Food and Agriculture Organization
of the United Nations

MANUAL FOR VISUAL ASSESSMENT OF FOREST CROWN CONDITION

Manual for visual assessment of forest crown condition

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INTRODUCTION

Forest condition in Europe has been monitored since 1985, through the implemtation of the **International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests** (**ICP Forests**) in the framework of the **Convention on Long-range Transboundary Air Pollution** (**CLRTAP**) under the **United Nations Economic Commission for Europe** (**UNECE**). The number of countries participating in **ICP Forests** has grown to 41, and includes Canada and the United States of America, enabling the application of the scheme in what has become the largest biomonitoring network in the world. From the beginning, **The programme** has been chaired by Germany. The Institute for World Forestry of the Johann Heinrich von Thünen-Institute (**TI**) hosts the **Programme Coordinating Centre** (**PCC**) of **ICP Forests**. Activities of **ICP Forests** was, until 2011, cofinanced and conducted in close cooperation with European Commission (**EC**).

With the primary aim of assessing the effects of air pollution on forests, **ICP Forests** provides scientific information to **CLRTAP** to fulfill legally binding protocols on air pollution abatement policies. For this purpose, **ICP Forests** developed a harmonized monitoring approach comprising a large-scale forest monitoring protocol (*Level I*), as well as forest ecosystem monitoring (*Level II*).

The **ICP Forests** strategy for 2007 to 2015 is to pursues the following two main objectives to:

(a) provide a periodic overview of the spatial and temporal variations in forest condition in relation to anthropogenic and natural stress factors by means of Europea-wide (transnational) and national large-scale representative monitoring on a systematic network (monitoring intensity Level I); and

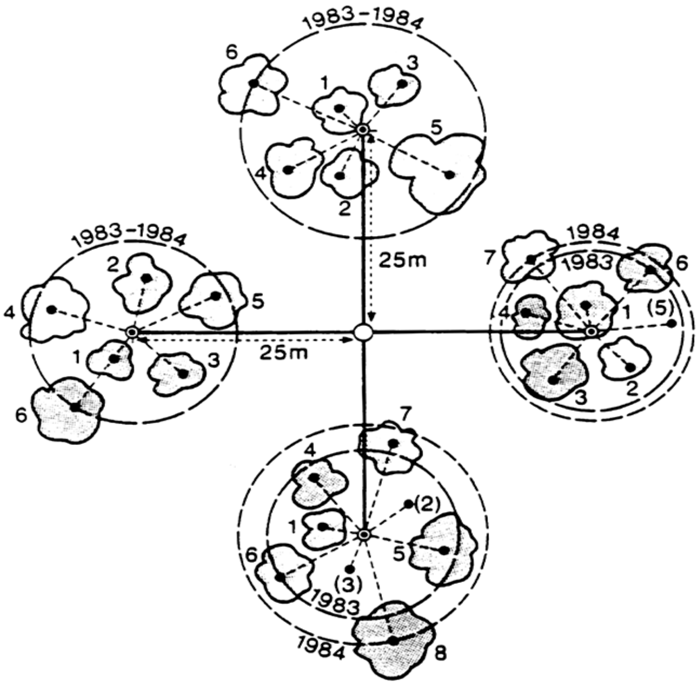
(b) gain a better understanding of cause-effect relationships between the condition of forest ecosystems and both anthropogenic impact and natural stress factors by means of intensive monitoring on a number of permanent observation plots selected in the most important forest ecosystems in Europe (monitoring intensity Level II).

The complete methods used in forest monitoring according to **ICP Forests** are described in detail in the ***Manual on Methods and Criteria for Harmonized Sampling, Assessment, Monitoring and Analysis of the Effects of Air Pollution on Forests*** (**ICP Forests 2010**). For many years, forest monitoring was conducted jointly through the actives of **ICP Forests** and the European Commission (EC), based on EU cofinancing under relevant **Council and Commission Regulations**. The monitoring results are also utilized in international forest and environmental policies other than those of **CLRTAP**, such as **Forest Europe** (**FE**), the **Convention on Biological Diversity** (**CBD**), the **UN-FAO Forest Resources Assessment** (**FRA**), and **EUROSTAT** of the **EC**. In order to better meet the new information needs with respect to carbon budgets, climate change and biodiversity, the forest monitoring system was further developed in 2009 to 2011 within the project: **Further Development and Implementation of an EU-level Forest Monitoring System** (**FutMon**) under EU cofinancing.

