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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 VI
Phenological Observations

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ICP Forests Expert Panel on Meteorology and Phenology

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CONTENTS

1 Introduction

Knowledge about the timing and the duration of certain life events (phenology) provides valuable information in explaining the actual condition of the trees themselves. Changes in the timing of life events may be caused by fluctuations and changes in climate, but also by other environmental impacts such as air pollution. Such changes do not only affect the condition of the trees, but also ecological processes at the stand and landscape level.

Phenological data (from intensive phenological phases as well as biotic and abiotic events) are required for integrated evaluations of different aspects of level II plots (e. g. in connection with meteorological parameters, crown condition assessment, deposition, increment). This will contribute to a better understanding of their effects on the measured values of the various ecological parameters and stand characteristics on these plots

2 Scope and application

Phenological Observations in the Intensive Monitoring Programme (Level II) are optional. This Part of the Manual aims at providing a consistent methodology to collect high quality, harmonized and comparable phenological data at selected UN/ECE Level II monitoring plots. Harmonization of procedures is essential to ensure data comparability. To have their data used in the international database and evaluations, National Focal Centers and their scientific partners participating to the UN/ECE ICP Forests programme should follow the methods described here.

Within the aims of the Level II monitoring programme, Forest Phenology is defined as the systematic observation and recording of:

- recurrent development stages of forest trees over the course of a year,
- emergent biotic and abiotic (e.g. damaging) events and phenomena.

2.1 Observation and recording at the plot level

Further background information on ecological processes on the plot, as well as an early warning system on events affecting the condition of the trees, can be obtained by recording the most obvious phenological phenomena and effects of biotic and abiotic (damaging) events.

A cursory examination on the plot and the buffer zone is recommended to be performed on those Level II plots where continuous measurements (e.g. meteorological observations, deposition and/or soil solution measurements) are being carried out.

2.2 Intensive phenological monitoring at the individual tree level

Intensive phenological monitoring, based on visual observations on individual trees on the plot or the buffer zone, is recommended to be performed at least on those Level II plots where continuous monitoring of meteorological parameters is carried out.

Table VI-1: Quick reference with details about reporting units, data quality, plausibility limits: phenology

Variable	Level I	Level II	Level II core	Reporting unit	MQO	DQO
PLOT LEVEL						
Observation date	n	o	m*	ddmmyy	full agreement	90 %
Event code	n	o	m* +	7 classes	full agreement	90 %
Score of the event (except flowering, damage)	n	o	m*	5 classes	+/- 1 class	80 %
Score of the event (flowering, damage)	n	o	m*	4/2 classes	+/- 1 class	80 %
INDIVIDUAL TREE LEVEL						
Observed part of the crown (vertical)	n	o	o	5 classes	full agreement	90 %
Observed side of the crown (lateral)	n	o	o	8 classes	full agreement	90 %
Direction of observation	n	o	o	3 classes	full agreement	90 %
Observation method	n	o	o	3 classes	full agreement	90 %
Observation date	n	o	o	ddmmyy	full agreement	90 %
Event code	n	o	o	7 classes	full agreement	90 %
Score of the event (flushing, autumnal colouring, leaf/needle fall, lammas shoots / secondary flushing)	n	o	o	5 classes	full agreement	50 %
Score of the event (flowering, damage)	n	o	o	4/2 classes	full agreement	80 %

n – not assessed, o – optional, m – mandatory
DQO is the Data Quality Objective (minimum acceptable accuracy) for measurements, also referred to MQO (Measurement Quality Objective)
* only mandatory when no tree level assessment made
+ mandatory are only flushing, autumn colouring and damage assessment

3 Objectives

The main objective of phenological observations on the Level II plots is to provide supplementary and complementary information on the status and development of forest tree condition during the year. The data obtained will essentially contribute to estimating the effect of climate change on forest ecosystems, because it will enable:

- to determine the course of the annual development stages of forest trees on the intensive monitoring plots and their dependence on local (e.g. meteorological and site) conditions, including damaging events, in order
- to document and explain possible changes in the timing of these stages (starting time, length of period and magnitude) in relation to environmental factors of natural and/or anthropogenic origin such as air pollution and climate change,

- to utilize this knowledge in interpreting observed changes in tree condition (e.g. crown condition, growth, nutritional status).

