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CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

International Co-operative Programme on
Assessment and Monitoring of Air Pollution Effects on Forests

MANUAL

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

Part V

Estimation of Growth and Yield

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1 Introduction

This manual focuses on growth and yield assessment within Level II plots. Recommendations for cross-linkages between growth and yield measurements and assessments of e.g. crown condition are proposed, in order to enhance the scope of periodic measurements. Proposals focus on maximising data collection efficiency and aim towards whole tree assessments. It is recommended that all periodic non-destructive sampling and measurements are carried out on the same sampling area (plot/sub-plot).

1.1 Definition

Increment is defined as the periodic growth of trees *(shoots in coppice forests)* and stands, including basal area, height and volume.

1.2 Objectives

The primary objective of the monitoring of forest growth in Level II plots is to provide an additional assessment of tree and stand condition. These assessments, together with others undertaken at Level II, will form the basis for comparisons of particular forest types throughout the ECE region.

1.3 Use of the data

Growth studies by periodic non-destructive measurements are mandatory on Level II plots. At least 15 years of data will be required from the plots before reliable estimates of increment change can be obtained. Tree ring analyses on either cores or disks sampled from felled or dead trees are optional on Level II plots.

The increment data collected on the Level II plots will not be suitable for extrapolating to larger areas. In this respect, the plots should be seen as permanent monitoring plots and not as inventory plots.

2 Sampling

The monitoring of increment is divided into two parts:

- The monitoring of future increment is done by means of periodic measurements of all the trees *(shoots)* in the plots or subplots.
- To establish past growth patterns, a single sampling for tree ring analysis should be done on several trees *(shoots)* in the surroundings of the plots; this can be done by sampling increment cores or disks.

2.1 Sample plots

The minimum Level II plot size is 0.25 ha, expressed on a horizontal plane, as currently specified in Part I of the ICP Forest Manual. This size is sufficient for any assessment of increment that might be undertaken in the plot. For the measurement of increment, the plot may be sub-divided into sub-plots. The size of these sub-plots should be in agreement with the mensurational procedures of the country concerned and must be large enough to provide reliable estimates of stand increment over the entire measurement period. **The exact size of any sub-plots must be determined and reported**. When establishing plots, due regard should be given to the time required to undertake growth studies; plots should be viable for at least 15 years. Increment measurements should preferably not be started on a plot within 5 years of any previous thinning, but should be continued through subsequent thinning cycles.

Each plot should have a buffer zone. For increment, it is recommended that this buffer zone is equivalent in width to the mean height of the dominant trees *(shoots in coppice forests)* in and around the plot. Existing mensuration sample plots that will be viable for at least 15 years can be used as the increment sub-plot if they are in a homogeneous stand suitable for Level II plot establishment.

For coppice forests, maquis and similar vegetation types, see the relative specifications in each paragraph. As a general rule, coppice forests no longer managed but which continue to produce a large shoots on each stool (stored coppices), must be considered as coppice as far as the measurement procedure is concerned. Thinned coppices undergoing conversion to high forest (only one (two) shoots per stool released) and showing physiognomy and structure similar to stands originated from seed, must be considered as high forests as regards the measurement procedure.
The establishment of plots for increment monitoring in maquis and similar vegetation types must be avoided in degraded, open grown stands where permanent wide gaps in the canopy cover are due to recurrent and ongoing constraints like grazing, repeated wildfires, extreme soil and site conditions. In such situations the standing crop is usually made up of small-sized shoots and stools showing a heavily reduced re-sprouting capacity. In these conditions, the growth rhythm of the tree species is very slow and severely influenced by external disturbances which, coupled with the measurement of small-sized shoot populations, can considerably affect assessment of the increment error by periodic inventories.

Periodic measurements must be undertaken no less than every fifth year. Measurements should be reported every five years when possible, the first measurement period extending the winter of 1994-1995 (from the end of the vegetation period 1994 to the beginning of the vegetation period 1995) to the winter of 1999-2000 (from the end of the vegetation period 1999 to the beginning of the vegetation period 2000), and subsequent periods winter of 1999-2000 to winter of 2004-2005 and winter of 2004-2005 to winter of 2009-2010.

