REPORT

ON IMPLEMENTATION OF THE PROJECT

INTERIM DRAFT REPORT ON IMPROVED GHG EMISSION FACTORS FOR NUTRIENT-RICH MANAGED ORGANIC SOILS IN BALTIC STATES

WORK PACKAGE

FILLING KNOWLEDGE GAPS ON GHG EMISSIONS FROM ORGANIC SOILS (C1)

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Authors	Lazdiņš, A., Armolaitis, K., Butlers, A., Čiuldienė, D., Kull, A., Laiho, R., Larmola, T., Lind, S., Mäkiranta, P., Ostonen, I., Penttilä, T., Saarnio, S., Schindler, T., Soosaar, K., Vanags, M.,Vigricas, E., Jauhiainen, J.
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Organization	Latvia State Forest Research Institute "Silava"
Contact information	Riga street 111, Salaspils, LV-2169 Phone: +37129183320 E-mail: ieva.licite@silava.lv Web address: www.silava.lv
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"LIFE OrgBalt compiled the first regional Baltic/ Finnish GHG emission factors for managed nutrient-rich organic soils (current and former peatlands), which have been made available for the customary scientific review and further verification for national GHG inventories in the hemiboreal region in Finland and the Baltic countries. While the project analysed selected CCM measures for drained organic soils in agriculture and forestry and developed spatial models and tools, it also identified remaining knowledge gaps. To bridge the remaining limitations and fill the gaps, it is essential to continue GHG measurements and model development, as well to broaden and complete the scope of the evaluated CCM measures in the after-LIFE-project period, notably by including rewetting and restoration of peatlands that are currently considered to be among the most recommended CCM measures on drained peatlands in the EU. In addition, the developed Simulation and PPC models still include limited macroeconomic considerations and lack assessment of all environmental impacts. For all these reasons, these models should be used carefully in CCM strategy development for identification of gaps in climate neutrality transition policy and funding frameworks and need further optimization for broader applicability as decision-making tools."

SUMMARY

Organic soils contribute to the atmospheric greenhouse gas (GHG) concentrations, as they can both remove and emit GHGs, and have globally extensive carbon (C) and nitrogen (N) stores. Area-based emission factors (EFs), describing the net annual soil GHG emissions/removals, have been developed to reflect the impacts of ecosystem type, land management, and environmental conditions. Quantifying the soil GHG balance, especially for carbon dioxide (CO_2), in forests and other ecosystems on organic soils are technically challenging. Soil GHG balance formed by using monitoring by chambers includes typically at least one year lasting periodical or continuous measurements of GHG flux at soil surface. Period of two years monitoring at each site is implemented in the Life Org Balt project.

Annual soil CO_2 balance is formed by using (1) summarized CO_2 flux data over the year in monitoring and (2) data on mass-based C stock changes, such as C inputs and decomposition as litter aboveground and belowground. More specifically, the mass-based C-stock changes (not covered by gaseous CO_2 flux measurements) include: (1) aboveground biomass and biomass production, (2) belowground biomass and biomass production, (3) litter inputs, including woody debris, and (4) soil organic carbon. Soil GHG balance for methane (CH_4) and nitrous oxide (N_2O) can be done based on gaseous flux monitoring only. For forming soil GHG balances for CH_4 and N_2O there is no guidance on how living vegetation presence or litter dynamics should be taken into account in flux measurements, except that vegetation presence can be reported for CH_4 monitoring locations.

In this document we describe monitoring approach, implemented methods, preparation of sites for monitoring and data collection methods implemented in Life OrgBalt project sites. Reported methods are based on experiences on spatio-temporal data collection that exceeds the typical average data criteria for EF formation in the seasonal climate conditions in boreal and temperate zones.

Soil greenhouse gas balance monitoring method harmonization in LIFE OrgBalt

Prepared jointly within Life OrgBalt partnership for providing field work basis on monitoring site planning, set-up, and data collection.

TABLE OF CONTENTS

Contents

Figures

Tables

Abbreviations used:
C = carbon
CH_4 = methane
CO_2 = carbon dioxide
EF = emission factor
GC = gas chromatography
GHG = greenhouse gas
GPP = gross primary production
IRGA = infrared gas analyzer
IRS = infrared spectroscopy
LAI = leaf area index
N_2O = nitrous oxide
NEE = net ecosystem CO_2 exchange
PAR = Photosynthetically active radiation
P_G = Gross photosynthesis
R_{TOT} = Total respiration
WL = water level

1. INTRODUCTION

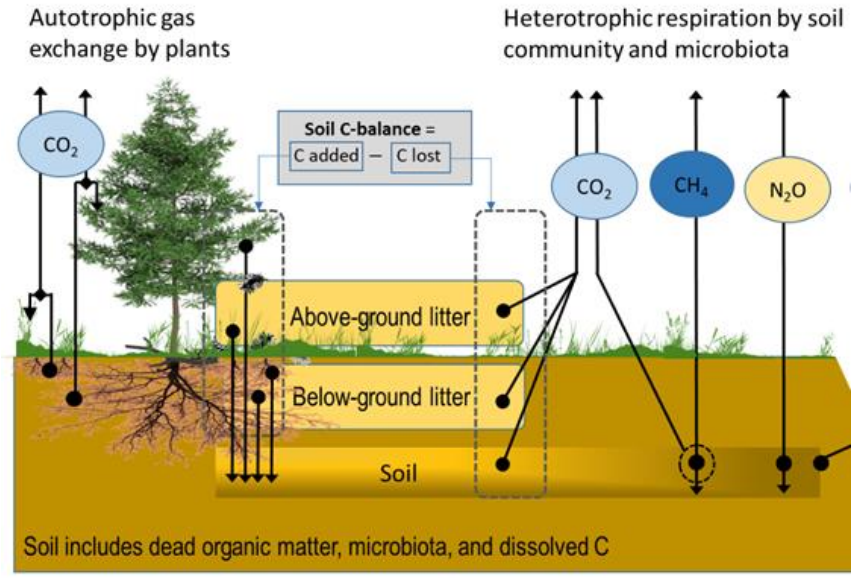
1.1 Soil greenhouse gas balance – IPCC approach

Organic Organic soils contribute to the atmospheric greenhouse gas (GHG) concentrations, as they can both remove and emit GHGs, and have globally extensive carbon (C) and nitrogen (N) stores. Currently, both the IPCC (2006) agriculture, forestry and other land use (AFOLU) guidelines and the IPCC (2014) Wetlands Supplement may be used for reporting the annual GHG emissions and removals for soils under anthropogenic land uses. Area-based emission factors (EFs), describing the net annual soil GHG emissions/removals, have been developed to reflect the impacts of ecosystem type, land management, and environmental conditions. Countries may opt for different methodological levels in their GHG reporting, so-called Tiers 1 to 3, where Tier 1 is the simplest approach with default EFs of the IPCC. The accuracy of EFs can be improved as more peer-reviewed data become available and quantify a wider set of specific management options and ecological conditions for a given country or region.

Quantifying the soil GHG balance, especially for carbon dioxide (CO_2), in forests and other ecosystems on organic soils are technically challenging. Monitoring needs to take into account that:

- C-sequestration into plant biomass takes place in a potentially voluminous and diverse vegetation community with uneven spatial distribution,
- C-transfer from biomass into dead organic matter takes place both in aboveground and belowground part,
- physical and biochemical characteristics in organic soils change over time,
- CO_2 release through heterotrophic processes takes place both in recently deposited litter and in a soil composed of previously accumulated dead organic matter,
- CO_2 formed in the heterotrophic processes in the soil must be separated from similarly large CO_2 emissions formed in autotrophic root respiration in flux measurements,
- rates of biological processes change over the year and differ between years depending on weather conditions, stand development and management.

In this report, "soil CO_2 balance" is specified to include C transfer fluxes to the soil as above- and belowground litter, and losses by decomposition of litter and soil organic matter (Figure 1).



(modified from Jauhiainen et al., 2019)

Figure 1 GHG fluxes and C-mass transfer in a forest system.

1.2 Forming soil GHG balance

Soil GHG balance necessitates frequent on-site gaseous flux measurements over time. Eddy covariance (EC) method, based on a high-frequency monitoring of the studied gas concentration in the air from tower and simultaneous measurement of the vertical wind speed using a 3-D anemometer offers direct, area-integrating way to study biosphere-atmosphere exchange of GHGs (Baldocchi, 2003; Foken et al., 2012). The EC method is still quite expensive, and does not suit well for monitoring work in large number of sites in off-grid locations. Alternative flux data collection based on portable flux monitoring chambers and frequent flux monitoring visits on the sites is described in this document.

Soil CO_2 balance formed by using chambers includes typically at least one year lasting periodical or continuous measurements of CO_2 flux at soil surface without the presence of ground vegetation and roots, and optionally including or removed aboveground litter from the soil surface. Annual soil CO_2 balance is formed by using (1) summarized CO_2 flux data over the year in monitoring and (2) data on mass-based C stock changes, such as C inputs and decomposition as litter aboveground and belowground. More specifically, the mass-based C-stock changes (not covered by gaseous CO_2 flux measurements) include: (1) aboveground biomass and biomass production, (2) belowground biomass and biomass production, (3) litter inputs, including woody debris, and (4) soil organic carbon.

Soil GHG balance for methane (CH_4) and nitrous oxide (N_2O) can be done based on gaseous flux monitoring only. For forming soil GHG balances for CH_4 and N_2O there is no guidance on how living vegetation presence or litter dynamics should be taken into account in flux measurements, except that vegetation presence can be reported for CH_4 monitoring locations (IPCC, 2014). Wetland plants that have roots with aerenchymatous tissue are known to pipe out CH_4 from waterlogged peat layers (Askaer et al., 2011; Kokkonen et al., 2019) or attenuate the emissions in drained sites (Strack et al., 2006). Furthermore, belowground biomass disturbance, e.g. rhizosphere and mycorrhizal mycelia removal by trenching, has been shown to result in increased N_2O flux in drained organic forest soils (Ernfors et al., 2011). It seems clear, however, that in studies of CH_4 and N_2O fluxes, vegetation should be kept intact if possible. Annual soil CH_4 and N_2O balance are based on summarized fluxes over the year in monitoring.

2.3 Contemporary methods applied to greenhouse gas flux monitoring

There are two main (dark) closed chamber methods used for monitoring GHG fluxes between soil and the atmosphere in field conditions. In both closed chamber methods, a known area and volume of airspace on top of the monitored soil surface is closed by a chamber headspace, GHG concentration development is followed inside the chamber over time (i.e. deployment period), and GHG flux rate is determined by combining information on the closed soil surface area, the volume of the closed airspace, and the GHG concentrations over deployment period. The practical difference between the methods is timing between the air sampling event at the field and GHG gas concentration analysis that provides the final GHG flux reading. The first method involves a series of individual air samples collected during deployment time from the closed chamber at the field, storing the samples for transportation, subsequent GHG concentration analysis in the laboratory and calculus of the GHG flux. The second method

involves closing the monitored airspace by closed chamber and circulation of air between the closed chamber and GHG analyzer, and instant GHG concentration analysis and flux readout provided at the field. The first method is often referred to as the 'static chamber method' and the latter as 'dynamic chamber method'.

Traditionally the static chamber method has been more practical because (1) the GHG concentration analysis is based on common laboratory equipment and the analytical method by gas chromatography, and (2) several important GHG species including CO_2, CH_4 and N_2O can be analyzed from the same gas sample, which usually makes the cost per sample affordable. The downside of the method is general slowness and labor intensiveness (e.g., long deployment time at air sample collection especially for CH4 and N2O, potentially long duration of time in sample transport/storage prior to the analysis by gas chromatography) before the actual GHG fluxes can be calculated.

The first portable gas analyzers suitable for use in field conditions and using the dynamic chambers were for CO_2 data collection (trademarks such as ADC, EGM, Licor, etc.). Monitoring multiple GHG species (CO_2 and/or CH_4 and/or N_2O) has become possible in field conditions only recently due to technical development in instrumentation and because of the pricing of analyzers (e.g. Licor, Picarro, Gasmet, etc.) have gradually become more affordable. The key benefit of this method (in comparison to static chambers) is speed due to short deployment time and instantly available flux readout(s) for GHG(s). Instantly available GHG flux readout at the monitoring location allows the possibility to renew flux monitoring if the technical failure (e.g., leakage in the chamber) occurs. Short deployment time makes it possible also to collect GHG data from a higher number of monitoring points/conditions compared to the static chamber method. The downside of the method includes the high price of analyzer, still somewhat developing techniques for use in demanding weather/climate conditions and sites, and analyzer-specific limitations in GHG species included.

In the following chapters we summarize monitoring approach implemented in Life OrgBalt project sites for forming data collection. Reported methods are based on experiences on spatio-temporal data collection that exceeds the average data criteria needed for EF formation in seasonal climate in boreal and temperate zones.

2 SITE PREPARATIONS

2.1 Hierarchy in monitoring site composition

Data collection should be conducted on a continuous area (i.e. continuum of organic soil within a catchment area) that includes monitoring environment characteristics, and such area can be called as a research ***site***. It needs to be decided which part of the site represents best for monitoring activities for vegetation communities and for environment conditions. For research purposes, ***monitoring plot*** should be established at a representative location on the site. If there is only one measurement location on a site, 'plot' and 'site' are in practice synonyms to each other.

At some areas with clearly differing conditions in close-by locations, multiple measurement plots can be established (Figure 2). For example, different vegetation types grown on neighboring field-strips, different water depths maintained in neighboring field-strips, and control/partial harvesting/clear-felling trials in one forestland can be used for comparing GHG emissions in independent differing (environment) conditions.

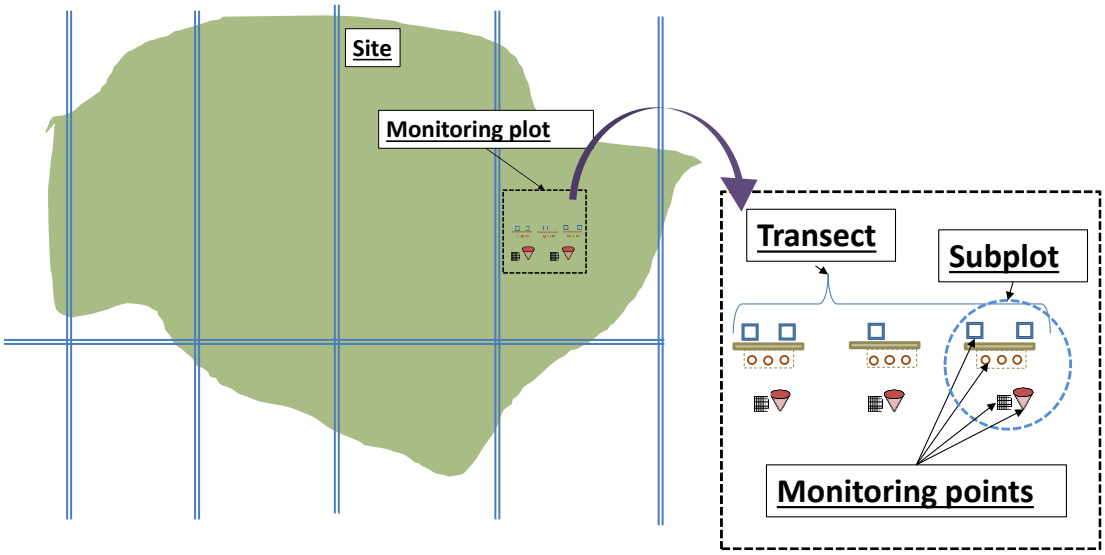


Figure 2 Hierarchy of names used for monitoring at the site.

To collect representative data from the site, measurement/monitoring locations should be organized so that collected data can be combined and compared in an organized and hierarchical way. Monitoring point, subplot, and site form a 3-level hierarchy for inspecting data. Data collection from ***monitoring points*** (e.g., for GHGs/ biomass/ litter/ environment data/ soil sampling/ ...) will form groups in ***subplots,*** i.e. replicated representative locations within each site (Figure 3). In Life OrgBalt we have three (3) subplots, and each subplot includes multiple monitoring points (defined in detail in following chapters) for sampling and monitoring.

Monitoring transect. In LIFE OrgBalt each subplot should be at minimum distance of 5 meters from the other two subplots. Most common arrangement of subplots is a ***transect*** (subplots set along an imaginary line). Drained area soil water level (WL) likely differs by the distance from the ditch, and transect form set-up includes these differences, i.e. by setting the first subplot 5-10 m from the closest ditch and next subplots perpendicularly towards the center of the strip/field (Figure 3). Water level may be somewhat lower close to ditch. In natural undrained areas or locations with poorly drained locations, it is more important to observe other dominant site characteristics influencing soil GHG emissions, such as vegetation communities and soil surface microtopography in planning locations for the subplots. Plants with known potential to transport gases from the soil to the atmosphere should be registered and include into the monitoring plan if they are characteristic for the site or subplot location. Similarly, on undrained areas can include differing microtopography forms (e.g. some combination of hummock/ lawn/ hollows), and it is recommended to include these forms in GHG monitoring if they are characteristic (seeFigure 4 and Figure 5).

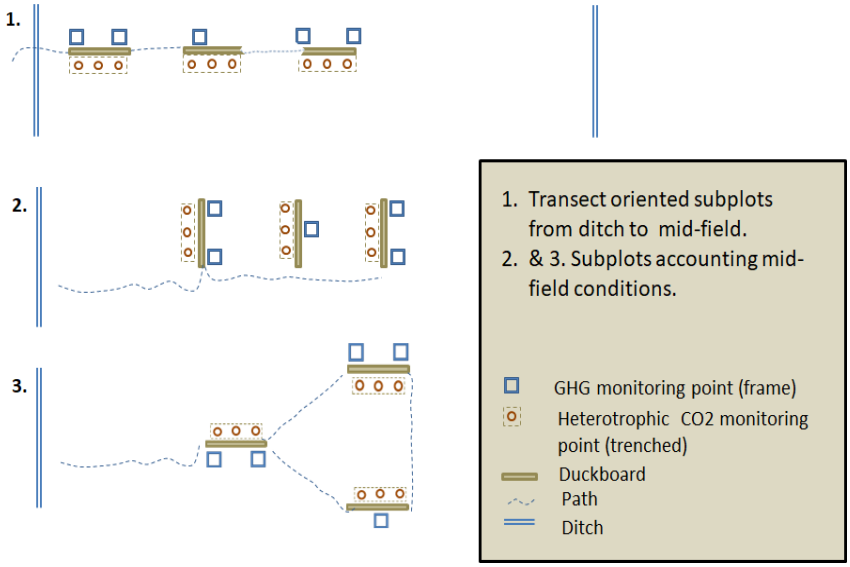
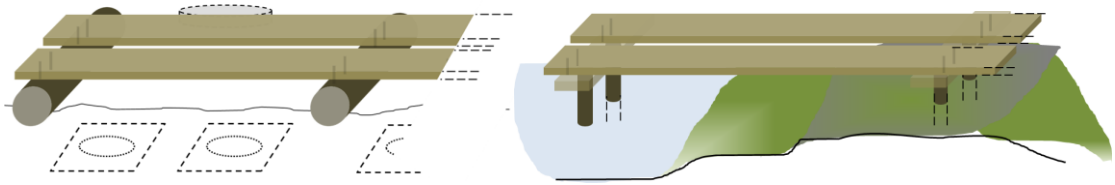


Figure 3 Examples of different subplot set-ups in monitoring plot.

