetation.
- Litter biomass is measured to correct the yearly ANPP estimated from AGB and is measured with litter traps at the Class 1 stations.

This document is structured in three different sections with the aim to facilitate the use and application:

- Measurements: in this section the sensors, setup and methods to correctly collect the data and info are described. It includes sub-sections on sensors characteristics, practical indication for the setup/collection, info on the sampling design and guidelines for the installation/sampling also in respect to other sensors/measurements.
- Maintenance: in this section all the maintenance and calibration guidelines are described, including the general timeline.
- Submission: this is the section related to the data preparation and submission to the ETC. It includes the list of all the parameters, the correct formatting and how to submit them to the database. It is linked to the BADM system needed to submit the metadata and not continuous measurements.

It is important to remember that the exact application of the protocol at site level is also discussed with ETC in order to find agreed solutions for specific cases. If a specific part is relevant only for a specific ecosystem or station Class this is also reported in the document.

This Instruction document is based on the following ICOS Ecosystem protocols:

- Gielen et al. (2018). Ancillary vegetation measurements at ICOS ecosystem stations. INTERNATIONAL AGROPHYSICS, vol. 32, p. 645-664, ISSN: 0236-8722, doi: 10.1515/intag-2017-0048

MEASUREMENTS

Sensors and Material needed

Digital Hemispherical Photography (if seasonal max GAI < 6 m² m⁻²)

- Digital camera
 - o Digital Single lens reflex camera: at least 12,3 Mpixel (no compact camera)
- Fish-eye lens, compatible with the camera
 - o Field of view: 180°
 - o 4.5mm for APS-C cameras and 8mm for full frame cameras
- Tripod or telescopic monopod with levelling head
- Measuring tape or stick of 1.3m to set tripod height
- 3D Bubble level or self-levelling mount
- Compass to align the camera to the true North
- Inclinator to determine the slope of the terrain in case of complex terrain.
- Material for calibration of the lens and camera (see appendix A)

Linear ceptometer (if seasonal max GAI > 6 m² m⁻²)

- Linear ceptometer with external PAR sensor and tripod; accepted models are:
 - o SS1 SunScan Canopy Analysis System (Delta-T Devices) (Figure 1)

Additionally needed are a compass and a soft microfiber cloth. More info on the required instrumentation for these measurements is found in the Instructions for SS1 Canopy Analysis System for Green Area Index Measurements.



Figure 1: The SS1 Sunscan Canopy Analysis System from Delta-T Devices.

Allometry (tree diameter and height)

- Data sheet
- Diameter tapes or calliper (precision 1 mm)
- Height and distance measurement device (laser range finder with inclinometer)
- Compass
- 1.3m long wooden stick

For the continuous tree diameter measurements in the Class 1 sites, an automatic dendrometer is needed. As this is a continuous measurement, all required information can be found in the separate instructions for the automatic dendrometer.

Litter collection (Class 1 sites only)

- Paper bags + labelling material
- Drying oven
- Desiccator

- Electronic balance with a measurement precision of at least 0.1 g or 1% of sample weight, whichever is the smallest
- Litter traps
- Rope and meter
- Calliper or diameter tape

The collection of litter in forests is done by litter fall traps. These traps have to be fixed at about 1m above the forest floor to ensure adequate water drainage. The opening of the collectors has to be installed so that it is horizontal. In case of sloping underground, ensure that there is clearance from the ground raising the trap height if needed. The collector has to be attached to a frame of weather-proof material, with a minimum collecting area of 0.5 m² (radius = 0.39m). The area underneath the collector has to be kept clear from vegetation to avoid contact between the understorey vegetation and the nets. It is recommended that the litter bags or collecting funnels are at least 0.5 m deep and are weighted to prevent litter from blowing out of the traps. Litter nets/bags of inert light coloured materials such as polyethylene or nylon are suitable materials since these materials have been shown to not interfere with the major ions present in litter. The mesh size of the bags must be large enough to allow easy drainage of water and it is recommended to adapt mesh size to the dimension of the smallest elements, i.e. for needles from coniferous species up to 0.5 mm. During the winter season in areas of heavy snowfall, traps may be lowered to the ground to avoid breakage of the collector structures, preferably on to a plastic mesh sheet to avoid direct contact with the soil.

Spatial and temporal sampling

The ancillary vegetation measurements are carried out in the continuous measurement plots (CP), which are in forests circular plots with a surface of 2000 m² and a radius of 25,24m. Class 1 stations should have at least 4 of these plots and Class 2 stations at least two. The location of the CPs is discussed and described in the Instruction document on Spatial Sampling Design, however in forest ecosystems it must be ensured that the 2000 m² area does not overlap between CPs. In case of plantations or forests with trees distributed along rows, the CPs must have a rectangular shape (to be discussed and agreed with ETC). In this case, the CPs must extend from a mid-row to a mid-row with the longer side parallel to the tree rows and they must include at least four rows of trees (e.g. see Figure 4b). The length of the CPs must be calculated in order to have a total area of 2000 m². The different ancillary vegetation measurements are performed inside the CPs following different temporal schemes (Figure 2).

The North in this document refers to the true North, which is different from the magnetic North measured by a regular compass. To derive the true North from the magnetic North, please follow the following steps:

- 1) Calculate the declination between the true North and the magnetic North. There are many online tools that allow you do to so (e.g. <https://www.ngdc.noaa.gov/geomag-web/#declination>).

- 2) Adjust the bezel ring of your compass according to the declination so that you are able to point towards the true North.

Green Area Index

Green Area Index is measured in the CPs at least six times a year for both deciduous and coniferous forests: two times during the period of leaf development, once at the peak GAI, two times during the leaf fall period and a final measurement during the dormant season. Additional sampling dates must be added:

- Once just before and after a thinning.
- After a major disturbance, such as a storm event, insect attack etc.

Aboveground biomass

Aboveground biomass of both the overstorey and the understorey is measured in the CPs in.

Overstorey:

- A default measurement every 3 years, after the growing season (frequency may depend on growth rate of the trees and should be discussed with ETC) in the CPs.
- A measurement after each major disturbance, such as a storm event.

Understorey:

- A measurement every year at peak biomass of herbaceous species in the CPs.

Litter biomass

Litter biomass is measured in the CPs of Class 1 stations.

For non-woody litter:

- One measurement every two weeks during periods of litter production. This is defined as the period when litter material is found in the litter traps (i.e. fall).
- Additional measurements after a major stress event, such as a storm, a drought, etc.
- Outside the main period of litter production the litter should be collected every month, except for periods of snow cover.

For woody debris (fine and coarse):

- One measurement after the end of the growing season.
- Additional measurement in case of major disturbances.

The specific measurement calendar, function of the ecosystem characteristics, is agreed with the ETC.

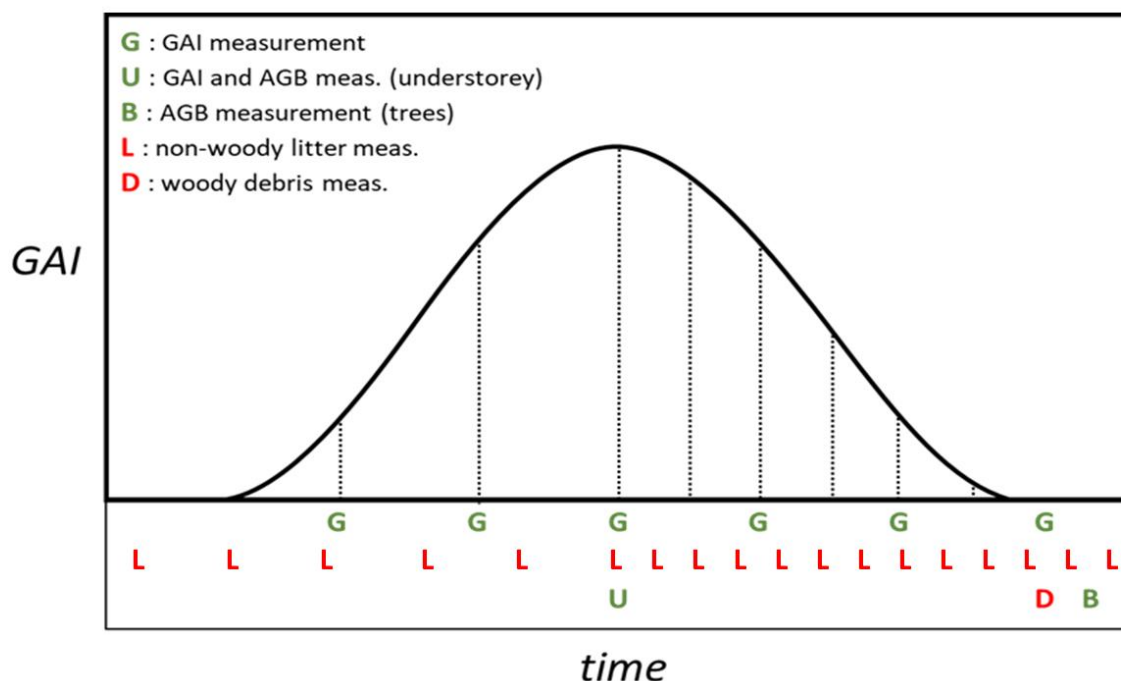


Figure 2: Default scheme of the temporal sampling for ancillary vegetation measurements at forest stations. Note: understorey GAI and AGB is measured at peak of herbaceous species GAI. For the litter fall the measurements are function of the litter production and specific for the ecosystem.

Measurements at each Continuous Plot

This section describes per method how to carry out the measurements in each CP and, if needed, how to calculate the values required to submit to ETC from these measurements.

Ceptometer measurements

The ceptometer has to be used to measure GAI in the plot if the expected value of seasonal max GAI is larger than $6 \text{ m}^2 \text{ m}^{-2}$, otherwise GAI has to be measured by DHP.

Weather conditions

Do not measure when there is precipitation. Water droplets and snow on the probe or the external PAR sensor lead to incorrect PAR readings. Do not measure at temperatures outside the ceptometer's range of operation, i.e. below 0 °C.

Light

Measurements are preferably done in stable light conditions, i.e. under a uniformly blue or grey sky (Figures 3 a-b). If measuring in unstable conditions, restrict measurements to the brief periods

of rather stable light (Figures 3 c-d). Under broken clouds, these are either the sunny intervals or the intervals during which the sun is clearly blocked by a cloud. Avoid measurements at the critical moments in between. It is recommended (but not mandatory) to consistently measure in the same light conditions throughout the growing season. This means that you could try to either do all measurements in the presence of direct sunlight or do all in the absence of direct sunlight. Such consistency is not easy to achieve and for this reason, as already mentioned, not mandatory.

Do not measure at solar zenith angles greater than 60°. Of course, high zenith angles cannot be avoided in winter, when the sun does not rise above 30° in the sky. At high latitudes, the same goes for measurements in early spring and autumn.

Do not measure at above-canopy PAR < 200 $\mu\text{mol m}^{-2} \text{s}^{-1}$, as the accuracy of the ceptometer degrades at these levels.

