United Nations Economic Commission for Europe (UNECE)

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 III
Quality Assurance within the
ICP Forests Monitoring Programme

Version 2021-1

CONTENTS

1 Introduction

Quality Assurance (QA) is essential in forest monitoring to promote, achieve and maintain high enough Data Quality (DQ). High DQ results from a process in which each step of the survey of concern is properly addressed, from the definition of the objectives to the comparability of the data in space and time, data storage, processing and reporting. QA is a cross-cutting issue as it is of major importance for all the surveys in ICP Forests, including all the various steps within a survey.

Several QA related activities have been carried out in ICP Forests since the beginning of the programme. The development of a Manual and the crown condition intercalibration exercises both already started in 1987, the soil inter-laboratory comparisons started in the early 1990s. Later, the activities were extended, with particular emphasis on the analytical aspects and laboratory inter-comparisons, while field sampling long received less attention (Ferretti et al., 2009).

At the meeting of the Programme Co-ordinating Group (PCG) in Hamburg in 2003, the issue of a common approach to some aspects of QA was first discussed and a decision made to put forward a set of Quality indicators and a QA reporting. Some Expert Panels (EPs) submitted proposals, but no common reporting was developed. The issue was brought up again at the PCG meeting in 2006 and a Quality Assurance Committee (QAC) with members of the PCG was established by the ICP Forests Task Force (TF) at its 22nd meeting held in Zvolen, Slovakia, in May 2007 (see QAC documents at http://www.icp-forests.org/QAC.htm).

2 Scope and application

This Manual Part III presents the overall QA approach within the ICP Forests. It is not a formal Quality Assurance Plan because it does not concern all its typical issues (EPA, 2002). Rather it serves as a reference document for the Expert Panels (EPs) and Working Groups (WGs) active within the ICP Forests to design and implement their own "Quality Assurance and Quality Control" (QA/QC) procedures.

The major aim is (i) to prevent mistakes in data collection ("Quality assurance" as meant within the "QA/QC" term) and (ii) to control and evaluate the fulfillment of defined quality requirements ("Quality control"). It is also useful for external data users to understand the procedures adopted to improve the ICP Forests DQ and to understand the actual confidence that can be placed on the data generated by the Programme. Details about specific QA/QC procedures are described in each of the individual parts of the Manual and compiled in Part XVI for all surveys depending on analyses in laboratories[1].

3 Objectives

The objective of this Manual Part is to describe the elements of the Quality Assurance programme and the QA/QC procedures that EPs and WGs should develop and implement within their own field of application.

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

4 The QA Toolkit

The various elements of the QA activities within the ICP Forests constitute the QA Toolkit. The QA Toolkit can be defined as the set of instruments and actions designed to ensure that methods are unambiguous, clearly presented, accepted and applied consistently across all participating countries. Within its own specific field, each EP and WG is asked to be compliant with the QA Toolkit. The QA Toolkit includes the following items:

- <u>ICP Forests Manual.</u> It documents clear standard operating procedures (SOPs) formally approved by the ICP Forests TF (Chapter 4.1).

- <u>Indicators of DQ.</u> It is important to develop and define a series of explicit, unambiguous indicators of DQ that prevent subjective statements on the level of data quality. They can be also used to document the progress/maintenance of DQ (Chapter 4.2).

- <u>Methods to ensure and evaluate DQ.</u> Continuous training, field, photo and laboratory intercomparison exercises and control assessments are central to ensure high DQ, and to collect data to document status and trends of DQ (Chapter 4.3).

- <u>Response actions in case of below-threshold DQ.</u> It is important to foresee a list of actions to improve DQ if results from DQ evaluation reveal DQ below the minimum acceptable level (Chapter 4.4).

- <u>DQ evaluation and reporting activities</u>. Continuous evaluation of DQ and reporting about the uncertainties related to the data collected by the Programme (Chapter 4.5).

4.1 The ICP Forests Manual

4.1.1 Manual structure and organization

The Manual is the basis of the approach of the Quality within the ICP Forests. As a comprehensive document, the Manual describes the background of the Programme, its structure, design, and methods. The different parts of the Manual deal with specific surveys and provide clear and concise definitions of the scope and application, objectives, sampling, measurements, QA/QC procedures (including training and intercomparison exercises) and DQ requirements, reference materials and relevant bibliography. They are designed to provide all necessary details for every specific step of each survey while bearing in mind the final information need and avoiding redundancy and unjustified statements. The common structure of all the parts of the Manual includes:

1 Introduction, where the nature of the survey is put in context of the whole monitoring programme;

2 Scope and application of the described methods, with a table for quick reference;

3 Objective for the survey of concern, in an operational format;

4 Location of measurements/observations and sampling;

5 Measurements/observations to be carried out mandatorily or optionally, reporting units and DQ requirements;

6 Data handling;

7 References:

8 Annexes.

4.1.2 Update and revision of the Manual

Survey methods, variables to be measured and QA/QC procedures are under continuous screening by the EPs and WGs. This continuous process provides the basis for two kinds of amendments, the Manual update and the more comprehensive Manual revision.

