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Convention on Long-range Transboundary Air Pollution (CLRTAP)

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

MANUAL

on

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

Part II

Basic Design Principles for the ICP Forests Monitoring Networks

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1 Introduction

Most of the success of a monitoring programme rests on its design. Design can follow a top-down approach when administrative structure, aims and objectives of the monitoring are simple and can be easily identified (Parr et al. 2002). On the other hand, design may be quite complex when the programme has to face multiple objectives and purposes, carried out by an international and multi-agency co-operation (when different conceptual and operational perspectives have to be considered), and have to integrate existing monitoring “traditions” (which are always reluctant to change) (Parr et al. 2002). Under such circumstances, a top down approach is hardly feasible, and the bottom-up approach remains the only option (Köhl et al. 2000, Parr et al. 2002).

This is particularly true for the two ICP Forests monitoring networks: although developed following generally agreed principles, given the nature of the programme the national networks originate from national initiatives and - as such - reflect more or less country-based design concepts. For example, the large-scale (Level I) network is in many cases a subsample of National Forest Inventories. As such, for example, the definition of the target statistical population and the plot design may be different from country to country (Cozzi et al. 2002). The same applies to the intensive monitoring (Level II) network, with a number of different plot designs being used in ICP Forests. After 35 years of monitoring this situation cannot be denied, ignored or changed. Rather it can and must be acknowledged and managed as responsibly as possible.

Part II of the ICP Forests Manual provides guidelines about (i) how to achieve basic design requirements and at the same time (ii) allow the continuation and consistency of the existing data series.

2 Scope and application

Part II of the ICP Forests Manual focuses on the description of the overall monitoring structure, the selection and design of sample plots (Level I and Level II), data collection (plot and stand description and geo-referencing, the variables to be measured) and data submission.

The guidelines provided here permit a minimum level of harmonization which is essential to ensure data comparability across participating institutes and proper data processing. To have their data added to the international ICP Forests database and used in evaluations, National Focal Centers and their scientific partners participating in the UNECE ICP Forests programme should follow the methods described in this Manual.

3 Objectives

Monitoring design has the objective to ensure consistency between the aims of the programme and the activities carried out to achieve them. In this context, it is worth recalling the two main features of ICP Forests described in the Strategy Paper 2016–2023 (c.f. Annex 1 in Part I of this Manual: http://www.icp-forests.net/page/icp-forests-manual):

- The systematic large-scale monitoring (Level I) provides periodic overviews of the spatial and temporal variation in forest health, vitality, and forest soil condition.

- The intensive monitoring (Level II) is carried out on permanent, highly equipped forest monitoring plots to foster integrative studies on cause-effect relationships based on consistent and harmonized long-term data series.

Given these objectives, relevant design issues are:

1. the type, number and characteristics of large-scale and intensive monitoring plots that will permit quantitative estimates with known uncertainty of forest condition at a given time and changes over time (Aim 1); and the identification of relationships between a given set of predictors and response variables (Aim 2). These issues will be covered in Chapter 4.
2. The set of investigations necessary to obtain data on forest condition (Aim 1) and on the stress factors of concern (Aim 2). This will be covered in Chapter 5.1
3. The set of variables to be measured within each survey is under the responsibility of individual Expert Panels and will be covered within individual parts of the Manual.
4. The Quality Assurance procedures, summarized in Chapter 5.2, were developed following the approach described in Part III and will be described for each survey in Parts IV–Part XVII of the Manual.
5. The rules for data submission are summarised in Chapter 6.

4 Monitoring design

4.1 Definitions

4.1.1 Definition of monitoring intensity levels

The two objectives of ICP Forests provide already some guidance for design and ask for two different levels of monitoring intensity: the systematic, large-scale (Level I) and the intensive (Level II) monitoring. The two intensity levels of the monitoring are defined by the number, depth, and temporal resolution of investigations carried out on the plot and by the number of plots covered by the investigations. The two monitoring levels differ for the following three elements:

- Network design: Level I requires data to be formally representative at a large-scale, intentionally covering the UNECE region (56 countries, most of which are located in Europe or in the EECCA[1] region). As such, a probabilistic sampling is required in order to allow design-based inference. On the contrary, no formal representativeness is required for Level II, and monitoring plots can be allocated according to different criteria (purposive sampling).
- Variables to be assessed: Level I plots are mostly concerned with forest condition, and attributes to be measured are typically those able to describe tree condition. Level I is also the basis for large-scale assessments of forest soils, foliar nutrient content, and biodiversity. In short, Level I envisages a limited number of assessments on a large number of plots. Level II aims at understanding cause-effect relationships between the condition of forest ecosystems on one side and anthropogenic as well as natural drivers and stress factors on the other. As such, it requires assessments to

[1] Eastern Europe, Caucasus and Central Asia (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan)

cover a range of responses (from tree condition to growth and biodiversity), predictors (e.g. deposition, gaseous air pollutants, meteorology) and intermediate variables (having the role of response and predictors, according to the analysis, e.g. soil, soil solution and foliar nutrition) (Vos et al. 2000). In short, Level II envisages – according to the general trade-off between number of objects (plots) and number of parameters – a large number of assessments on a limited number of plots.

- Plot design: given the differences in the assessments to be carried out and the distinct aims, Level I and II vary also in plot design, both in shape and size. Unlike Level I, Level II must accommodate a number of different investigations while at the same time prevent conflicts between them. Level II can be considered as a long-term monitoring and research infrastructure hosting permanent equipment. A shared requisite for Level I and II is the area frame: both Level I and II plots should have a known area.

4.1.2 Definition of monitoring plots and sites

4.1.2.1 Level I plots

A Level I plot is an area of defined dimension and shape. Most commonly plots are circular plots defined by the coordinates of the centre and by a radius. However, the design of the plot is under the responsibility of the individual countries but should at least be consistent within each country.

Level I plots are allocated over the statistical population of concern according to defined sampling design which may be different from country to country (see below), provided it is on a probabilistic basis. In the past, in some cases there was no fixed/defined plot: a fixed number of trees for crown condition were selected around co-ordinates of grid intersections and following a standardized scheme. This kind of design is not – by definition – a plot in formal terms, and has limitations with respect to area related statistical estimates. For countries wanting to keep such a design, it is worth noting that data can be processed only to derive sample statistics but are not suited for estimation purposes and will not be considered in that respect. However, for the sake of time series it is possible to maintain the existing sample trees. Guidelines how to achieve a proper plot design while maintaining the former sample trees (and the existing time series) are provided in Annex II.

4.1.2.2 Level II sites

A Level II site is a designated forest area of homogeneous ecological condition within which a Level II plot is installed. The area is not necessarily of defined shape and size, but must be large enough to accommodate the set-up of a Level II plot of a minimum size of 0.25 ha and a surrounding buffer zone (see below). The plot plus the buffer zone constitute the Level II site.

4.1.2.3 Level II plot

A Level II plot is an area of defined shape and size (mostly 0.25 ha) located within a Level II site. Desirably, all the *in-site* measurements are carried out within the plot's boundaries and according to appropriate statistical requirements. When it is not possible (e.g., limited area, destructive sampling), some measurements can be located outside the plot, but within the Level II site boundaries. Data collected within the plot and with a proper statistical design can be considered formally representative for the plot. Data originated from measurements located outside the plot, or within the plot but with an incorrect design, cannot be considered formally representative for the plot. They can however be assumed to be indicative for the site, although with unknown confidence.

4.1.2.4 Level II sub-plots

For specific purposes (e.g. tree condition in dense stands, deposition sampling, ground vegetation assessment), one or more sub-plots may be necessary. A sub-plot is an area of defined dimension and shape within which the measurements are carried out. To be representative for the plot, the sub-plots must be selected according to a statistically sound procedure.

4.1.2.5 Level II buffer zone

The buffer zone is an area surrounding the Level II plots designated to ensure plot protection against direct influence of nearby paths, roads and disturbances. The size and shape of the buffer zone depends on local conditions. However, it must be large enough to protect the plot from direct disturbances and – at the same time – still be characterized by the same homogeneous ecological conditions in terms of aspects, slope, canopy cover and soil condition. The buffer zone must be used for *in-site* measurements that cannot be carried out within the plot's boundaries. By definition, these measurements are not formally representative for the Level II plot. However, they can be considered indicative for the site.

4.1.3 Definition of mandatory and optional variables

Two main sets of variables are defined, called "*mandatory*" and "*optional*" variables. The status means that within the respective surveys the mandatory variables must be measured. On the other hand, "optional" identifies those variables that may or may not be measured. This status must not be confused with the obligation of EU-member states to assess and submit data under relevant EU regulations.

4.1.4 Definition of types of measurement

Two series of measurements are defined: *in-site* and *off-site* measurements.

In-site measurements are all those assessments that are carried out within the Level II sites. They include tree condition, tree growth, tree phenology, biodiversity, ozone injury on a plot's main tree species, soil sampling, soil solution, foliar sampling, throughfall and stemflow deposition sampling, litterfall sampling, leaf area index, soil moisture and temperature, and below-canopy meteorological conditions.