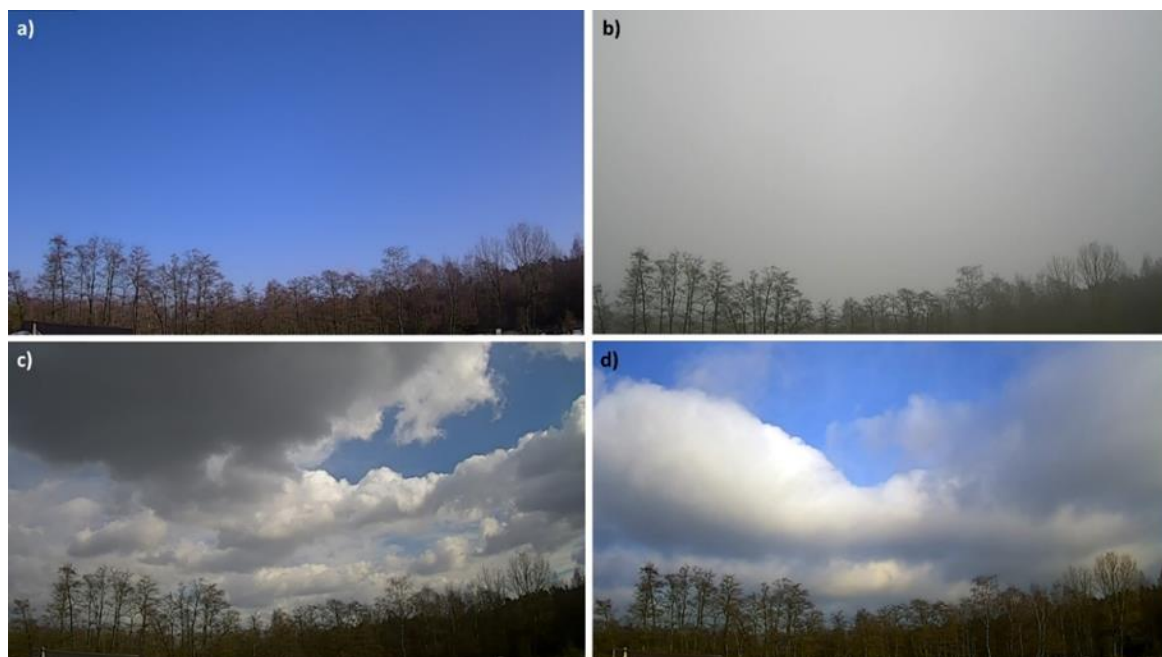


Figure 3: Measurements with the ceptometer are preferably done in stable light conditions, i.e. under a blue sky (a) or a uniformly grey sky (b). If measuring in unstable conditions, such as occurring under partly cloudy skies (c,d), restrict measurements to the brief periods of rather stable light.

Measurements in the plot

Measurements with the ceptometer are carried out at 25 locations in circular CPs and 36 locations in rectangular CPs. At each location, below-canopy PAR (PAR_b) is measured with the ceptometer probe, while above-canopy PAR is measured simultaneously with the external PAR sensor installed in a nearby clearing or on the EC tower. A detailed explanation of the measurements at each point can be found in the instruction documents for ceptometer measurements (Instructions for SS1 Sunscan Canopy Analysis System for Green Area Index measurements)

The systematic measuring grid of points has to be installed within each CP (Figure 4). For a standard circular CP, a grid of 25 points must be used with 7.5 m between points and with the middle point (ID = 13) coinciding with the centre of the CP (Figure 4a). The 4 corners of the square have to be at equal distance from the centre of the plot, with the upper one facing North. In case of rectangular CPs, 36 points are used along 4 transects orthogonal in respect to the tree lines and equally distant one from the other ($L/4$ where L is the length of the CP side parallel to the tree lines, see figure 4b). The measurements are then taken around three locations along each transect: the inter-row passing through or closer to the CP center (points 5, 14, 23 and 32 in Figure 4b) and the first and last inter-row included in the CP (points 2 and 8, 17 and 11, 20 and 26, 35 and 29 in Figure 4b). Around each of these locations three measurements are taken, one on the point and two in the direction of the tree lines at $1/6$ of the interline distance (see Figure 4b and zoomed example). In both cases (circular and rectangular CP), to avoid interference from stems and trees on the measurements, we advise to move the measurement point away from a tree using the 10° rule that implies that a sampling point should be at a minimum distance of 5.7 times the diameter of the tree. In practice, this can be easily checked by constructing a stick in the form of a T, where the long end is 5.7 times longer than the short end. When pointing this device toward a tree the width of the tree should be less than the short end of the T device. Thus this device could be used to decide if trees are too close to the measuring point. In case the sampling point is too close, one should move the point away from the tree in any direction. Once a point is determined it has to be kept constant over the lifetime of ICOS.

When measuring for the first time, mark the measurement locations with a wooden/metal stick with a clear tag on it. In addition, measure the final location of the ceptometer measurement point with respect to the center of the CP. See the appendix C for the determination of the nominal positions in case standard circular CP is reported, both as distances E-N and distance-angle.

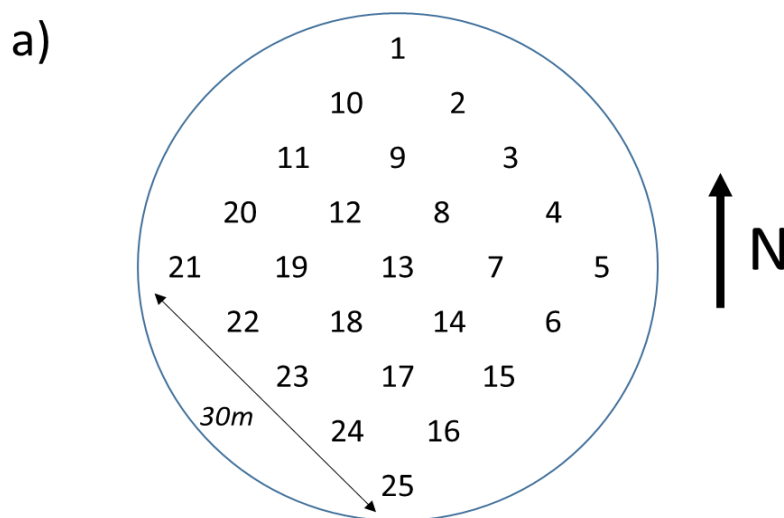


Figure 4: The fixed systematic grid of ceptometer measurements in one plot. The points have to be marked in the field in order to allow for repeated measurements. a) Points distribution and numbering in case of standard circular CP. Orientation is toward true North, not magnetic N.

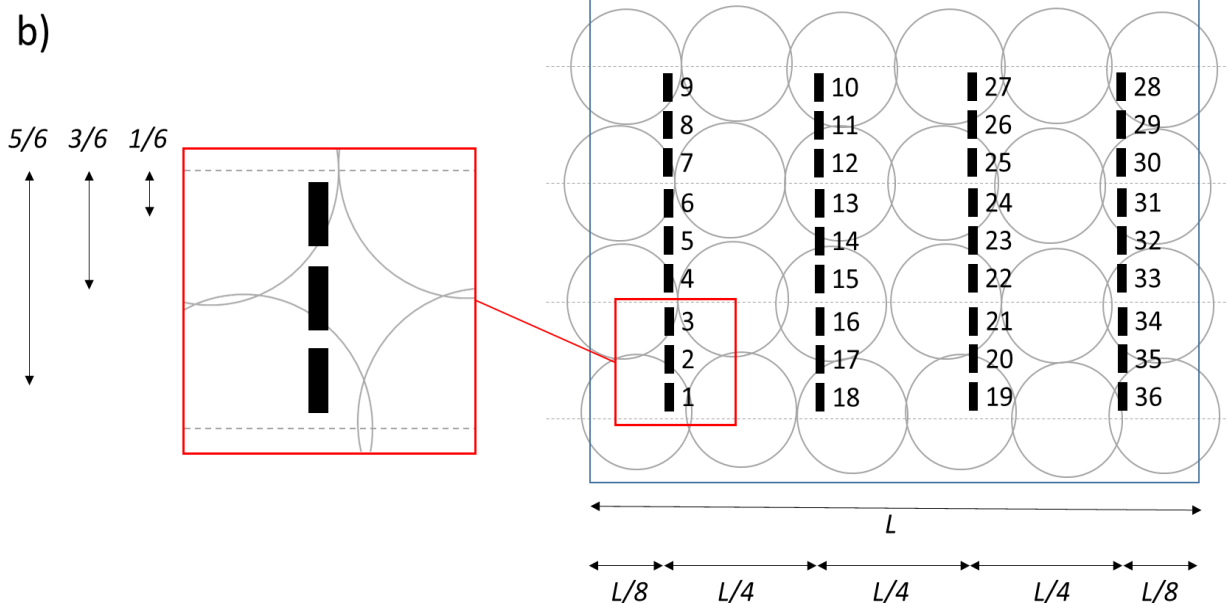


Figure 4 (continued): The fixed systematic grid of ceptometer measurements in one plot. The points have to be marked in the field in order to allow for repeated measurements. b) Distribution of measurement points in case of rectangular CP. L is the length of the CP in the direction parallel to the tree lines. The red square is a detailed view of the first three points showing the distances in respect to the tree line (1/6, 3/6 and 5/6 of the inter-rows distance).

Note: If a significant understorey of small trees is present (>10% of overstorey GAI), it is possible to discuss a method to estimate understorey GAI with the ETC.

Digital Hemispherical Photography

DHP has to be used to measure GAI in the plot if the expected value of seasonal max GAI is smaller than $6 \text{ m}^2 \text{ m}^{-2}$, otherwise the ceptometer has to be used.

Weather conditions

- Hemispherical pictures can only be taken in the absence of direct sunlight, as sunlit foliage might appear as bright pixels on the image and wrongly be classified as sky. Diffuse light is ideal to get a good hemispherical picture. The best diffuse lighting conditions occur on entirely overcast days (grey skies). The sky condition in Figure 3b is ideal as there is a uniform cloud cover and the light is evenly scattered in the sky. All other cloud/sky/lighting conditions shown in Figure 3 (Figure 3a, 3c and 3d) should be avoided. In Figure 5, two DHP examples are shown in which the sky conditions are not acceptable (Figure 5a and 5b). In Figure 5c and 5d, there is an entirely clouded sky, however Figure 5c would not be accepted due to overexposure (note the little peak on the right side of the histogram). This may occur when there is only a veil of cloud cover that is thin enough to allow beams of light to penetrate. It could have been corrected with a faster shutter speed, allowing less light to enter the camera (see required camera settings further on).