The Manual update consists of minor changes like e.g. the clarification of wording, correction of obvious mistakes, and the introduction of missing codes for unconsidered cases. Minor changes can be implemented at any time, but need to be discussed among the respective EPs/WGs and the PCC. All minor changes will be listed at the end of the respective Manual part and be made available on the ICP Forests website.

The Manual revision by contrast is a more comprehensive process, when all individual Manual parts are subject to in depth review and more substantial modifications. All major Manual changes during a Manual revision need to be accompanied by a rationale document summarising the significant modifications and the motivation for each change. Revisions are carried out on a 5-year basis to allow methodological consistency as well as concentrated implementation and planning ability during interim periods. Each Manual revision must be formally approved by the Task Force.

4.2 Data Quality Indicators

DQ indicators in ICP Forests are standardized, evidence-based measures of DQ developed for each survey and facilitate the documentation and monitoring of the programme's quality. They need to be explicit and rigorous, although reasonable and understandable. They are defined for selected variables and designed to be consistent with the importance and the expected precision/accuracy of the concerned survey.

Four DQ indicators can be applied. They are specific for each survey:

- Data Quality Objectives (DQOs) define the expected level of precision/accuracy for individual measurement/observations.

- Data Quality Limits (DQLs) provide the minimum acceptable proportion of measurement/observations within the DQOs.

- Plausibility Limits (PLs) set the range of acceptable values for measurements/observations. They have to be regularly updated.

- Data Completeness Limits (DCLs) define the minimum acceptable proportion of data within the PLs..

4.3   Methods to ensure and evaluate Data Quality

Table 1: Quick reference of activities to be organized to ensure and evaluate Data Quality by survey type (o – optional, m – mandatory). All activities defined as mandatory are to be reported in the database.

Survey type (Manual part)	Activities at international level				Activities at national level	
	Experimental comparisons of methods	Field inter-comparison of observers	Photo inter-comparison of observers	Laboratory ringtests	Preparation effort as required for each survey (including needs for training and/or intercalibration)	Control assessments
Crown condition and damaging agents (Part IV)	o	m	m	-	m	m
Tree growth (Part V)	o	o	-	-	m	o
Tree phenology (Part VI)	o	m*	m*	-	m	o
Ground vegetation (Part VII)	o	o	-	-	m	o
Ozone injury on plants (Part VIII)	o	m	m	-	m	m
Meteorological measurements (Part IX)	o	-	-	-	m	-
Soil sampling and analyses (chemistry) (Part X)	o	-	-	m	m	m
Soil sampling and analyses (physics) (Part X)	o	-	-	o	m	-
Soil description (Part X)	o	o	-	-	m	o
Soil solution sampling and analysis (Part XI)	o	-	-	m	m	m
Foliar sampling and analysis (Part XII)	o	-	-	m	m	m
Canopy Leaf Area (Part XVII)	o	o	-	-	m	-
Litterfall sampling and analysis (Part XIII)	o	-	-	m	m	m
Deposition sampling and analysis (Part XIV)	o	-	-	m	m	m
Ambient air quality (Part XV)	o	-	-	o	m	o

*: mandatory only for assessments by individual trees

4.3.1   Requirements in the preparation of each survey

To prevent mistakes or inhomogeneity in data collection, the National focal centres (NFCs) must thoroughly organize and prepare each survey. The minimum preparation effort needed for each survey type must be explicitly defined in the respective Manual part, including:

- Requirements for skills from crew leaders or all operators (either as a previous background, or to be taught in training courses).

- Requirements for transcription of the ICP Forests method into written field guidelines adapted to the specific national monitoring design, and applicable by all operators involved with no or minimum room left to their interpretation.

- Requirements for training courses, if skills are to be taught or updated by NFCs, or if field guidelines and remote technical assistance provided to operators are not sufficient to ensure an adequate implementation of the survey.

- Requirements for intercalibration courses, if needed to harmonize field observations among operators.

The implementation of the minimum preparation effort defined for each survey type must be confirmed by NFCs when they transmit their data to the ICP Forests database.

