

# INTERPINE

Forestry Innovation

## Forest Condition Monitoring (FCM) of *Pinus radiata* in New Zealand Field Data Collection Procedures

Prepared for **New Zealand Forest Owners Association**

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Version 1.2.1



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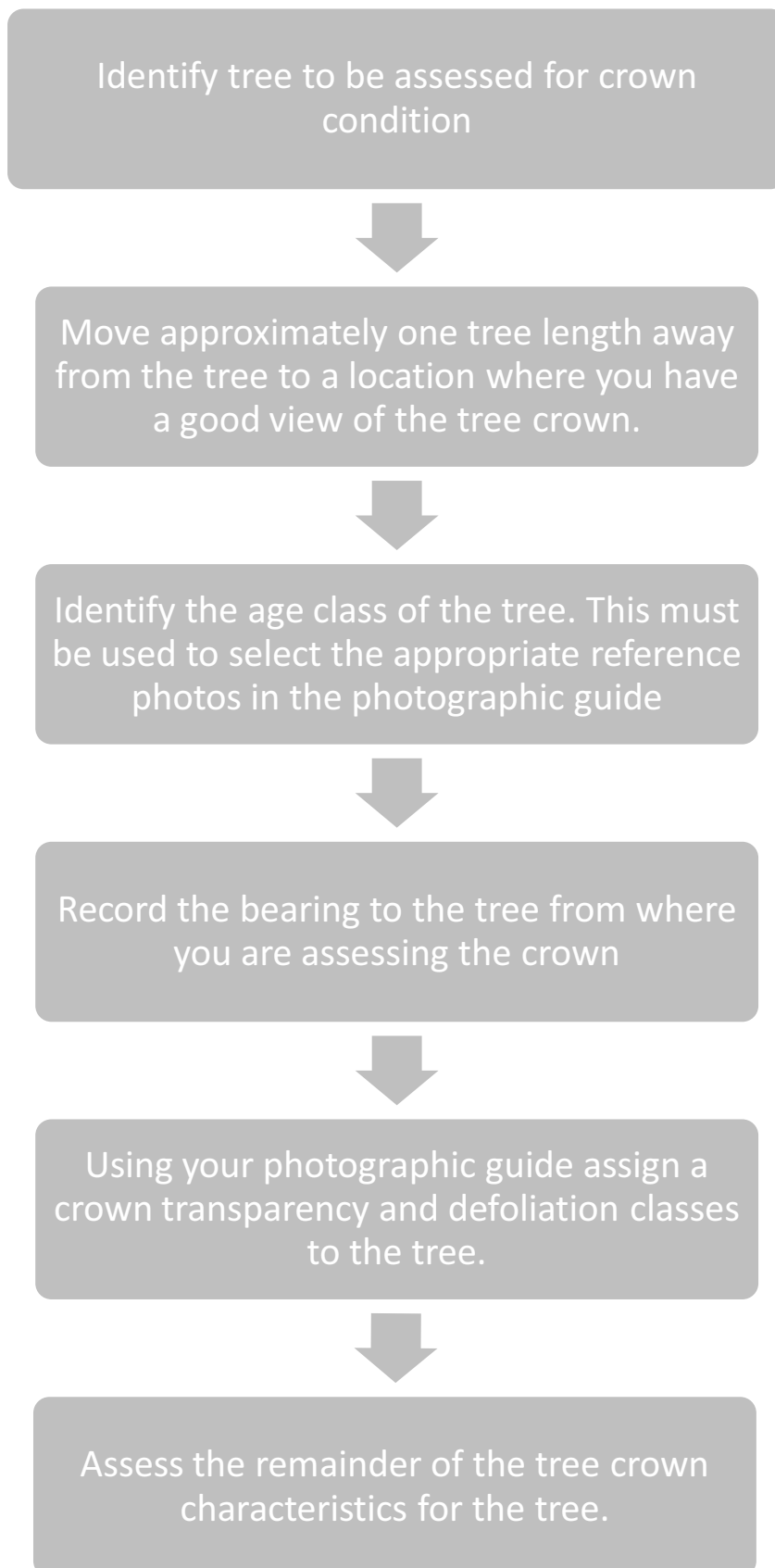
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# 1 SUMMARISED MEASUREMENT PROCEDURE

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Version	Description	Date
1.2.1	FCM field procedures manual prepared for the NZ Forest Owners Association for use in the 2010 CMS Planted Forest survey	May 2010

**Table 1. Quick guide to forest condition indicators.**

Indicators: Description	Scale				
	0	1	2	3	4
<b>Crown Transparency:</b> The amount of skylight visible through the live, normally foliated portion of the crown	0-100% transparency (5% classes)				
<b>Crown Defoliation:</b> The amount of needle loss in the assessable crown as compared to a reference tree.	0-100% foliage lost (5% classes)				
<b>Stem Visibility:</b> The amount of stem visible through the foliage and branching		Less than 25% of the stem is visible	25-50% of the stem is visible	50-75% of the stem is visible	More than 75% of the stem is visible
<b>Needle Retention:</b> The number of needle age classes (to nearest year) present in lower third of the unsuppressed green crown	1yr old needles absent	1yr old needles present	2yr old needles present	3yr and older needles present	
<b>Crown Dieback:</b> The recent dieback of branches with fine twigs in the upper and outer portions of the tree	1-100% of crown is dieback (in 5% classes)				
<b>Crown Depth:</b> The depth of green foliage present in the crown		Green foliage in lower quarter of crown	Green foliage in lower-mid quarter of crown	Green foliage in upper-mid quarter of crown	Green foliage in upper quarter of crown
<b>Dothistroma:</b> <i>Dothistroma pini</i> causes needles to turn brown with red bands	1-100% of total crown foliage with infection (5% classes)				
<b>Resin Bleeding:</b> Resin on the outside of the tree stem	Not Assessed	Nil or light resin bleeding	Moderate resin bleeding	Severe resin bleeding	