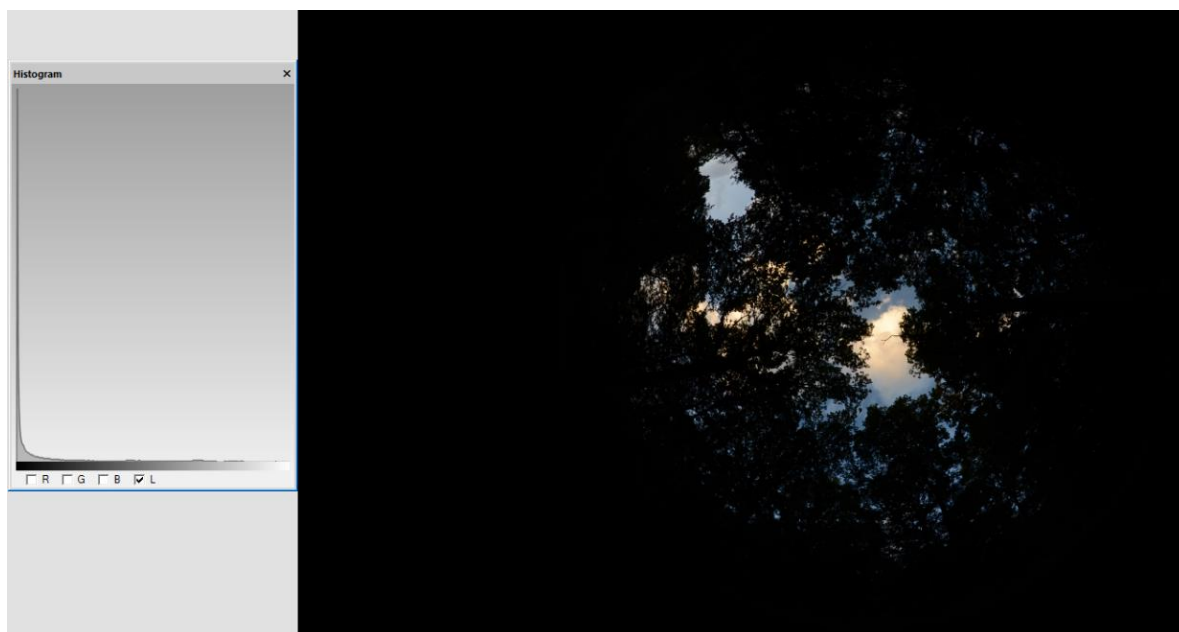


Figure 5a: DHP examples of different lighting conditions. Unsuitable sky condition: There is no overexposure, but the light is not diffuse and the sky is not completely overcast. The contrast between the trees and the blue sky will be different compared to the white cloud. In addition, some parts of the clouds reflect the sunlight creating an orange glow.

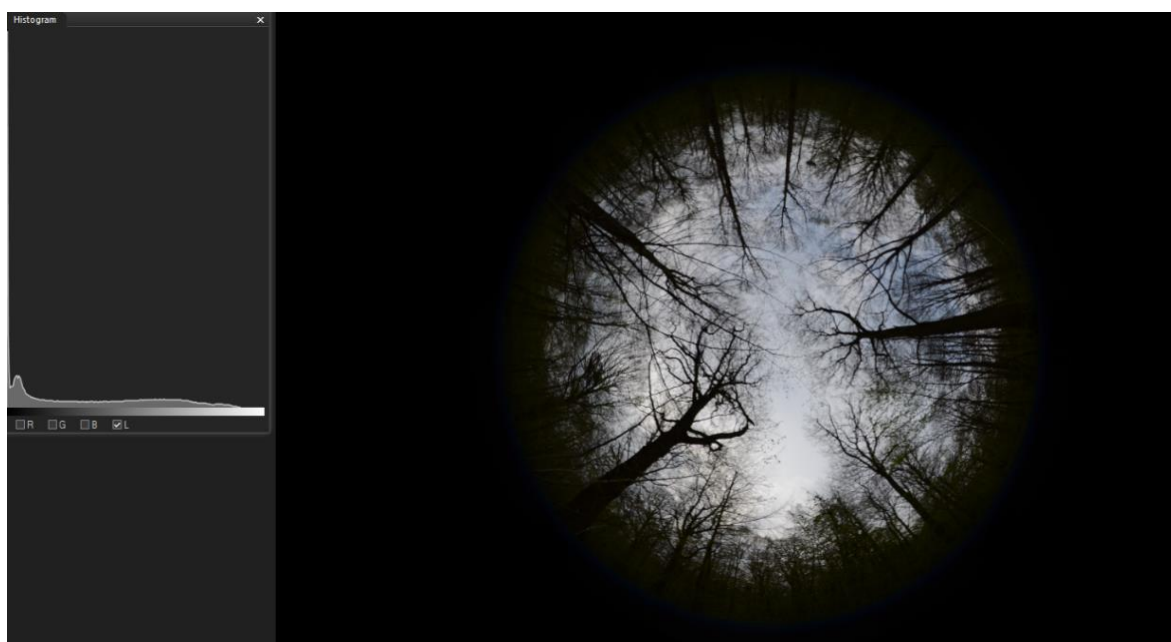


Figure 5b: DHP examples of different lighting conditions. Unsuitable sky condition: There is no overexposure and the light is fairly diffuse (notice the even distribution in the light histogram), yet the contrast between the trees and the blue sky will still be different compared to the white cloud.



Figure 5c: DHP examples of different lighting conditions. Suitable sky condition with incorrect camera setting: There is an entirely grey/white, yet probably very thin cloud cover. With insufficient shutterspeed, this creates overexposure (notice the small peak in the histogram on the right side), which will discard the picture for analysis.

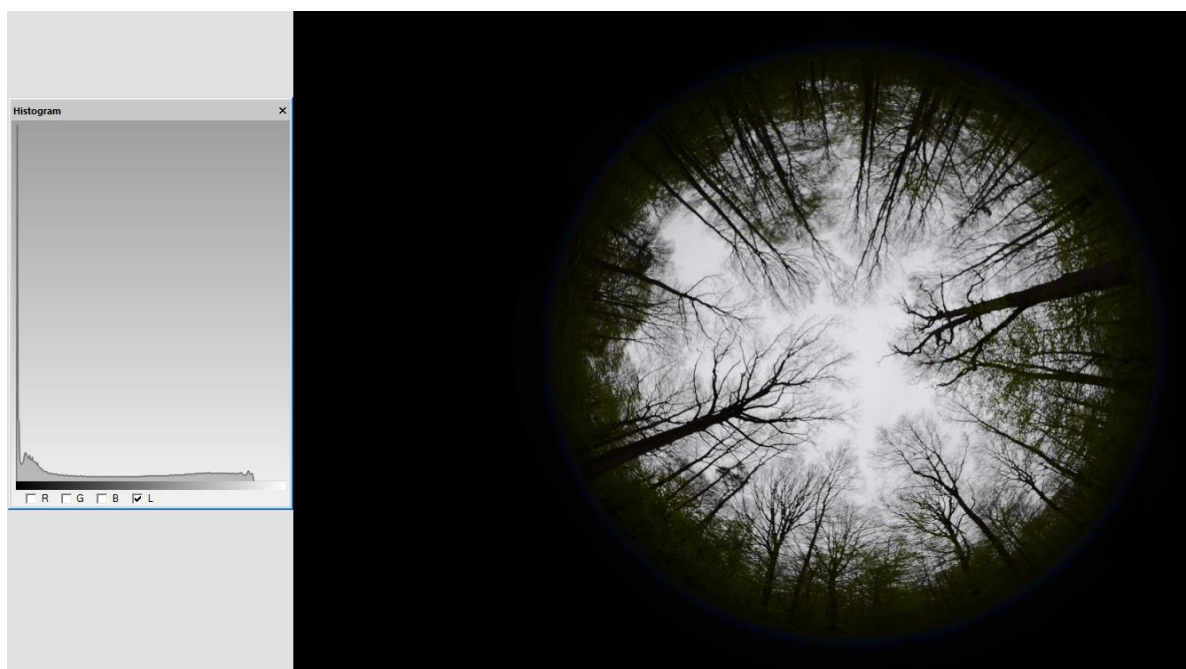


Figure 5d: DHP examples of different lighting conditions. Suitable sky condition with correct camera settings: This is a perfect example.

- In exceptional cases, when overcast days are too scarce, pictures can be taken before sunrise and after sunset, when the sun is hidden behind the horizon and the vegetation is not directly sunlit. Keep in mind that during these times of the day the light environment changes rapidly and camera exposure settings are only valid for a short time. Before starting a campaign in these lighting conditions, the situation should be discussed with the ETC.
- Rain must be avoided, because rain droplets on the lens create blurred images.
- Heavy wind must be avoided, because moving plant elements might cause blurry images, and thus corrupted results.
- Foggy conditions within the canopy have to be avoided.
- Snow on the canopy has to be avoided.

Initial plot setup and installation

- A systematic measuring grid of 9 points has to be installed within each measurement plot (Figure 6). In a standard circular CP the points are 15 meters one from the other with the middle of the systematic grid collocated with the center of the plot (Figure 6a). The four corners of the square have to be at equal distance from the center of the plot, with the upper one facing North. Additional four measurement points might be added in agreement with ETC if the standard error of the GAI within the plot is larger than 5% of the mean. In case of rectangular CPs the points are distributed as shown in Figure 6b with the locations 1, 2 and 6 in the inter-rows (location 1 collocated with the CP center) and the others between the inter-row and the tree lines at the same distances that are reported in the detailed view of Figure 4b. In both cases (circular and rectangular CP) and to avoid interference from stems and trees on the measurements, we advise to move the measurement point away from a tree using the 10° rule that implies that a sampling point should be at a minimum distance of 5.7 times the diameter of the tree (see ceptometer measurements).
- The minimum distance between the lens and a leaf has to be 10 times the length of the leaf. Thus in case a leaf has a length of 10 cm, the minimum distance to the lens has to be 100cm. Leaves that are too close for their size have to be removed.
- When sampling for the first time, mark the measurement location with a wooden/metal stick with a clear tag and determine the final location. Each location must be marked with an ID following the scheme in Figure 6 that will be requested in the data submission.
- Measure the mean slope and slope direction of the CP, considering the full area covered by the ancillary measurements (full area of the CP). The easiest way to do this, is by having one person at the center of the plot holding an inclinometer and one person with a target walking over the perimeter of the plot. Search for the maximum height difference, note

slope (angle in degrees) and direction (aspect in degrees North). In case of complex terrain, please contact the ETC for further instructions.