METHODS OF ASSESSMENT

The large-scale forest monitoring grid comprises over 7500 plots. The selection of Level I plots is the responsibility of participating countries, but the density of plots should resemble that of the previous 16 x 16 km grid. For this reason, the number of plots in each country should equal the forest area (in km^2) of the country divided by 256 (ICP Forests, 2010).

According to the coordinate grid of sample plots, a ***sample plot*** is marked with a rod of a vivid colour in its centre. Samples of trees for the assessment of crown condition are systemically selected as 4-point cross clusters (**Figure 1**). Four subplots oriented along the Cardinal points (*East, West, North* and *South*) at a distance of 25 m from the central place (the rod) are established. In each subplot, the 6 trees nearest to the subplot centre are selected as sample trees, resulting into 24 sample trees per plot. The samples include all tree species with a minimum height of 60 cm.



(ICP Forests, 2010)

Figure 1. Sample plot as a 4-point cluster (subplots) with 6 tree samples per plot

The crown canopy classes (after Kraft) are used as a criterion for selecting the trees, but only if the trees lack significant mechanical injuries (**Figure 2**). Social status is a measure of the height of a tree relative to the surrounding trees. Information on social status is useful as an aid to interpreting crown condition and increment data for the individual trees.

Five classes of social status are recognized (**ICP** Forests, 2010):

- ***dominant,*** including free-standing trees with upper crown above the general level of the canopy;
- ***codominant***, which includes trees with crowns forming the general upper level of the canopy;

- ***subdominant***, which includes trees extending into the canopy and receiving some light from above, but shorter than the dominant and codominant classes;
- ***suppressed***, including trees with crowns below the general level of the canopy, receiving little direct light from above;
- ***dying*** *trees**.***

Note: The assessment of social class of a tree is in some cases difficult. Suppressed trees should not be equated with dying trees as, in a mixed-age stand, they represent potential future generations of trees. Classification on steep slopes presents a problem as even relatively short trees may receive direct light from above. In such cases, classification should be based on the relative height of trees.

The selected trees are permanently marked with numbers for referencing in future permanent assessments. When trees are removed due to management measures or for other reasons, they are replaced with new trees. If a stand s clear felled', the central point is maintained until the establishment of a new stand (ICP Forests, 2010).