Reducing surface disturbance and wearing – duckboards. All wet and low bearing soils next to GHG monitoring points at subplots should be equipped with duckboards that form platforms for frequent GHG and environment (WL, temperature, etc. data) data collection. Duckboards aim to prevent (i) changes and wearing in soil and vegetation during the visits and (ii) reduce potential disturbances e.g. forced bubbling and diffusion GHG emissions from the soil. On drier sites, sufficient stability for working and reduced disturbance to the soil will likely be achieved by supports laid on the soil surface (see Figure 4). On wetter and softer soils, stilts may be needed. Temporary duckboards e.g. movable wood planks can be used on higher soil bearing capacity sites and sites subject to frequent soil management (see Annex 1). Duckboard supports should not be next to GHG monitoring points (CH_4 and N_20 points). Permanent duckboards must be ready at each subplot at least one week before the start of GHG monitoring in order to allow soil and vegetation recovery from the caused disturbance.



(left) on drier sites characterized by flat topography by using *supports on the surface, and (right) on sites characterized by low bearing and undrained sites by using stilts.*

Figure 4 Duckboard structures.

GHG monitoring points - number of points and minimum distances. To make data collection practical, all data collection points should be close enough to allow easy and repeated moving around during sampling, especially for a gas sample collection from multiple static chamber units deployed simultaneously at all three subplots. Similar GHG flux monitoring points should not be side by side, whereas the different type of monitoring points can be close-by.

An increase in the number of spatial replicates, i.e. the number of monitoring points, increases the spatial representativeness in gaseous flux monitoring by chambers. In studies utilizing chamber

techniques, on an average there were 8 replicate flux monitoring points per site for CO_2 (range 2 to 48), 5 for CH_4 (2 to 16) and 5 for N_2O (2 to 16) (Jauhiainen et al., 2019).

- For CH_4&N_2O flux monitoring, the minimum number of GHG sampling points in each site is 5. The recommended minimum distance between these monitoring points is *c*. 5 meters but a wider spread should be applied if space is available. These GHG flux monitoring points should be arranged at the 3 subplots as follows; 2 points in the 1st subplot, 1 point in the 2nd, and 2 points in the 3rd subplot (see Figure 3).
- For monitoring heterotrophic CO_2 emissions, the minimum number of monitoring points in each site is 9. These monitoring points should be arranged in clusters of 3 points in each subplot (e.g. 3 + 3 + 3), and the recommended minimum distance from point to point is *c.* 1 meter (see Figure 3).

Each subplot should be equipped with piezometer pipe for manual WL monitoring, and the closest piezometer pipe should be used for providing WL data for GHG flux monitoring points close to it. Water level distance from the soil surface influences GHG flux rates (CO_2, CH_4 and N_2O), and thus sites with clearly differing soil surface microtopography may need inclusion of soil surface topography in monitoring point set-up if microtopography differences are characteristic (Figure 4). In such sites, relative surface area proportion of different monitoring included microtopography surfaces needs to be estimated once during field data collection.

2.2 Setting up Heterotrophic CO_2 monitoring points

Trenching. Heterotrophic CO_2 monitoring points should include emissions from organic matter decomposition only (i.e. exclude autotrophic respiration emissions from alive vegetation aboveground parts and roots (Figure 5). Monitoring points can be prepared for heterotrophic CO_2 emission monitoring by soil trenching i.e. by cutting a slit in soil down to estimated root zone depth around the flux monitoring soil surface, omitting surface vegetation from the trenched surface, and thereafter preventing living vegetation re-establishment inside the trenched area.

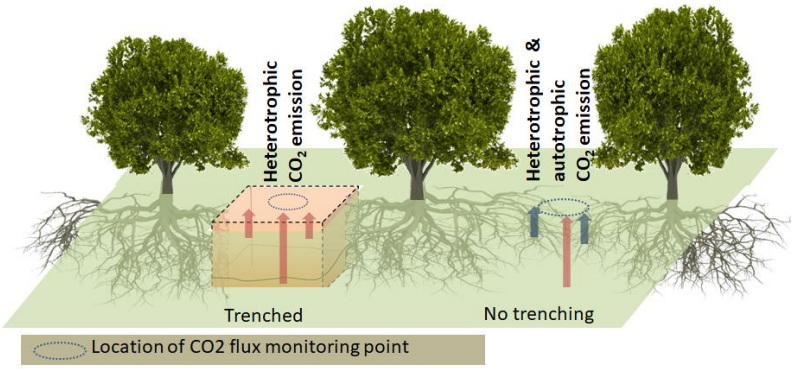
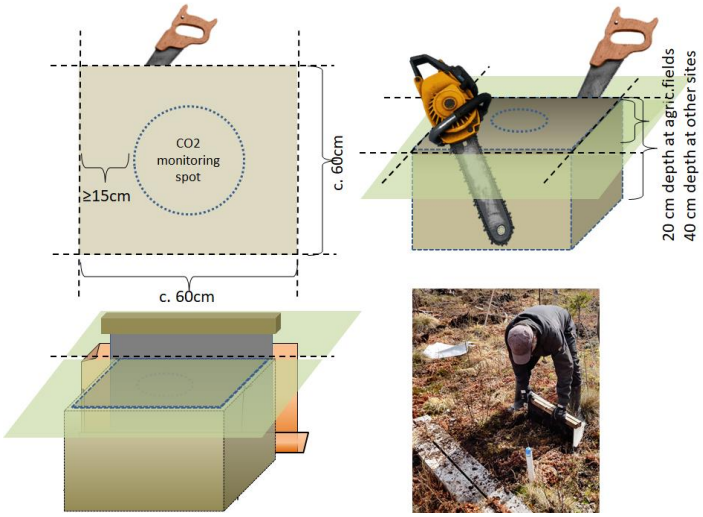


Figure 5 CO_2 flux sources in trenched and without soil surface modifications.

Trenching at forests and mixed tree & ground vegetation stands. First, the soil around the flux monitoring point is cut to a depth below the rooting zone i.e. 40 cm depth by chainsaw, saw, straight-bladed spade from 60 cm x 60 cm square-shaped area, and after that, root isolating fabric is inserted

into the formed slit by pushing/hammering it down aided by a piece of flat veneer (Figure 6). Pieces of fabric should have overlapping layers in vertical corner seams. The trenching depth (slit depth from the soil surface) is 40 cm in forests, and mixed tree & ground vegetation stands.

Root isolation fabric must be installed earliest possible before the start of heterotrophic CO_2 flux monitoring on the site, in forest sites previously during previous year. Root isolation fabric material can be 'felt like' non-woven geotextile fabric commonly used in gardens to prevent root ingrowth to flowerbeds, stone-paved paths.



Safe zone (top-left), soil cutting (top-right), fabric installation (low-left), and photo of fabric insertion (low-right).

Figure 6 Root isolation fabric installation.

Trenching at agriculture lands (cropland, grassland) are subject to recurrent soil management including tilling (preparation of field) or shallow slurry manure injection (fertilization), and these operations may form difficulty for using root isolation fabrics. Timing and likelihood of such soil disturbing actions should be considered to decide if setting root isolation fabric is purposeful, or alternatively repeated regular trenching without use of root isolation fabric is more practical. The trenching depth (slit depth from the soil surface) is 20 cm in agricultural lands.

If the fabric cannot be used in agricultural lands in Life OrgBalt, trenching lines can be cut down to 20 cm depth before the growing season start, and clearing sprouted vegetation from the enclosed area. To ease establishment/maintenance of these "fabric-free" sites, the trenching area could be Ø 60 cm circular (as an alternative to 60 cm x 60 cm square shaped). A spade is likely a useful tool. The cut lines should be renewed after GHG measurements each time the site is visited, and a spade should always be kept carried along.

It is important to consult especially agriculture landowners about the use of fabrics; (a) because of soil management operations needed, (b) because potential use of land as pasture (animals there), and (c) because we show good manners and respect. If the installation of root isolation fabric is not objected by the land owner and the soil management actions take place rarely (once a year?), the installed fabric can be renewed (i.e. old fabric removed before farming action and setting a new after the management action).

Soil surface maintenance at heterotrophic CO_2 monitoring points. Plant growth controlling is started at the same time as the installation of root isolation fabrics. Two soil surface maintenance approaches are available for preventing respiration emissions from live vegetation; alternatively by (i) regular cutting of sprouting vegetation from the soil surface and fallen litter removals or (ii) by using precipitation water-permeable 'soil cover fabric'. For actions needed during the site set-up for flux monitoring see guidance given in the chapter "Soil heterotrophic CO2 flux measurements".

Each heterotrophic flux monitoring point location should be identifiable in the flux monitoring data, and thus monitoring point locations need unique codes in records.

2.3 Setting up CH_4, N_2O and NEE monitoring points

Vegetation should be kept as intact as possible in these monitoring points to include CH_4 and N_2O fluxes from soil, and vegetation. Because disturbance to vegetation parts aboveground and belowground are minimized, the points can be used for monitoring net ecosystem emissions (NEE) because CO_2 fluxes from soil and vegetation above- and belowground parts are included. Each CH_4, N_2O and NEE monitoring point location should be identifiable in the flux monitoring data, and thus monitoring point locations need unique codes in records.

If flux monitoring is by static chambers, frames/collars (bases for the static chamber headspace) are inserted into the soil so that the frame lower edge is inside the topmost soil, there is no air passage below the lower edge, and the frame is horizontally balanced. Tools (e.g. saw, knife) can be used for cutting the soil materials (wood, roots close to surface) for easing the frame insertion. The upper edge of the frame should be close to the soil surface level in order to avoid difference in climate conditions in- and outside the frame. It is advised to keep frames/collars permanently inserted, but in frequently managed agricultural lands, the frames must be removed prior to land farming operations and they should be reinserted back at the original locations at least 24 hours before the next gas sampling event. If the frames can not be permanent installations, location of each frame can be marked on the soil, for example, by a small but easily detectable stick. Marker sticks should be high enough to be visible also in winter with deep snow cover.

If CH_4&N_2O fluxes are monitored by analyzer using dynamic chamber, there are no permanent frame installations on the monitoring points but each point location should be marked, for example, by a small but easily detectable stick.

It is advisable to mark monitoring locations on the ground, prepare codes of the GHG flux monitoring locations ready, take a picture and make an inventory of the vegetation inside the collar (%-a cover of vegetation functional types**1**/ species). It is advised to take a picture of each sampling collar (including northern direction indicator or compass) every year in spring at the start of the vegetation period, during maximum annual biomass (in June-July) and at the end of the vegetation period to assess seasonal and interannual changes in vegetation cover by general vegetation classes.

1 Functional types. 1.) graminoids, 2.) herbs, 3.) ferns, 4.) moss, 5.) shrubs

2.4 Installations for environment- and mass-based data monitoring

Piezometers for water level monitoring and water sampling. Piezometer pipes should be installed on a typical low soil surface level on the subplots. Aim to leave "standard" length of the piezometer pipe above the soil surface (e.g. 50 cm) and mark the soil surface level on the pipe side by scar or pen. The marking is useful for check-up if the pipe has been pushed/pulled during periods between the site visits and it provides a practical standard for pipe section above soil surface. Piezometer pipe installations in the site include; 1 pipe for manual WL monitoring in each subplot next to cluster of GHG monitoring points (i.e., 3 pipes in flat terrain conditions), one pipe for manual WL monitoring in ditch closest to the first subplot (in drained sites only), one pipe for automated WL logging in each site, and optionally one pipe for water sampling for analyses in each site. It is good to set automated WL logging piezometer, manual WL data collection piezometer and (optional) water sampling pipe in the center-most/middle-most subplot close to GHG monitoring points. Piezometers should be on average at the same soil surface level with GHG monitoring points because both manual WL data and automated WL data files will be needed in flux data analysis.

In cropland and grassland, it should be agreed with farmers for leaving piezometer pipes in the site permanently, except for soil scarification period. Otherwise, these pipes should be reinstalled at least 24 hours before GHG flux sampling. Depth of wells at least 1.5 m, considering that during summertime WL can notably drop. It is recommended to start automated WL monitoring as soon as possible after the outline of activities on the site are ready.

Temperature monitoring. Soil temperature dynamics close to the surface can be expected to influence especially CO_2 and N_2O dynamics, and at greater depth in soil to CH_4 dynamics momentarily, diurnally and seasonally. Monitored soil temperatures should be compatible with monitored GHG fluxes and this condition is best reached by having a manual temperature monitoring at a fixed point next to each GHG monitoring point (similar soil surface cover, soil surface elevation level and shading conditions). Temperature monitoring point locations can be marked by small sticks on the ground. Manual temperature monitoring should be made at the same time as GHG data collection.

Automated temperature monitoring is needed for detecting soil temperature dynamics diurnally (changes in surface soil temperatures over night and day) and seasonally (faster changes close to the surface and slower changes deeper in the soil profile). Temperature monitoring by automated loggers should be in location best average GHG monitoring point conditions on the site, i.e., next to "chosen most representative" GHG monitoring point. It is recommended to start automated soil temperature monitoring on each site as soon as possible after the activity locations are ready. It would be good to also have a WL logger (piezometer) close/next to the location of the automated temperature monitoring. Automated soil temperature monitoring depths must be included also in manual temperature monitoring in order to ease data modelling (Table 1). The soil surface (zero) is a visible surface i.e., top of moss layer or other relatively solid surface. Automated soil temperature loggers must be secured in containers or plastic film that prevents soil water contact with the logger.

Table 1 Soil temperature monitoring depths.

Depth (cm)	Manual monitoring	Automated monitoring	Notes

Litter			Can be monitored in order to describe maximum temperature conditions. Depth is not representative for decomposition processes in soil.
0			Depth is not representative for decomposition processes in soil. Note! Defining the exact soil surface level in a consistent way may be difficult
-5	Recommended	Recommended	-5 and -10 cm depths below the loose litter layer describe temperatures in (1) most active soil profile depth close to litter, (2) mostly oxic environment, and (3) depth influenced by shorter-term temperature changes.
-10	Include	Include	
-15			At shallow drained sites -15 cm and -20 cm depths can be very useful for describing anoxic environment conditions. At deeply drained sites these monitoring depths may not describe either surface or in-depth soil environment conditions (1,2,3) very clearly.
-20	Include	Optional	
-30	Optional	Optional	Can be monitored.
-40	Include	Include	This depth is likely close to WL in the soil profile. A location for describing soil conditions in (1) settled "bulk" peat, (2) anoxic environment, and (3) depth influenced by slower (seasonal) temperature changes.

Biomass and litter monitoring points. All soil disturbance causing or long-term monitoring installations (such as root ingrowth socks, litter collectors, etc.) should be installed in conditions/time-period that supports the specific data type collection. For example, for Life Org Balt sites established now (towards the end of growing season) it is good to set litter-traps before the fall 2020 starts (thus autumn leaf-fall become harvested), and root ingrowth socks are set after the growing season ends (thus the socks settle for next growing season and include known growing season fine roots). Detailed outline and data collection plans are in Litter and biomass protocols section.

Monitoring point leveling. Monitoring point leveling (measuring difference) of the soil surface at the GHG monitoring points relative to the piezometer pipe location(s) and automated WL logger pipe location is strongly recommended at some timepoint during the GHG monitoring period. Leveling information collected from the site increases WL data and GHG data reliability.

To provide scale of tooling needed at sites (e.g. infrastructure, preparations, monitoring installations, and monitoring points), see Figure 7. The formed set-up at each site should be representative for the land use, vegetation, soil, and abiotic conditions (e.g. hydrology, light). Also, biomass and litter data collected from each site needs to be representative (i) for the land use, vegetation, soil, and abiotic conditions (e.g. hydrology, light), and (ii) for the closest GHG monitoring points on the monitoring plot.

Note that not all installations can be made similarly at all sites but environment characteristics and land management operations may necessitate alternative approaches at different sites but all installations should be made in a way that they are characteristic for particular site conditions. The monitoring plot design may vary between sites and countries. Examples of monitoring plot designs for various environments applied in Latvia are provided in Appendix 1 (see also Figure 8).

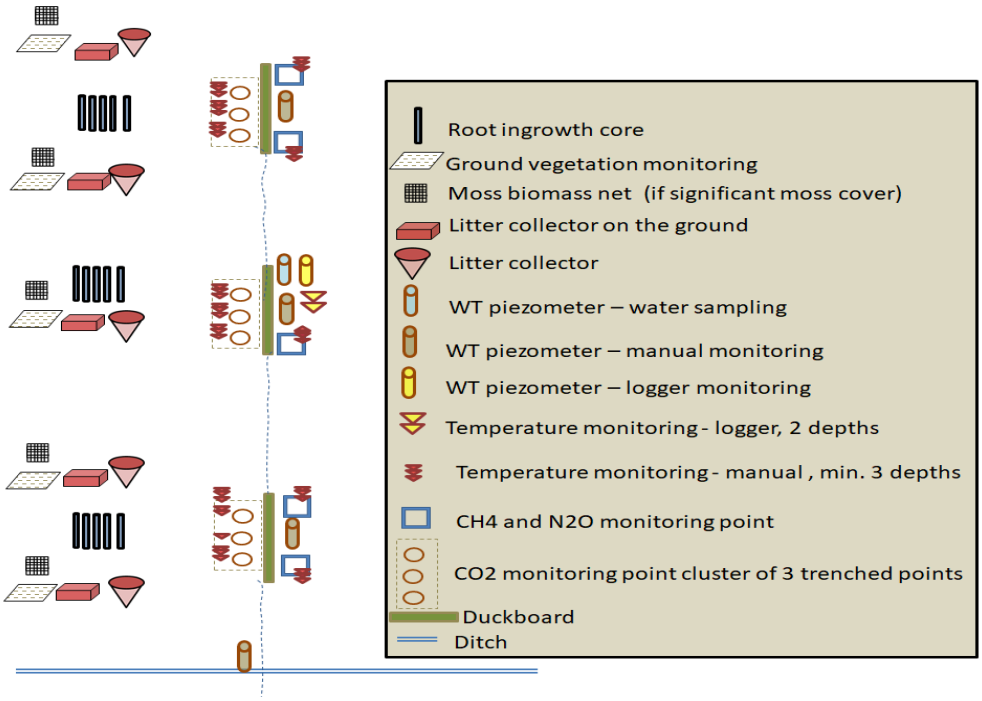


Figure 7 Presentation of monitoring points to be established on a monitoring plot.