4 Location of measurements and sampling

The phenological observations should be made on the plot and/or the buffer zone of Level II plots where continuous measurements are carried out. For individual tree observations, priority should be given to those plots where (at least) meteorological measurements are carried out. All species on the intensive monitoring plots are of interest; however, priority should be given to the most important species on the plot, which is already reported as the main species.

All phenological observations within the ICP Forests programme are focused on the crown of the trees. If possible, phenological observations should stick to the upper third of the tree crown (see 4.1.2.2).

4.1 Sampling design

4.1.1 Observation and recording at the plot level

Because the observer will make a cursory examination of the forest canopy, which consists of all included tree crowns, no formal sampling design is required. However, the observation should not be made from one or a few neighbouring trees, but the observer should look around, preferably from more positions across the plot.

4.1.2 Intensive phenological monitoring at the individual tree level

4.1.2.1 Trees that qualify as sample trees

The trees to be assessed should be selected from those trees on which Crown Condition assessments are carried out (Part IV) and that have been selected for continuous growth measuring (girthbands). However, good visibility of the upper part of the crown of the trees is necessary. If there are an insufficient number of crown condition trees visible, it will be necessary to select additional trees from the plot or from the buffer zone. In this case:

- trees should be dominant or co-dominant,
- trees on which continuous or periodical measurement of DBH and height is (planned to be) made should be preferred,
- trees selected for leaf/needle sampling and analysis are not to be included.

4.1.2.2 Selection of sample trees and observed part of the crown

Preferably the top of the crown (light crown, upper third of tree crown) should be visible and assessed from one observation point. If this is not possible, then the middle part of the tree crown is also acceptable. If a distinction between different tree crown parts is not possible, also the whole tree crown can be assessed. The same part of the crown should be considered for subsequent phenological observations throughout the whole year, as well as for subsequent years.

Upper third, middle part, and whole crown are defined based on the lowest significant volume of foliage (or buds, if observations are made before flushing) excluding epicormic branches (Fig. VI-1). If the crown is not continuous, the lowest part of the whole crown is considered to be the lowest

branch with a minimum diameter of 3 cm within 2 m of the main part of the crown. As a further alternative that is partly used, observations can also be continued to be made on the total crown including epicormic branches.

It should be avoided that the frequent monitoring of the selected trees from the same observation points does affect the condition of the plot e.g. the ground vegetation. For this it may be preferable to select trees that are clearly visible when standing outside the plot (buffer zone).

When using cameras the selection of the trees is limited to those trees that are within the range of the camera(s). It is recommended to select trees that may be representative for the whole range of single tree responses for each species, e.g. early flushing individual trees as well as late ones. Cameras should be installed based on the experiences from former years or during flushing.