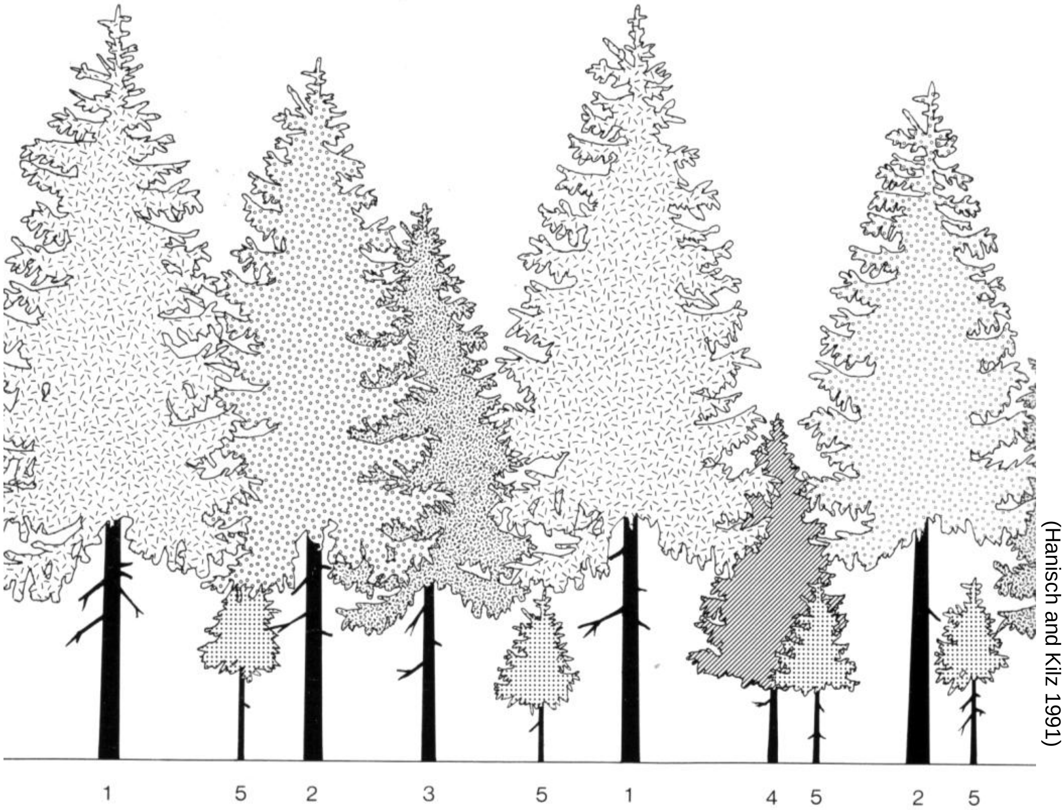


Figure 2. Social position of single trees in a stand (tree classes according to Kraft)
1 - dominant, 2 - codominant, 3 - subdominant, 4 - suppressed, 5 – dying

The estimation of crown condition strongly depends on the definition of the assessable crown. The crown present at the time of assessment is to be considered, regardless of the potential or theoretical crown, which may have existed in previous years. The influence of any other trees, whether present or absent, on the crown of a sample tree must be taken into account when determining its condition. In cases where the sample tree crown is influenced by competition, the assessable crown includes only those parts that are not influenced by other crowns, i.e. shading.

Parts of the crown directly influenced by interactions between crowns or competition are excluded (**Figure 3**). The assessable crown of a freely developed tree is defined as the whole living crown from the lowest substantial living branch upwards. The following parts of such a crown must be excluded from the assessment:

- Epicormic shoots below the crown: and
- Gaps in the crown, where it is assumed that no branches ever existed.

The assessable crown includes branches that recently died, but excludes snags that have been dead for many years (i.e. which have already lost their side-shoots). Snags represent the historic mortality of parts of the crown and have no influence on the current condition of the tree. therefore, they are excluded from the assessment. Dieback of shoots and branches represents an active process in the crown and is included.