2.5 Scheduling GHG monitoring at the sites over time

Flux data collection is annual and includes two warm seasons and the cold season between. In Life Org Balt the flux data collection is aimed to take place in a minimum**2** of 3-week intervals during the warm season and a minimum of 6-week intervals during the cold season. The intensive sampling period (warm season) should include spring (start of vegetation growth), vegetation growing season (summer) and senescence of annual plants, fall of deciduous tree leaves and repeated subzero temperatures (autumn). In practice, the periods can be defined (i) on basis of temperatures, e.g. warm season starts when average daytime temperature prevail above 0°C for 7 consecutive days in the region and ends when the topmost soil is found frozen in 2 consequent site visits, or (ii) define pragmatically warm season and cold season timing and duration.

Timing of flux monitoring visits at each site start alternative times if possible so that morning/noon/afternoon measurements are included representatively at each site. This can be done by frequent change of the order of sites included in the same-day monitoring agenda (i.e. site in morning & afternoon). Equally try to change the order of monitoring GHG monitoring points in each site (if is possible without confusion) by starting monitoring from the alternative ends of the monitoring transect.

Scheduling time at the monitoring site with a team of 1-2 people should aim (i) completion of planned data collection tasks, (ii) evenly shared workload within the team for efficient time use, (iii) minimized site disturbance. Although all team members should be able to do all tasks at the site, it may be good that at each site/day one person takes responsibility for taking care of specific measurement(s). Other team members can assist if they have time from their own specific duties. General site preparation and

2 If resources allow, higher smaller intervals in monitoring can be used (i.e. the minimum reasonable monitoring frequency is provided here).

maintenance duties, if they exist, can be done together. The most time-consuming tasks (e.g., static chamber work requiring long deployment time) should be started as soon as possible after arrival to the site. If the weather conditions are likely to turn unstable (rain/ rain showers/storm) during the site visit, most dry conditions requiring tasks should be prioritized in order to get most/all planned data collected. Experience is the best teacher for smooth work order.

3 GASEOUS FLUX MONITORING

3.1 Soil heterotrophic CO_2 flux measurements

Field equipment checkup. Before each GHG flux data collection at a field site; fully charged analyzer (+ spare batteries if needed), thermometer and temperature sensor (for soil temperature) are needed. Chamber equipped with: pressure valve, fan and thermometer (inside temperature of the chamber), battery for chamber fan, tubes to connect the analyzer and chamber, measurement forms (paper, mobile device or computer), device for measuring WL from piezometer pipes. It is advisable to make a checklist of the items needed at field.

Heterotrophic CO_2 measurements at the site:

1. Check the heterotrophic CO_2 monitoring point conditions on the site for possible disturbances caused by animals/trespassers/weather.
2. Decide the flux monitoring order
3. Prepare the flux monitoring points
    a. Remove gently any litter fallen on the soil surface with no disturbance on soil surface (if no soil cover fabrics applied)
    b. Lift all soil cover fabrics aside (see Figure 8)
    c. Cut possibly sprouted green vegetation parts from the CO_2 monitoring point soil surfaces.
4. Set ready the monitoring equipment on the #1 point (or cluster of monitoring points)
    a. Connect tubing between the chamber headspace and the analyzer, engage the analyzer and run the program set-up
    b. Attach batteries to the chamber and make sure that the fan goes on.
5. Collect data from the point #1 in monitoring on that day
    a. In the beginning of the measurements, ventilate the chamber by holding and sweeping the chamber in the air and letting air flow for a while.
    b. Start measuring by putting the chamber on to the monitoring point. Close the ventilation hole on the chamber and start by writing down start time (Licor) or PPM (EGM 5) and temperature inside the chamber. The measurement has now started.
    c. Follow the CO_2 concentrations during the measurement event; concentration increase should be steady during the entire measurement time.
    d. In a meanwhile measure soil temperature from the area where the surface vegetation is removed. Stick the temperature monitoring sensor to the ground next to the chamber to the upmost monitoring depth (e.g., 5 cm). Let it be until the temperature becomes steady, record the value, and continue monitoring in next depths.
    e. Measure WL from the closest piezometer pipe. Check that the pipe is correctly on the soil (the marking of the soil surface equals soil surface). Measure the depth of the WL

from the top of the pipe. (Remember to measure the length of the pipe above the soil surface. This information is needed when the actual WL depth is calculated)

f. Make notes on the weather conditions and possible notes of the "normal" deviating conditions on the point on the field notes.
g. When the measurement is done mark the end time (Licor) or PPM (EGM 5), flux reading and temperature inside the chamber. Then open the ventilation hole on the chamber and take the chamber up from the ground.

6. Prepare the next monitoring point ready and collect data as listed in '5' above
7. After finishing the flux measurements
    a. Renew trenching (if root isolation fabrics are not used)
    b. Cut possibly sprouted green vegetation parts from rest of the trenched soil surfaces
    c. Set the soil cover fabric on the top of trenched point

Figure 8 Root isolation fabric on heterotrophic CO_2 emission monitoring point.

3.2 CH_4, N_2O (and R_{tot}) flux measurements

Both static- and dynamic dark (opaque) chamber approaches can be used in flux monitoring. However, portable gas analyzers for simultaneous measurement of CH_4 and N_2O fluxes in sufficient accuracy are scarce (e.g. Gasmet) and as soil CH_4 and N_2O (& total CO_2 respiration) should be measured also in winter when air humidity is high (condensing conditions) or ambient temperature is low (lower than 0°C) the static chamber method (manual sample collection with syringe and vials for laboratory analysis) is required at least in cold period.

In sampling design (both in selection of sampling point location, sampling interval and selection of sampling time) it should be kept in mind that WL position in peat (depth of aerobic peat layer) and soil temperature in anaerobic zone are the main factors determining CH_4 fluxes while changes in peat/litter decomposition and WL/soil moisture affects N_2O fluxes the most. Thus CH_4 experiences clear seasonal and diurnal cycle while N_2O has characteristically irregular variability.

Field equipment checkup before leaving for sampling at a field site:

- For dynamic chamber method: fully charged analyzer(s) (+ spare batteries if needed)
- For static chamber method; (1) sufficient number of chamber headspaces (min. 5 chambers for simultaneous sampling) with vent/pressure valve, extension collars (if needed in agricultural

sites); (2) gas sampling syringes, tubing with vents and one-way valves, (3) pre-evacuated vials for collecting and storing gas samples (min. volume 50 ml),

- Thermometer and temperature sensor(s), measurement forms (paper, mobile device or computer) and stopwatch.

CH_4 and N_2O monitoring preparations. If flux monitoring is by static chambers, frames/collars (bases for the static chamber headspace), it is advised to keep frames/collars permanently inserted, but in frequently managed agricultural lands, the frames must be removed prior to land farming operations and they should be reinserted back at the original locations at least 24 hours before the next gas sampling event. If the frames can not be permanent installations, location of each frame can be marked on the soil, for example, by a small but easily detectable stick. Marker sticks should be high enough to be visible also in winter with deep snow cover. If CH_4&N_2O fluxes are monitored by analyzer using dynamic chamber, there are no permanent frame installations on the monitoring points but each point location should be marked, for example, by a small but easily detectable stick.

These GHGs are monitored from soil surfaces with minimized disturbance caused to soil and vegetation. It is advisable to mark monitoring locations on the ground, prepare codes of the GHG flux monitoring locations ready, take a picture and make an inventory of the vegetation inside the collar (%-a cover of vegetation functional types**3**/ species). It is advised to take a picture of each sampling collar (including northern direction indicator or compass) every year in spring at the start of the vegetation period, during maximum annual biomass (in June-July) and at the end of the vegetation period to assess seasonal and interannual changes in vegetation cover by general vegetation classes.

On very wet locations the soil bearing capacity during flux monitoring event can be increased by setting a temporary "flat" collar/ring on the soil surface or floating flat ring at flooded sites (Figure 9).

Figure 9 Floating flat styrofoam ring supporting chamber in a flooded site.

In winter conditions, snow cover should be kept as much as possible intact (incl. melted and frozen layers in snow) when placing the chamber. If snow cover is too soft to support the chamber the actual volume of the chamber (chamber volume minus volume filled with snow) should be reported to the lab or used in analyzer(s) program. If snow is soft (do not support a chamber from sinking) and more than 50% of chamber volume is filled with snow, the upper part of the snow is removed to leave only snow up to 25% of chamber volume which is reported to the lab or used in analyzer(s) program. Snow should be removed only in case if otherwise the chamber would sink in soft snow deeper than needed to ensure

3 Functional types. 1.) graminoids, 2.) herbs, 3.) ferns, 4.) moss, 5.) shrubs

50% of its original volume. In this specific case gas (inlet and outlet) sampling tubes would be sunken to the snow and incorrect results will occur. Also, too small headspace volume if extensively filled with snow may significantly affect concentration change during deployment period and result in overestimation of gas flux. Still, the deeper layer of snow (as little disturbed as possible) should be retained (appr. 25% of chambers volume) to mimic effects of snow cover.

If WL is above the ground surface, then water depth should be recorded and subtracted from chamber volume and active volume of the chamber should be reported to the lab or used in analyzer(s) program. If water level is deep enough to reduce active camber volume below 50% of the original volume the floating support ring should be used in flooded area (see Figure 10).

The use of chamber extensions. Extension collars should be used only in case of high vegetation if parts can not be removed (e.g. crops) or (partial) removal of plants might influence the efflux of CH_4 or N_2O. General guidance on the need of modifications is in Annex 1.

As a rule, the vegetation should be kept in its natural form. If this is not possible it should be considered if plants can be gently bended and fitted inside of the chamber without obstructing air movement at outflow tube in chamber head. If fitting plants within the chamber is not possible the plants could be clipped (cut part removed) in minimal amount to fit it freely in the chamber. Plants should be clipped minimum 24 hours before sampling.

In case of use of extension collars it should be clearly reported and added volume should be reported to laboratory if static chambers are used or counted for analyzer program in case dynamic chamber is used.

Closed static chamber CH_4&N_2O sampling at the site;

1. Check the GHG monitoring point conditions and permanently installed collars for possible disturbances caused by animals/trespassers/weather. If sampling area is potentially flooded, prepare enough floating support rings for chambers.
2. Decide the flux monitoring order and start deployment from point #1
3. Set the flux monitoring equipment ready (collars, sampling vials, stopwatch, etc.)
4. Evaluate the vegetation status/height inside the collars (in all 5 collars)
    a. Attach extension collar air-tightly on the permanent collars (if needed)
    b. Cut extensively tall vegetation that does not fit inside chamber system (permanent collar + extension collar + chamber headspace) down to level that plants do not obstruct air movement around the sampling outflow tube.
5. Reserve sample vials ready in preplanned order
6. Deploy closed chambers (i.e. attach the headspace) and start the stopwatch
    a. Note! Operating with 5 collars simultaneously, *c.* 5 min intervals with start of deployment will result in about 65 min time spent for collecting all samples.
7. Take an air sample from the chamber into a reserved pre-evacuated vial in agreed intervals from each chamber, Time-1 (chamber closed), Time-2, Time-3, Time-4 (at the end of deployment)
    a. For 60-minute deployment, sampling is after 1 min, 20 min, 40 min, 60 min.
8. Remove the chamber from the monitoring point after the last sample is taken
9. Record soil temperatures at agreed depths at each GHG monitoring point during the deployment (allow time adapting the probe temperature)
10. Check and append field notes; closed chamber volume during deployment at each monitoring point, WL in subplot wells, including information on general conditions at the site during monitoring (weather, air temperature, ...), time (hh:mm) of sampling started, and any deviations from typical monitoring procedures.
11. Store filled vials in stable room temperature before transport to the analysis by gas chromatography (GC).

Closed dynamic chamber CH_4&N_2O measurements. Data collection by portable GHG analyzer connected to the chamber provides flux readouts for GHGs immediately after the end of deployment. Analyzer operation guidance is not described here, but the following general operations should be performed at the monitoring site;

1. Check the GHG monitoring point conditions for possible disturbances caused by animals/trespassers/weather. If sampling area is potentially flooded, prepare sufficient number of floating support rings for chambers.
2. Decide the flux monitoring order and start deployment from point #1
3. Set the flux monitoring equipment ready (analyzer, chamber headspace, etc.)
4. Evaluate the vegetation status/height inside the collars
    a. cut extensively tall vegetation that does not fit inside chamber system (permanent collar + extension collar + chamber headspace) down to level that plants do not obstruct air movement around the sampling outflow tube.
    b. set extension collar on the ground and attach chamber headspace air-tightly to the collar (if needed)
5. Start measuring
    a. Put the chamber headspace on monitoring point.
    b. Close the ventilation hole on the chamber headspace
    c. Mark the (i) start time and (ii) temperature inside the chamber - the measurement has now started.
    d. Follow the GHG concentrations during the measurement event - concentration change over time should be steady
6. When the pre-agreed deployment time is over
    a. Mark the end time, flux reading and temperature inside the chamber.
    b. Then open the ventilation hole on the chamber headspace and take the chamber up from the ground
7. Record GHG monitoring point soil temperatures at agreed depths into field notes (allow time adapting the probe temperature)
8. Move to next GHG monitoring point in the subplot, … (continue from bullet 3. ->)
9. Append field notes: closed chamber volume during deployment, WL in the subplot well, general conditions at the site during monitoring (weather, air temperature, ...), and any deviations from typical monitoring procedures.

Field notes In addition to temperature and WL records made during GHG data collection, field notes should contain information about weather conditions (wind, temperature, clouds, rain), any irregularities of site conditions (use of extensions, cutting plants) or during sampling (non-regular sampling interval), snow cover depth or water depth above ground surface. In each sampling site, site code and monitoring point codes, starting and ending time of sampling should be fixed.

Data and sample storing after field day. Store the closed static chamber sampling vials in boxes where each vial is in fixed position. Provide each box with data sheet including box number, site identification, vial position and its corresponding parameters (site, subplot, point, sampling time (1, 20, 40, 60 minute), and copies of field notes. Separate copy of the information (field notes) should be kept by the sampling institution/responsible person.

If flux data was collected by closed dynamic chamber, use the analyzer specific software to move data in to storage, name files, check the data quality, perform flux calculations based on concentration data and auxiliary data, and add required flux values and auxiliary data into database. It is a good practice to collect the data at the end of each measurement date to minimize the potential loss of data. Save the data by using measurement date in the name.

GHG (CH_4, N_2O, CO_{2tot}) flux calculation and flux data quality control. GHG fluxes are calculated from the linear increase or decrease in GHG concentration in gas samples taken from the chamber with time,

using a linear regression equation (doi:10.1029/95JD02145, https://lter.kbs.msu.edu/protocols/113). Flux results are accepted if linear regression R^2>0.9 or regardless of R^2 value if concentration increase is less or equal of gas chromatography detection limit and in this case flux value is considered equal with 0.

3.3 Ground level NEE flux measurements

CO_2 is produced in soil in microbial respiration (heterotrophic respiration) and root respiration (autotrophic respiration). Also plant leaves have respiration both in light and dark (dark respiration). Chamber techniques can be applied to measure the so-called net ecosystem CO_2 exchange (NEE). When considering an ecosystem with plants the NEE is the difference between CO_2 uptake by plants and total respiration (above ground plants + roots + microbes). NEE can be measured with a transparent chamber, which allows photosynthetically active radiation (PAR) to enter the chamber and run photosynthesis in the enclosed vegetation during the measurement. Soil respiration (both autotrophic and heterotrophic) produces CO_2 to the chamber and vegetation fix CO_2 via photosynthesis. From the measured increase or decrease in CO_2 in the chamber the net ecosystem exchange can be calculated. Total respiration (R_{tot}) can be determined by protecting the chamber from light by some opaque material. In the dark autotrophic (plant dark respiration = plant respiration in the dark and plant respiration in light are assumed to be equal) and heterotrophic respiration still produce CO_2, but photosynthesis does not work. Total respiration can be calculated from the increase in the CO_2 concentration in the closed opaque chamber. Gross photosynthesis (P_G) is the amount of CO_2 fixed by the photosynthesis. Gross photosynthesis can be calculated from the equation:

$$NEE=P_G - R_{tot}$$

To consider. Sun light, temperature and plants have significant effects on the measured NEE and R_{tot} values. Therefore, you should keep them in mind when planning or carrying out the measurements.

Depending on the ecosystem, up to 90% of the variation in the GP is explained by photosynthetically active radiation (PAR). The sensor should be placed inside the transparent chamber since the plastic will reflect part of the incoming radiation. When measurements are carried out, PAR sensor should be aligned horizontally, without any shading from the equipment or from the measurer. It is also important to follow the movement of the clouds: during the transparent chamber measurement, the light levels should remain constant. Also, when planning the site set-up, keep in mind the natural movement of the sun, so that you can carry out the measurements during the desired time of the day. To create different light conditions, it is a good practice to do the measurements also using a PAR reducing net. This will reduce the light conditions and give you more data for the later analysis.

Temperature will affect the respiration rate. And when you use the transparent chamber, the inside temperature will increase several decrees during the 2-minute closure time. Therefore, a cooling system is needed so that the temperature inside and outside the chamber are within 2°C. This can be done using e.g. ice water path where the water is circulated using a pump through a radiator inside the chamber.

The amount of plants as well as their growing status will affect the CO_2 flow. When measurements are done, the plants within the collar area should be inside the chamber and no additional plants should be included. If the plants are tall, use extensions in order to minimize the damage on the plants. Also, use board walks to work and store the equipment. The plants will also grow and this should be recorded in one way or the other. You can measure e.g. leaf area index, plant height or green area (https://canopeoapp.com/#/login) as long as it is done frequently. Depending on the ecosystem you

study, the plant parameters will most likely saturate at some point i.e. you cannot anymore measure the changes in the plant development (plant stop growing height but will produce more leaves, the plant density is already at the maximum so additional leaves will not increase the biomass readings etc.). This is a typical problem e.g. in agricultural sites where the maximum biomass growth is the aim.