## 2 ACKNOWLEDGMENTS

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### Table of Contents

<b>1</b>	<b>SUMMARISED MEASUREMENT PROCEDURE</b> .....	<b>2</b>
<b>2</b>	<b>ACKNOWLEDGMENTS</b> .....	<b>4</b>
<b>3</b>	<b>INTRODUCTION</b> .....	<b>6</b>
3.1	PURPOSE OF THIS DOCUMENT .....	6
3.2	FOREST HEALTH MONITORING SYSTEMS .....	6
3.3	CROWN CONDITION .....	6
<b>4</b>	<b>FIELD PROCEDURES</b> .....	<b>7</b>
4.1	TREE SELECTION.....	7
4.2	CROWN TRANSPARENCY AND DEFOLIATION .....	7
4.3	CROWN DEFOLIATION SCALE.....	7
4.4	CROWN TRANSPARENCY SCALE.....	7
4.5	ASSESSABLE CROWN .....	8
4.5.1	<i>Assessable Crown for Measuring Crown Transparency</i> .....	9
4.5.2	<i>Assessable Crown for Measuring Defoliation</i> .....	12
4.6	STAND AGE .....	15
4.7	POSITION OF ASSESSMENT .....	15
4.9	ADDITIONAL INDICATORS OF FOREST CONDITION .....	16
4.9.1	<i>Stem Visibility</i> .....	16
4.9.2	<i>Needle Retention</i> .....	17
4.9.3	<i>Crown Dieback</i> .....	17
4.9.4	<i>Crown Depth</i> .....	18
4.9.5	<i>Dothistroma</i> .....	18
4.9.6	<i>Cyclaneusma</i> .....	18
4.9.7	<i>Resin Bleeding</i> .....	19
<b>5</b>	<b>PHOTOGRAPHIC GUIDE</b> .....	<b>20</b>
<b>6</b>	<b>QUALITY CONTROL PROCEDURES</b> .....	<b>52</b>
<b>7</b>	<b>DATA STORAGE</b> .....	<b>53</b>
7.1	ELECTRONIC RECORD NAMING CONVENTIONS.....	53
<b>8</b>	<b>BIBLIOGRAPHY AND SUGGESTED READING</b> .....	<b>54</b>
<b>9</b>	<b>APPENDICES</b> .....	<b>55</b>
9.1	APPENDIX 1 FOREST CONDITION ASSESSMENT FORM.....	55
APPENDIX 2	DATAPLUS APPLICATION HELP NOTES (XXX WIP) .....	56
9.1.1	<i>Forest Condition Level</i> .....	56

### List of Figures

FIGURE 1.	THE 100% AND 50% CROWN DEFINITIONS.....	9
FIGURE 2.	THE ASSESSABLE CROWN FOR MEASURING CROWN TRANSPARENCY IN A MID ROTATION TREE.....	10
FIGURE 3.	THE ASSESSABLE CROWN FOR MEASURING CROWN TRANSPARENCY IN A OLD CROP TREE .....	11
FIGURE 4.	OUTLINE OF ASSESSABLE CROWN TO BE USED FOR ASSESSING DEFOLIATION AS DEFINED BY ICP FORESTS.....	12
FIGURE 5.	AN EXAMPLE OF THE DEFINITION OF ASSESSABLE CROWN USED FOR ASSESSING DEFOLIATION .....	13
FIGURE 6.	AN EXAMPLE OF THE DEFINITION OF ASSESSABLE CROWN USED FOR ASSESSING DEFOLIATION .....	14
FIGURE 7.	THE SHAPE OF THE CROWN CAN VARY WITH THE AGE OF THE TREE. A. 3-4 YEARS OLD, B. 10-12 YEARS OLD, C. 21+ YEARS OLD (PHOTO SOURCE: L. BULMAN).....	15
FIGURE 8.	STEM VISIBILITY - A. STEM TOTALLY OBSCURED = 1, B. STEM PARTIALLY VISIBLE = 2, C. STEM MOSTLY VISIBLE = 3, AND D. STEM COMPLETELY VISIBLE = 4. ....	16

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FIGURE 10. A. CROWN WITH NO DIEBACK = 0%. B. CROWN WITH SOME DIEBACK = 10%. ..... 17

FIGURE 9. NEEDLE RETENTION AGE CLASSES: 1YR OLD NEEDLES (ELLIPSES), 2YR OLD NEEDLES (RECTANGLES), AND 3YR OLD NEEDLES (ARROWS) (MODIFIED FROM (BEETS & OLIVER, 1998). ..... 17

FIGURE 11. A VISUAL GUIDE TO THE ASSESSMENT OF CROWN DEPTH ..... 18

FIGURE 12. *DOTHISTROMA SEPTOSPORUM* CAUSES NEEDLES TO TURN RED/BROWN (FROM CHAPMAN, 1999) ..... 18

FIGURE 13. *CYCLANEUSMA MINUS* CAUSES NEEDLES TO TURN YELLOW-BROWN (FROM CHAPMAN, 1999)..... 19

FIGURE 14. A GRAPHICAL REPRESENTATION OF THE RESIN BLEEDING ASSESSMENT SCALE..... 19

**List of Tables**

TABLE 1. QUICK GUIDE TO FOREST CONDITION INDICATORS..... 3

## 3 INTRODUCTION

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### 3.1 PURPOSE OF THIS DOCUMENT

In response to a growing need for a health monitoring system for New Zealand forests, the NZ Forest Owner's Association (FOA) has commissioned (with the help of funding from the Sustainable Farm Fund) the development of a forest condition monitoring (FCM) system that will assist in the long term observation of forest health issues.

This document is a procedural manual that is designed to help conduct the field measurement techniques that underpin the FCM system. It has been written by Interpine Forestry Limited, in collaboration with industry experts in forest health issues. The techniques discussed in this manual have been drawn from years of research into long-term condition monitoring projects. It is intended that this document provides a standard procedure for field technicians so that forest condition attributes may be compared both spatially and throughout time with minimal user error variability.