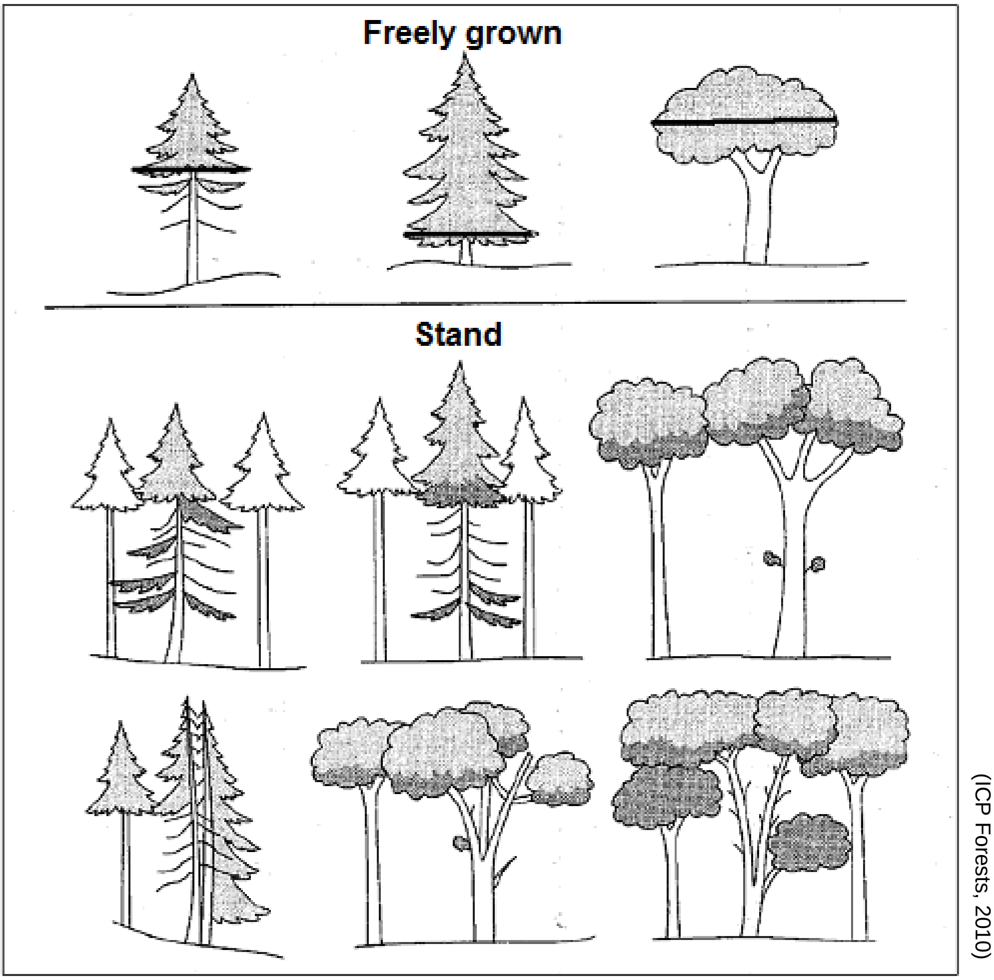


Figure 3. Assessment of the tree crown ranges from the tip of the tree to the widest horizontal span of the crown (above the black line for *freely grown trees* and the lighter colour indicates assessable crown for *forest stands*)

The definition of assessable crown varies between countries. It is therefore essential that for each country (region and tree species), the definition of assessable crown is documented.

In coppice stands, it may be necessary to consider the assessable crown as a single unit consisting of crown parts from different stems.

The visibility of a crown is the degree to which different parts of the assessable crown can be viewed from the ground.

Although crowns with poor visibility are not removed from the sample, information on the visibility of individual tree crowns is useful in the interpretation of the data from those trees. Such trees remain in the sample as the objective sampling design means that their exclusion could lead to bias in the results. Some parameters, e.g. stem and branch damage, may be assessable on such trees.

The following four classes for the visibility of assessable crown are used (ICP Forests, 2010):

- Whole crown is visible.
- Crown is partially visible only.
- Crown is visible with backlighting only (i.e. in outline). Note that some parameters can still be assessed when only back-lighting is present.
- Crown is not visible

Defoliation is defined as needle/leaf loss in the assessable crown when compared to a reference tree. Defoliation is observed regardless of the cause of foliage loss (for example, it includes damage by insects).

In order to evaluate the state of the crown, the needle/leaf losses are allocated to one of the five damage classes listed in **Table 1**. These classes are "0" (0 - 10 % defoliation), "1" (10 – 25 % defoliation) and so on.

A tree with more than 60 % and up to 100 % defoliation, which is still alive, is coded as "3". The code "4" is reserved for dead trees.

Hint: If the above-ground parts of a tree die (e.g. after a forest fire), the tree is classified as dead. The above-ground parts of a tree are considered dead if the phloem and xylem are dead.

Note that dormant buds may continue to flush for one or more seasons on cut logs, indicating that the tissues may remain alive for some time although some people may consider them as dead. Regrowth from the roots is excluded until the shoots attain the requirements for inclusion in the assessments. Although biologically inappropriate for practical reasons, regrowth from the base of the trees should be classified as new stems with new crowns.