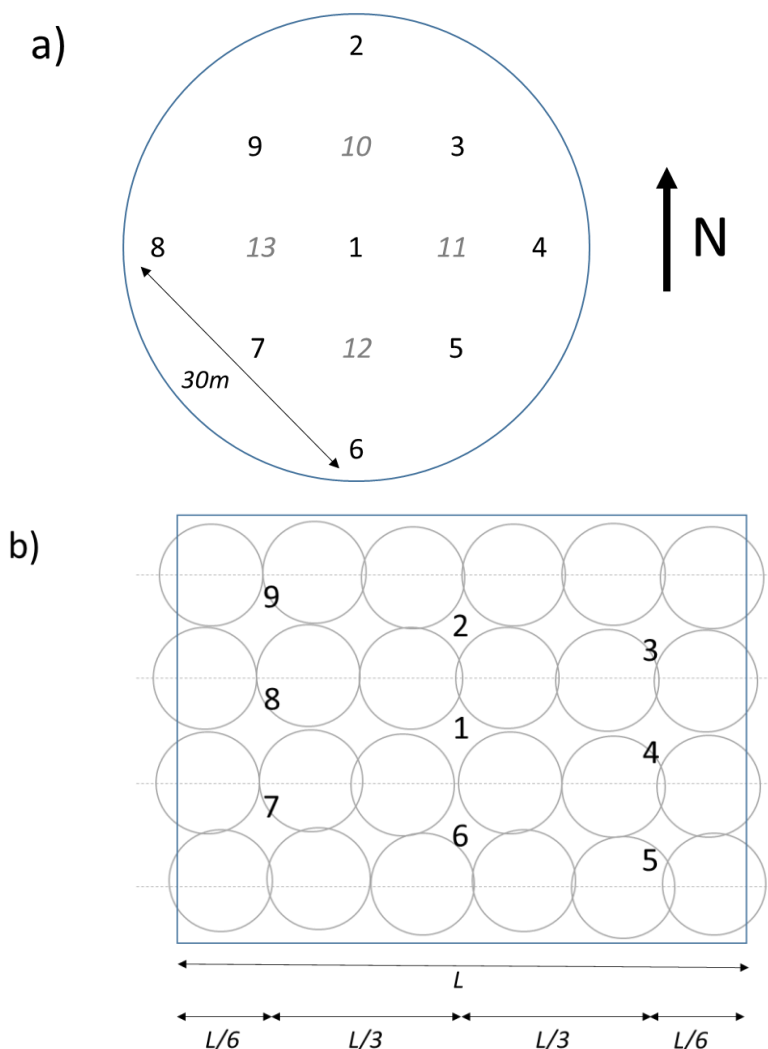


Figure 6: The DHP measurements in one plot with the measuring point nomenclature. a) Standard circular CP. The black numbers represent the mandatory sampling points, while the grey italic numbers represent additional sampling points which can be added in case of a very heterogeneous forest. Orientation is toward true North, not magnetic N. b) Rectangular CP. Numbers represent the sampling points. The distances along the tree line are expressed as a fraction of L , the total length of the CP. The distance between points 3, 4, 5, 7, 8, and 9 and the tree line must be calculated as for the ceptometer (see detailed view in Figure 4b).

Measurement at each point

1. Check the weather and sky conditions (see above).
2. Check the battery status of the camera and check whether a memory card with enough free memory is inserted in the camera.

3. Set the camera to RAW format and to maximum resolution.
4. Set the camera to only record landscape pictures. Check camera manual on how to do this.
5. Check the date and time (Local Standard Time). You can disable daylight saving time in the settings of most cameras.
6. Set the aperture to F8 and the ISO to 200 (in case of moving canopy due to slight wind, increase further up to 1000).
7. Remove not only the lens cap, but also the lens protection ring before mounting the camera on the tripod.
8. Set the lens to autofocus and take care that there are no objects closer than 15cm to avoid wrong focus. In addition, keep in mind the minimum leaf-lens distance of 10 times the leaf length (see above).
9. Install the tripod exactly above the mark of the measurement point.
10. Install the camera facing upwards on the tripod; mounting the camera on a gimbal is recommended.
11. Fix the camera with the lens top at 1.3 m above the ground level.
12. Level the camera using a 3D bubble level so that it points straight up (=level) and the centre of the hemispherical picture corresponds with the zenith. If on sloping terrain, the picture still has to be taken straight up (= level and thus not parallel with the slope) and afterwards the pictures will be corrected for the part of the slope. If in an area of 7.5 meters radius around the camera center the average slope and slope direction is different respect to the CP mean slope/direction, it must be measured and recorded (contact ETC for procedure).
13. Orient the camera such that the magnetic North is on the upside of the camera/picture (location of the flash socket). When using a compass to orient the camera, keep it far enough from electric devices or masses of iron that would deflect the needle.
14. Set the shutter at 1/30 sec or shorter.
15. Take a picture by using a remote control or use the time delay option to avoid blurry pictures.
16. Make sure that neither you nor any removable objects (parked cars, insects,...) are part of the picture.
17. Check the image by using the (pre)view option and check for overexposed pixels (check camera manual on how to do this). Overexposed pixels should be blinking on the screen of the camera. For Nikon cameras you can select the highlight option in the preview menu → playback display options → highlights.

18. In case of overexposure: Adjust the shutter speed and repeat step 10 to 17 until the picture contains no more overexposed pixels.
19. Store the picture in an uncompressed format (.NEF, .CR2, .CRW, .ARW, ...)
20. Measure and record the location of the point respect to the centre of the CP. In the appendix C the nominal positions in case of standard circular CP are reported both as distances E-N and distance-angle.

Note: If a significant understorey of small trees is present (>10% of overstorey GAI), it is possible to discuss with ETC a method to estimate understorey GAI.

Aboveground biomass measurements

Weather conditions

Biomass inventories can be measured under practically any weather conditions, but measurements on frosty days and after a period of severe drought have to be avoided as these conditions may induce considerable radial shrinkage of the stem. The measurements are ideally performed in the dormant season (before the start or after the end of the growing season). Destructive harvesting of the understorey vegetation has to be done when the vegetation is dry.

Overstorey manual measurement of diameter

All trees in the CP with a DBH larger than 5cm have to be numbered and measured. Use of a girthing tape is preferred over the (digital) caliper for measurements on tree stems. A girthing tape measures circumference, integrating stem diameter in all radial directions and eliminating diameter variability caused by direction when the stem shape deviates from circularity. When using a caliper, two measurements have to be taken, perpendicular to each other. The average of the two has to be submitted to the ETC.

Here are the step-by-step guidelines to measure DBH (refer also to Figure 7):

1. Determine the ground level. This is the level where the stem touches the soil. The soil includes the upper layer but not the woody debris that might accumulate above it over time. On sloping terrain, breast height is measured starting from the up-slope of the stem, i.e. the highest point at which the stem meets the ground.
2. Determine the breast height as that at 1.30 m above the ground level, measured along the longitudinal axis of the stem. If breast height falls on a branch or an uncharacteristic bulge, DBH should be measured above and below this point at equal distances from breast height and the average of the two measurements should be the one noted.
3. If a tree forks at or above 1.30 m, consider it as a single tree. If the crotch of the fork falls at 1.3 m, measure DBH just below the fork.
4. If a tree forks below 1.30 m, it is considered as 2 (or more) separate trees. Each branch gets its own tree ID, but to indicate that they share the same root system, you provide them with the same stump ID. Measure DBH and total height (from ground up) of each branch and note as separate trees.
5. If a tree has multiple suckers (e.g. in coppice) measure all of them at 1.30 meter and record that they are coming from the same stump and have the same root system.
6. DBH can be measured with girthing tape, a caliper or calculated from the circumference: Place the girthing tape or measurement tape perpendicular to the central axis of the stem. Make sure the tape is not kinked so as not to bias the measurement. Record DBH to the nearest mm directly from the girthing tape or divide the measured stem circumference by π to get DBH. In case a caliper is used measure two perpendicular diameters and calculate the average. Note that DBH should be reported in the BADM in cm with a 1 mm accuracy.

7. Note the tree species with an accepted full species name according to what is defined and explained in the Instruction for Plant Species Reporting.
8. When sampling for the first time, mark the height on the stem where DBH is measured, label each measured stem with a unique code, and determine the location (see also the Instruction document for Field-Map Instrument).

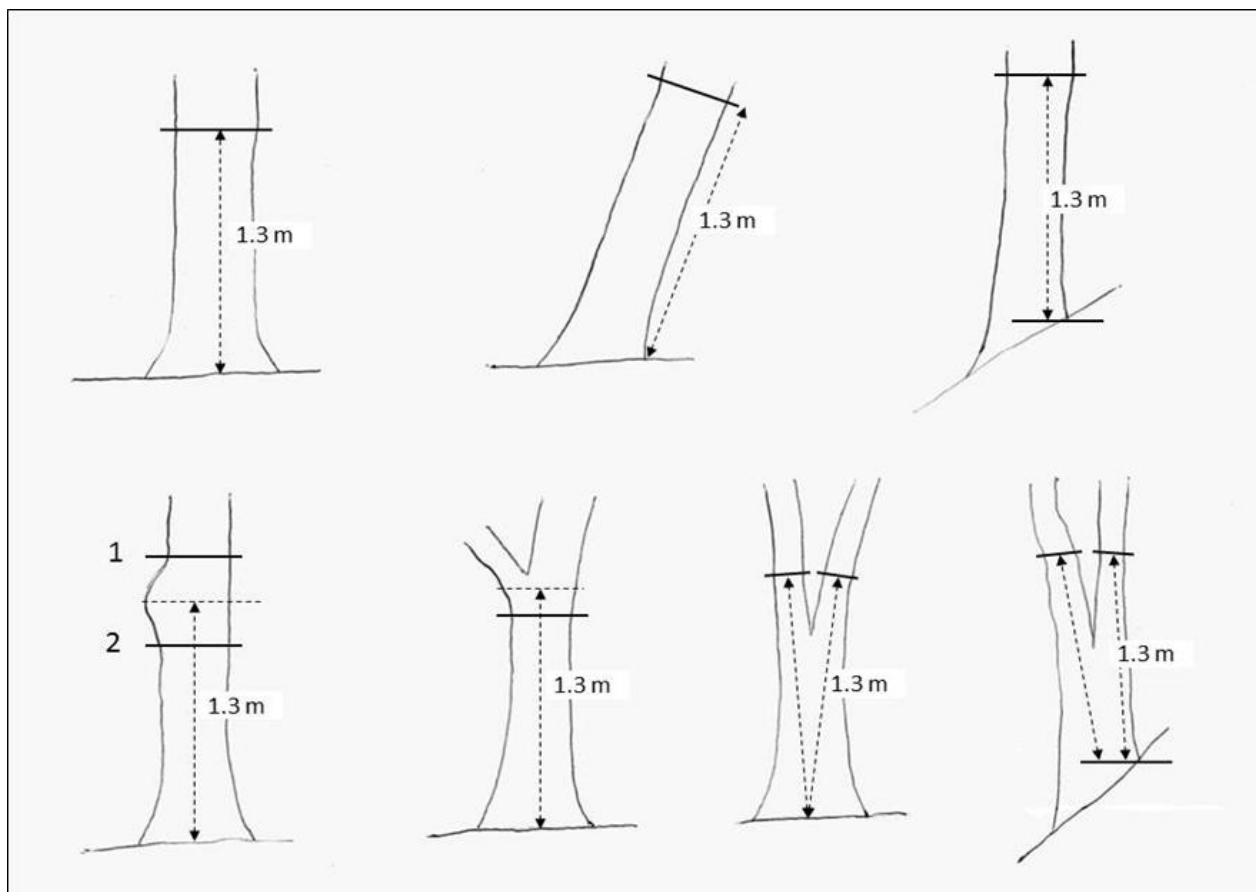


Figure 7: Measuring DBH on a tree

In subsequent samplings, measure DBH at the marked height. Note that 1) if a sampled tree has died, been removed or subject to windthrow between two samplings this must be reported and 2) trees that passed the diameter threshold between two samplings must be added in the sampling (assigning an ID to the tree). The tree health status should be measured during the growing season and noted.

Health status has to be assigned to a tree using one of six categories (healthy, minor diseases, major diseases, dead, fallen or removed) and each category is defined as follows:

- 1) Healthy: no visual indication of the crown being affected by diseases, herbivory, storm damage. Damage is defined by branches that have lost leaves or where leaves have changed color.

