Litterfall sampling and analysis

FutMon (Life+) Field Protocol 2009

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IM1 recommended,
mandatory on D1 and D2 Demonstration Project plots

Contents

1. Introduction

Litterfall is a key parameter in the biogeochemical cycle linking the tree part to the water and soil part. Both the biomass of the litter and its chemical content (including heavy metals) are needed to quantify the annual return of elements and organic matter to the soil. Litter decomposition is a major pathway of nutrient fluxes and determines the organic matter input to forest soils and has a strong influence on forest productivity.
Effects of anthropogenic and natural factors and climate change could influence both litterfall production and its seasonal progression. Processes like C-cycling and C-sequestration are closely related to stand leaf area index (LAI) and litterfall.
Changes in litterfall are responses to disturbances caused by pests or environmental factors like spring frost, drought, wind and pollution. Litterfall production is a quantitative parameter of stand vitality and gives additional information to visual assessment of tree vitality already observed in each plot. Direct observation of abnormalities of the leaves can be performed on the collected litter (leaf size, fungi, galls and necrosis) for symptomatology.
Litterfall also provides temporal and quantitative information about phenological development of the stand. The quantification of the foliage amount, flowering and fruiting patterns allows direct measurements of year-to-year variation in phenology as a reaction to climate, vitality, and global change.
Litterfall biomass of leaves is also one of the components of direct estimate of leaf area index (LAI), the stand leaf area per ground area. LAI describes a fundamental property of the plant canopy in its interaction with the atmosphere, especially concerning radiation, energy, momentum and gas exchange (Monteith and Unsworth, 1990). Leaf area index plays a key role in the interception of radiation, canopy interception (rainfall and deposition), in the carbon assimilation and water evapotranspiration during the diurnal and seasonal cycles, and in the pathways and rates of biogeochemical cycling within the canopy-soil system (Bonan, 1995; Van Cleve *et al.*, 1983). Finally, various soil-vegetation-atmosphere models models use LAI (Sellers *et al.*, 1986; and Bonan, 1993a). Litterfall collection and sorting of leaves/needles among species is the only way of getting accurate assessment of total leaf area index , particularly for broadleaves, and the contribution of each species to the total LAI. Indeed, the LAI for one species is not simply related to its density or basal area contribution to the stand and cannot be derived immediately from dendrometrical stand information.

2. Objectives

The main objectives of litterfall sampling and analysis are to quantify litterfall production and chemical composition over time. This record of litterfall variation will allow assessment of its role in nutrient cycling, across environmental gradients of climate (moisture and temperature) and soil conditions at both local and regional scales.
Also, there is a need to understand the relationship of climate and species on litterfall rates, the turnover of the biomass, the amount of litter produced, and its composition and chemical content. Furthermore, there is a need to improve our knowledge on the link between the C and the nutrient budgets/cycles.

3. Sampling

Litterfall sampling is time-consuming and hence expansive. The number of plots including litterfall monitoring depends on the aim of litterfall assessment and the Demonstration actions being undertaken by contributing countries within the FutMon 2009-2010 programme. It is strongly recommended that litterfall is assessed on the IM1 plots where intensive monitoring of

meteorology, deposition, soil solution, and phenology are also performed (to be future 'key plots'), and it is mandatory in plots selected for Actions D1 (tree vitality) and D2 (Nutrient cycling).

3.1 Siting and number of litterfall traps

It is recommended that the litterfall traps are set up in a design enabling comparisons with deposition and soil water results. The traps are fixed and may be placed randomly or systematically e.g. at regular intervals and in a sufficient number to represent the whole plot and not only the dominant tree species. As litterfall is a canopy parameter, and not a tree one, litterfall traps should be distributed all over the plot area. It is recommended to sample litterfall from at least 10 collectors per plot and even up to 20-30 collectors depending on plot size and tree species involved in the assessment. Leaves from deciduous trees are more susceptible to turbulent air movement than conifer needles. This effect may be mitigated by increasing the number of litterfall traps in deciduous species (i.e. 10 traps for coniferous species and 20 traps for deciduous species) or by increasing the collecting area of each trap (especially for species with large leaves like oak).

3.2 Material and dimensions

The countries are free to select the type of traps for the monitoring of litterfall. Figure 1 gives two examples of a litterfall trap. It is recommended that the litterfall traps are fixed not too close to the ground, in order to ensure water drainage. The opening area of the collectors must be horizontal. This means that specific trap fixation has to be prepared for plots on a slope. Canopy leaves and other litterfall inputs are sampled in litter bags. The bags are attached to a frame of e.g. wood of known area of minimum 0.18 m^2, preferably 0.25 m^2. The sampling area must be sufficiently large to be able to determine litter amount and quality. For tree species with large individual leaf area, the collecting area of traps must be increased (i.e. up to 0.5 m^2). It is recommended that the litter bags are at least 0.5 m deep to prevent litter from blowing out of the bags. Deposition of litter into these traps due to lateral movements by wind is assumed to be minimal. The material of the mesh must not interact with the litterfall sample. Litter bags of inert materials like polyethylene or mosquito nylon or natural cotton fibres are a suitable material not interfering with the major ions present in litter. The mesh size of the bags must be large enough to allow for easy drainage of water. It is recommended to adapt mesh size to the dimension of smallest elements, i.e. for needles from coniferous species up to 0.5 mm. In snowy areas during the winter season, elevated traps may be exchanged with one placed directly on the ground to avoid breakages due to heavy snow load