2.2 Periodic measurements

Measurements every five years of **dbh on all trees** (*shoots in coppice forests*) and **tree height and height to crown base on a sub-sample** of trees (*shoots in coppice forests*) in the plot in order to compute stand mean height and dominant height are **mandatory**.

Measurements of other indices (see Annex 1) on the plot or sub-plots are optional. It should also be reported if a tree has died, fallen or disappeared.

All trees with at least 5 cm diameter over bark (*stools and shoot in coppice forests*) **must be individually identifiable by numbering**. The height along the stem of dbh measurements must also be indicated. The spatial co-ordinates of all trees (*stools in coppice forests*) on the sub-plot should be recorded (optional) for both future relocation and for the adequate assessment of other factors known to significantly influence tree increment.
An assessment of the plot prior to any thinning operation is recommended. Maximum use should be made of any removed tree for additional measurements (e.g. stem analysis, biomass assessment, etc.).

2.3 Tree ring analysis

Increment cores or tree disks must not be sampled from the alive trees (*shoots*) on the plot, as this will influence some of the monitoring results. Trees (*shoots*) cut for thinning purposes should be used for stem analyses, where possible.

Trees (*shoots*) to be felled for stem analysis should be selected sufficiently far from the plots in order to avoid changes to trees in the plots (e.g. extra light, more available root space etc.), but close enough to represent similar site conditions.

Trees (*shoots*) selected for coring and stem analysis should be representative of individuals in the stands. All mandatory measurements made in the plots must also be made on sampled trees.

2.4 Stand records

The past history of growth in the stand is essential for interpreting future increment (e.g. data on thinnings, fertilization and other relevant changes to the forest stand must be available). All details of management operations undertaken in the plot are essential from the time of plot establishment, including:

- type of thinning
- time of thinning
- basal area removed
- volume removed
- number of trees removed
- fertilization
- litter raking
- grazing
- pruning or brashing

Any other uses of the plot should also be documented. The fate of individual trees from the start of the monitoring period must be recorded.

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Annexes

Annex 1: Guidelines for Measurements

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Annex 1: Guidelines for Measurements

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A1.1 Crown and tree measurements

The following guidelines are to be used for crown and tree measurements. Where methods are compatible, individual countries may continue using their national systems. DBH and other physical parameters are not to be measured during the growing season. Height estimates of broad-leaved trees are usually only practical when no foliage is present.

A1.1.1 Diameter at breast height (mandatory)

The diameter at breast height [dbh] (1.3 m height from ground level) of **all trees in the plots/sub-plots** with a diameter of 5.0 cm overbark (*and of all shoots with a diameter of 3.0 cm overbark in coppices)* or greater must be measured every five years. Diameters are to be measured perpendicular to the longitudinal axis of the stem (i.e. at an angle on leaning trees). Forked trees, with the fork below 1.3 m, are to be treated as two separate trees. Similarly, coppice shoots originating from a single stool are to be treated as separate trees *(e.g. stool 123, shoots 1,2,3, ...; stool 124, shoots 1,2,...)*. If there is an irregularity at 1.3 m, diameter measurements are to be taken at points above and below the irregularity and the values averaged. Trees with root buttresses above ground level are to have their diameters measured 1.3 m above the ground on the upper side of the tree. Lichens and loose debris are to be removed prior to the measurement. Measurements are to be made using a diameter tape or an instrument of similar accuracy, and are to be recorded to the nearest 0.1 cm. The point(s) of measurement are to be clearly marked on the tree, with the ideal marking consisting of a point at which the maximum diameter is measured and a point at right-angles to this (the second point being necessary when using callipers for the measurements). It is recommended that measurements are not be taken when air temperature is below minus 5 degree Celsius as tree stems shrink substantially below this temperature.