Off-site measurements are those that – by definition – are carried out outside the forest stand, in an open area close to the plot. They include open field bulk deposition, open field meteorology, gaseous air pollutants, and ozone injury at the forest edge (light exposed sampling site (LESS)).

4.2 Monitoring sites and plot design

4.2.1 Large-scale (Level I) monitoring plots

The selection and characteristics of Level I plots are always within the responsibility of the countries. However, to facilitate data evaluation, the following guidelines must be considered.

4.2.1.1 Plot density

The minimum number of plots per country should be equal to the forest area of the country (in km^2) divided by 256. This is to keep consistency with the traditional plot density adopted within the ICP Forests. For small countries and/or infrequent forest types, denser sampling should be considered (e.g. Köhl et al. 1994). Data from possibly denser national grids are not submitted to the central database.

4.2.1.2 Plot selection

A probabilistic sampling design is essential to ensure that large-scale monitoring plots fit the aims of the Level I monitoring. Plots should be allocated over the target statistical population in a way that – for each element of the population – a non-zero probability of being selected is ensured. When setting-up a new Level I network, different designs can be adopted (e.g., random sampling, systematic sampling, tessellation stratified sampling) which fit the above requirement. The definition of the sampling scheme is under the responsibility of the individual countries.

4.2.1.3 Plot selection to achieve harmonization/integration with existing networks

Different forest monitoring networks may already exist within a country. Due to their nearly ubiquitous presence in European countries, the most common networks are National Forest Inventories (NFI) and Level I. Two cases may exist (Ferretti, 2010):

(1) Level I and NFI are already merged in the same network. This may be the case because Level I was established on existing NFI networks (most frequent) or the other way round. In general, a subsample of NFI plots was used for Level I (Köhl et al. 1994; Neumann 1993). In these cases, networks are already integrated and harmonized or at least co-located. Some further harmonization may be necessary due to a possible adaptation of survey methods in agreement to international procedures, but this can be traced and documented.

(2) Countries with separate NFI and Level I networks. This may have happened because (i) there was no NFI in the past, and Level I was created prior to the NFI; (ii) NFI and Level I were developed independently; (iii) countries with a former joint NFI-Level I network (Case 1) abandoned (for a variety of reasons) their original NFI for a newly designed one, thus having now two separate networks. The result is that Level I and NFI are carried out on different networks.

In Case 2, it may be useful to apply some harmonization/integration concept that may allow maximum use of existing networks and information. A functional integration of networks (in the sense of Ferretti 2010) is suggested in Annex I.

4.2.1.4 Plot design and selection of sample trees and sample locations for other surveys

Plot design is under the responsibility of the countries, and must be reported when submitting data. Figure 1 shows different plot designs adopted for Level I in ICP Forests. While different designs are possible, it is important that plots are designed on a fixed area basis, a condition necessary for estimation purposes and to allow a better integration with NFIs. Deviations from the fixed area concept are only possible in exceptional cases for tree condition assessments in order to ensure time series. When such deviations are adopted (e.g. fixed number of trees without area related information), data can be used for descriptive statistics, but not in design-based inference. Although desirable, it is not necessary that plots are of the same size and shape between different countries; rather it is essential that they are of the same design within a country, respectively the federal states within Germany or Belgium. When NFI and Level I networks are separated, it is recommended that the Level I plots will in addition adopt the country-specific NFI design (see Chapter 4.2.1.3). As an alternative, and since it was already used for assessing tree diameter at breast height (dbh), dead wood, and ground vegetation, the BioSoil design is also recommended.

Annex II provides recommendations on how to move from a fixed-number of trees sample point to a fixed area plot, without losing the connection with existing data series.

On Level I, annual tree crown condition assessment is mandatory. On a voluntary basis tree growth, ground vegetation and foliar chemistry are assessed according to the respective methods (see Manual Parts V, VII and XII). To date a European-wide soil condition survey has been carried out twice on Level I plots. The concept foresees a repetition of the soil survey in larger time intervals (e.g. every ten to twenty years). Soil surveys should be carried out temporally synchronized in all participating countries. Methods for soil condition surveys are described in Part X.

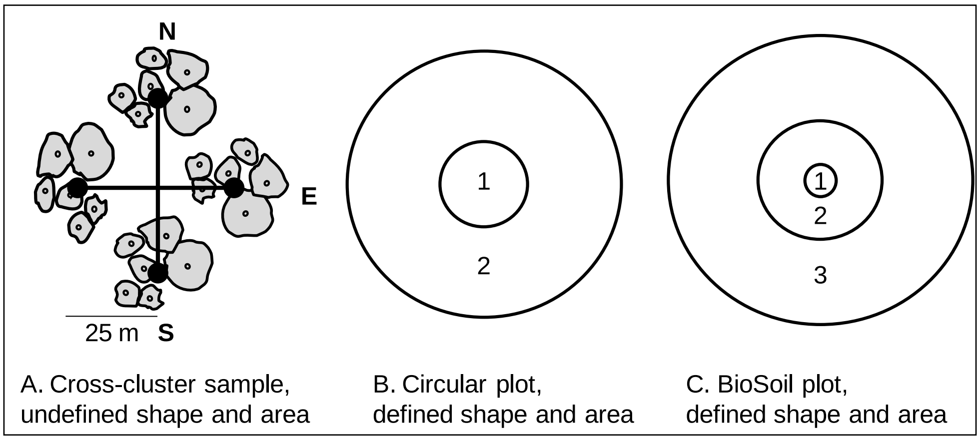

Figure 1: Examples of designs adopted for Level I plots. A. Cross-cluster sample; B. Circular plot: 1, subplot for all trees above given dbh thresholds; 2, subplot for large trees only; C. BioSoil plot: 1.30 m^2 subplot; 400 m^2 subplot; 2000 m^2 subplot. (drawing by M. Ferretti)

4.2.2 Intensive (Level II) monitoring sites

The selection and characteristics of Level II sites are always within the responsibility of the countries. However, to facilitate data evaluation, the following guidelines must be considered

4.2.2.1 Number of sites

The number of Level II sites should equal at least approximately 10% of the Level I plots.

4.2.2.2 Selection of sites

Sites are selected on a preferential basis taking into account:

- Ecological and logistic issues: The situation shall be as homogeneous as possible (regarding e.g. tree species composition, stand type and ecological conditions within the site). However, the more homogeneous the site, the higher is the chance its homogeneity will decrease with time as result of different factors (Palmer 1993). Sites should be accessible to allow routine operations;
- The importance of forest ecosystems within a country: One important selection criterion is that the Level II sites in a country should be located in such a way that the most important forest species and most widespread growing conditions in the country are represented. In order to facilitate data analyses; it is advisable to give priority to replicates within the same forest ecosystem type, rather than spreading plots over a huge variety of forest types;
- The existence of data series and the importance of their continuation: Whenever possible, sites should be selected which have been monitored during the last years. The great advantage of existing data on air quality and meteorological parameters from nearby stations should be taken into consideration whenever establishing Level II sites.

4.2.2.3 Site and plot design

There are different designs adopted for Level II sites and plots (Figure 2). Countries are responsible for selecting the most appropriate design, provided they can conduct the investigations as described in the Manual, Parts III-XVII. While different designs are allowed, some requirements must be attained:

- Plot boundaries must be permanently identified and geo-referenced.

- Plots must have a minimum size of 0.25 ha. The area of the plot must be always reported.
- Sub-plots are allowed, and the sub-plot selection criteria must be described. Sub-plot boundaries must be permanently identified and geo-referenced. The area of the sub-plots must always be reported.

The selection of sample trees and/or the positioning of measuring devices is described in the respective part of the Manual dealing with the concerned survey.

Examples of the location of a Level II site and plot with in-site and off-site measurements is given in Figure 2.

There should be no differences in the management of the plot, its buffer zone and the surrounding forest during the whole monitoring period (e.g. management operations should be comparable and disturbances by the monitoring should be kept to a minimum).