In general, the CO_2 analyzers cannot handle rainfall or even high humidity conditions. These conditions often lead to constant CO_2 concentration reading or problems with PAR readings.

There is a very clear seasonality in our climate. During snowy winters, it is considered that there is no CO_2 uptake, only respiration, due to the lack of green plants. Thus, the transparent chamber measurements are often only carried out during the snow-free season when the air temperature is above +5°C (threshold limit of the instrument). Since the data collected with the transparent measurements will be used to create site specific models. It is important to capture as a large range of PAR, temperature, and plant conditions as possible in order to improve the model performance. Also, continuous data of PAR, green photosynthesizing plant area and temperature are a must. It is also very important to measure the WL, because it (the depth of the aerobic layer) affects considerably the rate of heterotrophic respiration. Sometimes also for photosynthesis: if conditions are very dry or wet, plants may suffer from drought/flood and they do not photosynthesize normally.

Field equipment checkup: (1) Collars installed in the soil prior to the measurement; (2) transparent chamber for NEE measurement equipped with fans, PAR and temperature sensors (inside and outside temperature) is ready; (3) PAR reducing covers (25% and 50%) are available; (4) opaque cover for the chamber for R_{tot} measurement is available; (5) CO_2 analyzer (inc. data logger, tubing, power supply, etc.) is available; (6) extra cooling elements are available; (7) measuring tape; (8) field note forms, pen or pencil; (9) sensors for supporting measurements (temperature, soil moisture) are available; (10) watering can or similar (to pour water into the collar grooves, as collar and chamber are sealed with water) is available.

NEE measurement at field. Measurements of NEE are always done before the measurement of R_{tot}. Any supporting measurements done, should be done close to the flux measurement itself. Dataloggers should be used so that the CO_2 concentration data is compiled with the PAR and temperature data from the chamber. Depending on the analyzer, you might also need the H_2O concentration data for the CO_2 flux calculations. Flux measurements include four phases: (1.) transparent chamber only, (2.) chamber covered with 25% reduced PAR net, (3.) chamber covered with 50% reduced PAR, and (4.) chamber covered with 100% reduced PAR - dark chamber R_{tot}.

1. Record the monitoring point collar identification code. Add water into collar water grooves and adjust them horizontally if needed.
2. Take a picture of the collar from above to identify later leaf area index (LAI) or greenness index for the flux modelling.
3. Prepare the cooling system (if needed) and switch on the IRGA (depending on the system, warm up time might be needed)
4. Connect the analyzer to the chamber with tubing and necessary cables.
5. Ventilate the chamber against the wind, place the chamber on to the collar, and close the septa
    a. Always start the measurements from the ambient CO_2 concentration as also the CO_2 concentration affects the rate of photosynthesis.
    b. Do not breath into the chamber while ventilating the chamber since you have CO_2 in your breath.
6. Write down the time of closing the septa (= start of the measurement). The analysis for CO_2 concentration should start immediately. This part depends on the analyzer that is used.
7. During the measurement:
    a. The CO_2 concentration at the start should be the ambient level at your site
    b. The CO_2 concentration should change steadily

    c. Temperature difference inside and outside the chamber should be ≤2°C
    d. The light conditions should remain steady
8. Once you have finished the measurements, stop logging the data, open the chamber by removing the rubber septum, and remove the chamber from the collar.
9. Once you have done the 1st phase (transparent chamber) measurement, repeat the measurement for reduced PARs and R_{tot}.
    a. Use appropriate nets and dark covers.
    b. Ventilate the chamber between the measurements so that you always start with ambient CO_2 concentration.
10. Record the supporting variables (i.e. soil temperature, soil moisture, PAR, etc.) approximately at the same time with the chamber measurements
11. Measure the difference between collar upper edging to soil surface at least from 5 locations as a check-up measure data for quantifying (possible) soil surface topography unevenness to the measurement camber volume.

Field notes. It is good practice take notes on concurrent environment conditions during the flux measurements and whether there were issues that might have an effect on the measurement and following data interpretation. Record at least: date, start time (and end time), measurement site ID, measurement collar ID, measurement type (is it transparent, shaded or dark), describe the conditions (e.g. are plants growing as assumed, is there some damage on the plants, did you have to re-adjust the collar on the soil, weather conditions (wind, temperature, clouds, rain)), and all environmental parameters which are not measured automatically.

Data download, flux calculation and flux data quality control. Use the analyzer/Logger specific software in data collection. It is a good practice to download data at the end of each measurement day to minimize data loss. Take photos of the field notes so that you have a backup of the papers as well and store these photos together with the flux & other logger based digital files.

Various analyzers employed may have specific requirements for the data processing. See the instrument manual for that information. Generally, CO_2 concentration change in the chamber is not linear but a non-linear. There are calculation packages available for the data processing. For example, https://doi.pangaea.de/10.1594/PANGAEA.857799 is a site where you can correct/not correct the water vapor dilution effect on the CO_2 concentration, view the measured data by measurement, calculate multiple ways the CO_2 flux and also use multiple quality control factors.

Data processing and modelling of gross primary production (GPP) and R_{tot} for annual budgets will be based on papers that report different equations for GP and R_{tot} models (for example, Karki et al., 2019).

4 EVIRONMENT DATA COLLECTION

Selection of environment parameter monitoring is needed to complement regularly monitored GHG fluxes; (a) in order to form annual GHG emission estimates that take in account diurnal and longer term changes in environment conditions. Typical such temporally changing monitoring parameters include soil temperature (Jauhaiainen et al., 2019). Other important GHG flux rates influencing parameter is WL. Both soil temperature and WL are basic monitoring parameters both during flux monitoring event and by data loggers. Also soil moisture may have importance on fluxes in CO_2, CH_4, and/or N_2O, and it is useful to include periodic monitoring. GHG emission level differences between sites are resulted in part due to soil characteristics, and thus soil sampling for nutrient analyses, and other soil characterizing studies (e.g, infra red screening) are recommended. Water temp, pH, conductivity, oxygen content (repeated measurements in wells, during every site visit, from every well, except wells

for continuous WL measurement). In addition to WL, also chemical analyses (e.g. pH, redox, NH_4^+, NO_3^-) made from periodically collected water samples may have correlation with concurrent GHG emission levels, and thus provide insight to flux dynamics over time. The next paragraphs exemplify sample collection methods and equipment applied to sample collection and on-site environment parameter monitoring.

Soil sampling. Soil sampling equipment for collection of undisturbed soil samples of certain volume (e.g. 100 cm^3) from certain depths reaching from the surface to organic soil profile permanently in waterlogged conditions is needed. If organic layer is deep, also greater depths (e.g., 50-75 and 75-100 cm) should be included in sampling. It is important to take a sample to the whole depth of the litter layer. Customized sampling kits should be used for litter sampling. Different types of box samplers and cylindrical peat corers are available (Figure 10). In addition to samplers, also sharp spade for digging sample pits and plastic bags (depending volume of the sample), and stickers for identification of samples are needed.

Figure 10 Sample ring kit (left), peat sampler (middle), and litter sample frame (right).

Sampling should be done in all 3 subplots in every reference and demo site. Sampling sites should be in a flat area representing average conditions in the site (i.e. preferably in the midmost subplot). Sampling can be done directly using the auger and undisturbed soil probe or by digging 50 cm deep pits and collecting samples directly from the wall of the pit. Choosing of the sampling method should be done depending on the local conditions. Usually it is easier to take samples from pits in wet and soft soil. In case of digging a pit for soil sampling, the typical problem is groundwater filling the pit. A bucket or plastic bag is necessary tool for emptying water from the pit before soil sampling. Litter samples should be taken nearby the pit using the litter sampler. Mixed samples should be taken using the auger from the bottom of the pit.

Sampling procedure (vertical sampling):

1. Remove coarse debris from the proposed measurement site.
2. Use the litter sampler to cut out a litter sample to the whole depth.
3. After extraction the litter sample should be cleaned from bottom to remove peat particles and transferred into a plastic bag. If the litter layer cannot be extracted with the sampler, it should be picked from the ground. Green plants should be removed from the sample. If the amount of litter is less than 300 g, the additional sample (about 300 g) should be collected for chemical analyses into a separate bag. If separate sample is taken for chemical analyses, it must be

indicated on sample bag which sample is for bulk density determination and which for chemical analysis.

4. If the litter layer can be easily separated from peat, soil sampling can be continued from the same point, otherwise soil should be cleaned carefully from litter at nearby location before proceeding to soil sampling.
5. The undisturbed soil sample probe should be used to extract samples from 0-10, 10-20, 20-30, 30-40 and 40-50 cm depths (Figure 11). Where found necessary, the soil auger should be used to access specific soil layers. If the probe reaches coarse root, stone or other obstacle sampling should be continued from a nearby place.
6. Every sample should be carefully transferred into a plastic bag labelled with a sample ID.
7. Soil auger should be used to collect samples from 50-75 cm and 75-100 cm depths. Extracted soil samples (from the specific depth) should be mixed in a plastic bucket and about 300 g sample transferred into a plastic bag for chemical analyses.

Samples can be stored at 4°C for a longer period before air-drying. Then all samples should be dried at 105°C degrees, weighed to determine bulk density, milled and screened through 1 mm sieve, samples for elemental analyses should be milled and sieved through 1 mm sieve. After preparation of samples following parameters should be determined: bulk density, pH(CaCl2), N, P, K, Ca, Mg, C and ash content.

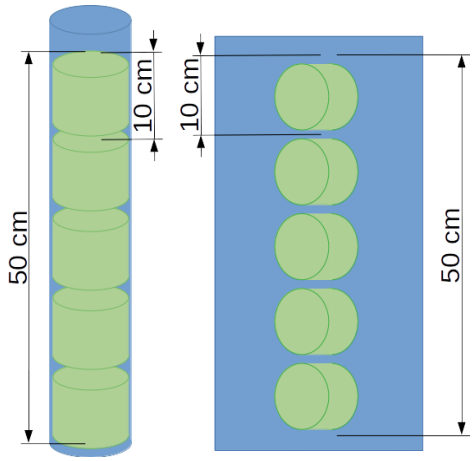


Figure 11 Vertical “soil corer” sampling (left) and horizontal “pit” sampling (right).

Water temp., pH, conductivity, oxygen content. Before measurement, piezometers caps should be removed and position (depth) of piezometer should be checked, particularly, in spring after melting of soil. The correct depth (if it is above ground level) and number of piezometer should be marked on the pipe the depth mark should be checked during every visit. It is recommended to use similar pipe lengths above the soil surface at all sites if possible. If a piezometer is destroyed, it should be reinstalled nearby and left untouched till next site visit before applied for sampling. No measurements should be done from significantly damaged piezometers.

Water temperature, pH, conductivity, and oxygen content has to be measured once per visit in every subplot after manual WL measurement. WL measurements from the piezometer should be made by using bobber / cork on a wire and measurement tape. Measured WL should be written in the field notes. Piezometer tube length remining above the soil surface should be checked and recorded.

YSI ProDSS analyze (www.ysi.com/ProDSS) or equivalent with dissolved oxygen, temperature and conductivity sensors for simultaneous measurement of these parameters can be used (Figure 12). Alternatively, water sampling into bottles and subsequent analysis in laboratory can be used for pH and conductivity determination (but not for oxygen content determination).

Figure 12 ProDSS Multiparameter Water Quality Meter.

YSI has a data logger; therefore, a time stamp can be later used to identify the measurement site, however, it is better to write down measurement results in the field notes. Data should be recorded after stabilization of all readings. Data from YSI should be extracted once per month, measurement location can be later identified manually using timestamp in measurement field notes.

Soil moisture measurement. For periodic on-site soil moisture monitoring, Stevens HydraProbe, provides this option in topsoil temperature probe, (Figure 13). The probe can be connected to PP-systems EGM-5 CO2 analyzer which ensures simultaneous logging of soil moisture, temperature, CO_2 and other data.

Figure 13 Stevens HydraProbe for soil moisture monitoring.

Topsoil moisture should be measured during measurement of soil heterotrophic respiration and CO_2 using combined moisture and temperature probe, which is connected to EGM-5 analyzer. The probe should be pushed into the ground after placing the chamber on a collar or heterotrophic respiration measurement start. The probe should be pushed into the ground to the whole depth at distance of 10-20 cm from the flux monitoring collar/chamber monitoring point. Data from the probe are automatically stored in the EGM-5 and can be extracted from the EGM-5 later simultaneously with CO_2 flux measurement data.

Periodic water sampling. For water sampling at field, it is recommended to be have vacuum pump (e.g. EcoTech vacuum pump (www.ecotech-bonn.de/en/produkte/bodenkunde/sickerwasser/pumpenkoffer/gelande_pumpenkoffer/) to pump out water from piezometers (Figure 14); water bottles for transportation of water samples (0.5-1.0 L samples); cooling elements and

transportation box or cooler with volume enough to accommodate samples from 2-3 sites (e.g. like in Figure 14). For sample storage prior to analysis, refrigerator (+4ºC) is needed.

Figure 14 Vacuum pump (left), cold box (middle), and freezing elements (right).

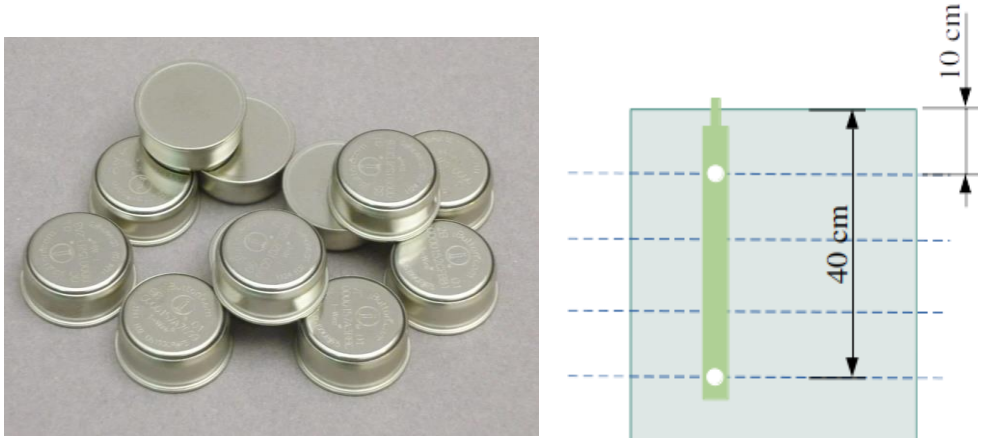
Water sample collection procedure:

- Sampling frequency: once in 3 weeks (during GHG flux measurements) after groundwater level measurements, but preferably before YSI or equivalent analyzer on-site measurements to avoid contamination;
- Sampling place: the same piezometers during whole study period;
- Sample count: one sample per study site;
- Sampling amount: 300 – 500 mL (preferably PE bottle completely full of water without air space).
- Sample labeling: Information indicated on water bottle: SIte ID, Subplot ID, sampling date
- Sample transportation in cold box with cooling elements, and storage as close to 4 °C as possible (freezing of the sample is not permitted) and sample storage time should minimized.

Table 2 Water parameters analyzed in Life OrgBalt.

Parameter	**Method principle**	**Instrument**	**Standard method**
Sample preparation	Filtration	Glass fiber filter VWR 516-0871	
N_{tot}, $N\text{-}NO_3^-$	Catalytical oxidation and detection by chemiluminescence detector	Skalar Formacs^{HT}, Formacs^{TN}	LVS EN 12260:2004
DOC	Catalytical oxidation and detection by ifrared detector	Skalar Formacs^{HT}, Formacs^{TN}	LVS EN 1484:2000
NH_4^+	Photometry	Shimadzu UV - 1900	LVS ISO 7150-1:1984
PO_4^{3-}	Photometry	Shimadzu UV - 1900	LVS EN ISO 6878:2005
K, Ca, Mg	Flame atomic absorption spectrometry	Thermo Fisher Scientific iCE3500	LVS EN ISO 7980:2000

Continuous soil temperature measurement. Soil temperatures are commonly monitored by 1-wire systems, e.g., Maxim Integrated DS1922L (www.ibuttonlink.com/products/ds1922l) or equivalent temperature sensors (Figure 14). Continuous soil temperature measurement in reference and demo sites should be done at 2 depths (10 cm and 40 cm) in the soil profile during a 24 months period when gas sampling is done. Temperature probes should be located in the subplot representing average conditions in the site subplot (middlemost subplot B) close to automated WL monitoring piezometer tube. Location of the temperature probes should be hidden to avoid destruction of the probe. Depending on the temperature readout frequency, data needs to be saved from internal memory by data readers. Readings from the temperature probe should be done at least every 3 months to avoid significant data loss in case of damage of the equipment. Although rugged in structure, loggers need additional protection against acidic and wet environment. For example, plastic containers can be produced for installation of sensors at certain depth and insulation of temperature probe (Figure 15).



Maxim Integrated DS1922L temperature loggers (left), and outlined installation of thermometers in soil (right).

Figure 15 Temperature loggers, and outlined installation of thermometers in soil.

Periodic soil temperature measurement. Soil temperatures at specific depths are monitored next to each GHG monitoring point during flux measurement. The data will be linked to temperature logger data for modeling GHG fluxes in temperature conditions not covered by direct measurements. Periodic temperatures are typically measured by T-type probes connected to data displays or data loggers (e.g., four channel external temperature data logger Pt1000 probes; www.cometsystem.com/products/temperature-data-logger-for-four-external-pt1000-probes/reg-u0141). Example of simultaneous 4-depth temperature monitoring set-up is shown in Figure 16.

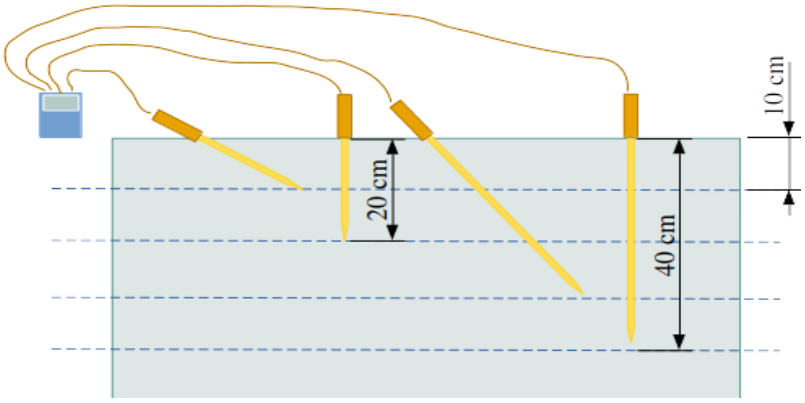


Figure 16 Example of location of temperature sensors in soil.