A1.1.2 Tree height (mandatory)

The periodic measurement of tree (*shoot*) height is mandatory. Tree (*shoot*) height is defined as the vertical distance between the highest point of the crown and the ground surface. It differs from tree (*shoot*) length, which is defined as the bole length from ground level to the tip of the tree (*shoot*; Fig. 1). Where possible, measurement are to be made to the nearest 0.1 m; it is recognised that this level of accuracy may not be achieved, but is to be attained where possible. It is advised to record the position (e.g. distance from the tree and azimuth) from which the measurement is carried out in order to allow future measurements from the same standing position. Alternatively, measurement positions can be marked permanently on the ground. Although it is recognised that conditions of visibility may change after 10 or 20 years (growth of the understorey, crown development, ...), this is one way of limiting measurement errors.

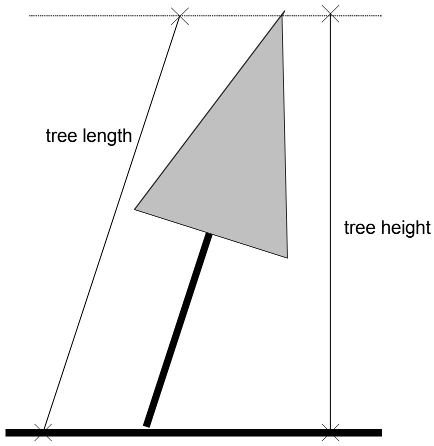

Figure 1: Tree height and tree length.

<u>Hint:</u> in some cases (e.g. dieback, shoot death), the top of the tree is defined as the highest ”living” bud of the crown. Although it is not easy to see the top when measuring deciduous trees during winter, this may avoid measuring dried dead branches at the top of the tree and which have a tendency to break off prior to the onset of spring.
<u>Hint:</u> for leaning trees, it is advised to take height measurements perpendicular to the direction of leaning be performed.
<u>Hint:</u> when a tree stands on a slope (> 6°), it is advised to take height measurements at the same elevation (altitude) than the tree base or above it.

Ideally, all trees (*shoots*) in the plot should be measured; where this is not possible, a representative or significant **sample of all tree species** (e.g. >5% basal area) in the sub-plot must be measured.
The sampling design must be developed in such a way that will enable the estimation of mean and top/dominant height by species; height curves for the stand, as well as tree (*shoot*) and stand volume calculations, are optional. Technical details are in Annex 2. Description of the methodology and sampling design employed must be provided in the DAR-Q.

A1.1.3 Height to Crown Base (mandatory) and Crown Width (optional)

The periodic measurement of height to crown base is mandatory on trees where tree height is measured and the crown base is visible. Crown width (crown occupancy) measurement is optional. Crown width should be measured on trees for which height is assessed. Although desirable in order to ensure maximum connection between the different surveys carried out on Level II plots, it is recognised that growth measurements do not necessarily express the same ”crown volume” as that determined by assessments of crown condition.

<u>The height to the crown base</u> is defined as the vertical distance between the crown base and the ground. The crown base is defined as the base of the lowest significant volume of foliage (or buds, if measurements are taken at winter time) and not the point where the branches supporting the foliage are attached to the trunk; epicormic branches are not included. When this is variable, average should be taken. If the crown is not continuous, the lowest part is considered to be the lowest branch with a minimum diameter of 3 cm within 2 m of the main part of the crown. If the accepted national method differs from the described method the national method can be used. This must be documented in the data

accompanying report. *In coppice forests, the crown of the stools is made up by the elementary crowns of the shoots and is considered as a whole. Height to crown base is therefore measured on each stool.*

It is advised that recording of the crown base be carried out in the same position and at the same time as the tree height measurement. Care should be taken to ensure subsequent assessments are carried out from the same spot. If possible height to crown base should not be measured when tree crowns are covered with snow.