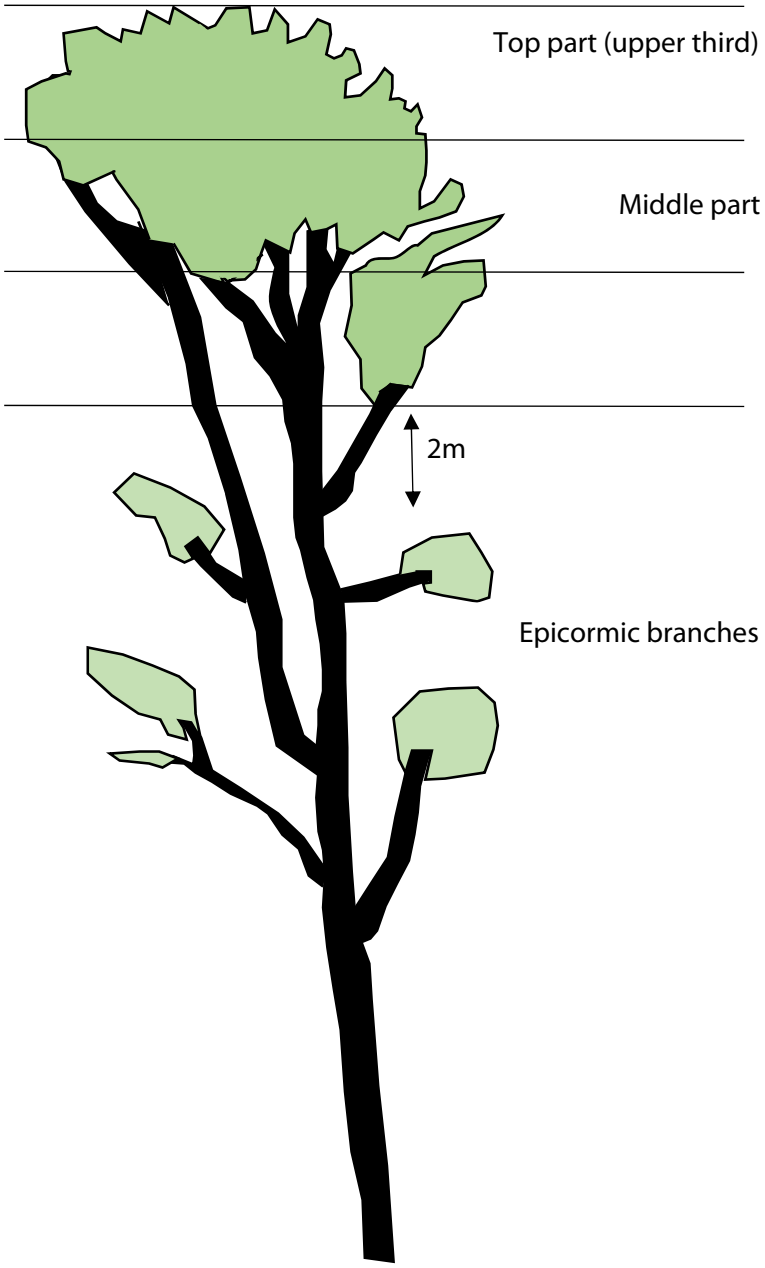

Figure VI-1: Definition of assessed parts of the tree crown (Drawing: S. Fleck)

4.1.2.3 Number of trees to be sampled

At least 10 trees per main species per plot should be selected. The number of trees to be selected for phenological monitoring depends on the tree species and the stand conditions. All trees should be numbered. If they already have numbers (e.g. for crown condition or increment assessment) these numbers should be kept and used. If there is no number, a new number shall be given starting with an "M". Do not start with already existing numbering series (1,2,3 etc.). For continuous measurement with permanently installed cameras, at least 5 representative trees should be observed.

4.2 Sampling equipment

When making the phenology assessments manually, it is recommended to use binoculars.

Instead of manually, the phenological assessments can be made using cameras that make automatically pictures of the plot and/or the crowns of single trees with defined time intervals. Technical information on the use of cameras can be found in Annex 2.

4.3 Sample collection, transport and storage

No collection of samples is foreseen with the tree phenology survey, except for damages, where plant material may be sampled to analyse the cause of the damage.

For the handling of images obtained when using camera techniques see Annex 2.

5 Measurements

5.1 Parameters to be assessed and reporting units

A number of variables are suggested for plot- and individual tree observations. The observations and recordings should be easy and simple, and limited to the following events:

- Occurrence of flushing, flowering, Lammas shoots or secondary flushing, colour change and leaf/needle fall
- Biotic damage (pests and/or diseases) (see Part IV B).
- Abiotic damage (e.g. frost, wind, hail) (see Part IV B)

Detailed descriptions can be found in Annex 1 and in the technical documentation (see ICP Forests webpage). A synthesis is reported in Table 1. The code number for each event is as follows:

Event code

Code	Description
1	flushing
2	autumnal colouring
3	leaf / needle fall
4	leaf or crown damage
5	other damage
6	lammas shoots / secondary flushing
7	flowering

5.1.1 Methods of observation

5.1.1.1 Plot level

The observation and recording should concentrate on the obvious effects of the events on the basis of a cursory examination. Only events that have occurred and/or have changed their abundance / intensity since the last visit should be recorded. As the individual stages of a phenological event occur, assessments need to be repeated until the last stage of the event is reached.

5.1.1.2 Individual tree level

In principle, all phenological phases are of interest for phenological monitoring. However, from the practical point of view (e.g. financial input, ease and reliability of the monitoring, European wide comparability, compatibility with other surveys like crown condition) it is necessary to concentrate on a limited set of phases. A distinction is made between evergreen and deciduous species:

Evergreen species	Deciduous species
Needle/Leaf appearance	Leaf unfolding / Needle appearance
Lammas shoots	Secondary flushing
Flowering	Flowering
	Autumn colouring
	Leaf/Needle fall

Needle appearance and leaf unfolding are defined as the stage when the first fresh green needles or leaves become visible from the buds. For Lammas shoots and secondary flushing the same definition is used when flushing occurs later and clearly distinct from spring flushing.