### 3.2 FOREST HEALTH MONITORING SYSTEMS

Since the 1980's, in response to forest health concerns over the environmental impacts of issues such as air pollution and acid rain, forestry authorities in Europe and North America began to implement forest condition monitoring systems (Innes 1993). These monitoring techniques were based on the supposition that crown condition indicators like crown transparency and defoliation are an excellent indicator of overall tree and forest health.

In New Zealand however, there has been no concerted effort to monitor long-term forest health and all reports on the "supposed" decline of Radiata pine health have been based on anecdotal evidence. Small scale research projects involved in FCM have been carried out in recent years (Bulman L. S., 1997), (Bulman L. S., 2003) yet no systematic wide-scale FCM project had been established. The FOA's intentions to implement an effective FCM system are driven by the need for quality information showing how the health of New Zealand's key production forests is changing over time. It is considered that this information will not only play a crucial role in understanding the long-term production trends of New Zealand forests, but also as an early warning system for large scale health issues that may not be explicitly apparent at the tree level.

### 3.3 CROWN CONDITION

Crown condition offers a useful, quick and scientifically valid method of forest health assessment. Despite this, crown condition measurement carries numerous dimensions of variability, namely spatial variability (from tree to tree and plot to plot), chronological variability (from year to year), and assessor variability (due to an element of subjectivity in measurement). The writers of this manual have been diligent in their attention to the sources of this variability, attempting to implement procedures that will improve crown condition assessment precision.

## 4 FIELD PROCEDURES

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### 4.1 TREE SELECTION

Field crews will be assessing tree condition in LUCAS plots where extensive volume measurements are being recorded. It is important that the crown condition assessment does not affect any other measurements recorded in these plots. The crown condition measures outlined in this manual should be assessed on all trees where height is being measured. The condition of the canopy should in no way affect the selection of height trees, the guidelines for height tree selection set out in the Planted Forest data collection manual must be strictly observed.

### 4.2 CROWN TRANSPARENCY AND DEFOLIATION

Crown transparency and defoliation are the most important measures of crown condition in this forest condition monitoring surveys. Crown condition is strongly correlated with the health of a tree, therefore by observing changes in crown condition overtime we hope to track changes in tree health. The following sections contain information on the effective measurement of crown condition.

### 4.3 CROWN DEFOLIATION SCALE

Crown defoliation is defined as the amount of needle loss in the assessable crown as compared to photograph of a fully foliated reference tree. The scoring system used in this field guide is based on crown defoliation indices used in European forest health surveys (UNECE 2006).

Crown defoliation is assessed in 5% intervals. The following provides a guide to measurement.

- 0% corresponds to a tree with full foliage;
- 5% indicates that >0-5% of the tree's potential foliage has been lost;
- 20% indicates that 16-20% of the tree's potential foliage has been lost;
- 55% indicates that 51-55% of the tree's potential foliage has been lost;
- 100% designates a tree with no foliage

### 4.4 CROWN TRANSPARENCY SCALE

Crown transparency is defined as the amount of skylight visible through the normally foliated section of a tree crown. Crown transparency is assessed in 5% intervals. The following provides a guide to classification.

- 0% corresponds to a tree with full foliage allowing minimal skylight through its crown
- 5% indicates that 5% of the trees potential crown is transparent
- 50% indicates that half of the tree's potential crown is transparent
- 100% designates a tree where the crown is completely transparent i.e. it has no foliage.

The photographic guide provided in Section 5 shows a range of photos showing varying degrees of crown defoliation and transparency for three age classes. These photos should be used in the field to set a benchmark for assessment and reduce the variability that may arise between assessors. It is strongly recommended that field assessors undertake revision training prior to each assessment period. The intention of the training is to ensure that each assessor is able to calibrate their own measurement perception with the photographic benchmarks.

## 4.5 ASSESSABLE CROWN

There are numerous measures of assessable crown used throughout the world for assessing crown transparency and defoliation. The assessable crown includes recent dieback (i.e. branches which still have their side-shoots) but excludes the following:

- Natural gaps in the crown where it is assumed that no branches ever existed or where mechanical damage has occurred;
- Parts of the crown which are visibly or mechanically impaired by neighbouring trees;
- Snags that have been dead for many years; and
- Very large gaps between foliated branches.

Defining the assessable crown is difficult and can lead to variable results between assessors. In order to reduce this variability crown transparency is to be measured using two different measures of assessable crown, the entire crown method and the top 50% method. For the assessment of defoliation the assessment should be made for the section of green crown from the widest point of the crown up to the top of the tree.

The three methods for defining assessable crown to be used in this survey are:

1. The entire crown method - including all dead branches (***crown transparency***);
2. The top 50% of the tree crown (***crown transparency***);
3. The section of crown from the point where the green crown is widest up to the top of the tree (***defoliation***).

#### 4.5.1 Definition of Assessable Crown for Measuring Crown Transparency

The figures in this section provide a visual reference for field crews which indicate how the assessable crown is defined when measuring crown transparency. Two assessments of crown transparency should be made one including 100% of the unpruned crown and the other including the top 50% of the unpruned crown.