Table 1. The damage classes used in estimating needle/leaf losses
(Hanisch and Kilz 1991)

№	Degree of defoliation	Defoliation class	Percentage defoliation
1	*none*	**0**	*0 - 10 %*
2	*slight*	**1**	*10 - 25 %*
3	*moderate*	**2**	*25 - 60 %*
4	*severe*	**3**	*60 - 100 %*
5	*dead tree*	**4**	*100 %*

The second important damage characteristic is foliar discolouration, i.e. in most cases, a yellowing of the needles or leaves. The percentage of discoloured needles is estimated in one of five classes **(Table 2).**

Table 2. The damage classes used in estimating needle/leaf discolouration
(Hanisch and Kilz 1991)

№	Degree of discolouration	Discolouration class	Percentage discolouration
1	*No discolouration*	**0**	*0 - 10 %*
2	*Slight discolouration*	**1**	*10 - 25 %*
3	*Moderate discolouration*	**2**	*25 - 60 %*
4	*Severe discolouration*	**3**	*60 - 100 %*
5	*Dead tree*	**4**	*100 %*

The needle/leaf loss classes and discolouration classes are plotted against each other to determine the final damage classes **(Table 3).**

Table 3. The final damage classes for foliage (needle/leaf)
(Hanisch and Kilz 1991)

Defoliation class	Discolouration class		
	0 or **1**	**2**	**3**
	Final damage class		
0	**0**	**1**	**2**
1	**1**	**2**	**2**
2	**2**	**3**	**3**
3	**3**	**3**	**3**

The best time of year for assessing tree crowns is from the end of July until the end of August (earlier at higher elevations).

PHOTO GUIDE FOR VISUAL ASSESSMENT

The concept of reference tree is one of the most controversial issues in the monitoring programme, yet it is crucial for to the assessments. Two different types of reference trees are recognized: local reference trees and absolute reference trees. Use of absolute reference trees may lead to higher defoliation estimates than comparisons with local reference trees, but the results are perhaps more amenable to temporal and spatial analyses. Most countries have adopted local reference trees as standards. This local reference takes into account the growth and the development stage of the tree.

A local reference tree or a conceptual (imaginary) tree is defined here as the best tree with full foliage that could grow at a particular site, taking into account factors such as altitude, latitude, tree age, site conditions and social status. The tree has 0 - 10 % defoliation. This tree should represent the typical crown morphology and age of trees in plot. Absolute reference trees are the best possible trees of a genotype or species, regardless of site conditions, tree age, or other factors. Photo guides exist which provide guidelines on absolute reference trees in different parts of Europe.

The photographs included in the manual are selected mainly as an aid in evaluating classes of damage in relation to foliage loss.

For this purpose, the booklet contains four photographs of each of the four main European forest genera as follows:

A. ***Broadleaved*****:** *Quercus*, *Fagus* species; and

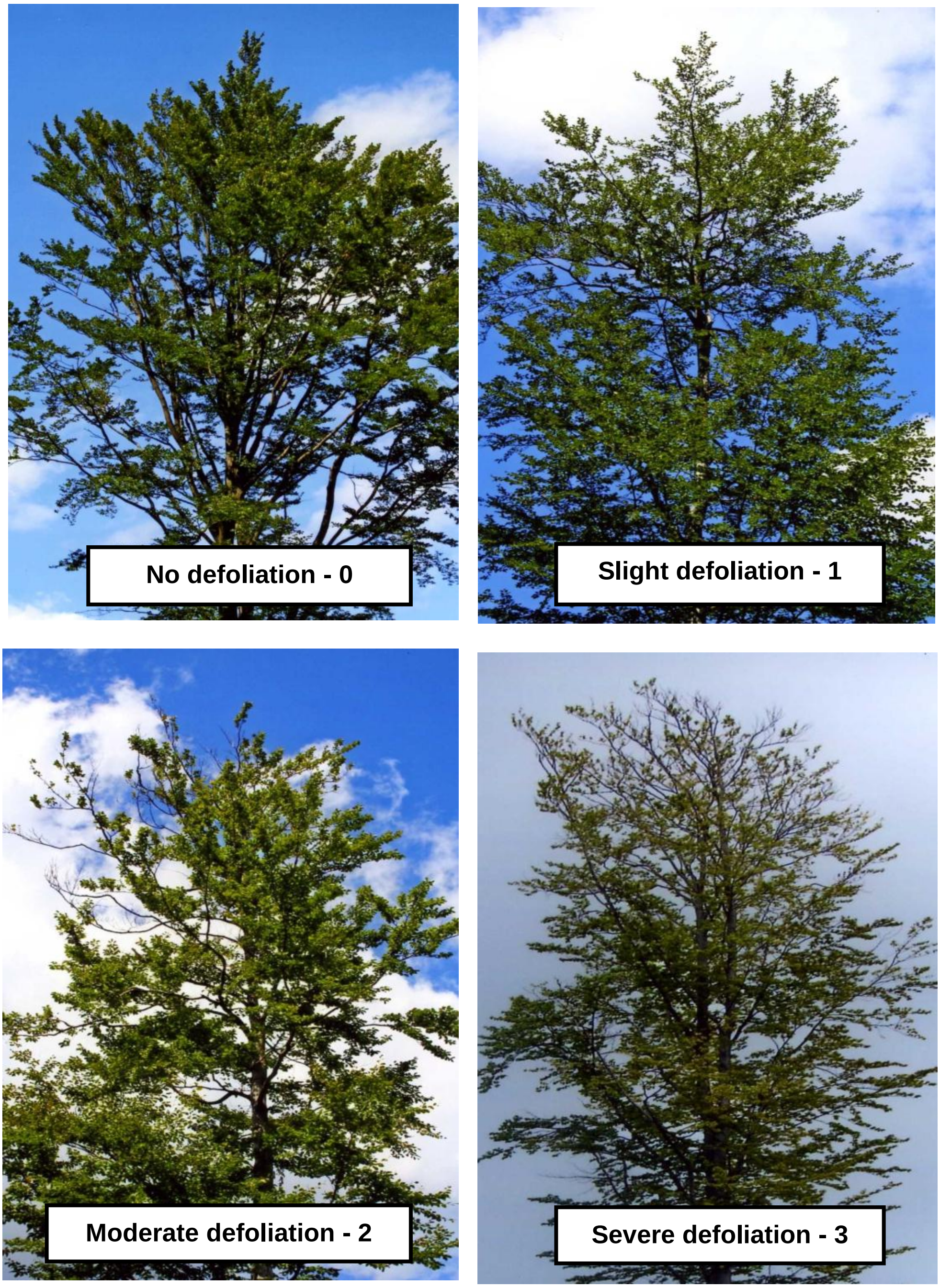
B. ***Coniferous:*** *Pinus, Picea* species.

The first photograph shows a completely healthy tree and the other three show the plant in what may be considered the centre of the range of three classes of damage due to defoliation: *slight, moderate and severe*.

In order to allow, as far as possible, a differential diagnosis between new types of damage (such as the many alien invasive forest pests introduced by international trade of plants and plant products) and damage due to causes which can be readily identified (in particular fungi, insects and known abiotic stressors of local origin), photographs of the most frequently encountered situations which may be attributed to these causes, are given for each of the six main genera in the manual: "*Handbook of the Major Forest Pests in South-East Europe*"*.*

(Photos: P. Fabianek & ICP Forest Intercalibration)

Figure 4. Visual assessment of crown condition for *Quercus* spp.