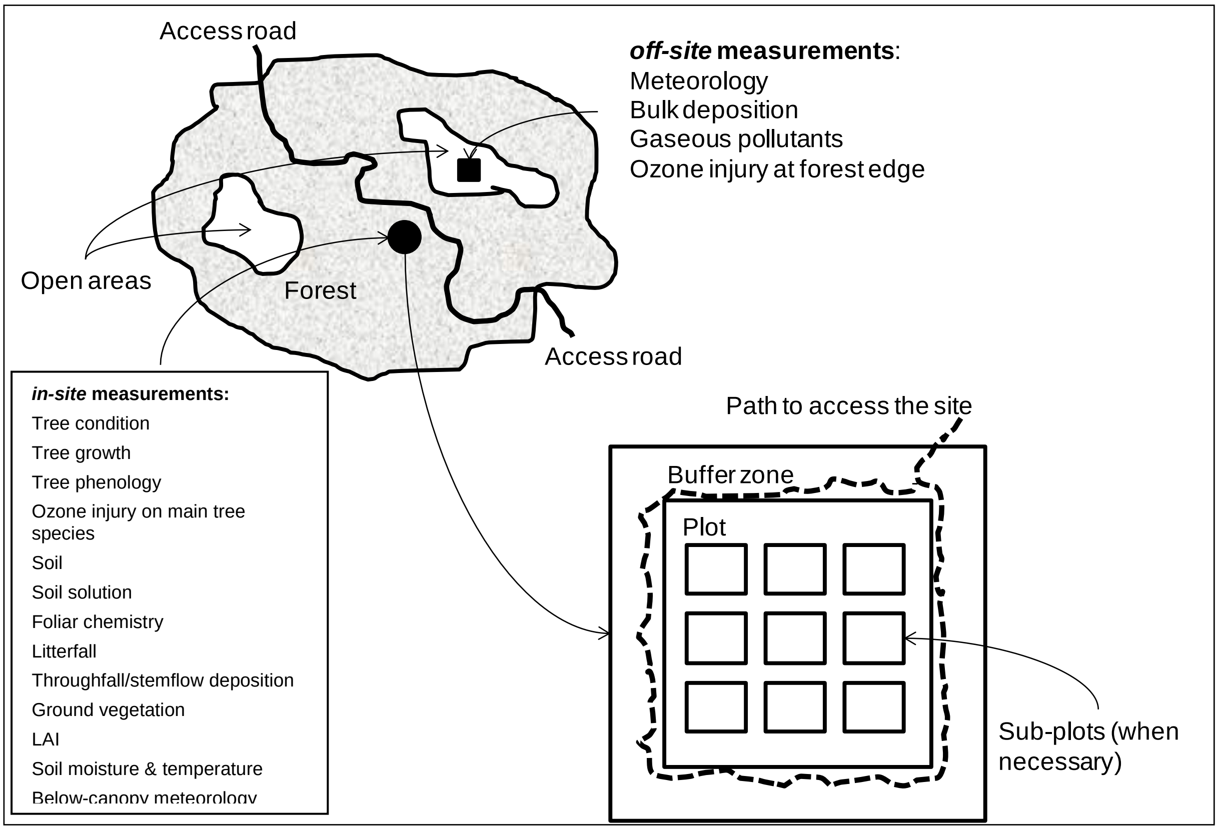

Figure 2: Example of the location of a Level II monitoring site and its organization, with buffer zone, plot and sub-plots. In-site measurements are those that must be carried out within the site; off-site measurements are those to be carried out in an open area close to the plot. Note that different shapes (e.g. rectangles, polygons) and sizes (min 0.25 ha) are possible, as well as different types of internal organization of the plot. Size and shape must, however, be known and reported (drawing by M. Ferretti)

4.2.2.4 Types of Level II sites and plots

Two types of Level II sites/plots are identified:

(1) Level II standard: on these sites the following surveys are mandatory

- Crown condition (annually)
- Tree growth (every 5 years)
- Foliar chemistry (every 2 years)

- Ground vegetation (every 5 years)
- Deposition (continuously)
- Soil solid phase (every 10-20 years)
- Meteorology (at least on 10% of the plots) (continuously)

It is acknowledged that deposition is currently not monitored on all Level II plots because it was initially not mandatory. Participating countries are, however, highly encouraged to extend the deposition survey to all Level II plots.

(2) Level II core: these sites are a sub-sample of the previous standard Level II sites. On core sites, the same surveys as on the standard Level II sites are carried out. In addition, the following surveys are conducted:

- Litterfall (continuously)
- Leaf area index (annually)
- Tree phenology (several times within a year)
- Tree growth (intensive) (every year by growth bands)
- Soil solution (continuously)
- Soil water (continuously)
- Air quality (passive and/or active sampling, continuously)
- Visible ozone injury (at least once per year, where relevant)
- Meteorology (continuously)

Core plot surveys are carried out on a voluntary basis. In case that countries are willing and interested to carry out intensified monitoring beyond standard Level II surveys, it is strongly recommended to carry out the complete set of core plot surveys in order to facilitate transnational and integrated statistical data evaluations and process-based modelling. Preference shall be given to a smaller number of intensive monitoring plots with complete sets of core plot surveys instead of operating bigger numbers of plots that carry different combinations of surveys beyond the Level II standard surveys. (In response to specific national interests and needs and/or thematic focuses - different combinations of surveys can be applicable.)

4.2.2.5 Options for Level II monitoring sites after a severe disturbance or during the stand regeneration stage

Unplanned severe disturbances (e.g. by storm, fire or insect attack) can cause large gaps in the canopy, so that a Level II site (i.e. plot plus buffer zone) does no longer satisfy the requirement for homogeneity in ecological conditions. As a result the collected data can hardly be assumed to still represent the whole site area.

In addition, at some point in time, forest stands under even-aged silvicultural systems are to be regenerated into young stands, which can lead to practical difficulties for the continuity of some monitoring activities and may fail to result into a new stand of interest (e.g. if the main targeted tree species doesn’t succeed to regenerate).

Different options are possible to handle such situations:

- to relocate the plot to an adult stand with homogenous canopy cover,
- to keep measuring the plot at the same location, providing that methods can be adapted to overcome the practical difficulties induced by such contexts,
- to do both (which is recommended, as it combines advantages from the former two options but it does require additional resources).

Since this choice relies on local capacities, it is preferably given to the NFCs. It must be noted, however, that either choice can have strong strategical implications for the whole international Level II network. E.g. whereas the Level II plots have generally been installed in adult forest stands, an increasing share of plots in juvenile stands can help considering the stand development stage as an additional explanatory factor for ecosystem responses, while possibly lowering the capacity of the network to detect and evaluate impacts due to environmental changes. As a consequence, plots that have achieved very heterogeneous canopy cover after severe disturbances or/and that have turned to the regeneration stage must be systematically reported as well as the choice made to handle them. In addition, for all stands under even-aged silvicultural systems the approximate year when they are supposed to enter the regeneration stage must be estimated and reported, so that the occurrence of such situations can be foreseen in the coming decades and taken into account in the ICP Forests strategy.

To help NFCs in their choice, pros and cons of either option are synthesized in Annex IV.

In case the choice is made to relocate a plot, care should be taken to keep trace of the exact position of the abandoned plot area and of the monitoring devices in order to be able to reuse the same location later. The replacement plot can be located either close to the replaced one or in a different context, but in any case it must be identified with a different plot code.

5 General information on monitoring plots and stands

5.1 Measurements and reporting units

5.1.1 Plot description (stored in 'System Instalment')

Plot descriptive information has to be submitted once at plot installation or whenever changes have occurred (e.g. due to storm damage, species change) (Table 1).

Table 1: Quick reference of variables to be reported for the general plot description (o – optional, m – mandatory)

Variable	Reporting unit/type/format	Target plot type		
		Level I	Level II standard	Level II core
Country code	Code	m	m	m
Plot number	Number	m	m	m
Plot size	Hectare	m	m	m
Plot design	Code	m	m	m
Installation date	Date	m	m	m
Plot status	Active/not active	o	m	m
Latitude	WGS84	m	m	m
Longitude	WGS84	m	m	m
Altitude class	Code	m	m	m
Altitude	Meters	o	o	o
Orientation	Code	m	m	m
Slope	Degrees	o	m	m
Relocated plot	Number	m	m	m

5.1.1.1 Plot number

The plot number is an identifier and must be unique within each participating country or region (e.g. federal state). For each new plot a new plot number has to be used and submitted. In case that an existing plot is replaced by a newly installed plot, a new plot number (never been used before) has to be chosen for the new plot.

5.1.1.2 Plot design

The plot design of Level I and Level II plots is described by codes:

Code	Description
110	Level I cross-cluster plot
120	Level I circular fixed area (one radius defined)
121	Level I circular fixed area (more than one radius for one centre point defined)
122	Level I more than one circle (distinct centres)
123	Relascope used to determine trees
130	Level I combination of 110 and 120
131	Level I combination of 110 and 121
140	Level I quadratic plot
141	Level I rectangular plot
150	Level I polygonal plot
199	Other Level I plot design
210	Level II quadratic plot
211	Level II rectangular plot
220	Level II polygonal plot
230	Level II circular fixed area (one radius defined)
231	Level II circular fixed area (more than one radius for one centre point defined)
232	Level II more than one circle (distinct centres)
299	Other Level II plot design

For Level II plots, a map or a scheme should be added as a data accompanying report to better describe the plot design within the site, including: scale, location and size of the subplots, perimeter of fence(s), location of the sample trees and samplers, ungulate species actually excluded or not excluded from fenced areas. The design of the open field plot can be described in a separate map or scheme within the same document accompanying report.

5.1.1.3 Plot coordinates:

A plot centre, so called “reference point” has to be marked permanently. Its geographic coordinates are specified in geographic degrees, minutes and seconds. Format description is made available in the online documentation on the ICP Forests website.