For the flowering phase, the appearance of male flowers is to be recorded.

Autumn colouring is defined as the stage when the color of the leaves start to change from green into yellow, red, orange or brown during late summer and autumn.

Leaf fall is defined as the stage when the leaves drop from the tree.

In addition to the above mentioned phenological phases any damage occurring to the foliar or the crown of the trees, as well as any other damage should be scored.

Reference on phenological phases

Information and photographs of phenological reference stages for the most important groups of species of the Level II plots can be found at the web page on phenology in the ICP Forests programme: http://icp-forests.org/documentation/Annex/Pheno_phases.html. This information can also be used as a guideline for monitoring other species. The photographs on the web pages may be printed and/or copied for internal use as field guides, however, without permission they may NOT be used for further publication.

Methods of observation

The observations can be made manually by a field observer or with the use of automatic cameras that take pictures of the selected trees with a certain time interval. In the case cameras are used the images taken are assessed according to the same criteria that are used for the field observations. The method used for making the observation should be reported on form .PHI.

Crown to be assessed

Preferably the top of the crown (light crown, upper third of tree crown) should be visible from one observation point. If this is not possible, then the middle part of the crown is also acceptable. If a distinction between different tree crown parts is not possible, also the whole tree crown can be

assessed. The same part of the crown should be considered for subsequent phenological observations throughout the whole year, as well as for subsequent years. The part of the crown observed should be reported on form .PLP at the time the trees are selected, or whenever it changes, using the codes in the forms document.

5.1.1.3 Scoring

Basis of the scoring of all event observations (event code 1 – 3 and 6) are the total amount of buds or leaves/needles in or after the respective phenological reference stage. Therefore, if 20% of all buds of a tree/stand are exactly in the phase referenced as flushing and another 30% of all buds passed this phase and are visible as leaves, this means 50% altogether and should be reported as score 3. For flowering and damage observation only the absence or presence is necessary to report. If possible also the intensity of flowering could be estimated and reported as scores 7.1 to 7.3..For leaf coloration the relevant quantity to assess is the percentage of the total leaf area (including the leaves that have already fallen) that is no longer green.

The scoring system is summarized in the following tables:

Score of the event (except flowering damage)

Code	Description	Quantification
1	± not occurring	<1%
2	infrequent or slight	1 – 33%
3	common or moderate	>33 – 66%
4	abundant or severe	>66 – 99%
5	complete or total	>99%

Score of the event (flowering and damage)

Code	Description
6	flowering / damage absent
7	flowering / damage present
7.1	flowering sparse (optional)
7.2	flowering moderate (optional)
7.3	flowering abundant or mast (optional)

Observed part of crown

Code	Description
1	top of the crown
2	middle of the crown
3	top and middle of the crown
4	whole crown
5	total crown including epicormic branches

Observed side of crown

Code	Description
1	North
2	North-east
3	East
4	South-east
5	South
6	South-west
7	West
8	North-west
9	All sides

Direction of observation

Code	Description
1	from below
2	at crown level
3	from above

Observation method

Code	Description
1	field observation
2	digital camera
3	Both field observation and digital camera

5.1.2 Frequency of observations

5.1.2.1 Plot level

Observation dates may coincide with the collection of deposition samples or soil solution. A frequency of at least once every second week during the growing period is recommended.

5.1.2.2 Individual tree level

The minimum required frequency is once a week during the critical phases, but daily observations is the optimum.

5.2 Quality Assurance and Quality Control

Adequate Quality Assurance is of great importance, especially for the monitoring at the individual tree level. At national level, National Focal Centres (NFC) are responsible for quality control. For monitoring at the plot level a short explanation is necessary for the personnel making these observations but, in general, special in depth training will not be required. For the monitoring at the individual tree level, instruction and intercalibration of the field staff by the NFC is required. Also at the international level, training and intercalibration courses are being organized. A photo-training course should be organized every year, and field training every third year.

Control assessment should be carried out by an independent control team, at least once a year on e.g. 10% of the plots. These data should be submitted using form .PHC.

A photo guide with phenological stages for various tree species is available from the internet (http://icp-forests.org/documentation/Annex/Pheno_phases.html).

5.2.1 Plausibility limits

Not of relevance for scoring in codes.