Mesh trap

Solid Funnel with bag

3.3 Frequency of sampling

It is recommended to collect litterfall bi-weekly or at least monthly in periods of heavy litterfall, such as main autumn abscission. This is to avoid pre-collection decomposition of litterfall due to long stay in the traps during rainy autumns. The samples may be pooled to periodic samples once the monthly variations in amount and quality have been investigated.
In regions with snow and frost in wintertime and in remote areas it may be necessary to let the traps stay over winter in the forest. Litterfall may then be collected once before the winter period and once after snowmelt, as frost limits drainage and litter decomposition.

4. Litter analysis

4.1 Sampling, preparation and storage

The bags must be carefully labelled before sampling with information on study site, species, sample type, trap number, and date of collection. As a minimum the litterfall should be collected as a pooled sample per plot per year. It is up to each country to have a more detailed sampling (e.g. collection of litter from each trap for each sampling period). The litter from each trap can be collected into the labelled bag using a small brush and dustpan if the trap is fixed, or by replacing the sampling bag at each plot visit, when the bag is attached separately to the bottom of the trap. The litter should be transferred to large bags using nitrile gloves.
The samples should be transferred immediately to the laboratory. All contamination should be avoided in the laboratory.

4.2 Drying, sorting and weighing

Especially in mixed stands and if leaf area index is to be derived, it is recommended to sort the litter by species. Insects, insect debris, or other faecal droppings may be removed or stored (if desired) as a special type of litterfall. It is recommended as a minimum to measure the plot specific amount of litterfall of at least foliar and non-foliar fractions for chemical analysis on IM1 and D2 plots. For D1 beech, spruce and oak plots an annual value for the biomass of fruit fractions will be of main interest.
It is expected for **FutMon D1 action** that litterfall from beech and oak sites are routinely sorted into the following fractions for dry weighting and chemical analysis. Any green immature cones from fir, spruce or pine should also be recorded. The updated codes for Littefall fractions are:

Code	Fraction of Litterfall
10	Total
11	Foliar litter
11.1	**Foliar litter of main tree species**
11.2	**Foliar litter of other tree species**
12	Non foliar litter total
13	Flowering total
13.1	**Flowering main tree species**
13.2	**Other Flowering**
14	Fruiting/seeds total
14.1	**Fruiting/seeds (main species + green cones)**
14.2	**Fruit Capsules (main species + empty cones)**
14.3	**Rest of fruiting**
15	~~**Budshells**~~ **Bud scales**
16	Twigs/branches
17	**Fines and Frass**
19	Other biomass

For **Fut Mon D2 action** finer sorting than ‘foliar vs non-foliar’ is also recommended, placing old cones with capsules, as carbon levels will be different to immature fruit.

After this sorting, the total amount of litter is dried at air temperature for approximately a week. If air-drying is not immediately possible, it is recommended to cool the samples below +5 °C until drying can be performed. After this first drying the litterfall is sorted in at least two fractions: foliar

litter and non-foliar litter. Many countries sort in at least three fractions: foliage, wood (bark, branches, twigs, etc.; with area exceeding 5 mm x 5 mm or diameter more than 2 mm) and fruits cones and seeds. Each fraction is weighted. Then subsamples of each fraction (or the whole amount of each fraction, if the quantity is not large) are dried at maximum 80 °C to constant weight in grams with 2 decimal points (usually 48 h will be sufficient). After this drying, the mass of 100 leaves or 1000 needles is determined at 105 °C. Knowing the percentage of moisture in the sub samples, the whole amount of each fraction can be converted to dried mass at 80 °C.

5. Litter quality: chemical analysis

5.1 Treatment before analysis

For chemical analysis the litterfall samples or sub-samples are dried to constant weight in an oven at maximum 105 °C, as for foliar sampling. The samples are then ground to a homogeneous powder. The chemical analysis of litter is similar to the foliar chemical analysis. For techniques and analytical methods see the chapter IV of the ICP Manual on Sampling and Analysis of Needles and Leaves, Annex 2.

Elements to be determined:
Mandatory: Ca, K, Mg, C, N, P, S
Optional: Zn, Mn, Fe, Cu, Pb, Cd, B

5.2 Additional measurements:

Litterfall may be used to assess the leaf area index (LAI in the units m^2/m^2), particularly for broadleaf deciduous species, as well as determining other foliar parameters like length, width, and thickness of needles/leaves. The most suitable definition of LAI is half the total green leaf area (one-sided area for broad leaves) in the plant canopy per unit ground area (Chen and Black, 1992). Globally, LAI in forest stands varies from less than 1 to above 10 but also exhibits significant variation within biomes at regional level, as a result of climate and management (stand structure, species composition, thinning). For a given plot, even without any thinning, one can observe year-to-year LAI fluctuations due to stand reaction to stresses like drought, frost, defoliation or complex forest decline. From that point of view, LAI is a stand vitality parameter.