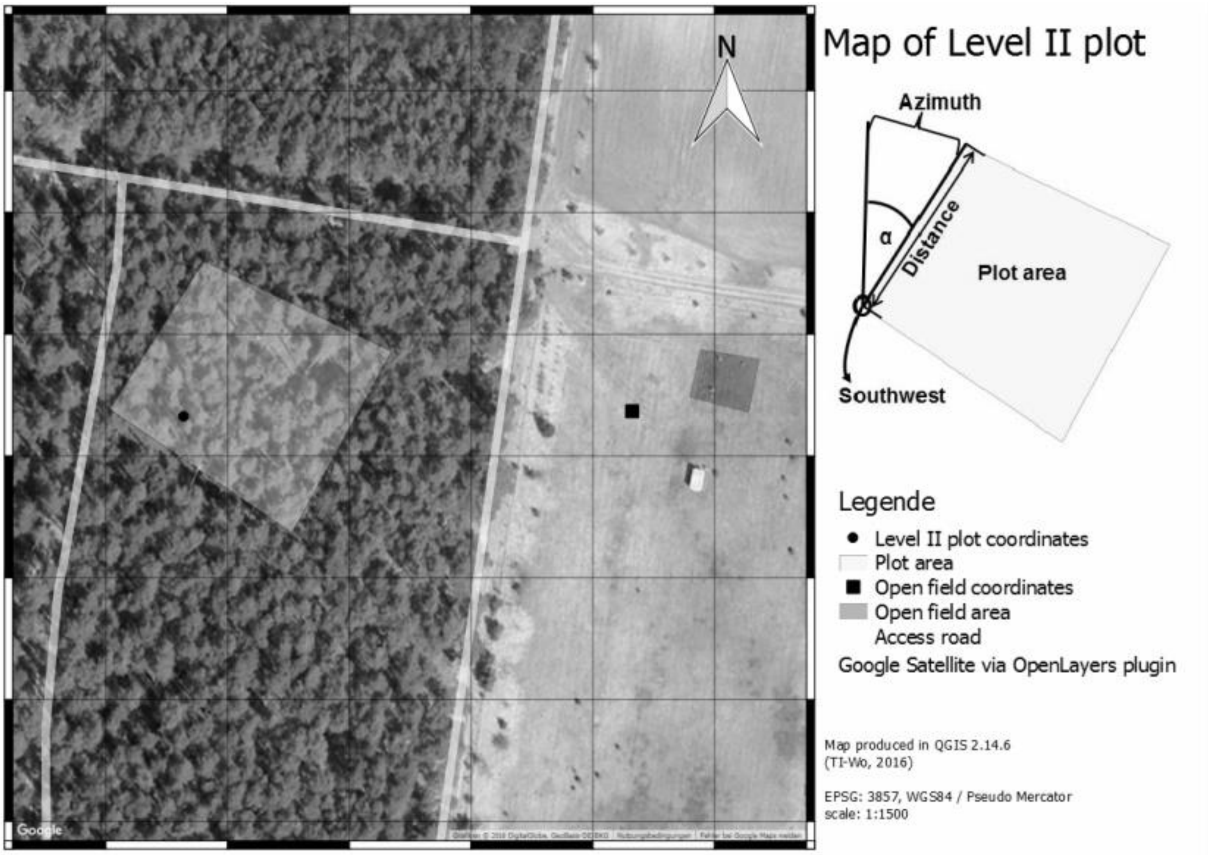

Figure 3: Exemplary definition of a plot area providing the exact coordinates for the SW-corner of the plot as well as the azimuth from North and the distance to the other corner points

5.1.1.4 Relocated plot

In case a new plot is installed in order to replace another one, the number of the replaced plot is to be reported.

5.1.1.5 Additional information

For definitions of additional attributes, see the online documentation.

5.1.2 Stand description

Information on the stand must be reported every five years. Reporting should occur every full and half decade (year 2010, 2015, 2020, …). Table 2 presents an overview of variables to be reported. Each variable is explained in the following text.

Table 2: Quick reference of variables to be reported for the general stand description (o – optional, m – mandatory)

Variable	Reporting unit/type/format	Target plot type		
		Level I	Level II	Level II core
Country code	code	m	m	m
Plot number	number	m	m	m
Stand history	code	o	m	m
Previous land use	code	o	m	m
Origin of current stand	code	o	m	m
Main tree species	code	m	m	m
Type of tree species mixture	code	o	m	m
Top height	meter	o	m	m
Determination of top height	code	o	m	m
Forest type	code	m	m	m
Age class	code	m	m	m
Number of tree layers	code	o	m	m
Coverage of tree layers	5% steps	o	m	m
Canopy closure	5% steps	o	m*	m*
Protection status	code	o	m	m
Fencing	code	o	m	m
Non-timber utilisation in the plot	code	o	m	m
Non-timber utilisation in the buffer zone	code	o	m	m
Management type	code	o	m	m
Intensity of management in the plot	code	o	m	m
Intensity of management in the buffer zone	code	o	m	m
Silvicultural system	code	o	m	m
Forest ownership	code	o	m	m
Estimated year of final cutting	code	o	m**	m**
Canopy gaps	code	o	m	m
Stand rotation number	integer	o	m	m
NFI status	Y/N	m	o	o
Other observations	text	o	o	o

*: mandatory only for plots with inhomogeneous canopy closure (e.g. due to severe damage caused by storm or biotic agents). **: unless the stand is managed to keep a permanent cover of adult trees.

5.1.2.1 Stand history

The continuity of forest cover is of relevance for a number of ecological forest functions, including forest species composition. Stand history is reported in 5 classes according to Bastrup-Birk et al. (2006):

Code	Description
1	Forested more than 300 years
2	Forested more than 100 years
3	Forested 25 - 100 years ago
4	Forested in the past 25 years
9	Unknown

5.1.2.2 Previous land use

Previous land use refers to the land use before the establishment of the first forest stand monitored in the plot. It is reported in 9 classes:

Code	Description
1	Farmland, cropland
2	Grassland
3.1	Shrubland, including heathland / moors
4.1	Wetland
5	Primary forest
5.1	Forest and woodland (other than primary forest)
6	Other
7	Reclaimed land from mining or industrial activities
9	Unknown

5.1.2.3 Origin of current stand

The origin of the stand on the plot is reported in 5 classes according to Bastrup-Birk et al. (2006):

Code	Description
1	Planted
2	Seeded
3	Natural regeneration
4	Mixed
9	Unknown

5.1.2.4 Main tree species

The tree species dominating the forest canopy in terms of canopy closure of the plot is reported using a three-digit code (see online documentation).

5.1.2.5 Type of tree species mixture

The type of tree species mixture on the plot is reported in 6 classes (Anonymous 2005):

Code	Description
1	Monoculture
2	Single tree-wise mixture
3	Group-wise mixture
4	Mixture by layers
9	Irregular, none of the above
99	Unknown

Monoculture refers to a tree population in which more than 90 % of the stand basal area consists of one tree species.

5.1.2.6 Top height

Top height is defined as the mean height of the 100 trees with the largest diameter at breast height (dbh) per ha. It can be derived from measured values (usually the case on Level II plots) or from estimates.

5.1.2.7 Determination of top height

The method of determination of top height is to be indicated in 7 classes.

Code	Description
1	All heights measured and top height calculated from them
2	Heights of at least 10 trees of the 100 thickest were measured
3	Top height was calculated based on earlier measurement of all relevant trees
4	Top height was calculated based on earlier measurement of at least 10 trees of the 100 thickest trees
5	Top height was calculated based on locally adapted dbh/height tables
9	Other method (please specifiy in data accompanying report)
99	Unknown

5.1.2.8 Forest type

The forest type of the plot is reported following the nomenclature of the European Environment Agency (EEA 2006), and further developed by UNECE/FAO (2010): see online documentation on the ICP Forests website.

5.1.2.9 Age class

The mean age of the dominant tree story is given in 20-year age classes between ≤20 years and >120 years or coded as irregular for uneven-aged stands (see online documentation on the ICP Forests website).

5.1.2.10 Number of tree layers

The number of tree layers is reported in 5 classes (Anonymous 2005):

Code	Description
1	One Layer
2	Two layers (each with a minimum of 10 % coverage)
3	Multilayered (each with a minimum of 10% coverage)
9	Irregular
99	Unknown

5.1.2.11 Coverage of tree layers

The coverage of each layer is reported in 5 % steps; only layers are included that have at least a 10 % coverage. The sum of the coverage of all tree layers may be > 100 %. The coverage of a tree layer is estimated as the proportion of the plot area covered by the vertical projection of living branches and foliage of that layer. (Note: If the subplots for ground vegetation can be assumed to be representative of the plot area, the assessments made of the coverage of the tree layer and of the high shrub sublayer during the ground vegetation survey can be used to estimate the coverage of tree layers at the plot scale).

5.1.2.12 Canopy closure

Canopy closure is defined as the proportion of sky hemisphere obscured by vegetation when viewed from a single point It can be clearly distinguished from canopy cover which is the proportion of an area covered by the vertical projection of tree crowns (cf. Jennings et al. 1999). Canopy closure is directly measured with optical methods. A view angle of 45° (equalling 3 rings of the LAI-2200 sensor) is to be employed during its assessment in ICP Forests for standardization purposes. Canopy closure represents the complement of the measured gap fraction:

Canopy closure = 100% - gap fraction (45°)

Optical measurements to derive canopy closure should preferentially be made in the month of maximum foliation. A range of different assessment methods is acceptable as long as they have been validated against hemispherical photographs (cf. Manual Part XVII). Canopy closure must be evaluated from multiple sampling points evenly distributed over the plot area.