5.2.2 Data completeness

For the scoring of the occurrence of the phenological events and phenomena (except flowering and damage) date completeness requires that for the plot (at the plot level) or for the tree (at the individual tree level) the beginning and the end of an event can be identified. This means that at least the scores 2 and 5 have been recorded.

5.2.3 Data quality objectives or tolerable limits

See Table VI-1.

5.2.4 Data quality limits and data interpretation

Due to the fact that the trees are selected in a non-random way, the data obtained cannot be considered representative for the whole plot, or for the species in the region in a statistical sense. Nevertheless, time series of phenological observations of the same object over many years can characterise the recurrent development of the forest over the course of the years.

6 Data handling

The National Focal Centres (NFC's) are responsible for data processing, data storage and submission to the central database and also for evaluations at the national level.

6.1 Data submission procedures and forms

Guidelines for the data submission can be found in Part II, Chapter 6 of the manual.

For the submission of the data to PCC the forms are to be used as specified in Table VI-2.

Table VI-2: Forms for submission of phenological data

Description	Form
Recording of phenological phenomena (plot level – extensive)	.PHE
Registration of trees selected for intensive phenological monitoring	.PLP
Recording of phenological phenomena (tree level – intensive)	.PHI
Submission of information related to digital images on phenological observations	.PHD
Submission of data on control observations	.PHC

6.2 Data validation

Guidelines for the data validation can be found in Part III, Chapter 5 of the manual.

6.3 Data submission to co-ordinating centres

All validated data should be sent yearly to the European central data storage facility at the ICP Forests Programme Coordinating Centre. Detailed time scheduled is provided by the relevant bodies.

6.4 Data processing guidelines

In addition to fulfilling the above-mentioned objectives and aims, phenological data (biotic and abiotic events, as well as intensive phenological monitoring results) are required for integrated

evaluations of different aspects of Level II plots (e. g. in connection with meteorological parameters, crown condition assessment, deposition, increment). This will contribute to a better understanding of their effects on the measured values of the various ecological parameters and stand characteristics on these plots.

6.5 Data reporting

Each National Focal Centre must submit an information describing deviations from UNECE recommended procedures or changes of assessment methods. Periodical quality control evaluations may be requested by the Programme Coordinating Centre to be part of integrated evaluations. References to any publications arising from the work on the Level I/ II plots should be notified so that they can be listed on the ICP Forests web site.

7 References

Brügger, R. & Vassella, A. 2003. Pflanzen im Wandel der Jahreszeiten. Geographica Bernensia. 288pp. ISBN 3-906151-62-X

Annex I – Technical Instructions for the Phenological Observations on Level II Plots

A1.1. Observation and recording at the plot level.

A1.1.1 Observation and recording

For recording of phenological phenomena at the plot level form .PHE is used.

Potential changes to the event codes given in section 5.1 are listed in the respective explanatory item on field <Event code> in the forms document available at the ICP Forests webpage.

Scoring system

Potential changes to the code for scoring of events are listed in the respective explanatory item on field <Score of the event> in the forms document available at the ICP Forests webpage.

In case damage has been observed a more detailed assessment has to be made according to the manual on Crown Condition and Biotic Damage Assessment (Manual Part IV). For the recording of the damage form .TRD has to be used.

A1.1.2 Data processing, validation and analysis

The NFC is responsible for the proper use of the data. If the field staff observes any damaging (biotic or abiotic) event, this should be reported immediately to the responsible person, who should decide on further actions.

A1.2 Observation and recording at the individual tree level

A1.2.1 Introduction

Intensive phenological monitoring on the Level II plots is concerned with observations on individual trees of the major species or group of species, and on a limited set of phenological phases.

A1.2.2 Location

A1.2.2.1 Selection of sample trees

Basic information on each tree has to be submitted using form .PLP. If a selected tree dies or is removed it can be replaced. The newly selected tree should be given a new number and it should be registered using form .PLP.

A1.2.2.2 Crown to be assessed

The part of the crown observed should be reported on form .PLP at the time the trees are selected, or whenever it changes, using the codes listed in section 5.1.

A1.2.2.3 Method used for making the assessments

The method used for making the assessments should be reported on form .PHI, using the codes listed in section 5.1.

A1.2.3 Phases to be monitored

For the recording of the phenological phenomena at the individual tree level form .PHI is used.

The event codes for the monitored effects and phenological phenomena are listed in section 5.1. Basis of the scoring of all event observations (event code 1 – 3 and 6) are the total amount of buds or leaves/needles in or after the respective phenological reference stage. For flowering and damage observation only the absence or presence is necessary to report.