- 2) Minor diseases: visual indication of the crown being affected by diseases, herbivory, storm damage. Damage is defined by branches that have lost leaves or where leaves have changed color. The crown is affected by less than 50%.
- 3) Major diseases: visual indication of the crown being affected by diseases, herbivory, storm damage. Damage is defined branches that have lost leaves or where leaves have changed color. The crown is affected by more than 50%, but healthy leaves are still present.
- 4) Dead: the tree contains no more living branches nor leaves.
- 5) Fallen: Use this when the tree that was listed has fallen on the ground and is left there.
- 6) Removed: Use this when the tree that was listed has been removed (harvested).

Trees growing at the edge of the plot are included if they have more than half of DBH within the boundary of the plot.

Overstorey automatic measurement of diameter (mandatory in Class1 stations only)

Please see separate the specific Instruction document on Continuous Tree diameters

Overstorey measurement of tree height

The periodic measurement of tree (shoot) height is also mandatory for every tree that is included in the DBH measurements. Remember that each branch forking below 1.30 m, is considered as a separate tree. Each branch gets its own tree ID, but the same stump ID. Tree (shoot) height is defined as the vertical distance between the highest point of the crown and the ground surface. Tree height is measured with a simple 3 step routine involving measuring horizontal distance and angle to stem base and tree top. Tree height has to be measured from a point where you can see the tree stem, as well as the stem base and (as best as you can) the tree top. This point should be at least as far away from the tree as the tree is high. This is to reduce the error in the measurement of the angle to the tree top (see Fieldmap Instruction document).

Overstorey calculation and allometric relations

In order to calculate total AGB from tree diameters and heights it is needed to use site specific allometric relations. The procedure to establish an allometric relation or to evaluate if an existing allometric relations can be used, is described in Appendix B.

Understorey

The aboveground biomass of saplings with a diameter of less than 5 cm diameter are not measured within the AGB measurements of the overstorey and they have to be included in the understorey, together with the herbaceous vegetation and shrubs.

AGB of the understorey vegetation has to be measured by destructively sampling (herbaceous vegetation and shrubs) and by allometric relations (saplings). This is done in five predefined 1 x 1 m plots for the saplings (non-destructive) with a nested design of one 0.25m x 0.25m plot within each 1 x 1m plot for the herbaceous vegetation and shrubs (destructively), all within each CP. The center location of the plots within each CP will be randomly assigned by the ETC. See Figure 8.

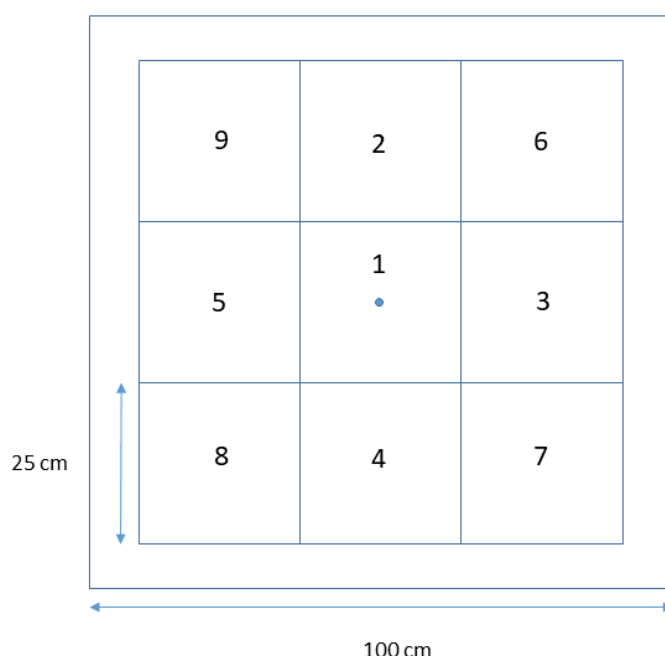


Figure 8: Sampling design for the understorey plots. The dot in the middle is the position received from the ETC. You receive five per CP. This is a nested sampling design where non-destructive measurements of the saplings are repeated every year within the same 1x1 m plot and the destructive measurements for herbaceous measurements and shrubs are performed every year in another one of the 0.25 x 0.25 m plots. Each number represents a sampling date/year for the destructive sampling (herbaceous vegetation and shrubs).

Saplings

The aboveground biomass of saplings has to be measured non-destructively using allometric relations. These allometric relations need to be established on plants that are harvested outside the CP before reporting understorey AGB via the BADM to ETC. A detailed description on how to do this can be found in appendix B.

Once allometric relations for saplings have been established, the diameters of all saplings are measured within the 5 predefined 1 x 1 m plots within each CP as follows:

1. Determine the ground level. This is the level where the stem touches the soil. The soil includes the upper duff layer but not woody debris that might accumulate above it over time.
2. Determine the circumference or diameter of the main stem at 5 cm above the ground level with a caliper or a girth tape. Record the value to the nearest mm.
3. Determine height of the sapling with a girth tape if it is needed for the allometric relation. Record the value to the nearest mm.
4. Use the allometric relations you calculated with Appendix B outside the plots to determine AGB for each sapling.
5. Sum the AGB per species per location.
6. Note the species with an accepted full species name according to what is defined in the Instruction on Plant Species Reporting
7. Use the GRP_AGB BADM to report the AGB per species and location in gDM/m² rounded to 1 gram or with a minimum accuracy of at least 1% of the measured value. Do not forget to add the area (1m²) and the plant type (Sapling).

Herbaceous vegetation and shrubs

The aboveground biomass of the herbaceous understorey vegetation and shrubs is measured by destructively sampling in one predefined harvest plot of 0.25 x 0.25 m within each 1x1m plot. The measurement requires two steps, one in the field and one in the lab.

In the field it is needed to:

1. Take all aboveground plant material of those plants that are rooted within the harvest plot. This means, if plant parts 'spill over' in other plots, you also take them for measurements. However, if other parts are in the current harvesting plot, but the root of that plant are in another plot, you leave them.
2. Separate green from senesced plant material.
3. Separate by plant type, if relevant: Herbs - Ferns – Moss - Shrub.
4. Put the green plant material in separate airtight bags and transport the material to the lab. Avoid the loss of moisture of the plant material between cutting and lab measurements as much as possible. Transporting the material in a cooled container is good practice.
5. [can be done also in the lab] In case of large quantities of harvested material, select a subsample from the green material per plant type and determine the fresh weight of each

subsample with a weighing scale and record to the nearest 1/10 of a gram or with a minimum accuracy of at least 1% of the measured value. The smallest of both.

Once back in the laboratory, these are the steps needed:

1. [if not done in the field] In case of large quantities of harvested material, select a subsample from the green material per plant type and determine the fresh weight of each subsample. Record the weight to the nearest 1/10 of a gram or a minimum accuracy of at least 1% of the measured value. The smallest of both.
2. Put the green (sub)sample material in separate paper bags and dry in a drying oven at 70°C until a constant weight is achieved. Usually 24-48 hours of drying suffices.
3. Place the dry material in a desiccator to let cool.
4. Determine the dry weight of each (sub)sample with a weighing scale and record to the nearest 1/10 of a gram or with a minimum accuracy of at least 1% of the measured value. The smallest of both.
5. In case of subsamples, calculate the dry weight of the total green material per plant type based on the ratio of dry weight to fresh weight of the subsample. Record to the nearest 1/10 of a gram or with a minimum accuracy of at least 1% of the measured value. The smallest of both.
6. Determine the dry weight of the senesced plant material per plant type with a weighing scale and record to the nearest 1/10 of a gram or with a minimum accuracy of at least 1% of the measured value. The smallest of both.
7. Report both green and non-green dry weight per plant type and location in gDM/m² rounded to 0.1g or with a minimum accuracy of at least 1% of the measured value. The smallest of both.
8. Use the GRP_AGB BADM to report the AGB per Phenological status (Green or Not Green), plant type (Herb - Ferns – Moss – Shrub) and location in gDM/m² rounded to 0.1 gram or with a minimum accuracy of at least 1% of the measured value. The smallest of both. Do not forget to scale the measured value to square meter and add the actual area (0.0625m²) using the AGB_AREA variable. If no understory of a certain type is found in a plot, please submit zero. This way, we know AGB was 'measured' but no understory was present.

Alternative understorey measurements for mosses

In certain situations, understorey moss samplings can be performed with less intensive, indirect measurements of yearly moss growth using the brush wire method, which is used in ICOS mires as well. Contact ETC to determine method (destructive or brush wire) for mosses in your site.

The following section describes the Brush wire method. At the start of the growing season:

1. Install three brush wires in the moss layer at each 1 m² location in each of the CPs. At each location, install the three wires randomly inside one 0.25x 0.25m subplot

Installation of a wire goes as follows (Figure 9):

- Insert the brush end of the wire into a small tube.
- Push it circa 4-5 cm into the moss carpet.
- Withdraw the tube, allowing the brush bristles to expand and lock the wire position.
- Place a piece of colored drinking straw on the wire to easily find it later.

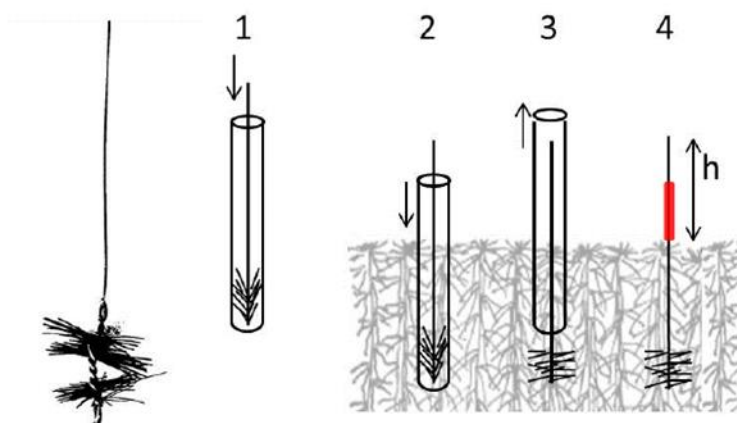


Figure 9: Installation of the brush wires. Figure copied without formal permission from Rydin and Jeglum (2013) *The Biology of Peatlands*, 2nd edition.

2. For each installed brush wire, measure the distance of the moss carpet surface to the tip of the brush (h; Figure 10a). Measure with a ruler to the nearest mm. In case of a flat uniform moss carpet, the distance can be measured on either side of the wire (Figure 10a and b). In case a few shoots on one side have grown abnormally fast, they should not be used to estimate the height. Instead, measure on the other side of the wire (Figure 10c).