5.1.2.13 Protection status

The protection status of the monitoring plot is described following the MCPFE classification (MCPFE 2006).

MCPFE Class 1: Main Management Objective ‘Biodiversity’:

- MCPFE Class 1.1: No Active Intervention

No active, direct human intervention is taking place. Activities other than limited public access and non-destructive research not detrimental to the management objective are prevented in the protected area.

- MCPFE Class 1.2: Minimum Intervention

Human intervention is limited to a minimum. Activities other than listed below are prevented in the protected area: ungulate/game control, control of diseases/insect outbreaks[2], public

[2] In case of expected large disease/insect outbreaks control measures using biological methods are allowed provided no other adequate control possibilities in the buffer zone are feasible.

access, fire intervention, non-destructive research not detrimental to the management objective, subsistence resource use[3].

- MCPFE Class 1.3: Conservation Through Active Management

A management with active interventions directed to achieve the specific conservation goal of the protected area is taking place. Any resource extraction, harvesting, silvicultural practices detrimental to the management objective, as well as other activities negatively affecting the conservation goal are prevented in the protected area.

- MCPFE Class 2 : Main Management Objective 'Protection of Landscape and Specific Natural Elements'

Interventions are clearly directed to achieve the management goals landscape diversity, cultural, aesthetic, spiritual and historical values, recreation, specific natural elements. The use of forest resources is restricted. A clear long-term commitment and an explicit designation as specific protection regime defining a limited area are existing. Activities negatively affecting characteristics of landscapes or/and specific natural elements mentioned are prevented in the protected area.

- MCPFE Class 3 : Main Management Objective 'Protective Functions'

The management is clearly directed to protect soil and its properties or water quality and quantity or other forest ecosystem functions, or to protect infrastructure and managed natural resources against natural hazards. Forests and other wooded lands are explicitly designated to fulfil protective functions in management plans or other legally authorised equivalents. Any operation negatively affecting soil or water or the ability to protect other ecosystem functions, the ability to protect infrastructure and managed natural resources against natural hazards is prevented.

5.1.2.14 Fencing

Fencing is reported in 3 classes according to Bastrup-Birk et al. (2006):

Code	Description
1	Fenced
2	Not fenced
3	Fenced in parts

5.1.2.15 Non-timber utilization in the plot

Non-timber utilisation is reported in 6 classes:

Code	Description
1	Grazing
2	Firewood collection
3	Litter raking
4	Other
9	No non-timber utilization
99	Unknown

Only regular non-timber utilization is to be reported which may have a measurable impact on nutrient and water cycles. Very occasional utilizations are not to be reported.

[3] Subsistence use to cover the needs of indigenous people and local communities, in so far as it will not adversely affect the objectives of management.

5.1.2.16 Non-timber utilization in the buffer zone

Same definition and classes as for non-timber utilization in the plot.

5.1.2.17 Management type

Management type is reported in 4 classes:

Code	Description
1	High forest
2	Coppice without standards
3	Coppice with standards
99	Unknown

5.1.2.18 Intensity of management in the plot

Intensity of management in the plot is reported in 4 classes according to Bastrup-Birk et al. (2006):

Code	Description
1	Unmanaged (no evidence)
2	Management (evidence but more than 10 years ago)
3	Managed (within the last 10 years)
99	Unknown

5.1.2.19 Intensity of management in the buffer zone

Same definition and classes as for intensity of management in the plot.

5.1.2.20 Silvicultural system

Silvicultural system at the site is reported in 5 classes (adapted from Anonymous 2005):

Code	Description
1	Clearcut system
2	Clearcut system with reserves
3	Selection system
4	Shelterwood system
99	Unknown

According to the Silvicultural-Systems Handbook for British Columbia (2003), terms can be defined as below:

- The clearcut system manages successive even-aged stands by cutting the entire stand of trees at planned intervals (the rotation) then regenerating and tending a new stand in place of the old.
- Reserves are forested patches or individual trees retained during harvesting to provide habitat, scenic, biodiversity, or other values, for at least one rotation. Any incidental seed or shelter to the regenerating stand and site that reserve trees supply is secondary to their purpose as reserve trees. Standards in coppice are a kind of reserve.
- Selection systems remove mature timber either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where an uneven-aged stand is maintained.

- In a shelterwood system the old stand is removed in a series of cuttings to promote the establishment of a new even-aged stand under the shelter of the old one. Generally, shelterwood systems aim at natural regeneration, although some planting may occur to diversify the species mix, bolster stocking and introduce improved seed.

5.1.2.21 Forest ownership

Forest ownership is reported in classes following the FAO Forest Resource Assessment 2010 (FRA 2010) (https://icp-forests.org/documentation/ExplanatoryItems/23.html)

- Public ownership: forest owned by the State, by administrative units of the public administration, or by institutions or corporations owned by the public administration.
- Private ownership: forest owned by individuals, families, communities, private co-operatives, corporations and other business entities, private religious and educational institutions, pension or investment funds, NGOs, nature conservation associations and other private institutions.

  - Individuals: Forest owned by individuals and families.

  - Private business entities and institutions*:* Forest owned by private corporations, co-operatives, companies and other business entities, as well as private non-profit organizations such as NGOs, nature conservation associations, and private religious and educational institutions, etc.

  - Local communities*:* Forest owned by a group of individuals belonging to the same community residing within or in the vicinity of a forest area. The community members are co-owners that share exclusive rights and duties, and benefits contribute to the community development.

  - Indigenous or tribal communities*:* Forest owned by communities of indigenous or tribal people.

- Other types of ownership: Other kind of ownership arrangements not covered by the categories above. Also includes areas where ownership is unclear or disputed.

5.1.2.22 Estimated year of final cutting

Unless the stand is managed to keep a permanent cover of adult trees, the year of the final cutting must be approximately estimated (while assuming that no unplanned disturbance will destroy the stand earlier).

5.1.2.23 Canopy gaps

Stand heterogeneity is evaluated with the cumulated area of large gaps in the canopy (gaps larger than those caused by thinning operations) due to e.g. storm damages. This is reported as a percentage of the plot area in 3 classes (less than 10 %, from 10 % to 50 %, more than 50 %).

5.1.2.24 Stand rotation number

The stand rotation number aims to count the successive tree populations that have been monitored in the same plot area. It starts from 1 with the first forest stand monitored since plot installation.

5.1.3 Management operations and natural disturbances

All noticeable forest management operations and all natural causes of tree losses in Level II plots since plot installation – and even from earlier if the information is available – must be listed, dated (as precisely as possible) and documented (as far as known), so that they can be taken into account as potential explanatory factors of ecosystem responses. This information must be updated at least every 5 years. The known absence of such events over a given time period is also useful information to be reported as well. Table 3 presents an overview of variables to be reported depending on the event type/category. Each variable is explained in the following text.

To be properly described, some events may require to be recorded as a combination of several lines in the same form. As an example, tree dieback due to bark beetles may be followed by the harvest of dead trees (to be reported as one line for a damage due to biotic agents + another line for sanitation cutting or final cutting), or dead trees can be left in the plot (to be reported as a single line for damage). Another example can be that one management operation or natural disturbance has different impacts in the plot area and in the buffer zone, which can be reported into two separate lines so as two concomitant operations conducted in each of the two areas with different attribute values.

Table 3: Quick reference of variables to be reported describing management operations and natural disturbances (o – optional, m – mandatory)

Variable	Reporting unit/type/format	Related event types/categories	Target plot type		
			Level I	Level II standard	Level II core
Event type	Code	All	o	m	m
Event location	Code		o	m	m
Starting date	Date		o	m	m
Ending date	Date		o	m	m
Number of trees before	Number per ha	Disturbance, Felling, Cleaning, Creating pathways	o	o	o
Loss in trees	% number per ha		o	o	o
Stand basal area before	m² par ha		o	o	o
Loss in stand basal area	% basal area per ha		o	o	o
Cutting/planting/sowing tools	Code	Felling, cleaning, creating pathways, planting, sowing	o	o	o
Logging method	Code	Felling	o	o	o
Extraction tools	Code		o	o	o
Extraction method	Code		o	o	o
Slash disposal	Code		o	o	o
Size of woody residues	cm		o	o	o
Soil compaction under pathways	Yes/No/Possible		o	o	o
Soil compaction over the whole area	Yes/No/Possible		o	o	o
Used product/material	Text	All but Disturbance	o	o	o
Chemical composition	Text	Liming, Fertilization, Chemical treatment	o	o	o
Quantity of input per hectare	kg/ha		o	o	o
Method of application	Text		o	o	o