5.3 Direct assessment of LAI

Litterfall collection is the most precise method to assess LAI in broad-leaved stands; this is the reference direct measurement. Periodic litter collection allows for the assessment of both maximum stand LAI and for monitoring the pattern of LAI decrease during the autumn, or other periods of insect attack. LAI is computed for each collection date from leaf litter dry biomass multiplied by a ratio to convert dry weight to leaf area. This ratio leaf area/dry mass is named **S**pecific **L**eaf **A**rea and is expressed as cm^2/g. It has to be determined for each species on a sub-sample of litter leaves (at least 200 leaves from different traps). When establishing this parameter, direct quantification of individual leaf dimension have to be computed and can be used by themselves as vitality indicator (for example, smaller leaves can be observed as a result of fruiting, defoliation, or severe drought e.g. Europe in 2003).

5.4 Indirect assessment of LAI

Leaf area index may also be estimated by indirect methods in the field using radiation interception by the canopy. Several wand-type canopy analyzers (like e.g. Li-Cor LAI2000) are available.

Hemispherical photography may also be used to measure LAI separately from the herbaceous, shrub, and overstory tree layers, particularly under the more sparse canopy of pines. However, such equipment is not suitable to quantify the contribution of individual tree species to the total stand LAI. Finally, these indirect methods need to be calibrated against direct measurements, as they do not measure LAI but Surface Area Index, including not only leaves but also stems, branches and all intercepting elements. It is recommended to measure at least maximum LAI reached at the middle of the growing season for broadleaves and at the end of the full new needle extension period for conifers.
A respective field protocol on radiation measurement and indirect LAI assessment is prepared under FutMon.

6. Quality assessment and quality control

6.1 Quality assurance programme

The condition of all traps is controlled at each visit to the plot. Several points have to be checked: horizontality of traps, integrity of bags to avoid litter loss; eventual cleaning after being emptied to ensure water drainage. It is recommended to number each trap unless bulk sampling is always performed. The visibility of this information must be checked before the litterfall assessments start.

6.2 Data validation

The national laboratories are encouraged to participate in the foliar inter-laboratory tests of the ICP-Forest programme. The results will be compared to the chemical analysis of the foliage of the respective plots. The Laboratory Quality Assurance information will be submitted together with the data on litterfall analyses. It is also suggested that ring-tests on the dried and fractionated parts of the litter samples be initiated, using litter available in sufficient quantity from sites with uniform stands.
Data checks should be performed as soon as possible after the performance of the analysis. Guidelines for the treatment of missing values and data below the detection limit are similar to the guidelines under the foliar analysis.

6.3 Data submission and reporting

The results of litterfall chemical analysis are reported to 105 °C (litterfall mass will need adjustment - see Tables 14b and c). Elemental litterfall fluxes are found by multiplying litterfall masses (expressed at 105 °C) times elemental concentrations. Validated data are sent at the end of the year to the European database on Forms .PLF, .PLM and .PLO (see forms document) and the Laboratory QA file on Litterfall analyses (XX2009LF.LQA).
ICP submission should be accompanied by a “Data accompanying report – questionnaire (DAR-Q) for. This DAR-Q includes all details on the sampling and analytical procedure, missing data, and other irregularities.

7. References

Bonan G.B. 1993. Importance of leaf area index and forest type when estimating photosynthesis in boreal forests. Remote Sensing of Environment 43:303-314.

Bonan G.B. 1995. Land-atmosphere interactions for climate system models: coupling biophysical, biogeochemical, and ecosystem dynamical processes. Remote Sensing of Environment 51:57-73.

Bréda N. 2003. Ground-based measurements of leaf area index: a review of methods, instruments and current controversies. Journal of Experimental Botany 54: 2403-2417.

Chen J. M., Black T. A. 1992. Defining leaf area index of plant canopies with branch architecture. Agricultural and Forest Meteorology, 57: 1-12.

Monteith J. L., Unsworth M. H. 1990. Principles of Environmental Physics. 2nd edition. Edward Arnold. 291 pp.

Sellers P.J., Mintz Y., Sud Y. C., Dalcher A. 1986: A simple biosphere model (SiB) for use with general circulation models. Journal of Atmospheric Science, 43, 505-531.

Staelens J., Nachtergale L., Luyssaert S., Lust N. 2003. A model of wind-influenced leaf litterfall in a mixed hardwood forest. Can. J. For. Res. 33(2): 201-209.

Van Cleve K., Oliver L., Schlenter R., Viereck L.A., dryness C.T., 1983. Productivity and nutrient cycling in taiga forest ecosystems. Canadian Journal of Forest research 13: 747-766.

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