Periodic soil temperature measurements are adding on and duplicating continuous measurements in case if the continuous measurement probes are damaged. Minimum measurement, in case it is done, is at 10 and 40 cm depth from soil surface, optionally, at 10, 20, 30 and 40 cm depth to build temperature change gradient for different layers. These data will be also supplemented by measurements of topsoil moisture / temperature measurements.

Measurement should be started after arrival to the site by inserting thermometer probes into soil and switching on a data logger. If soil is frozen holes should be drilled to insert the probes. After completion of other measurements in a particular site logger should be switched off and probes removed from soil.

Continuous water level measurement. Xtreem Capacitance Water Level Logger (http://odysseydatarecording.com/index.php?route=product/product&product_id=104) (Figure 17) or equivalent for continuous WL measurement. Piezometer (internal D at least 60 mm) with caps at both ends (1 per measurement site, located in the measurement (centermost) subplot characterizing average conditions in the plot.

Figure 17 Xtreem Capacitance water level logger.

Continuous WL measurement in reference and demo sites during the 24 months long period GHG monitoring is done by using divers in piezometers. The piezometers should be located in the area characterizing average conditions in the site (midmost subplot B). Location of the probe should be hidden. Depth of piezometers and logger installation depth (1.5-2.0 m needs to be recorded). This

piezometer should not be used for water sampling and it should stay untouched during the project implementation.

Considering different programming capabilities of different WL loggers, identification of each sensor can be implemented in different ways. It is good if the logging is set to take place on even hours (i.e. …, 10:00, 11:00, 12:00, …). Data download should be done every quarter (every 3 months). It is important to make reading in spring to see if the batteries are not tired and readings still continue.

Meteorological parameters. Ambient air temperature at standard 2 m height above ground level at 1 hour interval, daily (if available, hourly) precipitation data (precipitation amount (mm) and precipitation intensity (mm/hr)), daily duration of solar radiation and if possible, direct and global radiation (hourly) and photosynthetically available radiation (PAR) hourly values from nearest meteorological station or measurement site (e.g. hydrological station) most characteristic for the nearest study site.

5 BIOMASS AND LITTER DECOMPOSITION MEASUREMENTS IN FORESTS

The ultimate goal of this work is to estimate the annual soil carbon (C) balance for the sites. For this purpose, we monitor the soil C-stock change by combining data from mass-based measurements (i.e., measured or modelled biomass data, litter input rates, litter decomposition rates) and gaseous C-losses from the soil (i.e., GHG flux monitoring on the sites described in the previous chapters). In this section we form protocols for the mass-based measurements needed in this calculus including the following C-stock components: (1) aboveground biomass and biomass production, (2) belowground biomass and biomass production, (3) litter inputs, including woody debris, and (4) soil organic carbon.

Available models are used for estimating some of the C-stock components, because the project lifetime is relatively short compared to C-stock changes (e.g. tree biomass production) and some are too laborious to measure directly (e.g. belowground tree biomass C-stock). If available, previously collected biomass and biomass production data can also be used for estimating biomass production and thereby reducing field and laboratory work.

The following guidance is for Life OrgBalt sites that have no previous records on the biomass. If there are well conducted relatively recent previous tree biomass and biomass production records for the site, it is good to use existing data. However, it should be checked what data is included in tree data collection so that no overlap or gap (missing information) occur as the data is used together with measurements on ground level vegetation data. For example, height of tree seedlings (i.e., what height is included into tree biomass monitoring and what height is included in ground vegetation biomass monitoring) and diameter of dead wood on the ground (i.e., what is lowest diameter forming part of tree measurements and what diameter is part of litter deposition measurements) may form such discontinuity points. By checking previously applied protocols in data collection it is possible to maintain consistency in data records and supplementary or data upgrading measurements can be performed.

5.1 Tree, tall shrub, and tree seedling/sapling biomass

A tree is a perennial woody plant capable of reaching minimum 5 meters height *in situ*. The methodology should ensure that no double accounting of biomass takes place, including soil carbon input due to natural mortality or harvesting. As far as these criteria are considered, **partners are flexible to choose** the measurement method for the tree compartment. Before making the measurements, each

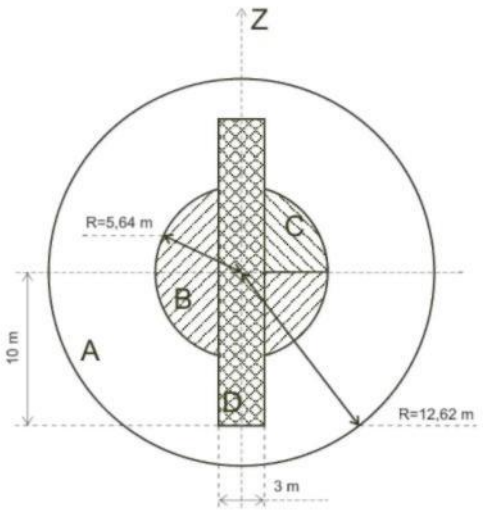
partner needs to know what **allometric equations** they will apply and design the details of the measurements so that they make it possible to use those equations. Allometric functions are available for all our common forest tree species (e.g., Lehtonen et al., 2004; Repola 2008; Repola 2009; Zianis et al., 2005; Liepiņš et al., 2017).

The aboveground biomass of trees, tall shrubs and saplings is measured non-destructively. Tree stand above-ground and below-ground (coarse root) biomass estimation will be based on measuring the tree stand diameter distribution (breast height diameter from root collar or ground level, depending on the allometric functions applied) of all trees on the sample plot, and further parameters (e.g., tree height and length of the live crown) for sample trees. Sample tree data provides a complementary set of variables for all trees. Biomass of different stand components (stems, branches, foliage, stump and coarse root systems) will be estimated with allometric functions that use breast height diameter, either alone or together with the complementary variables, as explanatory variables. Selection of complementary variables depends on the allometric functions applied, and common practice in gathering these variables, e.g. height of at least 9 sample trees of each species and height of rarely represented trees should be measured on a stand basis. Preferably, all trees in the subplots in forest land should be georeferenced, respectively, distance and azimuth from the subplot centre should be fixed.

Equipment for tree measurements. For the measurements you need Compass (360°) (e.g. Suunto KB-20 or Suunto KB-14), GPS receiver (precision ca. 1–3 m, + extra batteries, Measuring tape (30 m), calliper for trees, diameter tape (mm scale), 1.3 m long stick for measuring tree's breast height level, 30 cm long metal rod for marking of plot centre points or pole with one end sharpened and another painted to mark the plot centre, paint to mark measured trees, tree height and land slope measuring equipment (e.g. Haglöf Vertex IV hypsometer to measure tree height, in meters; slopes, in percentages, and distance of a tree from center of plots), and coloured flagging ribbon (several rolls for marking).

5.2 Tree stand measurement plots

The main element of the tree floor inventory is a permanent inventory sample plot of a fixed radius, the area of which is 500 m² (radius in a plane is 12.62 m) and in which trees, as well as fallen deadwood with bottom diameter of at least 14.1 cm are surveyed (Figure 18). This plot fully or partially overlaps with GHG flux measurement subplots.



Sample Plot Scheme (A – 500 m² sample plot, B – 100 m² sample plot, C – 25 m² sample plot, D – sample plot of undergrowth and advanced growth inventory).

Figure 18 Sample Plot Scheme.

A second sample plot shall be earmarked at the centre of the sample 100 m² plot (R= 5.64 m) in which all trees and fallen deadwood with the diameter of the butt-end 6.1 cm or more shall be surveyed. All trees of natural origin and their outgrowth, the diameter of which at a height of 1.3 m above the root collar (hereinafter – in height of 1.3 m) is at least 2.1 cm, shall be surveyed in the first fourth of such sample plot, calculating from the northern direction (25 m²).

The undergrowth and advanced growth shall be determined in a zone of the sample plot of 3 x 20 m, earmarked in a joint sample plot, in sample plots No. 1 and No. 3 in the eastern-western direction, in the sample plots No. 2 and No. 4 in the northern and southern direction.

Table 3 Coordinate system parameters of the tract and sample plot center.

Ellipsoid	WGS84
Projection	Transverse Mercator
Central meridian	24
Scale coefficient on meridian	0,9996
Deviation along x-axis	500000 m
Deviation along y-axis	-6000000 m

Determination of the forest type. In each sample plot the forest type of the forest stand shall be determined, using the national forest typology (e.g., in Latvia K. Bušs 1981).

Inventory of advanced growth and undergrowth. Advanced growth and undergrowth shall be itemised in all sample plots. The **trees** of the forest element which while being 1.3 m in height have not reached 1 cm in diameter shall be included in the advanced growth. If a forest element with a diameter of less than 2,1 cm forms a dominant stand, its trees shall not be included in the inventory of the advanced growth. The **undergrowth** and the advanced growth shall be itemised in a zone that is 20 m long and 3 m wide. The number of species and specimens for undergrowth and advanced growth trees, as well as the height and diameter of a visually selected average woody plant in the middle of it shall be determined. The average age shall be determined for each undergrowth and advanced growth species – branch whorls shall be itemised or a tree shall be sawn outside the sample plot and its growth rings shall be counted. During inventory of the undergrowth and advanced growth all sprouts which have grown up from the ground or stump shall be counted.

5.3 Survey of growing trees

Selection of inventory trees. Inventory trees shall be selected from the living trees in the sample plot, the diameter of which has been measured in height of 1.3 m above root collar. If an individual element of the stand is formed only by deadwood, the inventory trees shall also be measured for them. Generally, not less than 1 tree out of 7 trees should be selected. If only one tree species is represented in the sample plot, then trees 3-5 from Kraft Class I, also 3-5 trees from Kraft Class II and Kraft Class III trees, as well as 1-2 trees from Kraft Classes IV and V shall be selected as inventory trees. There is no need to separate stand into different levels. If several tree species are represented in the sample plot, then 2-3

trees from Kraft Classes I-III and 1-2 trees from Kraft Classes IV and V shall be selected as inventory trees for each of such species. If the number of forest element trees in the sample plot is very high, then not less than 1 tree out of 7 trees shall be selected. In selecting trees for inventory the 3rd tree, then the 10th tree, the 17th tree, etc. shall be selected. If a sufficient number of inventory trees is not collected systematically, then the missing trees shall be selected from thicker trees.

Additional measurements shall be taken for inventory trees – the height of trees shall be determined, as well as the diameter of the tree at the root collar, the height of the first green branch, the height of the first dry branch can be determined, if these values improve accuracy of determination of carbon input int soil and other carbon pools.

Determination of the distance of the tree to the centre of the sample plot. The distance from the centre of the sample plot to the centre of the tree in height of 1.3 m in horizontal direction shall be measured with the help of an ultrasonic or laser measuring device. The belonging of trees (growing trees, deadwood, fallen trees) to a sample plot shall be determined by their diameter in height of 1.3 m. A stand shall be mounted at the centre of the sample plot, to which an ultrasonic reflector shall be attached, for the determination of the distance. The source of ultrasound with the measurement indicator shall be held horizontally to the reflector by the central axis of the tree. The distance of only standing trees to the centre of the sample plot shall be recorded in the inventory card of trees. The distance for fallen trees shall be measured only to determine their belonging to the sample plot.

Determination of azimuth in order to identify the location of the tree. Azimuth of a tree shall be measured from the centre of the sample plot with an instrument intended for measuring of angles (compass), which has been secured with the help of a stand, with accuracy of 1^0. The stand shall be aligned at the centre of the sample plot with the help of a weight. The direction for trees which have toppled shall be determined according to the line connecting the centre of the sample plot with an imaginary perpendicular line drawn towards the centre of the stump. Azimuth shall be registered as an instrument reading, without taking into account the magnetic variation. Azimuth shall be measured only for growing trees and snags, azimuth need not be measured for stumps and fallen trees. Surveying of trees shall begin from magnetic North, clockwise.

Determination of the distance of the tree to the centre of the sample plot. The distance to the tree shall be measured in height of 1,3 m, towards the axis line of the tree (half of the diameter). If the tree is located in a relief slope, then the distance to it shall be measured towards height of 1,3 m (parallel to the land surface), determining the land surface angle and recalculating the distance on the horizontal plane. If due to a poor visibility of the tree (accurate determination of azimuth or measuring of the distance is hindered by the projection of another closer tree bole) or it is not possible to take an accurate measurement of the diameter of the tree in height of 1,3 m, the reason for the possible error shall be noted in the "Notes" of the tree measurement sheet.

Determination of the characteristics of a tree. Measurement and assessment of trees and stumps shall be performed in each sampling plot (subplot). The following shall be determined for each tree and entered in the tree inventory table: (1) the distance of the tree to the centre of the sample plot (+/- 1 cm); (2) the tree azimuth (+/- 1^0); (3) the species (according to the classifier); (4) the diameter of the tree in height of m (+/- 1 mm); (5) the height of the tree for inventory trees (+/- 0,5 m); (6) the height of the first green, first dry branch (+/- 0,5 m) if this increase accuracy of allometric estimates; (7) damages (type of the damage, intensity of the damage, height – location on the tree).

Determination of the diameter of a tree. For all trees in the sample plot, which have reached the diameter of 2.1 cm in height of 1.3 m, the diameter shall be measured in height of 1.3 m with accuracy of 0.1 cm. The place where the diameter was measured shall not be marked on trees.

In measuring the diameter of a tree, the following provisions of measuring shall be conformed to:

- the place where the diameter is measured at height of 1.3 m has to be determined using a ruler that is 1.3 m long. If trees branch lower than in height of 1.3 m, diameters of 2 trees shall be measured. If there is a scar or a protuberance at the height of 1.3 m, then the diameter shall be measured above and below this place, recalculating the average value afterwards;
- the diameter shall not be measured for trees, which have not reached the diameter of 2.1 cm in height of 1.3 m;
- if tree is located on the border of the sample plot, then its diameter in height of 1.3 m from the root collar shall be measured;
- if the vertical axis of the tree is located in the sample plot, then it shall be surveyed, if it is located outside the border of the sample plot, it shall not be surveyed;
- the diameter of all trees shall be measured including the bark; if trees are without bark, for example, dead, then the diameter shall be measured without bark and a relevant note shall be made in the notes.

Determination of the height of a tree. Height shall be measured only for trees selected for inventory and for all snags. The total height of a tree shall be measured, as well as the height of the first green branch and the height up to the first dry branch can be measured at every odd time of survey if it improves accuracy of the estimates. The height shall be measured with the height measuring device, with accuracy of 0.5 m. The height of a tree shall be measured from the place where the top of the tree is accurately visible. In case if a tree is growing obliquely, the distance for taking of the measurements of height shall be determined from the place located athwart to the top from the ground. Height shall be measured from the place towards which the slope of the tree is oriented. Generally, if it is possible to select a corresponding inventory tree, the height of oblique trees shall not be measured. In determining distance from the perpendicular projection of the top of the tree to the centre of the tree trunk, it is possible to calculate the length of the tree.

The height projection of a tree H_v in vertical plane and the distance of the top from the base H_h shall be measured. The height of a tree shall be calculated using the formula (**Error! Reference source not found.**):

$$H=\sqrt{H_v^2+H_h^2}$$, where

H_v – height projection of a tree in vertical plane;
H_h – distance of the top from the base.

The height of the beginning of the crown shall be measured in the same way. The beginning of the crown shall be determined according to the first green branches growing from the trunk.

Description of forest stands, if the diameter of a dominant trees is less than 1 cm. In forest stands, in which the diameter of dominant tree species in height of 1.3 m has not reached 1 cm or the height has not reached 1 m, trees shall be measured as follows:

- the average tree of the forest element shall be selected;
- the height of the average tree shall be determined;
- the diameter of the average tree in height of 1.3 m shall be determined:
- if height of 1.3 m has been reached, the diameter shall be measured; if the diameter is less than 1 cm, it shall be marked as 1 cm;
- if height of 1.3 m has not been reached, the diameter shall be marked as 1 cm.

Any element of the forest stand shall be marked with one measured and described tree, azimuth and marking the distance from the centre of the sample plot with 1.

In forest stands, in which the height of the dominant tree species has not reached height of 1.3 m, the age of trees shall be determined at the root collar; for planted trees the age of the plant need not be taken into account, if determination thereof is possible.

5.4 Measurement of dead wood (lying dead trees)

In measuring death rate, the species, position (stub or lying deadwood) and diameter at the thin-end and butt-end shall be determined. If a trunk is with stump laying inside a plot, the diameter of the butt-end shall be measured in the distance of 1,3 m from the root collar, assuming that the diameter of the thin-end is 1 cm. If the fallen deadwood is a broken top, the diameter of the butt-end shall be measured at the breaking point, assuming that the diameter of the thin-end is 1 cm. If direct measuring of the thin-end of the stub is not possible, it shall be determined by the height of the stub, assuming that the diameter of the thin-end of the stub is the same as the height of the stub. Freshly prepared assortments, wood at delivery roads, sown tree stumps, as well as stumps of broken trees less than 0,5 m short shall not be included in death rate. Such fallen deadwood shall be measured, which are more than 6.1 cm wide at the butt-end. The belonging of the fallen deadwood to the sample plot A or B shall be determined according to the location of the fallen deadwood in the sample plot.

If the butt-end of the fallen deadwood is located in a sample plot, the length of the whole fallen deadwood shall be measured also if part of the fallen deadwood is located outside the sample plot. If the butt-end of the fallen deadwood is located outside the sample plot, the fallen deadwood shall not be measured.

Death rate shall be classified according to its quality groups, i.e. (i) fresh death (until the bark of the bole begins to peal), (ii) death of average age (from the time when bark of the bole begins to peal until epiphytes begin to occur on less than 10 % of the cover of the visible surface of the bole), and (iii) pieces of rotten wood (cover of epiphytes is more than 10 % of the visible surface of the bole).

The data obtained as a result of surveying sample plots initially shall be registered in work tables or their equivalents on the field computer. Data shall be copied from field computers to the data base not less than once in two weeks. Logical control of data shall be performed and the data errors detected shall be returned to the field working group for correction in order to take repeated measurements in the sample plot. Data obtained in surveying of sample plots shall be permanently stored in the form of data base, ensuring a possibility to analyse the information in historical development. Permanent data bases shall ensure a possibility to supplement them with new indicators to be determined at any time.