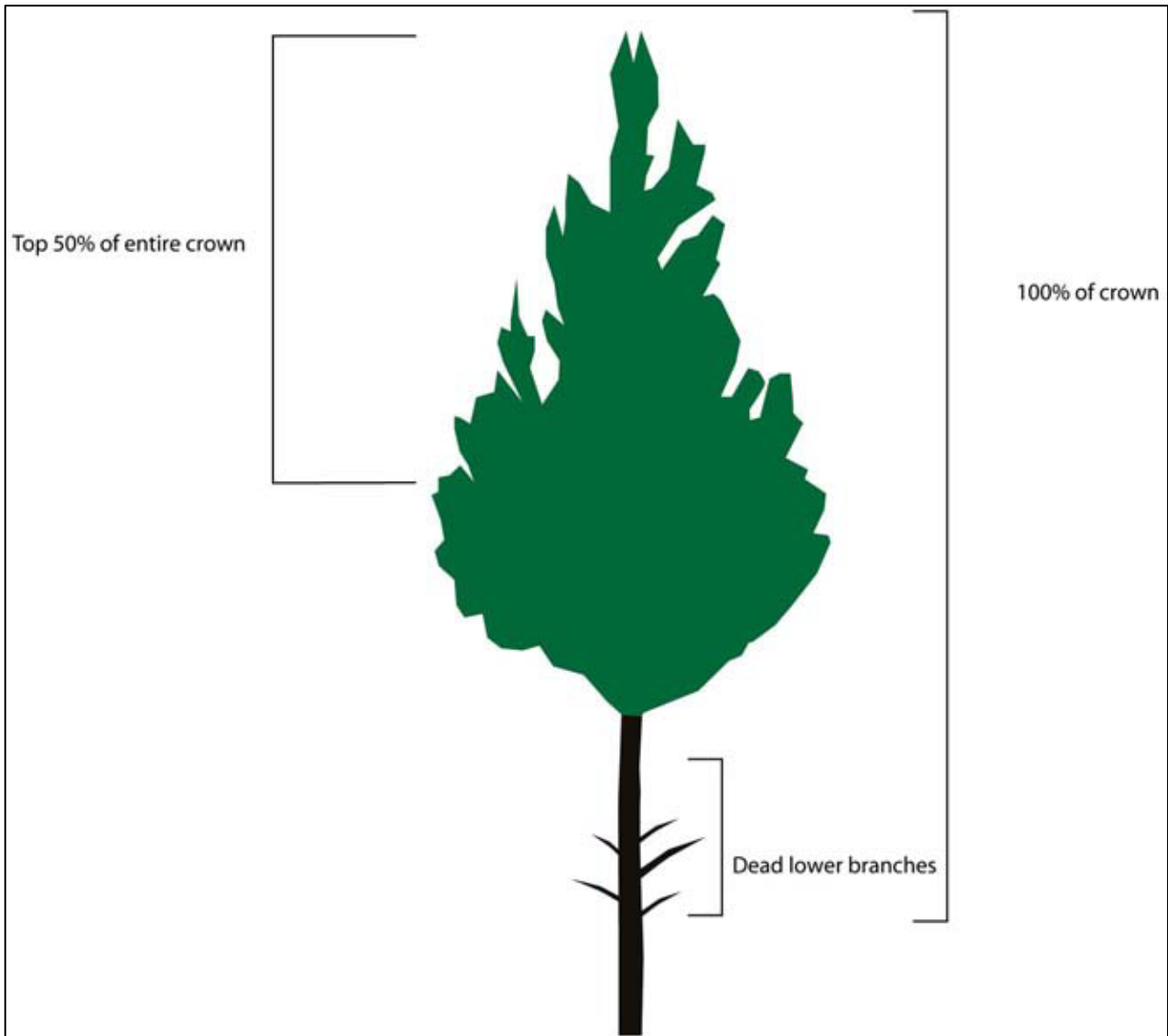


Figure 1. The 100% and 50% crown definitions

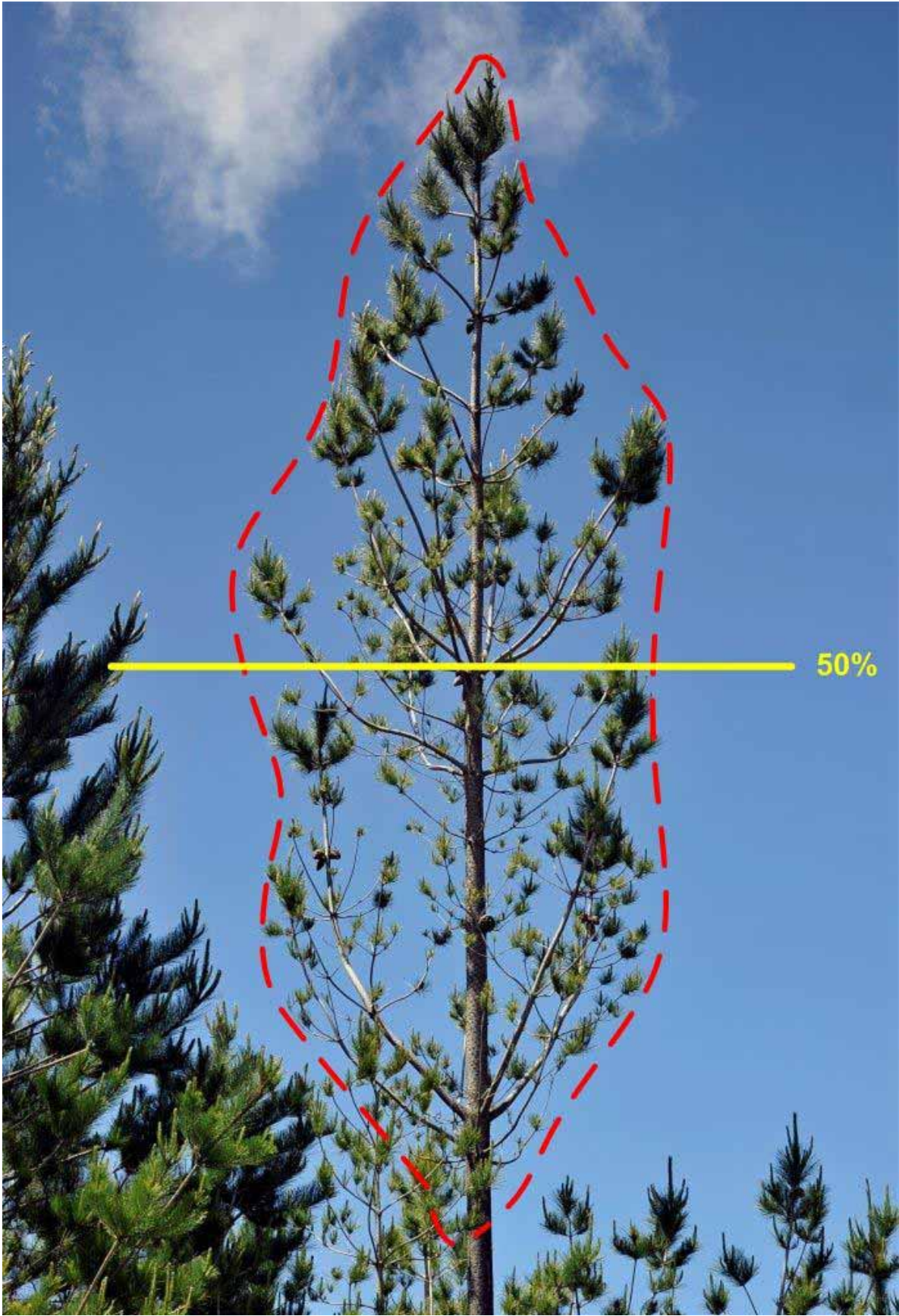


Figure 2. The assessable crown for measuring crown transparency in a mid rotation tree

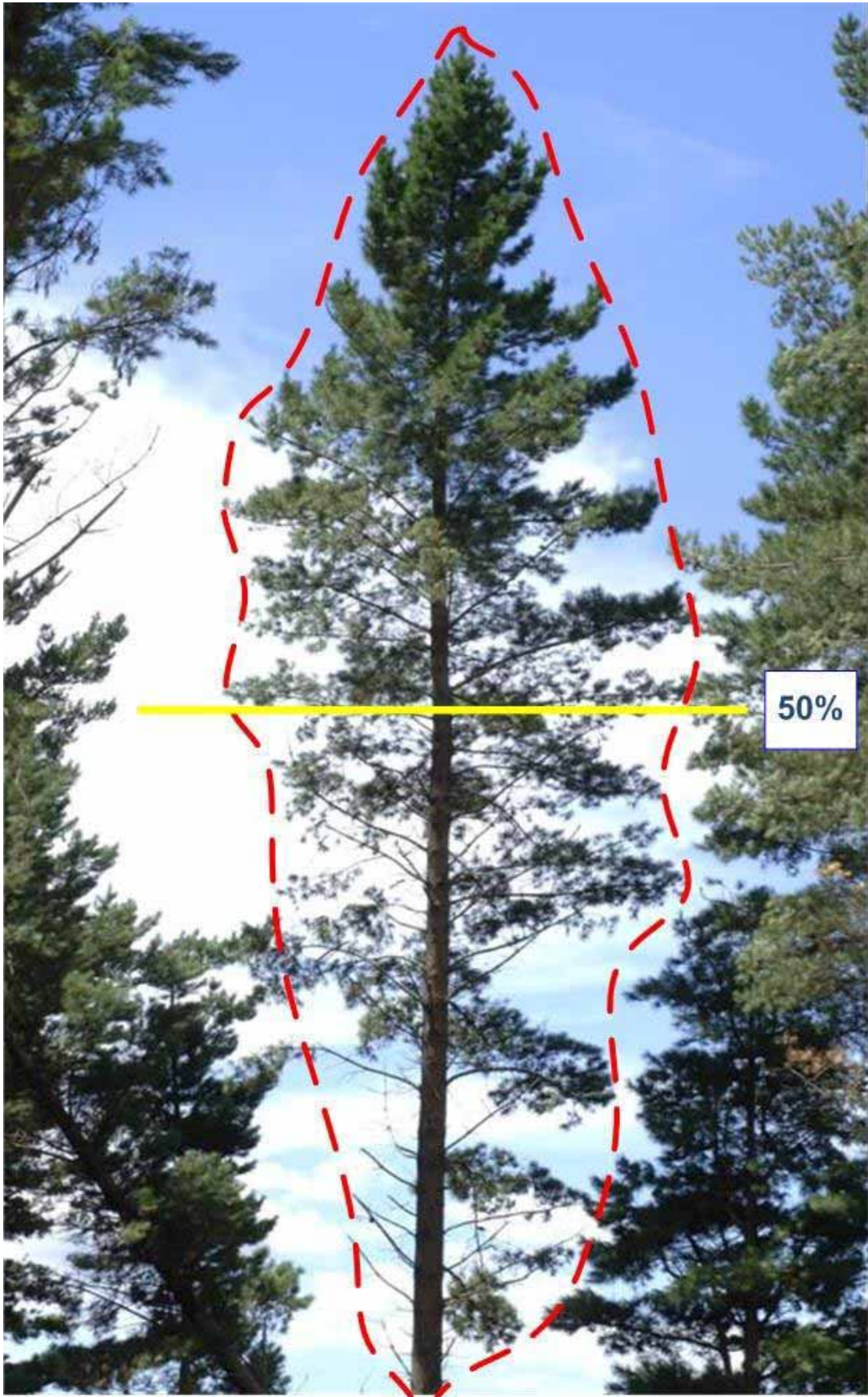


Figure 3. The assessable crown for measuring crown transparency in an old crop tree

4.5.2 Definition of Assessable Crown for Measuring Defoliation

Defoliation is assessed for the section of green crown from the widest point up to the top of the tree, in effect this is the section of crown which is free from shading by competitor trees; this ensures that the crown suppression caused by competition does not affect the assessment of defoliation. The figures in this section provide a visual guide to identifying the assessable crown when measuring defoliation.