Crown width is defined as the mean of two or more measurements of crown projection taken perpendicular to each other and excluding epicormic branches. At least four radii should be measured (Figure 2), with eight or more radii required to accurately map tree crowns in stands. When 4 radii are measured, these should be oriented North, South, East and West. Each radius should be measured from the stem, with an addition being made to allow for the radius of the stem. Measurements should be made to the nearest 0.5 m and reported as a mean for the tree. *Coppice forests: follow the procedure stated above for the assessment of crown length (measurement at stool level).*

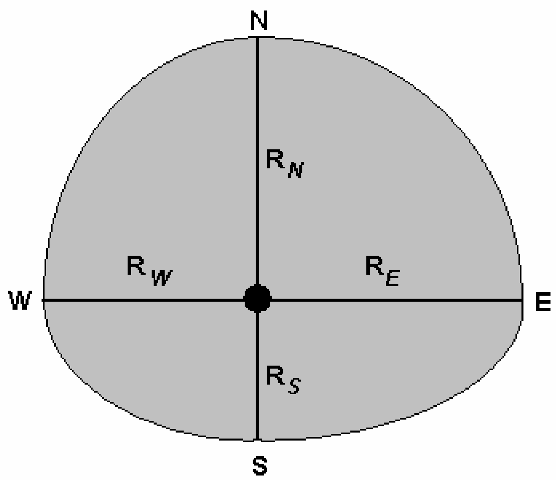

Figure 2: Measurements of crown diameter (4 radii).

A1.1.4 Tree mortality and removal (mandatory)

For the recording of tree mortality and removal the two digit coding system used in the assessment of crown condition should be used. A few additional codes have been added (indicated with *new*). Existing codes are indicated with ‘as in CC’ and not valid codes are marked with ‘not applicable’. It should also be noted that as tree growth measurements take place only every fifth year it will in most cases not be possible to identify causes. In these cases the codes for unknown reason or unknown cause need to be used.

Code 0: tree alive and measurable (new, note this is different than a missing value)
01 tree alive, in current and previous inventory (formerly blanc)
02 new alive tree (ingrowth)
03 alive tree (present but not assessed in previous inventory)

Code 1-: tree removed, disappeared
11 planned utilization (as in CC)

12 utilization for biotic reason (as in CC)
13 utilization for abiotic reason (as in CC)
14 cut, reason unknown
18 reason for disappearance unknown (as in CC)

Code 2-: tree still alive and standing, but no tree crown measurements taken or height measurements should not be used in stand or growth calculations.
21 lop-sided or hanging tree (as in CC)
22 not applicable, use 24 or 25 instead
23 not applicable
24 breakage of the tip(s) of the tree (shoot)
25 tree not in height growth sample
29 other reasons, specify

Code 3-: Standing dead (at least 1.3 m in height)
31 tree with intact crown, biotic reason (as in CC)
32 tree with intact crown, abiotic reason (as in CC)
33 crown breakage
34 stem breakage, below crown base and above 1.3 m
38 tree with intact crown, unknown cause of death (as in CC)

Code 4-: fallen alive or dead, (height below 1.3 m or tree stem or crown touches the ground at one place)
41 abiotic reasons (as in CC)
42 biotic reasons (as in CC)
48 unknown cause (as in CC)

A1.1.5 Bark thickness (optional)

Bark thickness is defined as the average thickness of the bark, measured from the surface of the bark to the wood using a handheld gauge. Measurements of bark thickness, to the nearest 1 mm, should only be taken on dead, fallen or felled trees because of potential damage to the vascular cambium.

A1.2 Radial increment from cores and disks (optional)

Two increment cores should be taken at breast height (1.3 m) from each tree (*shoot*) selected for increment analysis. Great care should be taken to ensure selection of the correct sampling points on the stem so that any ovality of the stem's cross section, or eccentricity of the pith, can be accounted for.

Increment borings should be taken perpendicular to the longitudinal axis of the stem and in such a way that the pith of the tree is reached, or almost reached. Each core is to be stored immediately in a protective container for transport to the laboratory. Each container is to be marked with the plot number, the tree number and the direction of the core. After the boring has been taken, the hole in the tree is to be sealed with a suitable wax.

Increment cores are not to be obtained from living trees (*shoots*) within the plot.