Aim of treatment	Code	Chemical treatment, Soil mechanical preparation	o	o	o
Main targeted plant species	Code	Chemical treatment, Formative pruning, Pruning, Cleaning, Weeding	o	o	o
Detailed site preparation type	Code	Site preparation	o	o	o
Thickness of prepared soil	cm	Soil mechanical preparation	o	o	o
Share of handled area	% total area	Soil mechanical preparation, creating pathways	o	o	o
Sown/planted tree species	Code	Sowing, Planting	o	o	o
Seed provenance – country	Code		o	o	o
Seed provenance – locality	Text		o	o	o
Planting stock type	Code	Planting	o	o	o
Seedling age	Years		o	o	o
Seedling height	Cm		o	o	o
Management system in forest nursery	Code		o	o	o
Share of living seedlings one year after plantation	% number per ha		o	o	o
Height of pruning	m	Pruning	o	o	o
Density of individuals	Number per ha	Sowing, Planting, Formative pruning, Pruning, Cleaning, Weeding	o	o	o
Other information	Text	All	o	o	o

5.1.3.1 Event type

The types of event are described by codes ordered by categories as following:

Code	Description	Category
00	No event (known absence of any kind of event)	No event
01	No management operations (known absence of any of them)	
02	No natural disturbances (known absence of any of them)	
D1	Damage – storm	Disturbance
D2	Damage – fire	
D3	Damage – biotic agents	
D4	Damage – abiotic agents (other than storm and fire)	
S1	Soil – mechanical preparation	Site preparation
S2	Soil – liming	
S3	Soil – fertilization	
S4	Slash removal	
S5	Stumping	
F1	Thinning / Selection cutting	Felling
F2	Sanitation cutting / Salvage cutting	
F3	Shelterwood cutting	
F4	Final cutting	
N1	Weeding	Non-remunerative silvicultural operations
N2	Cleaning	
N3	Planting	
N4	Sowing	
N5	Pruning	
N6	Formative pruning	
N7	Cutting of vines to preserve tree health	
I1	Creating / maintaining a drainage system	Infrastructure
I2	Creating / maintaining pathways for pedestrians	
I3	Creating / maintaining pathways for harvesting machines	
I4	Fence installation	
I5	Fence removal	
I6	Cleaning to preserve proper conditions for monitoring activities	
C1	Chemical treatment of the vegetation	Chemical
99	Other events – to be described in other observations or a DAR-Q	-

As adapted from Ford-Robertson & Winters (1983):

- Weeding is a cultural operation eliminating or suppressing undesirable vegetation, mainly herbaceous, during the seedling stage of a forest stand and therefore before the first cleaning, so as to reduce competition with the seedling stand.
- Cleaning is a cultural operation eliminating or suppressing undesirable vegetation, mainly woody (and including climbers), during the sapling stage of a forest stand and

therefore before – or at the latest along with – the first thinning, so as to favour the better trees.

- Thinning is a felling made in an immature stand in order primarily to accelerate diameter increment but also, by suitable selection, to improve the average form of the trees that remain, without permanently breaking the canopy.
- Selection cutting is the annual or periodic removal of trees (particularly the mature), individually or in small groups from an uneven-aged forest in order to realize the yield and establish a new stand of irregular structure (cf. selection systems).
- Salvage cutting is the exploitation of trees that are dead, dying or deteriorating (because overmature or materially damaged by fire, wind, insects, fungi, or other injurious agents) before their timber becomes economically worthless.
- Sanitation cutting is the removal of dead, damaged or susceptible trees, essentially to prevent the spread of insects or pathogens.
- Shelterwood cutting is any regeneration cutting in a more or less regular and mature stand, designed to establish a new stand under the protection (overhead or side) of the old (cf. shelterwood systems).
- Final cutting is the removal of the last trees left in a stand.

Besides silvicultural purposes, cutting operations primarily intended to maintain the infrastructure are to be reported as such. They include the creation or maintenance of pathways, either for pedestrians or for harvesting machines. The removal of some of the understory vegetation e.g. to preserve the visibility of canopy crowns or to make room for measurement or sampling devices is to be reported as cleaning to preserve proper conditions for monitoring activities.

5.1.3.2 Event location

The location of the event is described as one of the following codes: in the plot, in the buffer zone, or in both the plot and buffer zone.

5.1.3.3 Starting date

For any actual event, if the exact starting date is unknown, the closest known date when the event had not started yet is to be reported instead, so as to include the potential uncertainty into the time interval. Inversely, periods of known absence of a kind of event must be reported as strictly excluding time intervals reported for actual events of this kind (i.e. with no overlapping with the latter).

5.1.3.4 Ending date

For any actual event, if the exact ending date is unknown, the closest known date when the event was finished is to be reported instead, so as to include the potential uncertainty into the time interval. Inversely, periods of known absence of a kind of event must be reported as strictly excluding time intervals reported for actual events of this kind (i.e. with no overlapping with the latter).

5.1.3.5 Number of trees before

The number of living trees before any disturbance or felling or cleaning operation is to be reported per hectare.

5.1.3.6 Loss in trees

The loss in trees due to any disturbance or felling or cleaning operation is to be reported as a percentage of the number of trees per hectare before the event.

5.1.3.7 Stand basal area before

The stand basal area before any disturbance or felling or cleaning operation is to be reported in m^2/ha.

5.1.3.8 Loss in stand basal area

The loss in stand basal area due to any disturbance or felling or cleaning operation is to be reported as a percentage of stand basal area per hectare before the event.

5.1.3.9 Cutting/planting/sowing tools

Cutting trees (during felling and cleaning operations and when creating/maintaining pathways) or planting or sowing can be done either with tools hold in hands (e.g. chainsaw), or with forestry vehicles (e.g. harvester, equipped tractor) which may cause physical damages to the soil. This is to be reported in 4 classes.

Code	Description
1	Tools hold in hands
2	Forestry vehicle
3	Mixed
99	Unknown

5.1.3.10 Logging method

The method used to cut trees is to be described in 3 classes. This is important to know whether the nutrients especially contained in fine branches and leaves/needles may have been exported from the ecosystem.

Code	Description
1	Trees are cut into pieces where they have fallen down (before extraction)
2	Whole trees are extracted from the area, then cut into pieces outside
99	Unknown

5.1.3.11 Extraction tools

The tools used to extract fallen wood from the area are to be reported in 6 classes.

Code	Description
1	Forestry vehicle inside the area
2	Cable skidder positioned outside the area
3	Human or animal power
4	Aerial cableway or aircraft
5	Mixed tools including forestry vehicles inside the area
6	Mixed tools without forestry vehicles inside the area
9	Other (to be described in other information)
99	Unknown

5.1.3.12 Extraction method

The method used to extract the fallen wood from the area is to be reported in 4 classes.

Code	Description
1	Skidding
2	Carrying
3	Mixed
99	Unknown

Skidding means that the wood slides more or less wholly along the ground, potentially causing damages to the vegetation, and to the humus and topsoil layers. Carrying means that the wood is wholly off the ground while being moved.

5.1.3.13 Slash disposal

The method used to treat the woody residues after a felling operation is to be reported in 4 classes.

Code	Description
1	Piling
2	Lopping and scattering
3	Burning
4	Harvesting
9	Other (to be described in other information)
99	Unknown

5.1.3.14 Size of wood residues

The large-end diameter threshold below which woody residues are left on the ground after a felling is to be reported in cm.

5.1.3.15 Soil compaction under pathways

The compaction of the soil caused by felling operations on predefined pathways is to be described as actually observed (“yes”), absent (“no”), or as “possible” (if harvesting machines may have used predefined pathways but no field observation was made about the presence or absence of impacts).

5.1.3.16 Soil compaction over the whole area

The compaction of the soil caused by felling operations on the whole area is to be described as actually observed (“yes”), absent (“no”), or as “possible” (if harvesting machines may have been driven through the area without restriction but no field observation was made about the presence or absence of impacts).

5.1.3.17 Used product/material

The product or material used for a management operation event is to be described as text.

5.1.3.18 Chemical composition

The chemical composition of the product used for soil liming, soil fertilization, or chemical treatment of the vegetation is to be reported.

5.1.3.19 Quantity of input per hectare

For soil liming, soil fertilization, or chemical treatment of the vegetation, the input quantity is to be reported in kg/ha.

5.1.3.20 Method of application

For soil liming, soil fertilization, or chemical treatment of the vegetation, the method used for the application of the product is to be described as text.

5.1.3.21 Aim of treatment

The aim of a chemical treatment of the vegetation or of a soil mechanical preparation is to be reported in classes as following.

Code	Description
11	Soil mechanical preparation – Mainly aiming to restore soil physical properties
12	Soil mechanical preparation – Mainly aiming to help artificial regeneration
13	Soil mechanical preparation – Mainly aiming to help natural regeneration
19	Soil mechanical preparation – With another aim (to be described)
21	Chemical treatment of the stumps of cut trees against pathogenic fungi
22	Chemical treatment of trees against processionary moth
29	Other chemical treatment to help the targeted plant species (to be described)
31	Chemical treatment to eliminate the targeted plant species
99	Unknown

5.1.3.22 Main targeted plant species

The main plant species targeted is to be reported following the same code list as defined for ground vegetation assessments (cf. Manual Part VII.1). It can be the main species to which a chemical treatment is applied, or the main tree species benefitting from cultural operations (formative pruning, weeding, cleaning, pruning).