Scoring system

Flushing, colour changes, leaf/needle fall and flowering / damage

The proportion of needles or leaves of the visible part of the crown that are in the described stage or have already passed this stage is to be recorded using the codes given in section 5.1.

In case damage has been observed a more detailed assessment has to be made according to the manual on Crown Condition and Biotic Damage Assessment (part IV). For the recording of the damage form .TRD has to be used.

A1.2.4 Quality Control

Control assessment should be carried out by an independent control team, at least once a year on e.g. 10% of the plots. These data should be submitted using Form .PHC

A1.2.5 Data processing, validation and analysis

The NFC is responsible for the proper use of the data. If any damaging (biotic or abiotic) event is observed in the field, this should be reported immediately to the responsible person, who should decide on further actions.

Annex II – Guidelines for the use of digital cameras

A2.1 Advantages of the use of cameras:

- Enables frequent (continuous) monitoring, also on remote sites
- Assessments can be made any time when staff is available
- Enables comparison between sites
- Improves comparison between years
- Enables comparison between countries/regions
- Enables better timing of appearance of damages
- Provides the base for automated derivation of phenological phases

A2.2 Points to be considered:

- High investment costs
- Need for power supply
- Difficult in dense (conifer) stands
- Possible technical failures
- Possible vandalism

A2.3 The use of digital cameras for monitoring phenology

When using digital cameras the first priority should be that the quality of the pictures (resolution) obtained allows for the assessment of phenological phases at individual tree level according to the guidelines in the manual on phenological observations with 33% classes. In addition also other aspects of the crown such as damages can be assessed. A minimum number of 5 trees per plot should be assessable (tree selection as mentioned above in this protocol).

A2.4 Technical requirements

The cameras should be weather-resistent, e.g outdoor surveillance cameras are suitable. Important is that the pictures are of medium to high resolution (minimum requirements 6 Mpix with 300 pix/inch / 120 pix/cm), even with full zoom properties. For automated evaluation of the pictures, a camera sensitive to near infrared radiation is of advantage.

An alternative could be to use more than one so called fixed cameras that are not able to move and/or zoom with a lower resolution. The camera should have its own memory, or be connected to a data logger. The data logger and steering unit should be stored in a weather-proof place, and the whole system should be protected against lightning. Power supply can be obtained through batteries, solar panels or connection to the electricity network, if available. The working of the camera should be checked every time the plot is visited.A2.5 Location of the camera

The camera can be mounted to a mast that reaches over the top of the crowns, e.g. the towers used for the meteorological assessments or it can be installed below the canopy looking upwards. In order to be able to observe a number of trees, the camera should be movable and programmable so it can take pictures of the same spot at regular intervals. The position of the camera is selected so that it can cover an optimal number of individual trees within the plot at an area as large as possible. For observations from below the crowns the number of visible trees per camera is more limited. Alternatively more than one camera could be used. The camera should take pictures of the whole upper part of the crown. Trees around the camera are selected and registered using form .PLP. For each tree also the part of the crown observed, as well as the crown side visible on the picture are marked. The codes used are the same as for the manual single tree observations.

A2.6 Data handling

Pictures should be taken a number of times each day (at least 2) because the light conditions change during the day due to the position of the sun. At least every 2 months the data should be collected from the plots in order to secure the data. The camera can also be connected to a network, so the observations can be made at distance. In this case it is still advisable to have the pictures also stored at the plot for backup.

The pictures of the different plots should be analysed by one and the same person, or at least for the different plots of each tree species. This way the effect of the observer is eliminated within a country. The assessments should be made using the same stages and codes as used for the field observations. Only one observation per day should be made. The pictures may alternatively be evaluated with automated procedures.

The pictures should be stored by the associated beneficiaries so they can be used later for inter-calibration as well as for comparison between countries. During the phenological phases to be assessed for each tree at least one picture per day should be saved. For the rest of the growing season at least one picture per week is sufficient. If pictures are also taken during winter also one picture per week can be stored. At form .PHD metadata about the stored pictures should be submitted annually.

Pictures should be available to other partners of the project. In order to allow for a consistent and uniform identification and submission of the digital images the form .PHD and the respective Explanatory Items are to be applied.

Annex III– Minor changes after 2016

Date	Minor change to latest published version in 2016	Affected sections of this document