A1.3 Stem analysis (optional)

Any tree (*shoot*) used for stem analysis should first be assessed for crown condition, social class etc. After completion of the mandatory diameter/height measurements (as described above) and before felling, a mark is to be made at breast height (1.3 m) on the northern aspect of the stem. The tree (*shoot*) should be felled in a direction away from the plot to avoid possible damage to other trees (*shoots*) in the plot.

After felling, a 5 cm thick disk is to be cut at breast height (1.3 m) and the northern direction indicated on the cross section. A second disk is to be taken just below the lowest green branch following the same procedure indicated above. For trees (*shoots*) with a relatively long crown, a third disk is to be taken at the point where the top shoot reaches a diameter of 7 cm. The distance from the base of the tree (*shoot*) should be recorded for each stem section. This sample collection presents a minimum requirement, and data will be considerably enhanced if more sections are taken.

Trees (*shoots*) are not be felled in the plots specifically for stem analysis. Instead, advantage is to be taken of normal thinning operations. Where no such activity occurs, trees (*shoots*) growing outside the plot area (e.g. in the buffer zone) are to be used, as trees (*shoots*) from further away are unlikely to be representative of growth within the plots.

A1.4 Data analysis

The following sections are provided only as a guideline; individual countries remain free to analyse the data from their Level II plots in whichever way is felt to be most appropriate.

With available height it is possible to establish volume increment (m^3). However, the error associated with estimates of volume increment may be considerable, particularly in older trees. Before determining height growth, the reliability of the estimates must be established by estimating and subsequently measuring the height of a sample of trees. **Volume per tree or per ha should be calculated using the best available equations for the species and local conditions. The equations and the minimum diameter used for the volume calculations should be supplied in the data accompanying report.**

In-growth presents a problem as mandatory dbh measurements are only to be taken with a diameter of 5 cm over bark (*3 cm in coppice forests*). Where basal area increment of trees is recorded in year *t* but not in year *t-1*, the initial diameter should be taken as 0 cm. Standing dead trees are to be included in the assessment of basal area, but it is important to report the proportion of the basal area consisting of dead trees.

Given the variety of tree species, site qualities and management regimes in European forests, it is highly unlikely that data collected on Level II plots will be suitable for making more than superficial comparisons in stand growth rates across Europe. While such comparisons are possible, the sample sizes required are so large as to effectively prohibit any degree of statistical control over the data. Consequently, the majority of analyses are likely to be site-specific.

Within a plot, the available sample sizes may be sufficient to undertake a number of analyses. However, because of the initial sampling design, it will not be possible to extrapolate the results to larger areas.

The following analyses are suggested for individual plots:

- construction of diameter - increment curves for each species
- evaluation of the relationship between increment and other measurements of crown condition
- evaluation of site quality indices by comparing increment with measurements of site quality
- evaluation of climatic responses of trees.

Annex 2: Sampling for Stand height

A2.1 Definitions for tree heights

1. Mean stand height: Mean stand height is defined as the height of the mean basal area diameter tree.
2. Dominant height: Dominant height can be defined as follows:
   a. as the arithmetic mean height of a group of dominant trees;
   b. as derived from the diameter-height curve, using the mean basal area diameter of the dominant tree group.

The classification of dominance used must be defined in the DAR-Q, for example, for the 100 or 200 thickest or highest trees per hectare, by Kraft classes, etc.

A2.2 Tree selection for stand heights

In those cases where all trees in the plot/sub-plot cannot be measured, the following sampling procedures are recommended:

1. Height samples for the estimation of mean stand height. Sort numbered trees in the plot with a diameter of 5 cm (*shoots of 3 cm*) and above, in ascending order of measured dbh. A minimum of 30 trees (or 20%, or number for the desired level of precision to be agreed) through the diameter distribution will be selected using the sampling fraction as calculated below:

(i) Select every 'nth' tree where n = (total number of trees of 5 cm diameter and above) / number of sampled trees (not less than minimum)

(ii) Start selection at the tree at position n/2

(iii) Examples:

360 plot trees > 5 cm dbh, 30 samples required, n = 12 start on the 6th tree and take every 12th tree

360 plot trees > 5 cm dbh, 35 samples required, n = 10 on the 5th tree and take every 10th tree.