4.3.2   Training courses

At training courses operators (i) are familiarized with the methods to be applied; (ii) receive instructions for the implementation of new methods; (iii) receive training for enhancing accuracy and precision, and for handling situations where accurate measurements are difficult to obtain. Training courses should be developed for each survey. Guidelines for organizing training courses are given in respective parts of the Manual.

4.3.3   Intercalibration courses

Intercalibration courses are training courses organized in order to harmonize field observations among observers, at national or international level. Reference teams, which are designated by countries to participate to international calibration courses, can act as a link to other teams involved in national or infra-national intercalibration courses.

Intercalibration courses can be also used for intercomparison purposes (cf. Chapter 4.3.5) if they are designed and conducted accordingly. After the same subjects have been assessed independently by different observer teams and these assessments have been recorded, the results are compared between teams. Reciprocally, the discussion of the results of field intercomparison courses among participants is also useful for intercalibration purposes.

4.3.4   Testing the effect of using different methods

In some cases, the Manual allows different options in methods to be used for sampling, processing samples, measurements or observations. Differences in methods that could lead to inconsistencies in data, should be systematically reported during data submission and be evaluated by the related EP on the basis of existing literature and, if needed, by experimental comparison tests.

During intercomparison courses, which are primarily regularly organized to evaluate the effect of observers/labs, the impact of using different methods can also be evaluated. In addition, other experiments can be specifically organized to compare methods. If possible, bridging functions are determined to harmonize the data collected with the different methodological options identified.

4.3.5 Intercomparison rounds

At intercomparison rounds the results of individual observer teams or laboratories are compared against a defined standard. The standard is in most cases defined as closeness of agreement between the arithmetic mean of a large number of test results and the true or accepted reference value ('trueness'). Since in most cases, the 'true' value is not known, the intercomparison exercise usually compares the results of individual entities (laboratories, observers) with the median or the outlier-free mean value across all entities.

Intercomparison rounds should be organized on a regular basis, according to defined procedures and under the responsibility to be determined within each EP.

The two ways of data collection, (i) by direct assessments in the field and (ii) by collection of sample material and analysis in laboratory, are considered with the following actions:

- The aim of intercomparison courses (ICCs) for field surveys is to compare the results of different observers using the methods they usually use, but they can be designed to experimentally test the effect of different methods in addition (see chapter 4.3.4). They apply to assessments of tree condition, tree growth, tree phenology, biodiversity, ozone symptoms, and soil description. Intercomparison courses for some of these surveys can also be organized by means of photographic material.

- The aim of ring tests for laboratories is to compare the results obtained by laboratories with the analytical methods they usually use on ICP Forests samples. They apply to the surveys of soil and soil solution, foliar chemistry, deposition, soil physics and gaseous air pollutants. After their successful participation in ring tests, laboratories receive qualification reports. Laboratories with unsatisfactory ring test results have to requalify.

4.3.6 Control assessments

Control assessments are organized under the responsibility of the National Focal Centres (NFCs) to evaluate the results of field crews/laboratories in real conditions all along data collection campaigns.

- During field assessments of tree condition, tree growth and ground vegetation, independent controls by a different team of observers are organized on a defined percentage of the surveyed plots, and close to the date of their actual survey in order to minimize possible sources of variations in the assessment conditions.

- During the assessment of ozone symptoms, observers should take pictures of symptomatic and non-symptomatic leaves/needles for control by international reference experts. It is also recommended to take samples for further validation by microscopic analysis.

- During ambient air quality surveys based on passive samplers, the measurements of some samplers are compared with reference measurements made by active stations.

- For chemical analyses of soil, plant material and solutions, laboratories must control the consistency of their measurements over time, by regularly analysing reference materials and producing control charts.

4.4   Response actions

Results from quality evaluation activities should be followed by response actions, to support the continuous fulfilment of quality requirements and to call for improvements when problems are detected. Different response actions should be foreseen according to the severity of the problems encountered and the survey concerned. They are defined by EPs in their respective Manual parts. In general, problems are encountered during data submission to the ICP Forests database and during the intercomparison rounds.

For detecting poor data quality during data submission, tests are implemented as described in the ICP Forests online documentation[2].

Response actions for quality issues detected during intercomparison rounds are decided among the person responsible for the intercomparison round, the concerned EP and the Programme Coordinating Center (PCC)). These include:

- <u>Warnings</u>: the observer/lab is notified about the unsatisfactory results, and asked to check procedures and equipment, and repeat measurements.