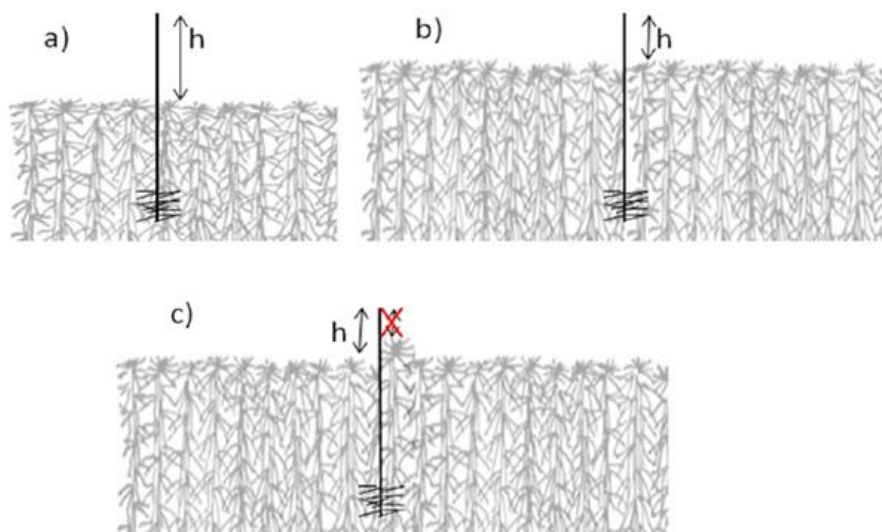


Figure 10: Measuring moss length growth with the brush wire. See main text for explanation. Figure copied with permission from Granath, G. and Rydin, H. (2013) "The Global Sphagnum Production (GSP) Project: methods and protocol - working document."

At the end of the growing season:

1. For each installed brush wire, measure again the distance of the moss carpet surface to the tip of the brush (h ; Figure 10a,c). Then derive for each brush wire the height increment over the growing season. Calculate for each location the average height increment of the moss carpet from the three wire measurements ($\langle h \rangle_{loc}$).
2. Harvest at each location one 10 x 10 cm block of moss that is more-or-less as thick as the height increment of the moss carpet at that location. Determine the thickness of the moss block to the nearest mm (d_{block}). Then dry the blocks of moss until constant dry mass. There is no need to separate between species or between green and non-green. Determine the dry mass of each block (DM_{block}).
3. Calculate for each block the dry mass per m^2 area and per mm thickness ($DM_{block} * 100 / d_{block}$). Calculate the average value of the five blocks per CP ($\langle DM_{block} \rangle_{CP}$).
4. For each location, calculate the moss biomass increment from (i) the CP value for the dry mass per m^2 area and per mm thickness and (ii) the average height increment at that location:

$$AGB_NPP_Moss = \langle DM_{block} \rangle_{CP} * \langle h \rangle_{loc}$$

5. Report this biomass increment to ETC using the AGB_BADM (enter value per location in AGB_NPP_Moss). Report value rounded to 0.1 g/m^2 or with a minimum accuracy of at least 1% of the measured value. The smallest of both.

It is not needed to repeat steps 2-3 every year to determine dry mass per volume. The frequency will be discussed between the ETC and the PI, depending on the productivity of the moss layer.

Litter biomass measurements

Weather conditions

Litter should preferably be collected in dry weather conditions.

Non-woody litter biomass (leaves and fruits)

Non-woody litter biomass is measured using litter traps that are installed in each CP.

For circular CPs a minimum of 5 locations must be used, positioned in a crosslike design (Figure 11), where the distance between the litter traps on the axis is 20m and where the central litter trap coincides with the centre of the CP. There is the possibility to add 4 additional traps located exactly in between the already placed litter traps (distance is 10m). The ETC will evaluate the need for this additional installation after the first year of measurements.

In case of rectangular CPs, a total of 9 litter traps must be used and locations must be the same as defined for the DHP (see Figure 6b and text related).

Locations of all the litter traps must be recorded (relative to the center of the plot) and provided to the ETC via the litter BADM together with the first litter data. This should be repeated whenever the location of the traps change. In appendix C, the default positions relative to the center of the plot for standard circular CPs are provided both as distances E-N and distance-angle. In case there is an object (e.g. a tree) at exactly the same position as the litter trap, the trap should be moved 2 m North of the tree.

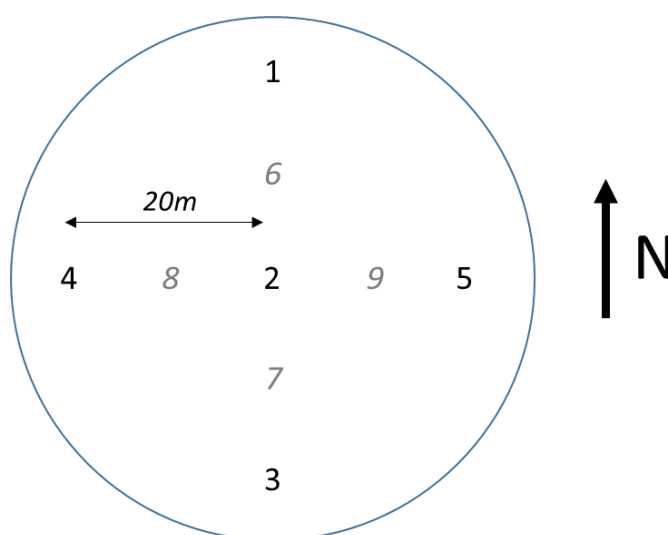


Figure 11: The location of the litter traps in one CP plot. Orientation is toward true North, not magnetic.

The measurement requires a step in the field and additional activities in the laboratory.

In the field it is needed to collect all the material from each litter trap in separate bags. Make sure the bag contains the ID from the litter trap and the ID of the CP. Remove all branches with a

diameter > 2cm from the collected material. Note that the litter traps with ID = 2 will be used for detailed measurements as described below.

Once back in the laboratory the steps needed are as follows:

1. Empty the bags and separate the litter into the four different fractions (twigs < 2cm, leaves, fruits, flowers). This is done in order to detect mast years.
2. Leaves and needles should be separated per species. In case of mixed forest, contact the ETC to determine sampling strategy and species to consider.
3. Litter traps with ID=2¹ of each CP. Once a year, after the start of the litter production, measure the area of all the leaves collected (per species). This is needed in order to calculate the Leaf Area Index based on litterfall and LMA. The area includes the petioles and should be determined as in the Instruction on Foliar Sampling (only methods to measure the full leaf area). In case of large sample size, one can discuss subsampling with the ETC. Report the leaf area of all leaves (per species) in the trap in cm².
4. Put the material in paper bags and dry in an oven at 70°C until a constant weight is achieved. Usually 24-48 hours of drying is sufficient. Keep the material separated by fractions and species (see point 1). Keep the leaves separated for the litter trap with ID=2.
5. Determine the dry weight of all fractions (for leaves and needles per species). All weights must be recorded at the 1/10 of a gram. Note that the litter value should be reported per trap in the BADM in gDM/m² (so scaled to area of one square meter) rounded to 0.1g or with a minimum accuracy of at least 1% of the measured value. The smallest of both. If no litter of a certain type is found in a trap, please submit zero. This way, we know litter was 'measured' but certain type was not present.

Fine woody debris (>2cm & <10cm)

The measurement of fine woody litter requires two activities as well, one in the field and one in the lab. In the field:

1. Mark a 1 by 1m area 3 meters East of the litter trap with ID 1 with a rope or with a frame. If the area is impossible to use (e.g. a tree is inside) then mark it 3 meters West of litter trap with ID 1.
2. Collect all the woody material in the 1 by 1m area with a diameter between 2 and 10 cm in bags. Make sure the bag contains the ID from the plot. In case a branch is lying partially inside and partially outside collect or consider only the portion inside the marked area
3. Mark the contours of the sample area so that it can be resampled at each measurement date.

¹ In case of a heterogeneous forest where traps with ID 2 are not representative for the plots, another trap ID can be selected instead. This is done only after discussion with ETC.

Once in the lab the steps are:

1. Empty the bags and keep collected material from the different plots separated.
2. Put the material in paper bags and dry in an oven at 70°C until a constant weight is achieved.
3. Determine the dry weight and record to the nearest gram. Note that the litter value per plot should be reported in the BADM in gDM/m² rounded to 1g. If no fine woody litter is found in a plot, please submit zero. This way, we know it was 'measured' but not present.

Note that at the beginning of the operations what is measured is a stock and this is part of the site characterization. After this, revisiting the measurement locations will give an estimate of the fine woody debris litter fall.

Coarse woody debris (>10cm)

Coarse woody litter is measured directly in the field:

1. Take a rope and mark three transects from the center of the permanent plot to the edge of the plot (25,24m), separated by 120° (Y-shape) with one oriented toward North.
2. Measure the diameters and length of all woody material with a diameter larger than 10cm that crosses the line of each transect. Note the diameter in cm rounded to 0.1 cm and length in meter rounded to 0.01 m. In the BADM, add the angle of the transect (0,120 or 240) in the Litter_ID field as '1' for 0°, '2' for 120° and '3' for 240°. In case no coarse woody debris is found on a specific transect or plot enter zero as litter_course_length value for that transect or plot.
3. In addition measure the angle between the rope and the woody material (branch, trunk etc.). The angle should be between 0° and 90°, zero when the branch lies exactly on the transect line and 90 degrees for a branch orthogonal to the rope.
4. Note the decay class for each of the woody parts following Maser et al. (1979) and Sollins (1982) as reported in Table 1.

Table 1: Different decay classes for coarse woody debris (after Maser et al. 1979, Sollins 1982)

Decay class	Structural integrity	Texture of rotten portions	Color of wood	Invading roots	Branches and twigs
1	Sound, freshly fallen, intact logs	Intact, no rot; conks of stem decay absent	Original color	Absent	If branches are present, fine twigs are still attached and have tight bark
2	Sound	Mostly intact; soft (starting to decay) but can't be pulled apart by hand	Original color	Absent	If branches are present, many fine twigs are gone; those remaining have peeling bark
3	Heartwood sound; piece supports its own weight	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish brown or original color	Sapwood only	Branch stubs will not pull out
4	Heartwood rotten; piece does not support its own weight, but maintains its shape	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Through-out	Branch stubs pull out
5	None, piece no longer maintains its shape, it spread out on the ground	Soft; powdery when dry	Red-brown to dark brown	Through-out	Branch stubs and pitch pockets have usually rotted down

MAINTENANCE

Sensor maintenance

Ceptometer: Check the dessicant of the external PAR sensor and the probe. Replace if needed.

Sensor calibration

The external PAR sensor of the ceptometer requires periodic calibration as its sensitivity is likely to shift over time. It should be sent to the manufacturer every few years for recalibration against a factory standard. Check your instrument's User Manual.

For the Digital Hemispherical Photography a calibration procedure is needed. Appendix A provides an explanation on how to perform the calibration.

Sensor repair and substitutions

Ceptometer: a new sensor should replace malfunctioning or broken PAR sensors. Probes with one or more malfunctioning photodiodes should be sent to the factory for repair.

Digital Hemispherical Photography: broken lens or camera should be replaced and the calibration should be repeated before new camera and/or lens are used for measurements.

SUBMISSION

Ceptometer measurements

Ceptometer measurements are submitted in the form of the raw txt output files that are produced by the instrument. All the information about the file naming convention and structure is provided in the relevant instrument Instructions documents. The files are submitted as soon as possible after each measurement date using the ETC interface.

Digital Hemispherical Pictures

The pictures have to be uploaded maximum two days after the field measurements one by one or in a zip-file via the PI area: <http://www.icos-etc.eu/icos/pi-area/>

The calibration parameters and metadata have to be uploaded by using the BADM system, either the standard file or the online tool. The BADM file includes the camera and lens used and defines the setup. Each setup receives an identification ID that is used in naming the picture file.