Using this method and at each periodic measurement, different plot trees may be selected for height measurement. If the same trees are to be measured at each periodic measurement, then the selection process is carried out only once. A number of the trees selected may also be top height sample trees.

2. Height measurements for the estimation of top height/dominant height. The 100 largest diameter (dbh) trees per hectare will be selected and measured for total height. The method of calculation for top height/dominant height is to be specified, e.g. arithmetic mean, height of dominant mean dbh, another function ...

Where a sub-sample is used, the sampling design must be described in the DAR-Q.

Tree replacement

Following death, snap or removal, replacement trees are to be selected. Selection criteria for tree replacement are to be based on the original sampling design, and are to be described in the DAR-Q.

Annex 3: Suggestions for Continuous Tree Circumference Measurements

Technical Details for Continuous Circumference Measuring on Level II Plots

In Level II plots, information on diameter increment is currently obtained by diameter measurement repeated over 5-year periods. This measurement technique provides mean annual increment values for each period.

The in-depth evaluation of the growth reactions of trees as influenced by biotic and abiotic factors needs more detailed and accurate information on the current course of growth. The *ad hoc* Expert Meeting on Phenological Observations on Intensive Monitoring Plots (Level II - Plots) in Punkaharju, Finland, 21 to 23 September 1997, recommended that girth bands for the permanent recording of diameter increment were an important method of assessment, not only for growth and yield studies but also for phenological observations. This technique can provide precise measurements of, for example, the onset and cessation of growth and the response of trees to stress phenomena across a number of species. Continuous measurement using automatic equipment is preferable, but weekly recordings on a fixed day of the week could be used if performed using manually read girth bands. At the very least, annual increment values should be obtained, gathered in a non-destructive way in the stand.

The application of girth bands on Level II plots

When selecting trees and methods for girth band application and data assessment it is essential to avoid disturbance to the plot by (frequent) trampling.

A3.1 Annual increment measurement of trees and stand

Annual increment data should be read once every year during the dormancy period and permanent plastic bands provide a practical way of doing this.

The following criteria are recommended for the selection of measurement trees:

- The optimal solution is to record annual increment for all numbered trees in the Level II plot or sub-plot.
- Depending on the species and homogeneity of the stand, a sample of 20 to 40 trees per plot and across represented species are appropriate for the development of linear increment/ diameter regression. The sample trees should be selected according to the diameter distribution curve of all trees or according to any bio-group survey that has been completed in the plot.
- Trees from which other measurements (e.g. height, crown data) are available are preferable, as are trees in the vicinity of any other monitoring (e.g. soil moisture) procedure.

A3.2 Continuous circumference measurement

It is recommended that continuous circumference measurements are performed in those plots where continuous monitoring of meteorological parameters is undertaken. The monitoring of soil moisture on these plots is an important supplementary measurement.

The number of sample trees selected for continuous circumference measurement will be limited by the high costs of the equipment, and will also depend on, for example, the tree species present and the stand conditions. As a recommendation, 5 to 10 trees of the main species per plot are considered as a suitable sample to characterise tree and stand growth, as well as reactions to biotic and abiotic influences.

The following criteria for the selection of sample trees are proposed:

- dominant or co-dominant trees of the main species in the plot
- crown condition and/or phenological assessments should be collected on trees selected for continuous circumference measurement
- trees selected for leaf/needle sampling and analysis should not be included
- sample trees chosen within the Level II plot should be easily reached from outside of the plot, in order to minimise trampling inside the plot.

The dendrometer should be mounted at 1.3 m height (DBH). However, in some cases, it may be useful to install dendrometers at different heights along the same tree (e.g. 5.0 m height, base of the crown).

A3.3 Literature

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PREUHSLER, GAST, GIETL, GRIMMEISEN, KENNEL, 1996: Permanent-Umfangmessung in Verbindung mit kontinuierlicher Meßung von Temperatur, Niederschlag und Bodenfeuchte. Beobachtungen an Kiefern der Waldklimastation Altdorf während der Testläufe zur Meßsensorentwicklung. (In KENK: DeutscherVerband Forstlicher Forschungsanstalten, Sektion Ertragskunde - Jahrestagung 1996 Neresheim; Freiburg 1996).