5.1.3.23 Detailed site preparation type

Site preparation operations are to be further described in classes as following.

Code	Description
11	Soil mechanical preparation – Any kind limited to the humus and topsoil (<10 cm depth)
12	Soil mechanical preparation – Ploughing
13	Soil mechanical preparation – Deep loosening with a subsoiler
14	Soil mechanical preparation – Bed shaping (to build ridges in wet sites)
15	Soil mechanical preparation – Preparation by isolated spots for one or few seedlings
19	Soil mechanical preparation – Other (to be described in other information)
21	Soil liming – With crushed limestone
22	Soil liming – With crushed dolomite
23	Soil liming – With wood ash
29	Soil liming – With another type of material (to be described in other information)
31	Soil fertilization – With synthetic fertilizer
32	Soil fertilization – With sewage sludge

33	Soil fertilization – With paper mill sludge
39	Soil fertilization – With another type of material (to be described in other information)
41	Slash removal – Windrowing
42	Slash removal – Burning
43	Slash removal – Harvesting
44	Slash removal – Grinding and scattering
49	Slash removal – Other (to be described in other information)
51	Stumping – Excavating then windrowing
52	Stumping – Excavating then burning
53	Stumping – Harvesting
54	Stumping – Grinding and scattering
59	Stumping – Other (to be described in other information)
99	Unknown

5.1.3.24 Thickness of prepared soil

The maximum depth reached during soil mechanical preparation is to be reported in cm.

5.1.3.25 Share of handled area

For soil mechanical preparation and for the creation or maintenance of pathways, the share of handled area is to be reported as a percentage of the whole area.

5.1.3.26 Sown/planted tree species

The sown or planted tree species is to be reported using a three-digit code (see online documentation).

5.1.3.27 Seed provenance – country

The country – or state of the United States of America – of provenance of the seeds of the tree species used in artificial regeneration (either sowed or planted) is to be reported with a code (see online documentation).

5.1.3.28 Seed provenance – locality

The locality of provenance of the seeds of the tree species used in artificial regeneration (either sowed or planted) is to be reported as text.

5.1.3.29 Planting stock type

The planting stock type is to be reported in 3 classes.

Code	Description
1	Bare-rooted seedlings
2	Container-grown seedlings
99	Unknown

5.1.3.30 Seedling age

The age of the seedlings at the time of the plantation is to be reported in years.

5.1.3.31 Seedling height

The mean height of the seedlings at the time of the plantation is to be reported in cm.

5.1.3.32 Management system in forest nursery

To promote the development of the rooting system of the seedlings, management system in forest nursery may include transplanting or undercutting operations. This is to be reported in 4 classes.

Code	Description
1	With transplanting
2	With undercutting
3	Without transplanting or undercutting
99	Unknown

5.1.3.33 Share of living seedlings one year after plantation

The success of a plantation can be evaluated through the percentage of planted seedlings that are still living one year later.

5.1.3.34 Height of pruning

In case of pruning (excluding formative pruning), the height of pruning is to be reported as the maximum height below which branches were removed in meters.

5.1.3.35 Density of individuals

The density of individuals is a quantitative indicator of the effort made in any kind of non-remunerative silvicultural operation. In case of sowing or planting, it is respectively the number of seeds or seedlings artificially installed per hectare. In case of weeding, cleaning or pruning, it is the number per hectare of seedlings, saplings, poles or trees, to the benefit of which the operation is made.

5.1.4 Surveys and measurements at plot and site level

Several assessments are carried out within individual surveys at the large-scale plots (Level I) and/or at the intensive monitoring (Level II) sites. Table 4 provides a quick reference to the various surveys foreseen, their target plots and expected frequency. Specific measurements foreseen within individual surveys as well as their status (mandatory/optional) are described and reported in detail in the individual parts of the Manual, also indicated in Table 4.

Table 4: Quick reference for surveys to be carried out on different plot types (Install – at plot instalment, project – within dedicated projects; *: recommended frequency may differ from the frequencies specified in the respective Manual Parts)

Survey	Provide data on	Methods described in	Target plots and frequency of assessment/measurement/sampling*		
			Level I	Level II	Level II core
Plot description	Location, size and status of the plot	Part II	Install	Install	Install
Stand description	Basic characteristics of the stand	Part II	5 yrs	5 yrs	5 yrs
Management operations and natural disturbances	Forest management operations and natural disturbances	Part II	-	5 yrs	5 yrs
Tree condition	Indicators of crown, branches and stem status of the trees	Part IV	1 yr	1 yr	1 yr
Tree growth and yield	Actual periodic growth of the stand and of individual trees	Part V	-	5 yrs	5 yrs
Tree growth and yield (intensive)	Intra-annual and annual growth of individual trees	Part V	-	-	1 yr to continuously
Tree phenology	Timing of the annual development stages of forest trees (plot level)	Part VI	-	-	weekly
Tree phenology (intensive)	Timing of the annual development stages of forest trees (individual tree level)	Part VI	-	-	continuously
Ground vegetation	Species richness and abundance	Part VII	project	5 yrs	5 yrs
Ozone injury on plants	Presence on visible injury attributable to tropospheric ozone	Part VIII	-	-	1 yr
Meteorological measurements	Basic (T, P, wind speed) meteorological variables, soil moisture and temperature	Part IX	-	continuously	continuously
Soil sampling and analysis	Soil profile and chemical concentration of elements and ions in soil solid phase. Information on soil water retention characteristics.	Part X	project	10-20 yrs	10-20 yrs
Soil solution collection and analysis	Chemical content of elements and ions in soil liquid phase	Part XI	-	-	1-2 weeks
Foliar sampling and analysis	Chemical concentration of elements in foliage of trees	Part XII	project	2 yrs	2 yrs
Sampling and analysis of litterfall	Amount, composition and chemical content of litter	Part XIII	-	-	2-4 weeks
Sampling and analysis of deposition	Chemical concentration of elements and ions in open field, throughfall and stemflow precipitation	Part XIV	-	1-2 weeks	1-2 weeks
Ambient air quality	Concentration of SO_2, NO_x, O_3 in the air	Part XV	-	-	1-2 weeks
Leaf area index	Total canopy leaf area	Part XVII	-	-	1 yr

5.2 Quality Assurance and Data Quality Requirements

At its 22nd Task Force Meeting in 2007, ICP Forests adopted an overall Quality Assurance (QA) perspective. The overall concept and the QA components are described in Part III, while individual QA/QC measures are reported in detail in individual Manual Parts for the respective survey based exclusively on field measurements, and in Part XVI for investigations involving laboratory analysis.

6 Data Submission

Data is submitted yearly to the central data storage facility at the ICP Forests Programme Co-ordinating Centre (PCC) using formats specified in standardized documents available under ICP Forests website.

6.1 Data Transmission to Programme Co-ordinating Centre

Data will be sent to the PCC using a data submission web application at any time of the year, however, deadlines for annual reporting should be considered. Data is submitted survey by survey and year by year. Thus, each NFC has to submit a complete set of files/forms per survey and year via the submission module. In general, this set includes a reduced plot file and data files. Additionally, all files containing respective QA/QC information (e.g. results of laboratory ring tests or field comparison courses) and data accompanying reports (word documents) should be submitted together with the data files.

An exception to the annual submission is the general plot information which is submitted only in case of a need for updating the ICP Forests database (e.g. new plots or improved/updated plot relevant information).

6.2 Data Validation

Submitted data will be tested in three stages: Compliance, Conformity and Uniformity tests (Houston & Hiederer 2009). Only those data which pass those stages successfully will be uploaded to the ICP Forests database.

Compliance tests will test the format of the submitted data.

Conformity tests focus on the submitted values and compare them with test ranges or test their relation to the values of other attributes or of the same attribute from former years.

Uniformity tests check the spatial and temporal comparability of the data by the production of graphs and maps. Whereas compliance and conformity checks will be applied in time by the submission application of the database during the transmission procedure, uniformity checks will be applied by the staff of the PCC data centre.

7 References

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Annex I – Recommendations for functional integration of Level I and National Forest Inventories for tree condition assessments

Marco Ferretti

(adapted after Ferretti M. 2010: Harmonizing forest inventories and forest condition monitoring - the rise or the fall of harmonized forest condition monitoring in Europe? iForest 3:1-4).

Adopting Level I methods on NFI plots

In addition to the ongoing annual assessments of tree condition on the existing Level I plots, Level I variables are assessed on (a subsample of) NFI plots (to be selected according to the country-specific NFI design). Permanent numbering on trees should be avoided in order to keep the plot as anonymous and undisturbed as possible. The Level I assessment on the selected NFI plots may be carried out at every NFI repetition (e.g. every 5 or 10 years) to favour data integration.

Adopting NFI methods on Level I plots

At the same time, the country-specific NFI plot design and variables are adopted on the existing Level I plots. This includes the selection of new sample trees on existing Level I plots while former sample trees at the Level I plots are retained. Annual Level I assessments are carried out on the old as well as on the newly selected sample trees.