5.5 Estimation of tree biomass production

Biomass production estimation will be based on annual diameter growth of measured sample trees between 2 consecutive inventories. The second inventory will be performed usually 5 years after the first one. The growth data will be used to construct diameter distributions, and the complementary set of variables, for the stand in consecutive years. The allometric functions will be fitted into these data sets, and the annual biomass production will be estimated as the difference between biomass values of consecutive years. Values will be transformed per square meter using sample plot area. Annual mortality can be estimated as the increase in dead trees between 2 consecutive inventories.

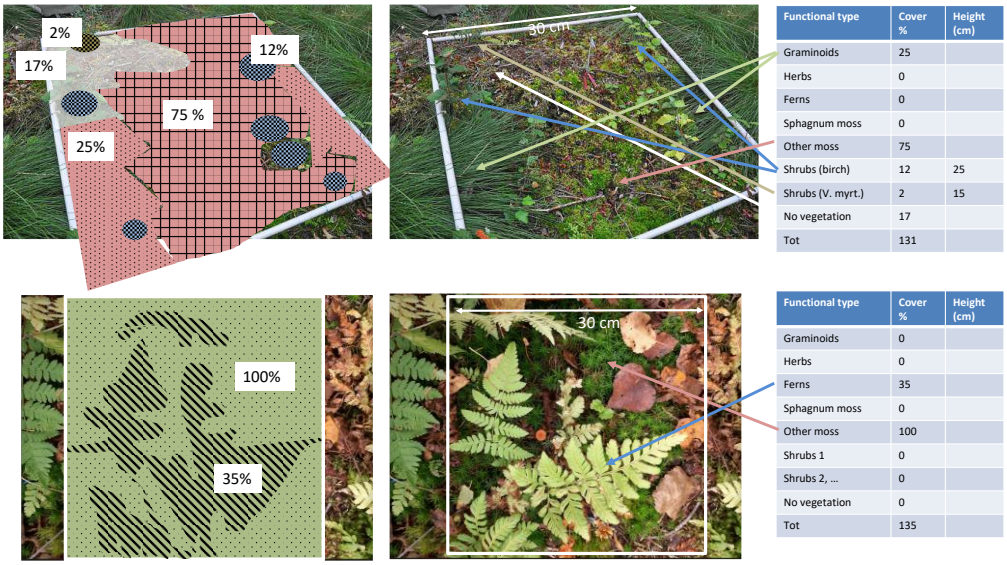
5.6 Ground vegetation biomass

This data is also used for estimating annual biomass production and litter inputs from ground vegetation, except for mosses in sites where there is an abundant moss cover.

Ground vegetation biomass is harvested from six 30 x 30 cm (area = 900 cm^2) sample plots per site, two at each GHG measurement subplot. Biomass will be harvested during the period of maximum ground vegetation biomass (usually in July-August). The collected biomass is separated by species or plant functional types, and further separated as listed below. Equipment needed includes: frame for delineating the sample plot, bags for the harvested biomass (different sizes), markers, scissors, secateurs (pruning shears), form for recording projection cover estimates.

Establish 6 plots per site (2 plots at each GHG monitoring subplot). Each sample plot is a 30 cm x 30 cm square area (delineated e.g. with a wooden frame), and;

- First, estimate the projection cover (% of area) of the vegetation inside the sample plot. Projection cover is estimated for plant functional types: 1.) graminoids (i.e., sedges, grasses), 2.) herbs, 3.) ferns, 4.) moss (*Sphagnum* and other mosses separately), and 5.) shrubs by species, and the cover proportions are recorded. For shrubs also the average height per species is estimated and recorded (Figure 19). Note that projection cover-% can exceed 100% because plants can grow in several layers and overlap each other.



Functional type	Cover %	Height (cm)
Graminoids	25	
Herbs	0	
Ferns	0	
Sphagnum moss	0	
Other moss	75	
Shrubs (birch)	12	25
Shrubs (V. myrt.)	2	15
No vegetation	17	
Tot	131	

Functional type	Cover %	Height (cm)
Graminoids	0	
Herbs	0	
Ferns	35	
Sphagnum moss	0	
Other moss	100	
Shrubs 1	0	
Shrubs 2, ...	0	
No vegetation	0	
Tot	135	

Figure 19 Estimating projection cover in different plant functional groups.

- Second, for the shrubs
  - Shrubs (≥50 cm high species that are not considered as trees, tall shrubs or tree seedlings in the tree survey!): number of separate shoots is counted by species, and an average shoot of each species is chosen for recording the height and taken as sample
  - Shrubs (≤50 cm high species) are collected into marked bags, each species separately (alternatively, all can be put in one bag, and species separation can be done in the laboratory – consider full time consumption and potential errors done in both field and lab!)
- Third, for the other vascular plants

    - Above-ground parts are collected into marked bags by functional types (i.e., graminoids, herbs, and ferns separately)
- Fourth, for mosses,
    - If **mosses do not form a significant component** in ground vegetation in the site, their living parts are also collected into marked bags. Living parts are separated based on change in color or visible beginning of decomposition. Preferably take too much and trim the dead parts off in the laboratory.
    - **For sites with abundant moss layer**, moss biomass estimation is explained in separate chapter in connection with moss biomass production
- Samples are stored frozen if not processed within one week
- Laboratory work before drying
    - Shrub separation is first done only for flagship sites, or for 20 samples per species altogether from different sites. After that, we will see whether the proportions can be modelled based on those data!
    - Shrubs (>50 cm high species): shoots are separated to leaves, live and dead stems, and current-year shoots
    - Shrubs (≤50 cm high species): for deciduous species, shoots are separated to leaves, live and dead stems, and current-year shoots; for evergreen species, shoots are separated in the same way, except that leaves of current-year shoots are further separated
    - Other vascular plant bags are ready for drying
    - Mosses: separate the samples roughly to *Sphagnum* mosses and other mosses ("forest mosses"). If there are just a few shoots of either group, they may be pooled to the more abundant group.
    - Mosses: check the cutting done in the field, and cut off the potential dead and decomposing lower parts of the moss growth. NOTE: this is not done per moss shoot but per the whole clump of moss.
- The samples are dried at 60-70°C and dry mass of each sample is recorded (the default drying temperature of each lab, within this range, can be used)
    - Dry mass records from each ground vegetation biomass plot: graminoids, herbs, ferns, possibly moss, shrub leaves by species (NOTE: current-year leaves separately for evergreen species), shrub live stems by species, shrub dead stems by species, shrub current-year shoots by species.

5.7 Ground vegetation biomass production

No new (additional) sampling is done for this purpose: the ground vegetation biomass samples are used for estimating biomass production.

Annual herbaceous ground vegetation biomass production. For annual plants, the harvested maximum biomass is used as such to represent annual aboveground biomass production and the amount of litter input.

Perennial ground vegetation biomass production. Estimates are calculated separately for each biomass sample plot. For deciduous shrubs (<50 cm high species), leaf production, and litterfall, is estimated as leaf mass obtained from the biomass samples. For evergreen shrubs, leaf production is estimated as leaf mass of the current-year shoots. Stem production is estimated as the mass of current-

year shoots. For the >50 cm high species, all of the above-mentioned mass values are multiplied with the number of stems recorded for the plot.

5.8 Moss biomass and moss biomass production

Moss biomass and biomass production are determined separately **on sites that are characterized by an abundant moss cover**. For other sites, biomass data from the ground vegetation sampling plots (as described above) is used as an estimate.

Moss patch projection cover. In sites with large moss cover, it is first evaluated which species or species groups are found, and what are the most abundant patch types. Patch is a separate moss-covered area dominated by the same species or species mixture all over (see Figure 20). Different patch types have different forest mosses or *Sphagnum* as the dominant moss. The projection cover (% of area) of each moss patch type in each subplot is roughly estimated visually, the estimates are recorded, and the main species or patch types are chosen for the analyses.

Moss biomass production, which is also assumed to equal litter production, is measured as follows. Square-shaped nets (each about 20 cm x 20 cm) will be placed on patches of (maximum) **three** most common moss species or moss patch types (**five nets per species/patch type**) at each site (i.e., not at each subplot) in the autumn of the first GHG monitoring year. The nets are firmly hooked on place e.g., with metal hooks used with tents (see Figure 20). Biomass grown through the nets is harvested in the autumn **one year later**, from the middle of the net, using a **10-cm diameter circular sampler**. For forest mosses, this biomass represents production and is simply dried at 60-70°C and weighed. For *Sphagnum*, a capitulum correction needs to be done (explained below), since the production estimate should cover only stem length increment, as the capitula remain more or less constant over time.

For *Sphagnum* samples, the mean **total length** of the moss (length from the cut to the tip of the capitulum - see Figure 21) is first determined. This can be done with a subsample of about 20 randomly chosen shoots. Then the capitula are cut off and the mean **stem length** is determined accordingly. The *mean length of the capitula* can then be calculated as *total length - stem length*. Next, the capitula of the whole sample are removed. The total dry mass of the stems only (including the stems that were used as subsample!) is measured, and *mass per unit stem length* is calculated as *total stem mass / mean stem length*. The production estimate is then calculated as *total stem mass + (mean length of the capitula x mass per unit stem length)*. These values are transformed to represent one m^2 (based on the area of the sampler).

Illustration of natural markers showing forest moss stem growth (left, modified from *Pouliot* et al., 2010), and *Sphagnum* structure (right, modified from Weston et al. 2015).

Figure 20 Illustration of natural markers showing forest moss stem growth.

For each moss patch type of the site, average patch-level production values are calculated. Subplot-level estimates of moss production will then be calculated by multiplying the site-level patch-level averages with the respective projection coverage for each patch type at the subplot: (*projection cover of the patch type (%) x average patch-level production)/100*. These patch-type-specific values are summed up for each subplot, and further for each site.

For the species/patch types not sampled for biomass production at the respective site, species/patch-specific production of the same species/patch at another site representing the same vegetation type, or a close species at the same site can be applied.

The site-level production estimates are also used as estimates of annual moss litter input.

Moss biomass. For estimating moss biomass, separate samples are taken from the same moss patches where production is measured. If these patches cannot be used (i.e. they are too small for both samplings), then other similar patches nearby are chosen. Five samples per patch type and site are taken with the **same 10-cm diameter circular sampler** as the production samples, deep enough that the whole live (or assumed live) part is collected. This can be done at the same time when the production samples are taken (or when the nets are installed, for as long as the net surroundings are not disturbed). In the laboratory, the dead part of the moss clump is cut and removed, based on visual assessment (colour change of the moss, visual estimate of beginning decomposition also indicates the change to dead part). The samples are dried (60-70°C) and dry mass is determined. The dry mass represents the biomass per the 10-cm diameter circular area, and must be transformed to a per m^2 estimate. Average patch-level biomass estimates are then calculated for each species/patch type per site. For each subplot, moss biomass estimates (g m^{-2}) are calculated as (*projection cover of the patch type (%) x average patch-level biomass)/100*.

Summary:

- The projection cover (% of area) of each moss patch type (dominant mosses; forest mosses, *Sphagnum*) in each subplot is estimated; main types of the whole site are chosen for analyses in that site
- metal nets per moss patch type, area ca. 20 × 20 cm, are anchored with metal hooks on top of the moss layer, to be harvested after one year, when a 10-cm diameter sample is taken from the middle of each net
- For forest mosses, the whole moss sample harvested from above the net represents production, and only its dry mass is determined, and transformed per m^2
- For *Sphagnum* mosses, capitulum correction needs to be done (as explained above)
- Five separate 10-cm diameter biomass samples are taken of each patch type
- The biomass samples are trimmed to represent live moss in the laboratory, and dry mass is determined, and transformed per m^2
- Subplot-level biomass/production estimates are calculated for each patch type as projection cover (%, estimated for the subplots) × patch-level average biomass/production of the site (g m^{-2})
- Equipment needed in the field: Production: Nets with a relatively wide mesh size (1-2 cm x 1-2 cm), metal hooks for fastening the nets (4 per net, J-shaped sturdy iron wire piece, or "tent hooks"), sharp scissors and/or very sharp knife, bags, marker, 10-cm diameter sampler (e.g. a used tin can with regular round shape; NOTE remember to measure and record the exact diameter!)
- Equipment needed in the field: Biomass: Sharp scissors and/or very sharp knife, bags, marker, 10-cm diameter sampler (e.g. a used tin can with regular round shape; NOTE remember to measure and record the exact diameter!)

5.9 Ground vegetation cover

This is recommended to be done **if** there is interest and the time resources allow it, as it is **not** necessary for constructing emission estimates. For monitoring ground vegetation community dynamics (biodiversity), **permanent** plots for inventorying projection cover – not to be disturbed by other measurements or passage. There are two alternative ways: a simpler one agreed on the project workshop for future project purposes, OR the "traditional" ICP Forest methodology used in most European countries for 30 years if one wants to produce data compatible with that.

The simpler option:

- 50 cm × 50 cm (center or two corners marked with durable 'sticks' to identify locations semipermanently),
- 6 per site
- Projection cover (%) of both field and bottom layer species estimated

ICP Forests[4] methodology:

The field crew consists of two professional observers, who have undergone theoretical and practical training in vegetation surveys prior to the annual growing season. Vegetation is surveyed in each study object in double sample plots (squares), 1 m^2 in size (Figure 22). Vegetation sample plots are established at least in a 25 m distance from forest stand edges. Sample plot design is shown in **Error! Reference source not found.**.

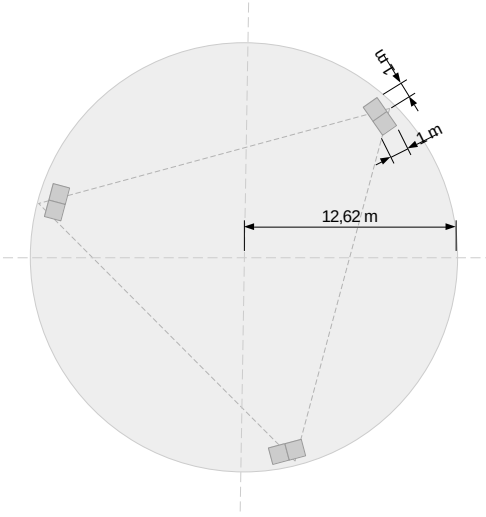


Figure 21 Design of sample plots (squares) for ground vegetation survey.

Each layer of ground vegetation is evaluated separately. The following layers are distinguished:

- moss layer - terricolous bryophytes and terricolous lichens;
- herb layer - all non-ligneous plants, and ligneous plants, if ≤ 0.5 m height, including eventual seedlings, and browsed trees; the percentage cover of grasses, herbs, sedges, dwarf shrubs, seedlings and browsed trees are also determined without identifying particular species;
- shrub layer (plants > 0.5 m and ≤ 5 m in height), should be accounted if not yet accounted as a forest floor.

[4] http://icp-forests.net/page/icp-forests-manual

The following materials should be carried to the field survey: plastic or metal pipes for sample plot delimitation, a plant atlas or an application installed on smartphone to identify unknown species, paper to wrap plant samples and prepared data tables to write down observations.

Pipes are placed on top of vegetation to create a sampling square. Observers assign a value up to 100% for each species in moss, herb and shrub layer. One of the observers fills the data table, registering the name of the species, and its percentage cover. Extra notes of site condition are taken, e.g., shading, litter, humus content, harvesting residues, percentage of bare soil. If a plant species is not identified, a genus is assigned. Samples of unrecognized species are collected, if the plant is not locally sparse.

5.10 Belowground biomass and biomass production

Fine root biomass. For the estimation of belowground biomass, 9 volumetric soil samples at each site should cored down to 50 cm (Figure 23). Roots and rhizomes should be separated and identified to main species or species groups either visually, or based on infrared spectroscopy with the models of Straková et al. (2020).

- Nine (9) peat cores taken from each experimental plot at the end of the growing season
- Zero-level estimated in the field, subsamples cut as 10-cm pieces down from that; surface vegetation are kept in the topmost sample;
    - Samples down to 50 cm depth in deep organic soils
    - Shallow organic soils may be tricky if roots reach down to mineral soil; somehow the coring should be extended down to the desired depth (either by a different corer, or some more laborious method such as shoveling…)
- Samples are stored frozen if not processed within one week
- Roots are washed out using e.g. soil sieves to prevent loss of roots
- Harvesting washed roots:
    - Roots with diameter ≤2 mm are harvested as ’fine roots’
    - Roots with diameter >2 mm and ≤2 cm are harvested as ’small roots’
    - Shrub and sedge rhizomes are separated to form specific biomass components, separate from the actual roots
- Roots are dried in 40°C (note the low temperature!) for 72 hours, weighed, and powdered if planned to include in IRS analysis .

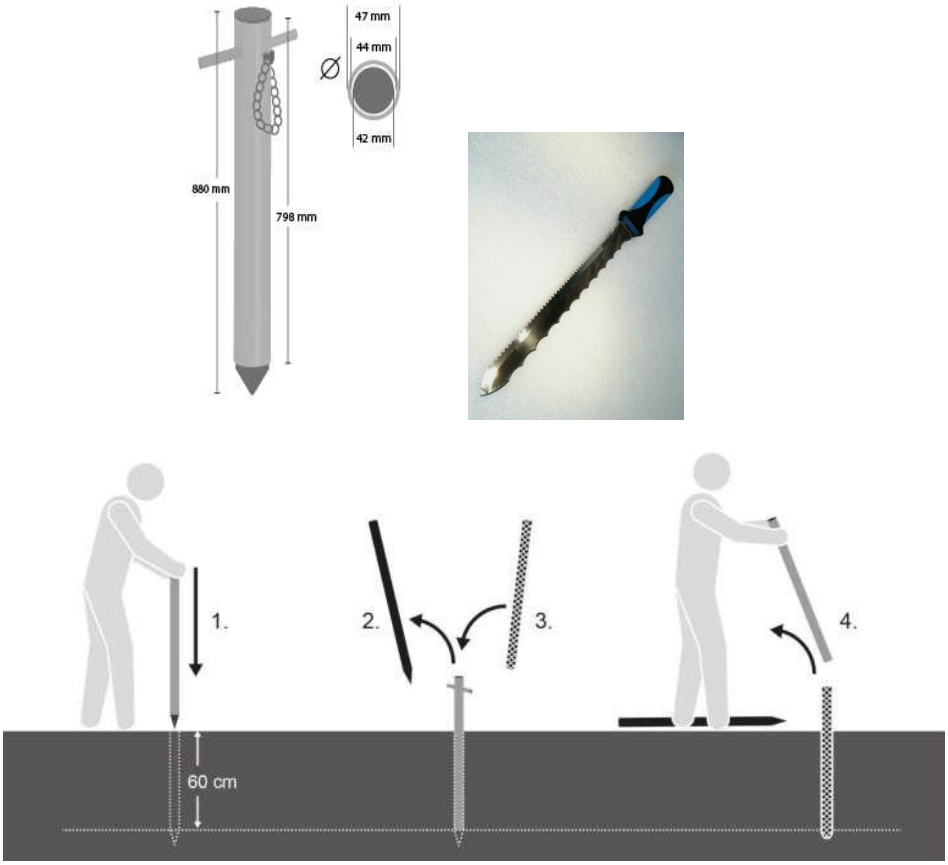
Fine-root production. Fine-root production is estimated using one of three optional methods: the mesh ingrowth-core method for peat soils (Laiho et al. 2014, Bhuiyan et al. 2017), the mesh-free ingrowth-core method or the root mesh method. The amount of ingrown roots represents fine-root production over the incubation period, which will be generalized into annual production.