Each DHP should be named using the following structure:

CC-###_DHP_\$\$_&&XX_L%%_YYYYMMDD.zzz

where:

- CC-### is the official station code (case sensitive)
- \$\$_ is the camera/lens setup identification ID (DHP_ID in the BADM)
- && is the type of plot where the DHP are collected (either CP or SP)
- XX is CP or SP number (from 01 to 20 for the SP)
- %% is the location ID inside the plot following the numbering (from 01 to 13).
- YYYYMMDD is the time stamp indicating the day of the picture collection
- .zzz is the file extension (raw images only).

For example the picture collected on August 24th 2017 at BE-Bra in the CP number 1 in location 4 with a combination camera/lens reported as setup number 1 (DHP_ID = 1) and a Canon camera (raw data extension .CR2) will have the name:

BE-Bra_DHP_S1_CP01_L04_20170824.CR2

Automatic dendrometer

Automatic dendrometers are treated as continuous variables and for this reason their submission follows the rules and methods described in the specific Instruction document.

Other data and metadata

All the other data, including metadata and description for DHP and ceptometer measurements, must be submitted using the BADM system either the standard file or the online tool. The BADM variables include the metadata related to the GAI measurements, the Tree species and characteristics, the AGB of the understorey, the Litter components and the DHP system characteristics.

The GAI metadata are submitted using the “ICOSBADM_GAI” (group GAI and CEPT) and “ICOSBADM_DHP” and in particular:

- The variables of the CEPT group to report the parameter of the SUNSCAN ceptometer if used for GAI measurements.
- The variables of the DHP group to report the parameters and characteristics, including the ID of the setup used to take the hemispherical photos.
- The variables of the GAI group to report the information of the plots where DHP or ceptometer are used (variables that can be used for forest are GAI_PLOT, GAI_DHP_ID, GAI_DHP_EASTWARD_DIST, GAI_DHP_NORTHWARD_DIST, GAI_DHP_DISTANCE_POLAR, GAI_DHP_ANGLE_POLAR, GAI_DHP_SLOPE, GAI_DHP_ASPECT, GAI_COMMENT, GAI_DATE)

The AGB metadata and measurements (understorey) and the tree positions and characteristics are submitted using the “ICOSBADM_AGB” (group AGB) and the “ICOSBADM_Tree”:

- The variables of the TREE group are used to report the tree positions, species, diameter, height, health status. These variables can also be collected and submitted using the Field Map (see the relative Instruction document)
- The variables of the AGB group can be used to report the understorey biomass (variables available for forest are AGB_PLOT, AGB_LOCATION, AGB_AREA, AGB, AGB_PHEN, AGB_SPP, AGB_PTYPE, AGB_COMMENT, AGB_DATE)

The litter metadata and measurements are submitted using the “ICOSBADM_Litter” (group LITTER) and in particular:

- The variables include the information on the location where litter is measured, the value and the characteristics of the material, including the specific variables of the litter trap with ID=2 (variables available for forest are LITTER_PLOT, LITTER_ID, LITTER_AREA, LITTER_EASTWARD_DIST, LITTER_NORTHWARD_DIST, LITTER_DISTANCE_POLAR, LITTER_ANGLE_POLAR, LITTER_TYPE, LITTER_FRACTION, LITTER_SPP, LITTER, LITTER_LEAVESAREA, LITTER_COARSE_DIAM, LITTER_COARSE LENGHT, LITTER_COARSE_ANGLE, LITTER_COARSE_DECAY, LITTER_COMMENT, LITTER_DATE)

For more information about the variables refer to the Explanations sheet of the templates. For info about how to submit BADM variables refer to the Instruction on Using BADM.

APPENDIX A: Calibration of the Hemispherical Camera

The processing of the digital hemispherical pictures requires five parameters. Two parameters are related to the projection function of the lens, and are thus only lens specific. The three remaining parameters, the two coordinates of the optical center and the maximum radius, are related to the projection of the lens on the sensor of the camera, and are thus unique for every lens/camera combination. Below are all the instructions on how to determine or define the parameters.

Determine the optical center of the camera-lens combination

The optical center must be determined for each camera-lens combination. In order to determine the lens center, prick four very little holes in the lens cap along one radius (avoiding the center of the cap) and use pictures of the holes turned 8 times, each time for about 45 degrees starting from the vertical position (Figure A1 top). The pictures have to be taken pointing towards a diffuse light source to obtain a good contrast (Figure A1 bottom). Please avoid direct light because this could project the holes on a different position on the CCD.

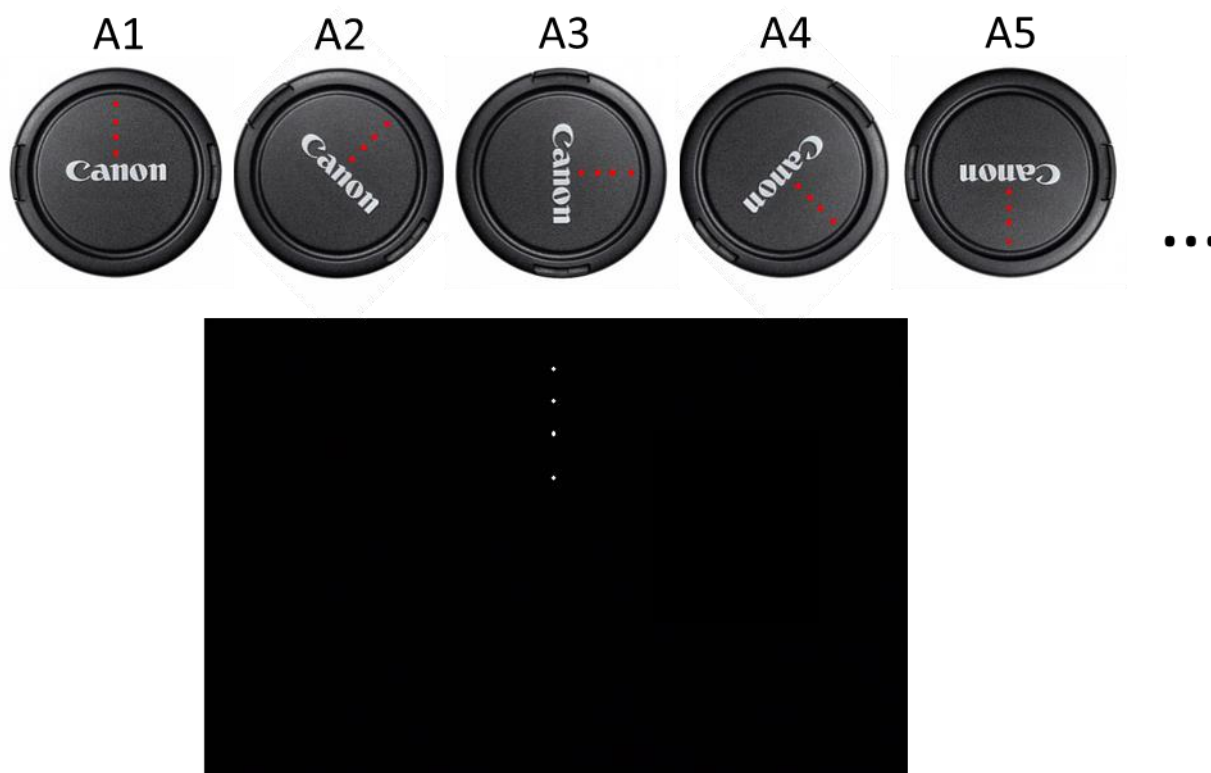


Figure A1: Optical center determination: the lens cap with the four holes is rotated 8 times (top, first 5 positions) and for each position a picture pointing a diffuse light is collected. The image coordinates (row and column) of each point must then be measured (bottom).

The center can be calculated using the executable tool provided by the ETC (dhpocc.exe, available on the ETC website together with the Instruction on Ancillary Vegetation Measurements in Forest and in Fileshare). It is needed to measure the position (row and column) of the center of each impressed point of the 8 images collected (for a total of 32 points, 4 points for each of the 8 angular positions). The row and columns of each point can easily be measured using simple image processing software considering the origin top-left (e.g. in Paint, simply place the mouse pointer on the point and read the row and column coordinates of the pointer, which are displayed in the corner of the screen). The 32 coordinates (row and column) must be reported in a .csv file with one header line reporting ANGLE,POINT,ROW,COLUMN. An example of the input file to use as template is provided with the executable tool. Note that the maximum uncertainty allowed in the optical center coordinates is 10 pixels; the tool calculates the uncertainty and provides warning messages. In this case it is needed to perform the characterization again.

Determine the maximum radius of the camera-lens combination

Defining the maximum radius is fairly easy. One should take 3 pictures in an open field (parking lot, meadow, ...) on a tripod and level (similar as taking a picture in the forest for GAI) with a minimum of objects blocking the horizon. Make sure to also remove the lens ring.

Open the picture(s) in paint.net, Matlab or any other image processing software. Note the highest and lowest pixel value of the circular view both vertically as horizontally. Deduct the minimum value from the maximum value in each direction and divide the result (diameter) by two to get the radius. For each picture, you calculate two radii this way (one horizontally and one vertically).

Take the average of the six measurements (2 times 3 pictures) to report as maximum radius.

Determine the projection function of the lens

The parameters of the projection function are linked to the lens brand and model. For all the lenses reported in the BADM (DHP_LENS variable and LIST(LENS)) these have been calculated and are available for the ETC.

For this reason, when using a lens already included in the LIST(LENS) (e.g. the Sigma 4.5 lens), there is no need to take any action, just report the lens parameters correctly when completing the BADM (GRP_DHP).

If the lens you are using is not yet included in the BADM LIST it is needed to estimate the parameters with the instructions belows.

The lens projection function maps the view angle θ of the scene to the polar distance p to the center. The view angle θ lies in the interval $[0, \pi/2]$. The polar distance can be assumed to lie in an interval between $[0, 1]$ for a generic lens projection function, and can then be multiplied by the maximum radius pixels of the specific camera setup. The calibration expects the function for the actual pixels, so multiplied by the maximum radius.

The calculations of these parameters is an important step for correct calculation of LAI. In case the following procedure is unclear, please don't hesitate to contact the ETC, they will provide support and help with the parameters estimation.

Before you start:

- If your lens has a variable focal length, make sure to use the same focal length (no zoom) for the calibration as for the actual DHP.
- Make sure you take the pictures at maximum resolution (same in calibration as in actual DHP campaigns).
- Remove the lens ring before taking the pictures as we need the full 180° field of view for correct calibration.

Preparing the setup:

- The experimental design consists of a square frame of 50*50 cm or 100*100 cm, about a 1.5 cm thick, with one side removed. The tree sides are on the inside equipped with rulers of 50 or 100 cm (depending on the size of your frame).
- Both camera and the experimental design should be set horizontally.
- The camera should be aligned along the main axis of the design using a front nail and a background line: Put a nail in the middle of the frame, make sure it stands straight. Add a background line a few meters behind the setup. Make sure this line is perfectly vertical and placed in the middle of the frame. When taking the pictures make sure to align the nail with the background line in your camera lens. Try to align this with the vertical diameter of your lens.
- The height of the camera should be the same as the frame. Try to align the top of the frame with the horizontal diameter of the lens.
- Where the nail touches the frame should be more or less the centre of your picture.