- <u>Further training and assistance</u>: if the re-measurements are of unsatisfactory quality, the observer/lab is provided with further training and will enter a requalification stage.

- <u>Requalification</u>: after additional training, the observer/lab participates in a new intercomparison round with the possibility to produce new results and to document improvements made to meet the quality requirements.

- <u>Flagging of data</u>: Data may be flagged in the database and reports for e.g. the following reasons:

  - A requalification was unsuccessful and/or the cause of unsatisfactory DQ cannot be addressed without hampering the comparability with existing time series at country level.

  - A country did not participate in a mandatory intercomparison round or did not conduct mandatory control assessments.

  - A country that fulfilled the respective quality requirements can be highlighted and acknowledged this way.

- <u>Exclusion of data from international data evaluations</u>: when the problem is very severe and it may hamper the outcome of data analysis, the data can be excluded from data processing and evaluations.

4.5   Reporting of Data Quality

4.5.1   Evaluating the quality of surveys

NFCs must confirm the implementation of the minimum survey preparation effort as defined for each survey type, by year and plot, during data submission to the ICP Forests database.

EPs should evaluate and report regularly (from every year to every 5 years, depending on the frequency of the data collection) about the fulfilment of at least some of the main quality indicators defined for each survey, and about their progression. To contribute to this purpose:

- International inter-comparison rounds and tests of methods must be systematically documented in reports. At least synthetic results by country must be saved in the ICP Forests database so that they can be provided to data users. Detailed results must be kept in a safe and proper way by the concerned EP so that they can be reused in further analyses.

- Results from mandatory and recommended control assessments in the field should be transmitted by NFCs and stored in the ICP Forests database to contribute to the evaluation of the quality indicators at the international level.

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[2] https://icp-forests.org/documentation/Tests/index.html

Data submission forms need to be adapted for a regular transmission of all quality information required from NFCs and their storage in the ICP Forests database.

4.5.2 Specific procedure for evaluating the quality in labs

Specific forms for quality information (QA/QC forms) were developed to monitor laboratory quality indicators and quantification limits. QA/QC forms must be submitted to the ICP Forests database together with the respective monitoring data. They are presently available for the surveys of soil and soil solution, foliar chemistry, deposition, and ground vegetation biomass and nutrients.

The results of the corresponding interlaboratory comparison tests (i.e. ring tests) are submitted to the ICP Forests database by the ring test organizers and can be linked to QA/QC forms. Each measured value for each variable can thus be linked to the respective laboratory quality indicator and ringtest result. For each single dataset this provides information on the quality and the uncertainties of the data.

The quantification limit of each variable enables the assignment of the code "-1" for values below the quantification limit in the data files.

5 Responsibilities for data quality

Within the limits of the resources at their disposal (but keeping in mind the fundamental importance of the implementation of quality procedures for the relevance of any investment made in long-term monitoring):

- NFCs are responsible for the proper application of the methods and QA/QC procedures defined in the ICP Forests Manual for collecting and reporting data of required quality from their respective country;

- EPs and WGs are responsible, within their respective fields of application and with the support of the PCC, for:

    o the definition and update of proper methods in the ICP Forests Manual including QA/QC requirements, procedures, and response actions following the Quality Assurance programme described in this Manual part,

    o the organization and reporting of international training courses, international intercomparison courses, and international tests of methods,

    o the regular evaluation of the implementation of the QA/QC procedures, and of the quality indicators in their respective survey,

    o the validation of the data consistency, and the consideration of the data quality in the interpretation of results in ICP Forests publications and in the documentation of the data;

- The QAC is responsible for the definition and update of the overall Quality Assurance programme described in this ICP Forests Manual part;

- The PCC is responsible for:

    o the administration and development of the database, and its related forms and routines, in consistency with the methods and QA/QC procedures defined in the ICP Forests Manual,

- o the support of NFCs during the data submission/ uploading process including a set of automated consistency checks, and feedback to NFCs in case of quality problems detected in their data,

- o the provision of the data and their documentation to data users upon request following the ICP Forests data policy,

- o the edition and distribution of the ICP Forests Manual, the communication of Manual updates, and other ICP Forests publications with information on data quality issues,

- o the information of NFCs in case of continuing quality problems of their data or their failing of inter-comparison tests, and the moderation to overcome these problems together with the EPs and WGs.

- o supporting the coordinating bodies (EPs, WGs, QAC, TF) involved in the ICP Forests Quality Assurance programme.

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Annex I – Minor changes after 2021

Date	Minor change to latest published version in 2021	Affected sections of this document

Annex I – Minor changes after 2021