Method 1. Mesh ingrowth core method. Preparation of root ingrowth cores:

- Mini ingrowth cores: prepared to diameter 3.2 cm (10 cm perimeter) and effective length of 50 cm, using 1 mm mesh polyester fabric
- Filled with **local soil that is roughly sieved** to remove living and freshly dead roots and rough woody or *Eriophorum* material (as shown here for mineral soils in Figure 24)
- The cores need to be packed tightly - too loose cores lead to poor root growth and underestimates
- 15 cores per site – 5 per each GHG measurement subplot (3 cores, 1 per subplot, are for bulk density measurement only).

Installation of root ingrowth cores:

- Timing: in late autumn before soil frost
- Easy in deep-peat soils with the corer-installer; problems only if peat is dense and dry, or there is a mat of thick roots, then probing is needed
- Soil auger is needed for mineral soils or shallow peat soils
- Soil contact in the surface need to be secured by hand after installation
- A plastic stick is put next to each core, and the part of the core remaining above ground is fixed in vertical position in the stick with a cable tie
- Recovered after two years.



Left: corer-installer (top left), long knife (e.g. insulation cutter) used during the core recovery (top right), and installation of ingrowth cores (bottom), (top left and low graphs from Laiho et al. 2014).

Figure 22 Installation of ingrowth cores.

Recovery of mesh ingrowth cores:

- In root core recovery (lifting out from the soil) it should be avoided pulling out roots grown through the fabric mesh and changes in peat core length and material composition
- By using a long knife, such as insulation cutter (see, Figure 25), cut peat around the root core as deep as you can reach from the surface level
    - avoid immediate vicinity of the core when cutting, so as not to damage the core

    - this is to detach any aboveground plant parts attached to or growing through the cores, and to cut the root systems, especially rhizomes and any hard lateral expansion, to avoid risk of pulling out roots from the cores
- Gently pull the core out of the soil
- Either mark in the core, or record separately, the distance from the core top to the soil surface (this will be used as zero-line when treating the cores in the lab)
- Lay the core horizontally on plastic foil, wrap into the foil, mark with site, subplot and core # identifier, and set in container for transport
- Keep cores in freezer until further treatment.

Post-recovery treatment of mesh ingrowth cores:

- Remove gently any attached plant/soil material that is outside the mesh, also all roots found outward from the core segments are cut and discarded.
- Each core is cut into 10-cm segments, starting from the zero-line of soil surface (marked or recorded in the field during recovery).
- Measure the diameters of the segments (two measurements at right angle of both the top and the bottom of each segment).
- One core per subplot is used to determine bulk density: after measurements, it is dried in 60-70°C and weighed
- Of the other cores, the roots inside the cores are gently washed clean with water and recovered.
- Estimation of whether the roots are living or dead is based on colour and friability; dead and live roots are separated into different fractions if there are abundant dead roots; also species/functional type separation can be done at this stage if that option is chosen.
- The roots are oven-dried to constant mass at 40°C (note the low temperature) and then weighed.

Method 2. Mesh-free ingrowth core method. Local soil is used and prepared as described above for mesh ingrowth cores. Number of cores to be installed in the site is also the same. The difference is that no mesh cores are prepared in the lab. Soil corer is used to remove the original soil in the core installation point. The hole is firmly marked with sticks, and the hole is tightly filled with the prepared soil (Figure 26). At recovery, the same corer is used to carefully remove the installed soil only, from between the sticks. Laboratory treatment also follows that of the mesh ingrowth cores. (Note that foxes may like to pull out the sticks and play with them, so thin metal sticks may be preferable).

Figure 23 Marking location of mesh-free ingrowth core on the ground.

Method 3. Root mesh method. In the root mesh method, mesh strips are installed vertically into the soil to a depth at least 30 cm (Hirano et al., 2009; Uri et al. 2017; Kriiska et al., 2019). Vertical cut into soil can be done by spade or by sharp stainless steel blade, and a straight and blunt steel blade for placing a mesh should be used. Mesh's are recovered after one year with intact peat remaining on both sides of the mesh. Mesh's are extracted from the soil as 10x10 cm blocks (Lukac & Godbold, 2010). Roots grown through the mesh during incubation period are shortened to 1 cm on both side of the net to create a 'virtual' core 2 cm thick, 5-10cm wide and 30 cm deep. Roots are removed from the net, washed and weighed and they represent annual production after first year. In boreal coniferous forests the stabilization of the root growth may take longer, thus root production also after second year should be measured. In case of measuring second or even third year root ingrowth, the fine root turnover from mesh's is measured and fine root production is calculated by multiplying the turnover rate of the mesh's by the mean fine root biomass estimated by soil coring (Kriiska et al., 2019). However, root mesh method potentially underestimates fine root production, while fresh dead roots that died during the incubation period are not identifiable.

6 LITTER PRODUCTION AND DECOMPOSITION IN FORESTS

New carbon is added to the soil as plant litters and root exudates. Root exudates are important for several soil processes, but their mass is relatively small and they will not be covered here. Plant litters are formed and enter the soil both aboveground (foliage, woody litters such as twigs and branches, etc.) and belowground (roots and rhizomes), and it is important to estimate both inputs. Decomposition of fresh litter inputs forms a major part of the CO_2 flux in soil respiration. In case where the CO_2 efflux from decomposing fresh litter is included in the soil respiration measurement, the litter inputs need to be added to the soil CO_2 balance calculation. If they are excluded and only the CO_2 efflux from decomposing "soil proper" is measured, the CO_2 balance of the fresh litter inputs needs to be estimated separately. This necessitates estimating the decomposition rates of the litters in addition to the inputs.

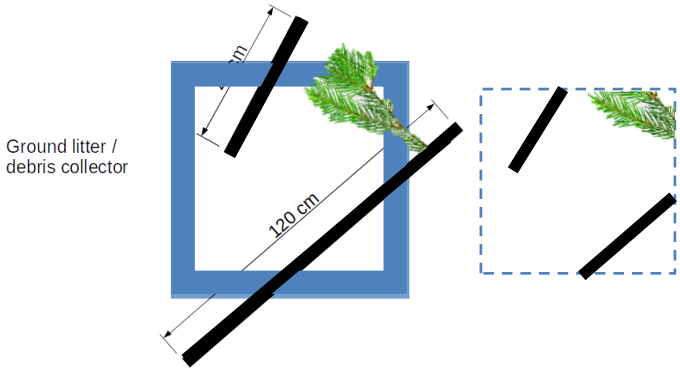
6.1 Aboveground litter production

Annual litter production can be calculated as the sum of aboveground litter of tree stand, vascular ground vegetation and mosses, and belowground litter of roots and rhizomes. For all litter components, C content of 50% can be applied for the conversion from dry mass to C.

1. Annual tree mortality. Estimates are based on the consecutive tree inventories on the sites. Woody diameter limit in the base of dead wood included in tree inventory needs to be checked, and only smaller diameter woody litter belongs to aboveground litter monitored here.

2. Aboveground litter production from trees and shrubs. For estimation of tree stand fine litter, i.e. foliar, cone and other small-sized litter, standard forest litter traps can be used (5-6/site). For the estimation of the aboveground fine woody litter (twigs, branches) from tree stand and shrubs, specific litter collectors will be placed at the surface level on the ground (frames sized 50 cm x 50 cm, 5 or 6 per site, two on each subplot or two on others, one in the middle subplot). They do not need to have

mesh bottoms, but those may be useful. They should not avoid shrub-growing areas so that they also capture woody litter of shrubs. Frame locations are cleaned of older woody litter upon installation. Tree and shrub twigs and branches longer than 10 cm and all dead shrub stems of shrub species that are not counted in the tree inventory fallen on the collector are collected (others are removed and discarded). If they stretch over the collectors are cut so that only the part inside the collector area is harvested (see Figure 27). The staff needs to carry shears or secateurs for this.



If woody litter fallen on the ground litter collector crosses the frame, only the materials inside the collector frame should be harvested for drying and weighing.

Figure 23 Decision of woody litter inclusion when using on the ground litter collector.

Branches and twigs with differing size enter both into fine litter collectors and inside the framed area on the ground, some branches may have also foliar litter attached. In order to avoid double counting or neglecting litters with specific characteristics, the following rules apply:

- fine-woody litter collector on the ground:
    - Tree and shrub twigs and branches longer than 10 cm fallen on the collector are collected (shorter ones are removed and discarded)
    - Only the parts that are inside the collector with are included in the sample
    - Dead woody shrubs falling over the collector frame should also be collected (e.g. raspberry shoots) for the parts inside the frame.
    - If the collected part has foliar attached, it is included in the sampled material
        - minor foliar proportion included in the wood mass can be included (and subsequently become dried and weighed together with the woody litter)
        - large proportion of foliage in the sample material should be separated, dried and weighed, and added to the value obtained from the foliar litter collector for the same time period.
- foliar litter collector above soil surface:
    - loose small-sized materials (e.g. bark, lichen, small woody pieces), foliar litter (needles, leaves), and cones are collected
    - branches and twigs longer that 10 cm are removed from the collected materials

- small woody pieces with length ≤ 10 cm are included in the foliar litter collector harvest
- If the larger (discarded) twigs and branches have foliage attached, it is also excluded from the sample together with the branch/twig

You may choose between two options in monthly litter harvesting at field; either (1) treat materials in each litter collector separately or (2) pool all harvested materials from different traps in one site materials together. If the litter collected from the different traps within a site is put into separate bags and treated as separate samples, we will get information about within-site variation (Figure 28). That may be interesting information for other purposes but is not necessary for forming soil CO_2 balance. Consequently, the option 2 for litter harvesting is pooling materials from similar replicate traps in one site together in one bag.

The litter collected from the fine litter traps is divided in the lab into main types: foliar litter (further to species if possible), cones (to species if possible), fine woody debris (twigs and branches, length ≤10 cm; further to species if possible; lichen is not removed). All litter fractions are dried in 60-70°C and weighed, and the litter dry mass values are recorded. As the separation is time consuming, you may do the separation of the fine litter only for year one, and use the proportions of total litter per each litter type to estimate the fraction of each litter type in year two total litter mass.

The fine woody litter (twigs and branches) from the woody litter collector should be roughly separated into two diameter classes (which will be utilized then also in the decomposition experiment for woody litter). This is best done of the pooled sample of the whole year (see below). Based on the composition of fine woody litterfall in the Finnish sites, we suggest division to litter with diameter ≥1 cm and litter with diameter <1 cm.

Samples collected from both collector types in one-year long period are pooled together (per each fraction and subplot) to represent annual litterfall for each subplot and litter fraction. Litter collectors should be emptied monthly during the snow-free season for 2 full years.

3. Production of aboveground litter of vascular ground vegetation. No new sampling is done for this purpose: the ground vegetation biomass samples are used.

Litter input from herbaceous vegetation is estimated based on biomass; litter production ~ biomass production ~ maximum biomass. Litter of herbaceous species is directly its biomass (renews annually).

The biomass of shrub species is separated to leaves and stems, and annual shoots for such species that allow this based on visual inspection (e.g. *Vaccinium myrtillus*). Litter of deciduous dwarf shrub foliage ~ leaf biomass. Litter of dwarf shrub stems is included in the fine woody debris fraction obtained from the specific collectors.

4. Production of moss litter. No new sampling is done for this purpose. Moss litter production is estimated assuming that it equals biomass production.

6.2 Belowground litter production

Belowground litter production may be estimated either 1) by multiplying biomasses with turnover rates that will be available for boreal conditions from Minkkinen et al. (manuscript under preparation), or 2) as production per biomass. If it can be assumed that there are no major changes in fine-root biomass over the study time, it can be considered that biomass production equals litter production.

6.3 Aboveground litter decomposition

In addition to litter decomposition studies (explained below), litter decomposition may be estimated using decomposition models for coarse woody debris of conifer and deciduous trees (e.g., Tuomi et al. 2011a, Pearson et al. 2017), and fine litter (e.g., Tuomi et al. 2011b, Straková et al. 2012) in different climatic conditions, if such models or data are available and considered feasible for use in the sites. Flagship sites will be chosen for litter decomposition study. The study should concentrate on such litter types that are poorly or not at all represented in earlier data and models.

Litterbag method (Straková et al. 2012) is used for estimating litter decomposition rates in cases where no applicable models exist. In the method (0) original litter materials are collected from the sites in the autumn at the time of major litterfall and **air-dried**; subsamples must be dried to estimate dry matter content, (1) known masses of air-dried litter sampled from the site are placed in mesh bags (ca. 1 mm mesh polyester fabric), (2) sets of filled bags will be placed on site to locations where such litter would naturally fall or be formed (see Straková et al. 2012), incubated a set period, harvested for analysis, and (3) remaining litter mass in each bag will be cleaned of possible ingrowth material and weighed. A time sequence of such data can be used to estimate mass and C loss dynamics.

Examples of air-dried litter materials: *Rubus chamaemorus* leaves, *Sphagnum* moss and woody litter of different diameter classes.

Figure 24 Examples of air-dried litter materials.

Litterbag sets for 4–5 recoveries should be prepared, 3–5 bags per specific litter type per recovery time per site. For foliar and moss litters, 0,5–1 g of material as dry mass per bag is sufficient. For woody litters, the mass could be adjusted to around 4 g. For woody litters, at least two size categories would be good to use. These could be diameter approximately ≥1 cm, and diameter approximately ≤0.5 cm, to capture the potential effect of liter diameter on the decomposition rate. (And yes, these are not exactly the same as suggested for categorization of litter from the woody litter traps, but the rate of the ≤0.5 cm fraction would be used for the whole <1cm fraction.)

The mass needs not to be exactly the same in each bag, but then the bags need to be numbered in a secure manner, and the initial masses must be recorded. A safe way is to place a small metal or plastic tag bearing the bag number inside the mesh bags. Also, the bag numbers should be marked with a good permanent marker in plastic ribbon loops that are attached to each mesh bag (Figure 30).

Weighed samples in bags, small diameter branches and larger diameter branches (left), ready *Sphagnum* bag (right).

Figure 26 Weighed aboveground litter mesh bags.

Specific incubation locations are selected for each litter type, locations where such litter naturally falls. A marker stick is set to each location where a set of litterbags are installed. The number of locations (sticks) per litter type is the number of replicate litterbags harvested in each recovery (3-5). The number of bags installed in one location is the number of planned recoveries. E.g., five recoveries – five bags per location, one is recovered in each recovery time. The plastic ribbon loops of the bags are placed around the stick so that the bags can be easily found in the later recoveries. Numbers in the ribbons of the remaining bags can be strengthened during the recovery times.

Summary:

- For selected sites choose main litter types typical to the site type
- Natural litter is collected in the autumn (deciduous leaf litter, spruce needles, and moss litter could be collected winter/spring, twigs and small branches any time) and air-dried or by use of existing materials.
- For mosses, the recently died stem parts (often 3-5 cm below the live tops/capitula but this needs to be estimated visually for each moss type)
- 5 bags and 5 recoveries per litter type would result in material need:
    - for 'small litters' 0,5 g dry mass per bag = at least 15 g dry mass = at least 50 g fresh mass;
    - for woody litters at least 150 g fresh mass for a 4 g dry mass content
- For woody litters, diameters ≥1 cm and ≤0.5 cm
- Litterbags are prepared from 1 mm mesh elastic mosquito mesh fabric (polyester or comparable)
- Each litter type in a separate bag (no combined litters; unless "total litter" composite samples are used)
- Only large enough to fit the contents rather flat (Figure 29)

- Sealed, with a sturdy plastic ribbon, into which the ID is marked with the very best possible black permanent marker (Figure 30, Figure 31)
- All bags are moistened before installation, with local site water if available (otherwise pure water)
- Installed in situ in groups of (number of replicates per litter type) x (number of planned recoveries) per litter type, into locations where such litters naturally fall
- Litterbags should be installed preferably at the end of growing season to mimic natural litter deposition, but ASAP after snow melting in spring is OK too
    - Make note of the installation date
- Marked with a permanent stick, around which the ribbons are placed; stick is marked with location ID
- Above-ground litterbags are set tightly to the surface and **anchored with natural litter** of the location
- Moss litter is installed **inside the moss patch** of that species (see Figure 30)
- Harvesting of litterbags takes place annually (1 year, 2 years, etc. after installation) at the approximate date of original installation
- Bags must be stored frozen if not processed immediately
- Processing of harvested litterbags in the lab: Check if there are clearly ingrown materials (fresh roots, rhizomes etc.) as these must be removed. Only initial material that is inside the bag should be harvested. Gently cut the bag open. Using tweezers, extract the litter material on, e.g., a Petri dish. Remove ingrown roots and other clearly alien material. If there is "dirt" (inflown small particle size material), use clean water and tweezers to gently rinse that off the litter material. Once cleaned, dry the sample in 60-70°C.

Litterbag installation: bags are placed tightly in conditions where the litter type inside the bag would naturally decompose, and some naturally fallen litter is placed on top.

Figure 27 Aboveground litterbag installation.

6.4 Belowground litter decomposition

A decomposition experiment can be set up, similarly to aboveground litters. You can use the roots recovered in the biomass study, or use e.g. nursery-grown tree seedlings (toxin-free) to harvest roots. For comparisons on relative decomposition process speed at differet conditions, generally available

standard litter material can be used (e.g. annual grass species e.g. *Deschampsia* sp., *Juncus* sp., *Calamagrostis* sp.). Litterbags are prepared to cover 10-cm depth segments; and in Life OrgBalt it is suggested to use 2 depths in sample setup. These bags are installed vertically into the soil, using, e.g., a straight-edged spade to open up the location, and a tooth-ended metal tool to push the bags in to the desired depth.