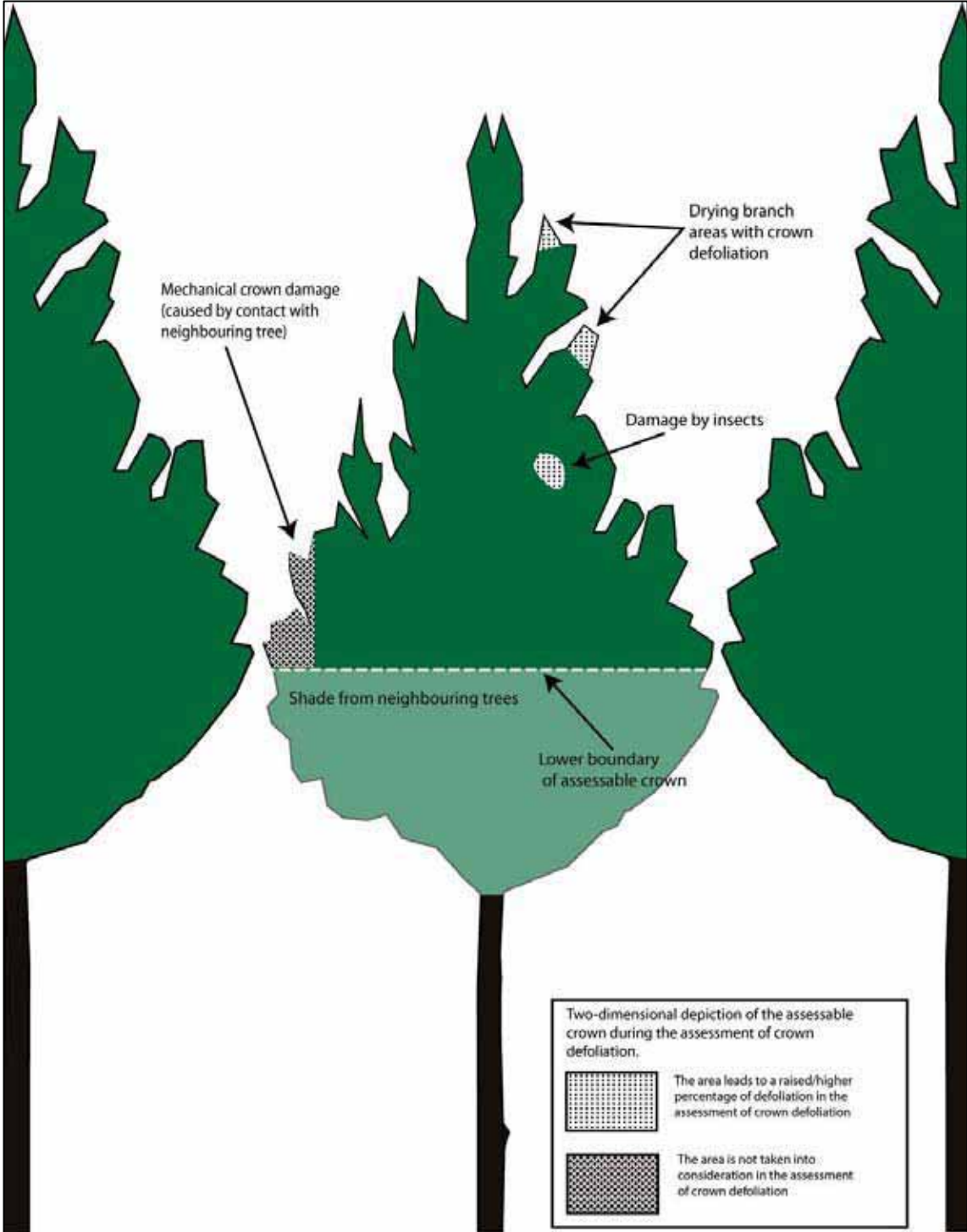


Figure 4. Outline of assessable crown to be used for assessing defoliation as defined by ICP Forests.