Advantages

This functional integration will result in several advantages:

- the existing time series is maintained by the continuation of the assessment on existing sample trees;
- a comparison between the two datasets (Level I and NFI) will be possible at defined time intervals (e.g., at each NFI cycle);
- combined and more precise estimates may be possible at defined time intervals (e.g., at each NFI cycle).

This latter possibility depends, however, on the nature of the Level I network (its origin and target statistical population), and on the assumption that Level I and NFI samples concern the same statistical population. NFI plots will stay undisturbed. The disadvantage is a slight increase of costs (Level I plots adaptation in the first year; some new attributes in addition on NFIs every 5 or 10 years).

Annex II – Recommendations for converting cross-cluster plots into fixed area Level I plots

Marco Ferretti

Figure A1 shows an approach to convert a cross-cluster design (with undefined shape and size) into a fixed area plot, while keeping the original sample trees. This kind of procedure is applicable for different plot sizes (e.g., different radii, according to the country) and/or may allow sub-sampling of trees (e.g. angle count sampling; concentric plots for smaller DBH classes) in case of dense stands and/or stands with many small trees where the assessment of all the trees is not feasible. This procedure can be of interest for those countries facing the integration of NFI and Level I.

Note that – according to this procedure – data series on original sample trees can be kept. At the same time, the adoption of a fixed area plot will favour the estimation process.

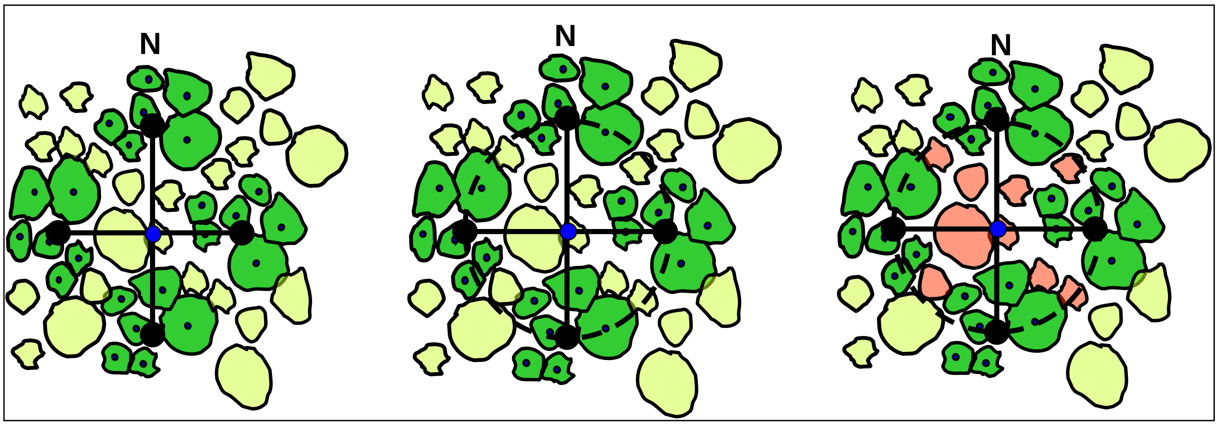

Figure A1: Example of change from a cross-cluster sample to a circular fixed area plot. Left, cross-cluster plot with six trees (dark green ones) selected at each cardinal direction, 25 m from the centre; middle, a 25 m radius plot is designed; right, the trees within the 25 m radius plot previously not considered are now incorporated into the sample of trees (red ones). The old sample trees are kept to ensure the continuation of the data series. The same procedure is applicable for different plot sizes (e.g. 18 m radius). Drawing by M. Ferretti

Annex III – Minor changes after 2020

Date	Minor change to latest published version in 2020	Affected sections of this document
17.11.2021	NFI status is saved in STA table in the database, not in PLT, because NFI status might change after some years. In STA, it can be updated every 5 years, but in PLT the status would be static.	“NFI status” was moved from Table 1 to Table 2.

Annex IV – Should Level II plots entering the stand regeneration stage be maintained under monitoring or relocated?

None of these two options is perfect. Both have advantages and disadvantages, which are summarized in the tables below, and which correspond to one another. Making a choice between them requires to consider both practical and strategical points of view.

Several strategical implications should be considered:

- Should the stand development stage be integrated as an additional explanatory factor in the Level II monitoring? On one hand, studying the development of a stand over a complete rotation period can be of great scientific interest. On the other hand, the severe effects of a final cutting and the frequent changes during the early stages of the development of a young stand may hide the impact of other environmental changes, which are primarily targeted at by the ICP Forests' scope and objectives. As a result, if Level II plots which were generally installed in adult stands, begin to consist of an increasing share of plots with young stands, the capacity of the network to detect and evaluate impacts due to environmental changes by other major stressors like air pollution and climate change may reduce.
- The continuity of the data series can be better maintained if monitoring activities are continued on the same plot during stand regeneration. But it is important to note that in such a case the data will be heavily impacted by the sudden environmental changes after a large natural disturbance or final cutting and following the establishment of a new stand. However, if the continuity of the data series at the scale of the whole network is to be considered, all plots are not likely to enter into the regeneration stage at the same time and large-scale monitoring results will be greatly affected by a significant proportion of plots in the regeneration stage.
- The longer the plots are monitored at the same location, the more the potential biases due to monitoring activities on the observed ecosystems – e.g. exclusion of ungulates by fencing (Boulanger *et al*., 2018), diverging forest management practices inside plots compared to the surrounding forest, soil trampling due to frequent assessments – are likely to accumulate and become of predominant influence. In general, care should be taken to minimize their occurrence and to quantify their impacts.
- Relocating plots gives the opportunity to adapt the set of sampled forest ecosystems to changes in the forest cover (e.g. forest expansion dynamics on former agricultural lands or grasslands, changes in the relative importance of tree species in the forested area) and/or to put more effort on ecological contexts where the impacts of climate change are more likely to be observed (e.g. ecological margins of tree species distribution).

Several practical consequences should be considered too:

- Monitoring plots entering the regeneration stage requires efforts and methods adapted to young stands. For example, trees can be too small for measuring some variables (e.g. DBH), for installing some devices (e.g. litterfall traps, throughfall and stemflow collectors), or for selecting permanent sample trees. They can also be too numerous (especially in naturally-regenerated stands) for labelling and surveying all of them on the whole plot area, and some may have to be cut for accessing the plot.
- Stand establishment may fail. Monitoring plots at the same location may then no longer be of interest.
- Relocating plots requires additional resources when properly abandoning the replaced plot (making additional assessments to properly end the data series, precisely georeferencing the area and the monitoring devices to keep able to reuse

the same location later, removing devices) and installing a new one (searching for a proper location, installing devices, …).

Table A1: Advantages and disadvantages of maintaining under monitoring Level II plots that have entered the stand regeneration stage.

Advantages	Disadvantages
1. **Opportunity for studying forest ecosystem dynamics over a complete stand rotation including the regeneration stage** (which is only rarely documented in the literature) 2. **Maximizing site lifetime, and the length of the data series** that can be continuously collected despite the practical difficulties induced by young stands (e.g. solid soil, flora, and all open-field surveys) 3. **Knowledge about tree growth and management practices from one forest generation to the next** (despite discontinuity in growth survey due to stand removal) 4. **No need for moving sites** (saving costs)	1. **Need for more plots** if it is intended to consider stand development stage as an additional factor while maintaining the same capacity of the network to evaluate the impacts of environmental changes 2. **Need for protocols adapted to young stand conditions and/or need to interrupt some surveys** until conditions are suitable again (e.g. throughfall, litterfall, growth survey of all trees in dense naturally-regenerated stands) 3. **Biases effects on monitored ecosystems can accumulate over the long term** and become a predominant factor 4. **Risk for stand regeneration to fail** and so for wasting effort on monitoring plots that are no longer of interest 5. **Possibly no control on the main tree species of the next generation to be monitored** (If the NFC has no influence on forest management)

Table A2: Advantages and disadvantages of relocating Level II monitoring plots that have entered the stand regeneration stage.

Advantages	Disadvantages
1. **Monitoring activities focused on ecosystem responses to environmental changes in adult forest stands** (no additional effect of stand regeneration stage) 2. **Maintaining optimal conditions for monitoring activities thus maximizing the number of variables that can be surveyed** 3. **Reduction of accumulated biases caused by monitoring activities to observed ecosystems,** when plots are relocated 4. **Opportunity to adapt the set of sampled forest ecosystems by installing new plots at a new location** (e.g. to better represent the main forest conditions, or to increase the chance to detect impacts of climate change) 5. **Keeping the possibility to maintain continuity in open-field surveys** (if plots are relocated nearby) **and to keep abandoned sites available for future research**	1. **No evaluation of the effect of stand development stages** on the ecosystem 2. **Data series start again from zero in new plots :** at least about 15 years are needed to start considering trends in ecological conditions 3. **Also the knowledge on site condition, stand growth and management start again from zero in new plots** (knowledge acquired on the replaced plots can still be made available in case they are reused later) 4. **Additional effort is needed to move plots** (to properly abandon the replaced plots and to install new plots)