Alternatively (as also for aboveground litters), existing data and/or models can be used. There are only little information on root decomposition in peat soils. Some new information will hopefully become available from the Finnish conditions in 2021-22 (decomposition rates of pine, spruce and birch fine and small roots; potentially also ground vegetation roots).

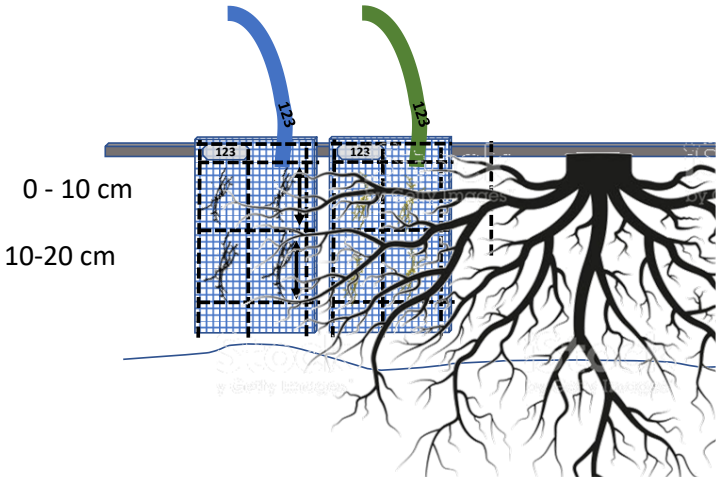


Figure 28 Illustrated setup of belowground litterbags

7 VEGETATION MEASUREMENTS AT CROP FIELDS AND GRASSLANDS

7.1 Vegetation cover estimation

Ground vegetation cover can be monitored from vegetation seasonal development measurements made during transparent chamber monitoring, by photographing chamber areas each time site is visited for GHG monitoring purposes.

7.2 Aboveground biomass and litter production

There are no single method to refer for estimating ground vegetation biomass production and aboveground litter production on crop fields and grasslands. Simple minimum-maximum method for estimation aboveground biomass and litter production can be applied, where aboveground biomass is measured in spring and after major changes in the biomass. Sampling includes all above ground vegetation collection from 30 x 30 cm areas (3 sampling plots per site, one plot at subplots 1, 2 and 3 next to GHG monitoring points)

Sampling:

- crops: at the time of starting growing season (minimum) at ground level (3 plots)
- crops: just before harvest (maximum) at typical height of plant harvesting cutting height (3 plots)
- at the end of growing season (minimum) at ground level cutting (3 plots)
- grasslands: at the time of starting growing season (minimum) at ground level cutting (3 plots)
- grasslands: before each grass cutting (maximum(s)) at typical height of hay harvesting height (3 plots)
    - multiple hay cutting occasions may occur during warm season and average biomass is estimated
- grasslands: at the end of growing season at ground level (3 plots).

The samples are dried at 60-70°C and dry mass of each sample and sample collection time is recorded.

Another potential method is described in Palosuo et al. (2015). Aboveground biomass potentially contributing to soil C store consists harvest residues (straw, leaves and stubble), which can be estimated by:

- (field study) measured on site after harvest and thereafter proportioned to expected loss rates
    - loss rates measured (separate decomposition study)
    - loss rates based on statistical parameters (e.g. Table 3 in Tuomi et al., 2009).
- (statistical approach) based on information on harvested yield and applicable statistics on aboveground C fractions as in Palosuo et al. (2015).

7.3 Belowground biomass

Assessing belowground biomass, we primarily estimate biomass of roots and rhizomes with a diameter <2mm, because this part of the root system is actively taking up nutrients, has the shortest lifespan and turns over fast.

Minimum maximum method is simple method for quantifying belowground biomass in crop lands and grasslands, but can be used also in forests. In the method soil is cored down to 30 cm depth (or until the rooting depth bottom is reached). 3 sampling plots per site, one plot at subplots 1, 2 and 3 close to GHG monitoring points. Soils samples are volume exact. Roots are separated from soil sample by gentle washing; tree and shrub roots should be separated to living and dead roots, while in case of crops and grasses we assume that all roots and rhizomes washed out from soil sample, are living (based on assumption that dead grass roots decompose very quickly). All samples are dried in oven at 60-70°C, and dry mass of each sample is recorded (living roots, dead roots separately, & total in extent that is possible).

Soil sampling times include:

- Spring before start of growing season: minimum root biomass in croplands & grasslands
    - Note. If tilling takes place in cropland, sampling should be after tilling before new seeds have germinated
- Crop lands - after harvest: maximum root biomass
- Grasslands - towards end of growing season: maximum root biomass

If there is strong disturbance in soil i.e., tilling at between two subsequent sampling events, timing of this disturbance should be recorded, and new (minimum) soil sampling made before new seeds germinate.

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Annex 1. Site management options in various GHG flux monitoring conditions

Site type	**Duckboards**	**CH4, N_2O (& dark CO_{2tot}) points. Tasks on the point/vegetation**	**Heterotrophic CO_2 flux points Tasks on the point/vegetation**	**Notes**
Annual crop plants on the agricultural field (monoculture). Regular management operations.	Temporary in wet conditions (during monitoring visits)	Removable collars + extension. Plants uncut or minimal cut to fit in chamber with extension. Deployment of collars and cutting plants (if needed) at least 24 h prior to the sampling.	Shallow trenching & renewed trenching (use of trenching fabric option). Ground vegetation removed (use of soil cover fabric optional).	Collars should be removed prior to any farming activities and returned a minimum 24 h prior to monitoring. Trenching to c. 20 cm depth as soon as the soil management is done.
Perennial low to moderate growth vegetation on the agricultural field (monoculture). Regular management operations.	Temporary in wet conditions (during monitoring visits)	Removable collars + extension. Plants uncut. Deployment of collars at least 24 h prior to the sampling.	Shallow trenching & renewed trenching after soil tilling in cultivated grasslands. Ground vegetation removed (soil cover fabric optional).	Collars should be removed prior to any farming activities and returned a minimum 24 h prior to monitoring. Trenching to *c.* 20 cm depth in spring.
Mixed ground vegetation height from low to moderate	Permanent	Permanent collars + extension. Plants uncut.	Trenching. Vegetation removed & soil cover fabric.	Trenching to *c.* 40 cm depth as early as possible.
Mixed ground vegetation height from low/moderate to tall	Permanent	Permanent collars + extension. Plants cut (after monitoring event) if the shoot tops reach the collar extension upper edge level.	Trenching. Vegetation removed & soil cover fabric.	Trenching to *c.* 40 cm depth as early as possible

Annex 2. Example of tree monitoring parameter calculations

The chapter provides example of calculation as it is done in Latvia. Simplified calculator (spreadsheet) to determine the main forest parameters is provided as separate file. Calculation method should be adopted to country specific measurement method, considering the additional parameters and the parameters, which are skipped due to limited added value in calculation of the soil carbon input.

1 Methodology for Calculation

1.5 General principles for the calculation of the indicators of wood resources in sample plots

1.5.1 In each sample plot the indicators of wood resources shall be calculated separately for each forest element, considering the smallest cluster of trees of the stand, for which the values of taxation indicators are determined, as the forest element.

1.5.2 Values of additive taxation indicators at the stand level shall be obtained as the relevant sums. Indicators that depend on the area shall be expressed per 1 ha.

1.6 Determination of the number of trees

1.6.1 Number of the forest element trees Ni:

$$N_i = \frac{n_i}{m}$$

Ni – number of the forest element trees, ha

l – number of the relevant forest elements (species of trees); , i=1,2...,l , where (1)

n_i – number of trees in the sample plot in i^{th} forest element;

m – recalculation coefficient of the sample plot concentric circle (concentric circle Am = 0.0025, concentric circle Bm =0.01, concentric circle Cm = 0.05).

1.6.2 Number of trees of a stand (level of a tree stand) N, ha^{-1}:

$$N = \sum_i N_i \quad , i=1,2...,l \quad (2)$$

1.7 Determination of the basal area of the stand

1.7.1 Basal area of the forest element Gi:

$$G_i = \frac{\pi}{40000m} \sum_j d_j^2 \quad , j=1,2...,ni \text{ , where} \qquad (3)$$

G_i – basal area of the forest element, $m^2 * ha^{-1}$

d_j – diameter in height of 1.3 m, cm.

1.7.2 Basal area of the stand (level of the tree stand) G, $m^2 * h^{-1}$

$$G = \sum G_i \quad , i=1,...,l \qquad (4)$$

1.8 diameter in height of m

1.8.1 Diameter of the forest element in height of 1.3m Di, cm:

$$D_i = 100\sqrt{\frac{4G_i}{\pi \cdot N_i}} \qquad (5)$$

1.9 Average height

1.9.1 Average height of the forest element H_i, m:

1.9.1.1 if the number of inventory trees of the forest element nu is less than 5, its average height shall be calculated as the arithmetic mean:

$$H_i = \frac{\sum_j h_j}{n_i} \quad , i=1,...,l, \text{ where} \qquad (6)$$

h_j – height of the tree, m

1.9.2 if the number of inventory trees of the forest element nu is more than 5, the height shall be calculated for each tree according to the measurements of inventory trees: heights shall be calculated for each of trees according to the measuring of the inventory trees performed:

Table 1: Output Information for Determination of Parameters of the Contour Line Equation

Diameters, cm	D1	D2	. . .	Dk
Height of trees, m	H1	H2	. . .	Hk

1.9.3 an equilateral hyperbola arc with the following equation shall be used for levelling of heights:

$$H = H_0 + \frac{D}{K \cdot D + C} \quad , \text{where} \qquad (7)$$

H_0 – 1.3 m.

1.9.4 the parameters of the contour line equation shall be found using formulas (20) and (21):

$$C = \frac{N \cdot \sum \frac{1}{D_i \cdot (H_i - 1{,}3)} - \sum \frac{1}{D_i} \cdot \sum \frac{1}{H_i - 1{,}3}}{N \cdot \sum \frac{1}{D_i^2} - \sum \frac{1}{D_i} \cdot \sum \frac{1}{D_i}} \quad (8)$$

$$K = \frac{\sum \frac{1}{H_i - 1{,}3} - C \cdot \sum \frac{1}{D_i}}{N} \quad (9)$$

1.9.5 after determination of the contour line height of each $D_{1.3}$ m tree is known.

1.10 Stock of the tree stand

1.10.1 Stock of the forest element M_i, $m^3 * ha^{-1}$

$$M_i = \frac{1}{m} \sum_j v_j \quad \text{, j=1,2...,l, where} \quad (10)$$

v_j – volume of the tree trunk, m^3

$$v_j = \psi \cdot h_j^{\alpha} \cdot d_j^{\beta \cdot \lg h_j + \varphi}$$

h_j – height, m;

d_j – diameter in height of 1.3 m, cm; , where (11)

Ψ, α, β, φ – volume coefficients of the bole which depend on the species of the tree (Table 2)

Table 2: Values of Volume Coefficients of the trunk (in Latvia)

Tree species	Ψ	α	β	φ
Pine	$1{,}6541*10^{-4}$	0,56582	0,25924	1,59689
Spruce	$2{,}3106*10^{-4}$	0,78193	0,34175	1,18811
Birch	$0{,}9090*10^{-4}$	0,71677	0,16692	1,75701
Aspen	$0{,}5020*10^{-4}$	0,92625	0,02221	1,95538
Black alder	$0{,}7950*10^{-4}$	0,77095	0,13505	1,80715
Grey alder	$0{,}7450*10^{-4}$	0,81295	0,06935	1,85346
Oak	$1{,}3818*10^{-4}$	0,56512	0,14732	1,81336
Ash	$0{,}8530*10^{-4}$	0,73077	0,06820	1,91124

1.10.2 Stock of the stand M, $m^3 * ha^{-1}$

$$M = \sum_i M_i \quad , i=1,2...,l \qquad (12)$$

1.10.3 Stock of snags Ms, $m^3 * ha^{-1}$ shall be calculated using the formulas (13), (14) and (15).

1.10.4 Stock of fallen deadwood M_k, $m^3 * ha^{-1}$ shall be calculated:

1.10.4.1 if the length of the trunk has remained for a fallen deadwood and it altogether is located within the borders of the concentric circle, its volume shall be calculated using the formulas (14) and (16):

$$M_{k1} = \frac{1}{m}\sum_j v_j \quad , j=1,2...,n \text{ where} \qquad (13)$$

n– the number of trees corresponding to Paragraph 154.1

1.10.4.2 if the fallen deadwood is a shiver of a tree or a part in the concentric circle of a torn-up tree, its volume shall be calculated according to the simple centre plot formula of F. Huber:

$$v_j = \frac{\pi \cdot d_{1/2}^2}{4} L$$

v_j – volume of the fallen deadwood, m^3 , where (14)

L – length of the part in the concentric circle of the fallen deadwood, m;

$d_{1/2}^2$ – diameter at the middle of the laying deadwood, m.

$$M_{k2} = \frac{1}{m}\sum_j v_j \quad , j=...,nk2, \text{ where} \qquad (15)$$

nk2 – number of the trees corresponding to Paragraph 154.2

1.10.4.3 Total stock of the fallen deadwood Mk, $m^3 * ha^{-1}$

$$M_k = M_{k1} + M_{k2} \qquad (16)$$

1.10.5 Stock of stubs Mst, $m^3 * ha^{-1}$

$$v_{st} = \frac{\pi \cdot d_{1/2}^2}{4} h_{st} \quad , \text{where} \qquad (17)$$

$$M_{st} = \frac{1}{m}\sum_{j} v_{stj}$$

v_{st}, m^3 – volume of an individual trunk;

$d_{1/2}$ – diameter at the middle of the trunk (to be measured directly), m;

h_{st} – height of the trunk, m.

, $j=1,2...,n_{st}$, (18)

1.11 Biomass of the tree crowns

1.11.1 Biomass of the tree crowns shall be calculated according to the volume of the tree bole (Table 3):

Table 3: Biomass of the Tree Crowns According to the Volume of the Tree trunk (to be improved with updated biomass expansion factors)

Height of trees, m	Biomass of the tree crown (t) per 1 m^3 of the bole volume		
	for pine	for spruce	for deciduous trees
6	0.15	0.47	0.18
8	0.12	0.38	0.15
10	0.10	0.31	0.13
12	0.08	0.26	0.11
14	0.07	0.22	0.09
16	0.06	0.18	0.08
18	0.05	0.15	0.07
20	0.04	0.13	0.06
22	0.04	0.11	0.05
24	0.03	0.10	0.04
26	0.03	0.09	0.04
28	0.02	0.08	0.03
30	0.02	0.07	0.03

Annex 3. Example of classifiers used in the monitoring of forest resources in Latvia

1. Forest stand types

No	Name	Code
1.	Cladinoso Callunosa	1
2.	Vacciniosa	2
3.	Myrtillosa	3
4.	Hylocomiosa	4
5.	Oxalidosa	5
6.	Aegopodiosa	6
	Forests with wet mineral soil	
7.	Callunoso-sphagnosa	7
8.	Vaccinioso-sphagnosa	8
9.	Myrtilloso-sphagnosa	9
10.	Myrtilloso politichosa	10
11.	Dryopteriosa	11
	Forests with wet organic soils	
12.	Sphagnosa	12
13.	Caricoso-phragmitosa	14
14.	Dryopterioso-caricosa	15
15.	Filipendulosa	16
	Drained forests with mineral soil	
16.	Callunosa mel.	17
17.	Vacciniosa mel.	18
18.	Myrtillosa mel.	19
19.	Mer curaliosa turf. mel.	21
	Drained forests with organic soil	
20.	Callunosa turf. mel.	22
21.	Vacciniosa turf. mel.	23
22.	Myrtillosa turf. mel.	24
23.	Oxalidosa turf. mel.	25

2. Tree species

No	Name	Code
1.	Pine	1
2.	Spruce	3
3.	Birch	4
4.	Black alder	6

No	Name	Code
5.	Aspen	8
6.	Grey alder	9
7.	Oak (common)	10
8.	Ash	11
9.	Linden	12
10.	Larch	13
11.	Other pines (Jack pine, Weymouth pine)	14
12.	Other spruces (white spruce, Douglas fir)	15
13.	Elm, flattering elm	16
14.	Beech	17
15.	Hornbeam	18
16.	Poplar	19
17.	Willow	20
18.	Goat willow	21
19.	Cedar	22
20.	White fir	23
21.	Maple	24
22.	Crabapple	51
23.	Cherry	56

3. Bush species

No	Name	Code
1.	Osier	30
2.	Junipers	31
3.	Rowan-trees	32
4.	Buckthorns	33
5.	Hazel-trees	34
6.	Bird-cherries	35
7.	Honeysuckles	36
8.	Viburnums	37
9.	Spindle-trees	38
10.	Ribes sp.	39
11.	Currants	40
12.	Hawthorns	41
13.	Jasmines	42
14.	Elders	43
15.	Spiraea	44
16.	Lilacs	45

No	Name	Code
17.	Cotoneasters	46
18.	Barberries	47
19.	Dogwood	48
20.	Rosa sp.	49
21.	Siberian peashrub	50
22.	Coniferous trees	52
23.	Deciduous tree	53
24.	Unidentifiable species	54
25.	Mezereon	55
26.	Common buckthorn	30

4. Damages

No	Name	Code
1.	Windthrows, windfalls, snow-breaks, snow crushes	10
2.	Water	20
3.	Wildlife	30
4.	Fire	40
5.	Diseases	50
6.	Insects	60
7.	Others	70

5. Damaged location

No	Name	Code
1.	Roots and stumps up to 30 cm above the root collar	1
2.	Lower part of the bole from stump up to the first green branch	2
3.	Whole bole from the height of the stump up to the top	3
4.	Upper part of the bole from the first green branch up to the top	4
5.	Top	5
6.	Branches in the living crown	6
7.	Branches which have grown out of the bole and are more than 2 cm wide	7
8.	Buds and sprouts	8
9.	Leaves and needles	9

6. Placement of deadwood

No	Name	Code
1.	Lying fallen deadwood	none
2.	Standing stub	2

7. Quality groups of dead wood

No	Name	Code
1.	Fresh	1
2.	Old (epiphytes cover >10% of the surface)	2
3.	Rotten wood	3
4.	Living stub	4