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Annex 4: Suggestions for Quality Control

Aim

Quality control is essential for the measurement of tree size and the calculation of tree increment. Therefore, following guidelines are proposed.

Quality Assurance

All measurements and assessments are prone to error. Errors will reduce the interpretability of the data and therefore need to be minimised. In order to minimise errors, some methods of quality assurance and quality control need to be implemented. The aim of quality control is primarily to ensure the reproducibility of measurements. For forest growth measurements, quality control is particularly important, because many of the measured variables will be used in combination to compute additional values. If data remain unchecked, this will lead to a propagation of errors.

It is important to distinguish the different possible types of errors and whether these are systematically different from the true value or fluctuate randomly around it. Sampling errors arise when only a portion (sample) of the population is assessed. Observation errors arise when measurements or observations deviate from the true value.

The following causes of measurement and assessment errors, which lead to different kind of errors, may be distinguished:

Systematic errors:
- instrument bias;
- measurement inaccuracy (including rounding errors).

Random errors:
- ambiguous definition of assessment variables (for example the usually difficult definition of the tree crown base);
- insufficient training (for example an observer targets the outer branches and not the tree top for the height measurement);
- measurement inaccuracy (for example the smallest unit is one degree using a Suunto);
- measurement circumstances (heavy understorey, large round- shape crown and leaning trees for tree height measurement);
- typing errors (entering the numbers into the field computer or into the data-base).

How and when to implement quality control ?

Quality control needs to be implemented before, during and after data collection. Therefore, quality assurance is needed:

at the planning stage:
- clear definition of the parameters to be assessed;
- optimal choice of instruments and assessment methods (precision versus costs);
- selection of qualified field teams;
- selection of an unbiased sampling design, e.g. an ”impartial” design that does not allow the subjective (prejudiced and/or influenced) selection of the sample trees;
- determination of a sufficient sample size (precision versus costs);

before the data collection:
- adequate training of field teams;
- calibration of instruments;

during the data collection:

- adequate plausibility tests in the field (preferably with a hand-held data recorder); data that will not be recorded can be derived from previous assessments (for example geo-references to help identify each tree); for repeated assessments of tree size, previous values should not be given, but can be used with hand-held data recorders to test for impossible changes and to ask the observer for a second assessment;
- minimisation of the variation of assessment circumstances, for example: (i) fix the point from which the measurement is taken, (ii) limit the allowable weather conditions when measurements are carried out;
- independent controls (5 to 10% of the data, or an adequate minimum from repeated observations). It is important to carry out the control survey at the same time as the field crew carries out the field measurements in order to minimise possible sources of variations due to e.g. different measurement conditions. When this takes place, the field crew and the control team should avoid influencing each other, e.g. they should not know the result of their counterpart. Alternatively, the control surveys should be undertaken within 1-10 days after the field crew assessment. In this case, the distance from the target tree and the azimuth of the observer position should be reported in order to allow the control team to perform the observation from the same position;
- repeated training exercises (in particular if a shift in assessment methods is expected);
- continuous calibration of instruments (in particular for mechanically-sensitive instruments);
- repeated measurements (e.g. two or more repetitions per tree) for tree height and height to crown base in order to check the consistency and reliability.

after the data collection.:

- adequate plausibility tests when data are read into the data-base (set certain standards for allowable minimum and maximum values);
- adequate plausibility checks during data analysis (for example, test if certain value combinations are possible or not).

when using the data:

- any analysis and subsequent interpretation of results must be undertaken taking into account the observed or expected measurement accuracy and precision.

How to assess the accuracy and precision of measurements ?

