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# MANUAL

on
methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests

## Part XI

# Sampling and Analysis of Litterfall

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# Contents




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# 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 and soils.

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, 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, 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 leaf 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 and BGC models use LAI (Sellers *et al.*, 1986; and Bonan, 1993a). Litterfall collection and sorting of leaves/needles among species is the only way giving strictly access to total leaf area index and to 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 from dendrometrical stand information.

## 2. Objectives

The main objectives of litterfall sampling and analysis are to quantify litterfall production chemical composition over time in order to,
assess the variation in litterfall amount and hence its role in nutrient cycling, across an environmental gradient of climate (moisture and temperature) and soil conditions,
understand the relationship of climate and species on litterfall rates,
understand the turnover of the biomass, the amount of litter produced, its composition and chemical content and 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. It is recommended that litterfall as a minimum is assessed on 10% of the Level II plots and preferably on those plots where intensive monitoring of meteorology, deposition, soil solution, and phenology are also performed ('key plots'). For all aims of litterfall assessment it is suggested that the sampling design of plots represents a wide range of soils, climates and stand structure of a given species.

### 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 an example 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 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. During the winter season traps may be exchanged with a trap placed directly on the ground to avoid breakdown of the traps due to heavy snow loads.

Figure 1. Litterfall traps
(Photo. U. Zehnder)

### 3.3 Frequency of sampling

It is recommended to collect litterfall at least monthly and even bi-weekly in periods of heavy litterfall. This is to avoid a pre-collection drainage and 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 is collected into the labelled bag by using a small brush and dustpan. Another way is to replace the sampling bag at each plot visit, which is possible when the bag is attached to the bottom of the traps. The litter is transferred to large bags using 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 fecal droppings may be removed or stored (if desired) as a special type of litterfall.
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.
It is recommended as a minimum to measure the monthly amount of litterfall of at least foliar and non-foliar fractions and eventually to pool the litterfall for an annual chemical analysis.

## 5. Litter quality: chemical analysis

### 5.1 Treatment before analysis

For chemical analysis the litterfall samples are dried to constant weight in an oven at maximum 80 °C, preferably at 65°C. The samples are grounded 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 : Na, Zn, Mn, Fe, Cu, Pb, Al, B

### 5.2 Additional measurements:

Litterfall may be used to assess the leaf area index (LAI in the unit $m^2/m^2$) as well as other foliar parameters like length, width, 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, with possible recovery.

### 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. Litter collection allows for the assessment of both maximum stand LAI and for the pattern of LAI decrease during the fall. 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 specific leaf area 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, of defoliation, of severe drought).

### 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 canopy analyzers (like e.g. Li-Cor LAI2000, SunScan from Delta-T, Demon from CSIRO) or hemispherical photography may be used to measure seaprately LAI from the herbaceous, shrub, and overstory tree layers. In any case, such equipment is not suitable to quantify the contribution of tree species in total stand LAI. Finally, these indirect methods need to be calibrated against direct measurements, as they did 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 end of the growing season.

## 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 traps 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 may be compared to the chemical analysis of the foliage of the respective plots. It is also suggested to perform ring-tests on the drying and fractionating procedures of the litter samples.

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 80 °C just like the litterfall mass (see section 4.2). The reason is that elemental litterfall fluxes are found by multiplying litterfall masses (expressed at 80 °C) times elemental concentrations. Validated data are sent every year to the European database accompanied by a “Data accompanying report – questionnaire (DAR-Q). This DAR-Q includes all details on the sampling and analytical procedure, missing data, and other irregularities. It is recommended to prepare a yearly national report on the data containing the results and the interpretation of the results.

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