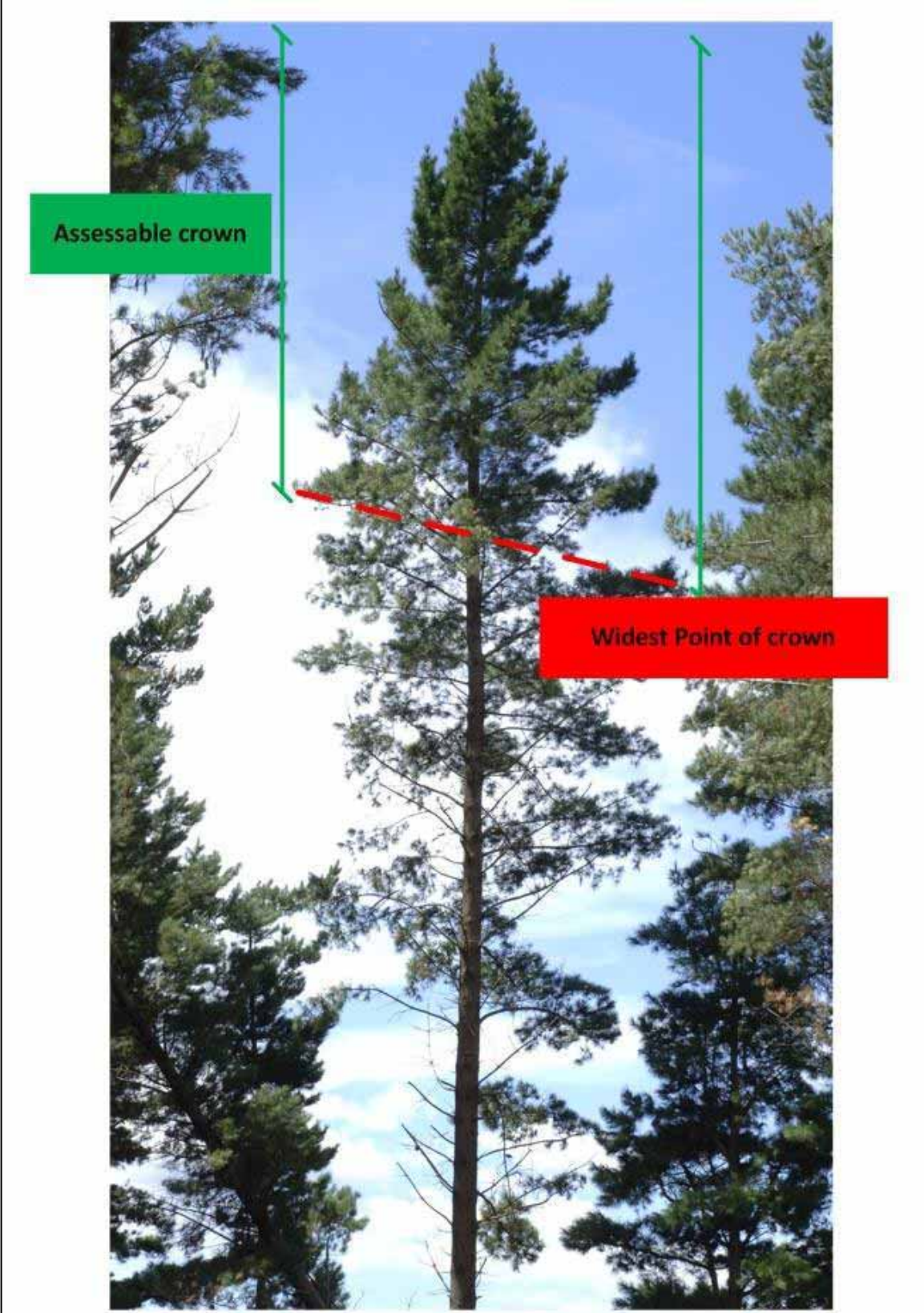


Figure 5. An example of the definition of assessable crown used for assessing defoliation

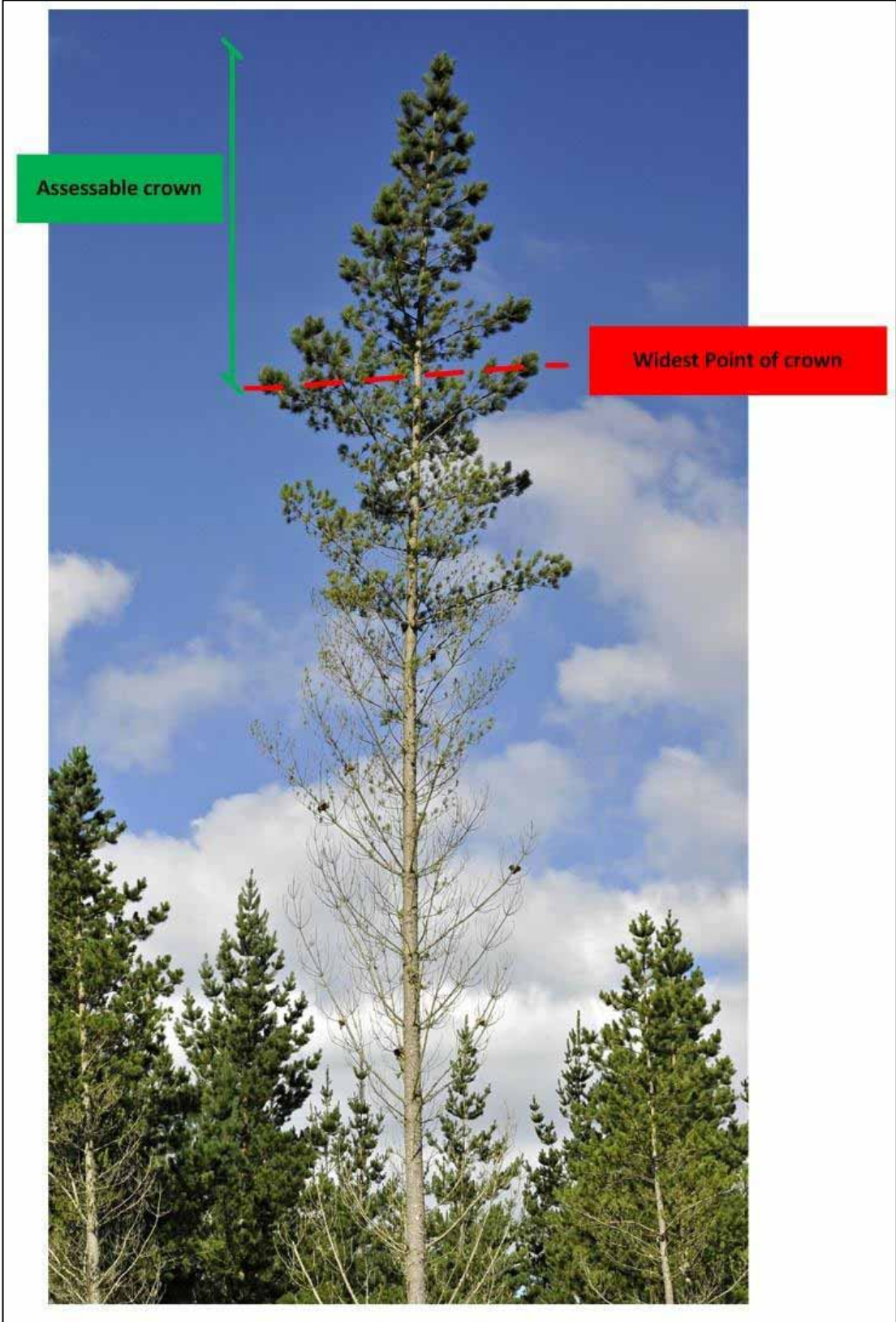


Figure 6. An example of the definition of assessable crown used for assessing defoliation

## 4.6 STAND AGE

Crown characteristics (including crown shape), are influenced by many factors, one of the most prominent being age (Figure 7). When assessing crown condition using the scale and photographic guide provided in this document, it is important to know the age class of the tree being assessed as this will dictate which guide is most suitable.