Cochran (1977) defines accuracy as the size of deviations from the true mean. Precision refers to the size of deviations from the mean value obtained by repeated applications of the sampling and assessment procedure. Accuracy estimates can be obtained from the supplier of the instruments, as well as from the literature. In addition, it is possible to test the accuracy of instruments and the assessment method in calibration exercises against a true value (known height of an object, for instance). The actual precision of field data collection can be expected to be less than the derived accuracy. The precision of collected data is a function of sampling and measurement errors. Again, estimates of precision can be obtained from the literature. However, assessment conditions and quality of the observer may vary substantially. Therefore, it is recommended to measure the actual precision under field conditions with independent control assessments. Ideally control assessments are carried out under similar field conditions. It is suggested that at least 5 % (and preferably 10 %) of the data are control checked. Based on these values, certain standards can be set during training exercises and field control assessments.

Measurement Quality Objectives

Based on the literature experience (e.g. Tallent-Halsell, 1994) and quality control surveys carried out in Italy (source M. Ferretti), a selection of values of expected and desired accuracy and precision of total height, height to crown base, diameter measurements and crown classes (e.g. the proposed set of mandatory parameters) are given in Table I. These values should be considered as guidelines for an evaluation of potentially problematic parameters.

Table I - Measurement Quality Objectives (MQOs) reported as Data Quality Limits (DQLs) for the proposed mandatory parameters. @= agreement. (Based on Tallent-Halsell, 1994).

Parameter	***Reporting units***	***Data Quality Limits***
Tree height	0.1 m	90 % @ ± 5 %
Diameter (DBH)	0.1 cm	90 % @ ± 5 %
Social class	5 classes	90 % @± 1 class
Crown base	0.1 m	90 % @ ± 5 %

Literature

Cochran, W.G. , 1977. Sampling techniques. John Wiley & Sons, New York, 3. Ed., 428 pp.

Tallent-Halsell N. G., 1994. Forest Health Monitoring 1994. Field Methods Guide. EPA/620/R-94/027. U.S. Environmental Protection Agency, Washington, D. C.

Annex 5: Guideline for Stand Volume Submission (Form 6e)

In the Data submission form for volume (6 e) many commonly known parameters are used, such as:

Sequence number of plots (1 to 9999)
Country Code (France = 01, Belgium = 02, etc.)
Plotnumber (max. 9999)
Latitude in +DDMMSS (e.g.+505852)
Longitude in (+ or -)DDMMSS (e.g. +035531)
Altitude (in 50 meter classes from 1 to 51

In addition, several specific parameters are added:
Date of sampling in DDMMYY (e.g. 221199)
Here the date of assessment is to be indicated.
For the following parameters a slight difference occurs between the first (1) and all following assessments (2).
Remaining alive stemwood volume per hectare (remaining = alive trees only) (in m^3/ha)
(1) and (2): The total stemwood volume of all living trees in the plot is to be totalled and divided by the total area to come to the Remaining alive stemwood volume per hectare
Newly dead stemwood volume per hectare (newly* dead)(in m^3/ha)
(1): The total stemwood volume of all dead trees in the plot is to be totalled and divided by the total area to come to the (Newly) dead stemwood volume per hectare

> Note: A problem may occur with the calculation of the volume of the dead trees. It is assumed that DBH is used (estimated over bark) to come to the tree height and hence to the volume. To ensure comparability with dead wood volume from other plots no specific snag-volume calculation ($DBH_{u.b.}$ and height of stump plus a special form factor), is expected.

(2): The total stemwood volume of the trees that died since the last assessment in the plot are to be totalled and divided by the total area to come to the Newly dead stemwood volume per hectare. **Note: the trees already dead in the previous assessment are excluded.**

> Note: The volume of the newly dead trees is considered to be the volume of the tree of the previous assessment without any growth.

Removed Stemwood volume per hectare (removed = alive in previous ass. trees missing since last inventory) (in m^3/ha)
(1): doesn't exist
(2): The total stemwood volume of the trees that have disappeared since the last assessment in the plot are to be totalled and divided by the total area to come to the Removed stemwood volume per hectare. **Note: the trees already dead in the previous assessment are excluded.**

> Note: The volume of the removed trees is considered to be the volume of the tree of the previous assessment without any growth.