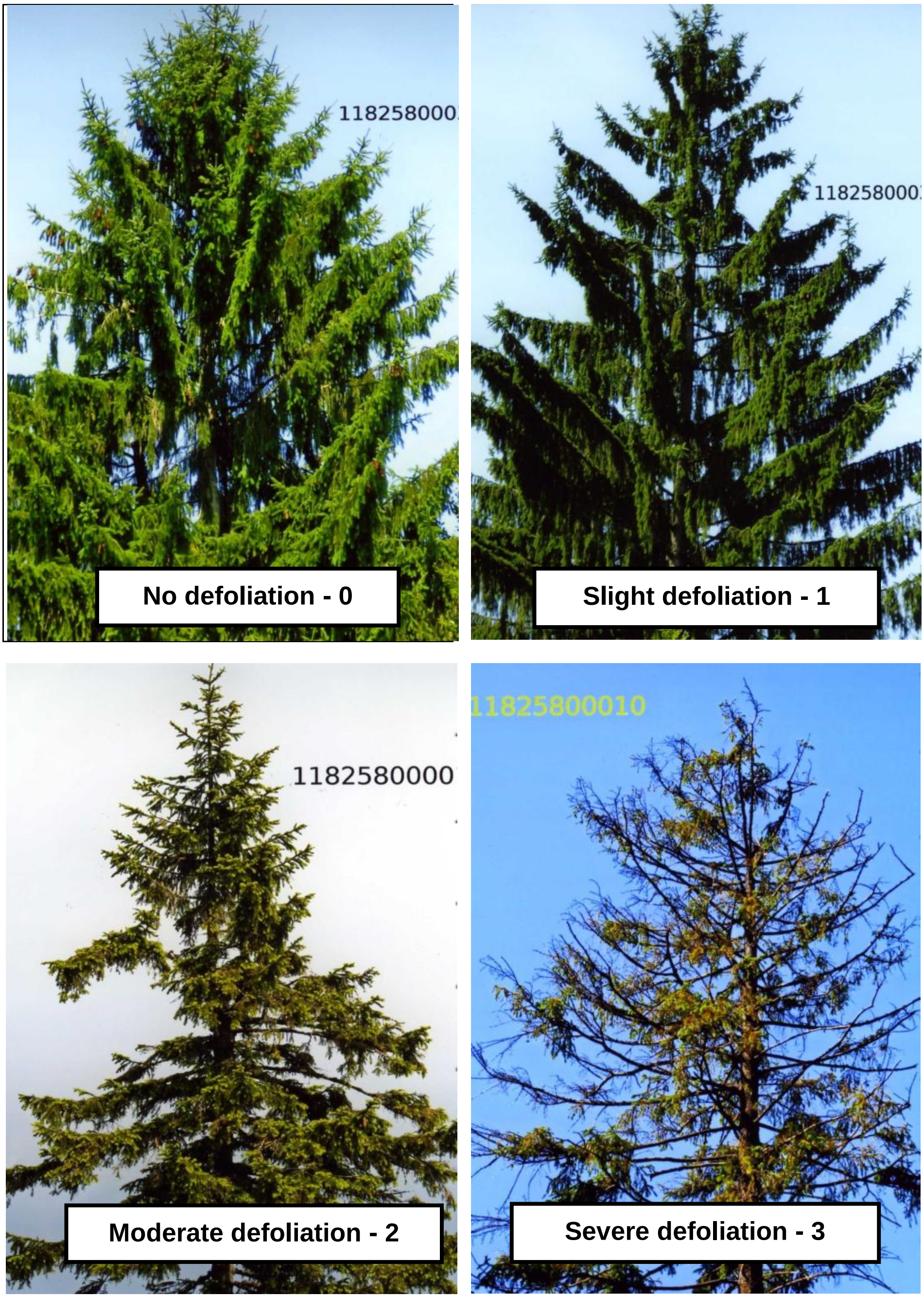


(Photos: P. Fabianek & ICP Forest Intercalibration)

Figure 5. Visual assessment of crown condition for *Fagus* spp.

(Photos: P. Fabianek & ICP Forest Intercalibration)

Figure 6. Visual assessment of crown condition for *Pinus* spp.



(Photos: P. Fabianek & ICP Forest Intercalibration)

Figure 7. Visual assessment of crown condition for *Picea* spp.

Annex 1

Table. 4. Overview of existing large-scale databases relevant for forest monitoring and research, including data access rules and manuals/protocols (Clarke et al, 2010).