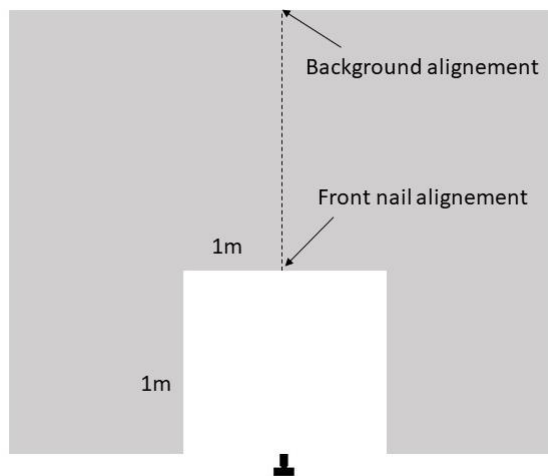


Figure A2: experimental design setup

Pictures collection and submission to ETC:

- Place the camera in such a way that the distance from the nail to the lens is 100 cm in one picture and 80 cm in the second.
- Email the ETC the 2 pictures to the ETC. Name the pictures according the following convention

CC-###_PRJ_S\$_ddd.zzz

where:

CC-### is the official station code (case sensitive)

\$ is the camera/lens setup identification ID (DHP_ID in the BADM)

dd is the distance from the nail (in cm)

.zzz is the file extension (raw images only).

It is important to also calculate the maximum radius and the optical center of your lens-camera combination and submit these values to the ETC via the BADM (follow the instructions above). The ETC needs these values to calculate the projection function.

APPENDIX B: Allometric relations

Tree wood and foliage biomass (AGB) can be derived from diameter measurements. To be able to do this, one needs to establish allometric relations. Existing allometric relations can be used to determine biomass only if the following criteria are met:

1. Mean annual temperature within 2°C of the research site
2. Mean annual precipitation within 200mm of the research site
3. Similar soil type (according to FAO)
4. Age class within 30 year range of the mean stand age at the ICOS station

If no allometric relations are available yet for the correct conditions, these must be determined destructively. The following paragraphs will show you how to do this:

Sensors and Material needed

- Measurement tapes (50m)
- Sample bags
- Chainsaw or handsaw
- Labels
- Canvas
- Solid flat base for balance
- Caliper
- A drying oven
- An electronic balance with a measurement precision of at least 0.1 g or 5% of sample weight, the smallest of both.

Procedure

Allometric relations allow us to estimate AGB from the diameter at breast height solely or in combination with tree height. Therefore, it is important to obtain site-specific allometric relations since the environmental conditions could alter the morphology of trees. Allometric relations should be established every 10 years at class one sites. However, allometric relations can change after management actions, like thinning or pruning. Therefore, after management, new relations should be established (to be discussed with ETC).

Tree selection

The DBH classes of the trees that are sampled should be representative of the trees in the forest stand, as measured within the permanent plots. Trees within each size class should be chosen randomly. A reasonable number to use is about 5 classes with a minimum of 1 tree per class. The number could be modified after assessing the site-specific fit. Trees for each class should be sampled randomly and possible causes for bias should be avoided, like selecting trees along a major road. For obvious reasons, trees cannot be selected from the permanent plots. We recommend the selection of trees from a neighbouring stand that is similar in structure to the permanent plots. The destructive measurements should be performed at peak GAI, since leave biomass should also be measured.

Measurements for trees

It is necessary to carefully choose representative subsamples of appropriate size from each of the biomass components.

1. Measure DBH and tree height
2. Remove branches from stems and leaves from branches and twigs
3. Separate the tree into its components: stem, branches and leaves
4. Collect leaves in large tarred bags and weigh fresh weight
5. Mix the leaves and take a subsample of about 100g and determine the fresh weight and store in labelled sample bags
6. Bundle up smaller branches and determine their fresh weight
7. Cut up to 4 small disks from branches amounting to about max 500g, determine their fresh weight and store in labelled sample bags
8. Cut stem into largest possible portions (determine by capacity of the scales)
9. Measure with the caliper (2x cross-wise) the diameter at the lower end and the length of the piece with measuring tape of each portion of the stem or branch that will be cut by chainsaw
10. Determine the fresh weight of the stem pieces. Note that the fewer pieces there are, the smaller is the error.
11. Take 2-3 disks (and if too large, radial sections of the disks) as subsamples amounting to about 0.2% of the total stem fresh weight, determine their exact fresh weight and store in a labelled sample bag

12. Place the subsamples in the oven (105°C) and allow to dry for at least 24hours. Discriminate between woody and non woody pieces (24h for non woody and 48h for woody)
13. Reweigh the sample every 24h and make sure the weight did not reduce by more than 2%, otherwise put the samples back into the oven and repeat the procedure
14. Calculate the dry weight of the samples based on the total fresh weight and the 'dry weight to fresh weight' ratio of the subsamples.

In case the stem is too heavy to weigh in the field the following alternative method can be used:

1. Measure the length and the diameter of the stem every two meters over the entire length.
2. Take four wood cores of the stem for each of these 2 meters stem sections
3. Determine the wood core volume and dry them at 105°C for at least 24h.
4. Weigh the dried wood cores and calculate the wood density (dry mass of core divided by its volume)
5. Calculate the total volume of the stems from the length and the diameter measurements
6. Estimate the total dry weight of the stem by multiplying the wood density with the volume of the stem.

Measurements for saplings

Allometric relations for saplings should be established once during the first measurement campaign. For obvious reasons saplings cannot be selected from the permanent plots. We recommend the selection from a neighbouring stand that is similar in structure to the permanent plots.

It is necessary to carefully choose representative samples of appropriate size. Select 5 saplings per species, covering the diameter range of the saplings.

1. Measure diameter at 5 cm and sapling height.
2. Weigh the fresh samples.
3. Place the samples in the oven (105°C) and allow to dry for at least 24hours.
4. Reweigh the sample every 24h and make sure the weight did not reduce by more than 2%, otherwise put the samples back into the oven and repeat the procedure.

Allometric relations:

To estimate the aboveground biomass in forests in a non-destructive way, allometric relations are mostly used. These relations are established between more easily measured variables (DBH, height, diameter at root collar, etc) and biomass fractions or total tree or shrubs biomass. Within the following paragraph, we describe how allometric relations should be determined at ICOS stations:

All functions for allometric equations can be used. However, here are some of the most common used equations:

$$AGB_x = aD^b \quad (\text{Eq A1})$$

$$AGB_x = a + D^b \quad (\text{Eq A2})$$

$$AGB_x = a + b D^c \quad (\text{Eq A3})$$

$$AGB_x = a(D^b H^c) \quad (\text{Eq A4})$$

$$AGB_x = a + b(D^c H^d) \quad (\text{Eq A5})$$

Where D is either DBH, diameter at breastheight for trees (130cm), or diameter at 5cm for saplings, H is tree or saplings height and AGB_x is the total above ground biomass or the respective aboveground biomass component (leaves, branches and stem). For saplings, no AGB components are considered, only total AGB. The parameters and equation with the best fit (R^2) should be selected and locally stored for further use.

For trees, the information from those trees used to calculate the allometric relations (DBH, height, biomass of parts etc.) should be reported through the allometric relations BADM.

For saplings, the resulting allometric relation should be used to calculate AGB of the saplings in the subplots as explained in the understorey section. The allometric relation itself should not be reported to ETC, nor the information from the saplings used to determine the allometric relation.

APPENDIX C: Standard locations of ceptometer, DHP and litter traps in a circular CP

The position of each DHP, ceptometer and litter trap location inside all the CPs must be measured and reported. In order to facilitate the identification of the initial design (that can be modified for the specific cases reported in the Instruction), the tables below report the locations, expressed as East-North distances and as distance and angle in respect to the CP center, for each measurement location. Each location should either be reported with EAST-NORTH values or by DIST-ANGLE values.

DHP Locations

ID	EAST (m)	NORTH (m)	DIST (m)	ANGLE (deg N)
1	0.00	0.00	0.00	0.00
2	0.00	21.21	21.21	0.00
3	10.61	10.61	15.00	45.00
4	21.21	0.00	21.21	90.00
5	10.61	-10.61	15.00	135.00
6	0.00	-21.21	21.21	180.00
7	-10.61	-10.61	15.00	225.00
8	-21.21	0.00	21.21	270.00
9	-10.61	10.61	15.00	315.00
10	0.00	10.61	10.61	0.00
11	10.61	0.00	10.61	90.00
12	0.00	-10.61	10.61	180.00
13	-10.61	0.00	10.61	270.00

You should either report EAST and NORTH in the BADM variables GAI_DHP_EASTWARD_DIST and GAI_DHP_NORTHWARD_DIST, or report DIST and ANGLE in the BADM variables GAI_DHP_DISTANCE_POLAR and GAI_DHP_ANGLE_POLAR.

Ceptometer Locations

ID	EAST (m)	NORTH (m)	DIST (m)	ANGLE (deg N)
1	0.00	21.21	21.21	0.00
2	5.30	15.91	16.77	18.43
3	10.61	10.61	15.00	45.00
4	15.91	5.30	16.77	71.57
5	21.21	0.00	21.21	90.00
6	15.91	-5.30	16.77	108.43
7	10.61	0.00	10.61	90.00
8	5.30	5.30	7.50	45.00
9	0.00	10.61	10.61	0.00
10	-5.30	15.91	16.77	341.57
11	-10.61	10.61	15.00	315.00
12	-5.30	5.30	7.50	315.00
13	0.00	0.00	0.00	0.00
14	5.30	-5.30	7.50	135.00
15	10.61	-10.61	15.00	135.00
16	5.30	-15.91	16.77	161.57
17	0.00	-10.61	10.61	180.00
18	-5.30	-5.30	7.50	225.00
19	-10.61	0.00	10.61	270.00
20	-15.91	5.30	16.77	288.43
21	-21.21	0.00	21.21	270.00
22	-15.91	-5.30	16.77	251.57
23	-10.61	-10.61	15.00	225.00
24	-5.30	-15.91	16.77	198.43
25	0.00	-21.21	21.21	180.00

You should either report EAST and NORTH in the BADM variables GAI_DHP_EASTWARD_DIST and GAI_DHP_NORTHWARD_DIST, or report DIST and ANGLE in the BADM variables GAI_DHP_DISTANCE_POLAR and GAI_DHP_ANGLE_POLAR.

Litter Trap Locations

ID	EAST (m)	NORTH (m)	DIST (m)	ANGLE (deg N)
1	0.00	20.00	20.00	0.00
2	0.00	0.00	0.00	0.00
3	0.00	-20.00	20.00	180.00
4	-20.00	0.00	20.00	270.00
5	20.00	0.00	20.00	90.00
6	0.00	10.00	10.00	0.00
7	0.00	-10.00	10.00	180.00
8	-10.00	0.00	10.00	270.00
9	10.00	0.00	10.00	90.00

You should either report EAST and NORTH in the BADM variables GAI_DHP_EASTWARD_DIST and GAI_DHP_NORTHWARD_DIST, or report DIST and ANGLE in the BADM variables GAI_DHP_DISTANCE_POLAR and GAI_DHP_ANGLE_POLAR.