Programme/project	Short name (Home page)	Database	Data access rules	Manual/protocols
International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests	**ICP Forests** *http://www.icp-forests.org*	Central data base with raw data at vTI, Germany	Open after registration and information of countries, 2 years reserved for internal evaluation	*http://www.icp-forests.org/Manual.htm*
International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems	**ICP Integrated Monitoring** *http://www.environment.fi/ default.asp?contentid=17110& lan=en*	Central data base with partly raw data, partly aggregated data at SYKE, Finland	Open after registration, large data sets are approved by Task Force	*http://www.environment.fi/default.asp?node=6329&lan=en*
The nitrogen cycle and its influence on the European greenhouse gas balance	**NitroEurope** *http://www.nitroeurope.eu*	Central data base with raw data at CEH, United Kingdom	Meta data: open access.raw data: open for partners and case by case decision for external users	Partly CarboEurope methods- Rainfall: EMEP methods- Own methods of partners, that need to be documented in method sheets
Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe	**EMEP** *http://www.emep.int*	Central data base with raw data at NILU, Norway: *http://ebas.nilu.no/*	All data are open for web download	*http://tarantula.nilu.no/projects/ccc/manual/index.html*
Integrated Project CarboEurope-IP Assessment of the European Terrestrial Carbon Balance. Data under the responsibility of IMECC from 2009	CarboEurope (**IMECC**) *http://www.carboeurope.org(http://imecc.ipsl.jussieu.fr/)Ecosystem data: http://www.europe-fluxdata.org*	Central data base with meta data at MPI-BCG, Germany. - Half-hourly Ecosystem data, Univ. of Tuscia Viterbo, Italy.- Raw data under responsibility of site managers	Metadata: open access.half hourly: open for partners and case by case decision for external users (but open from 2011)	Measurement protocols under *http://www.carboeurope.org*
Integrated Carbon Observation System	**ICOS** *http://www.icos-infrastructure.eu*	Raw data:- Ecosystem sites Univ. Tuscia, Italy- Atmospheric sites, LSCE, France	Metadata: open access Raw data: open access	Partly CarboEurope and IMECC (7 FP)- Partly under development- Concept papers available
European Long-Term Ecosystem Research Network	**LTER** *http://www.lter-europe.net*	Central data base with meta data at UBA, Austria. - Raw data under responsibility of site managers	Metadata: web-based, open. Raw data: links to other networks	Best practice guidelines *at:http://www.lter-europe.net/document-archive/central/Best%20practice%20guideline%20v3-June1.pdf*

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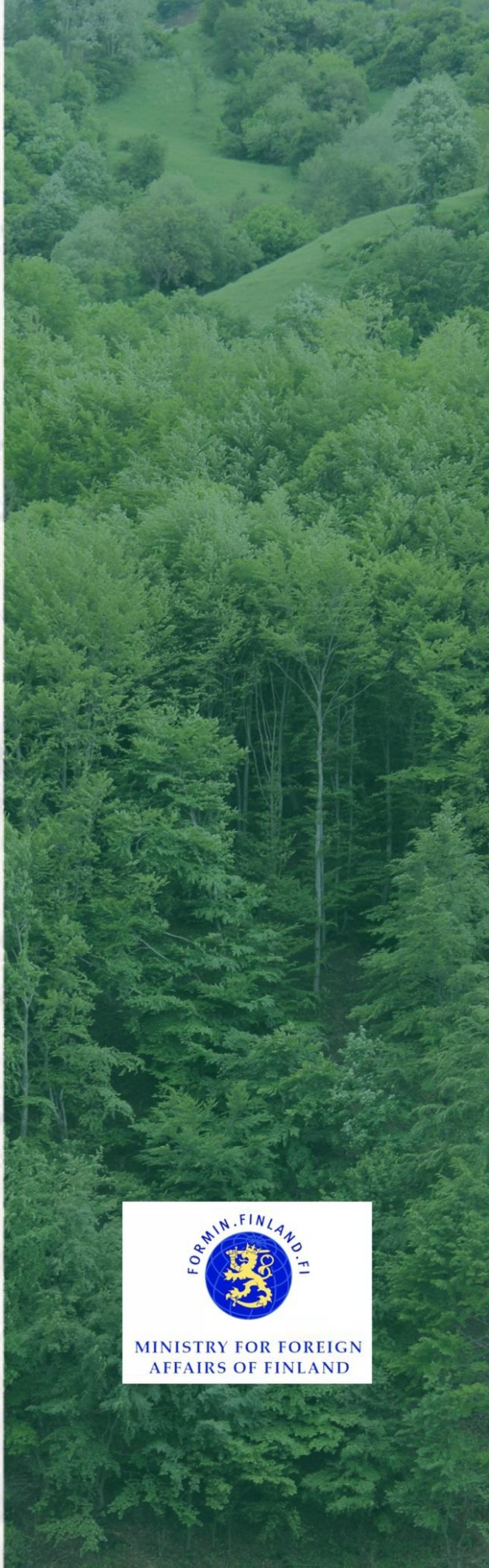
[online] URL: *http://www.icp-forests.org/Manual.htm* (Accessed 17 October 2014)



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