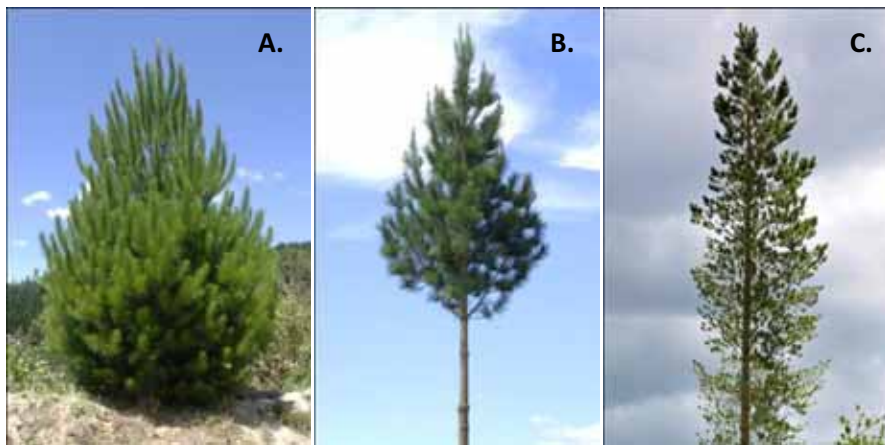


Figure 7. The shape of the crown can vary with the age of the tree. A young crop, B. mid rotation C. old crop (Photo source: L. Bulman).

## 4.7 POSITION OF ASSESSMENT

Crown condition indicators should be assessed from approximately one tree length away, upslope or to the sides of the tree if the ground is sloping. Binoculars should be used during the assessment of defoliation. Extra care must be taken if the observer is looking into the sun or if the weather is raining or foggy.

Re-measurement of crown transparency must be assessed from the same position as any previous measurements. The position of the assessor relative to the tree (distance and bearing to the tree) must be recorded so that effective re-measurement is possible. As these are unmarked plots the bearing and distance to the centre of the plot must also be recorded so that the tree can be identified during re-measurement.

## 4.9 ADDITIONAL INDICATORS OF TREE CONDITION

Crown transparency and defoliation are the key indicators that will be used to monitor the condition of New Zealand's forests and the maximum effort and care must be taken to ensure these are collected correctly. There are also a number of additional indicators which must be assessed for each tree where crown condition is assessed. These assessments will provide a quick and robust measure of tree condition and will contribute to the quality and reliability of the data set collected.

### 4.9.1 Stem Visibility

Stem visibility is defined as the amount of stem visible through the foliage and branches (Bulman L. S., 2008). A scale of between 1 and 4 (Figure 8) is used to assess stem visibility where:

- 1 = Dense branching, Less than 25% of the stem is visible through the unpruned crown;
- 2 = 25-50% of the stem is visible through the unpruned crown;
- 3 = 50-75% of the stem is visible through the unpruned crown;
- 4 = 75-100% of the stem is visible through the unpruned crown.

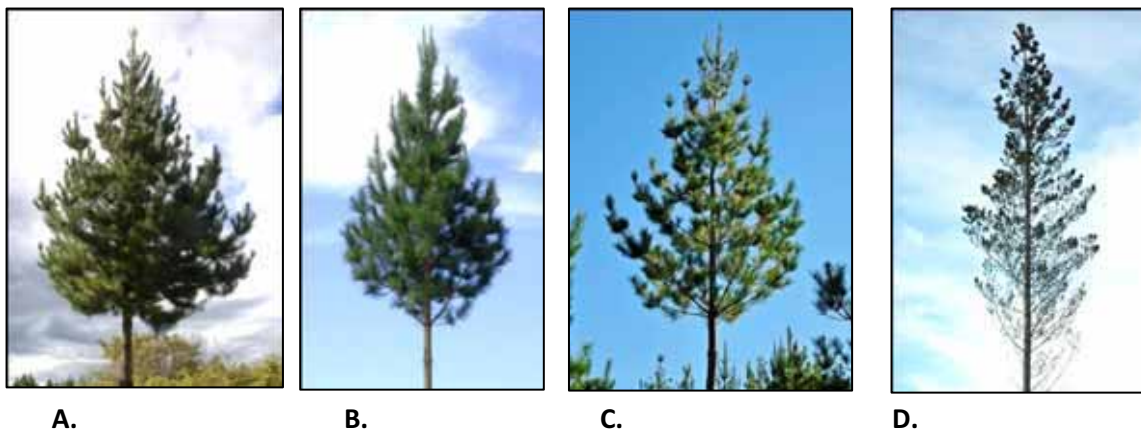


Figure 8. Stem visibility - A. Less than 25% of the stem visible through the unpruned crown = 1, B. 25-50% of the stem visible through the unpruned crown= 2, C. 50-75% of the stem is visible through the unpruned crown = 3, and D. More than 75% of the stem is visible through the unpruned crown= 4.

4.9.2 Needle Retention

Needle retention is defined as the number of needle age classes (to nearest year) present in the lower third of the unsuppressed green crown (Figure 9).

Needle Retention Class	Class Description
0	1-year-old needle age-class absent. Exclude immature flushes of needles from your assessment
1	1-year-old needle age-class present
2	2-year old needle-age class present
3	3-year and older needle age-classes present

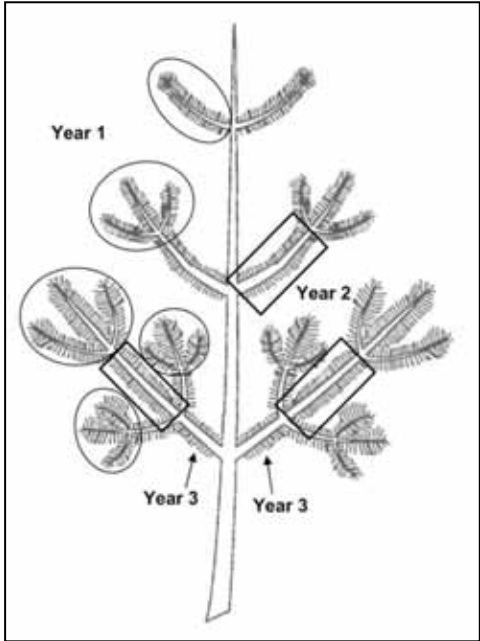


Figure 9. Needle retention age classes: 1yr old needles (ellipses), 2yr old needles (rectangles), and 3yr old needles (arrows) (modified from (Beets & Oliver, 1998).

4.9.3 Crown Dieback

Crown dieback is defined as the recent dieback of branches with fine twigs in the upper and outer portions of the tree (Schomaker et al., 2007). Crown dieback is measured as a proportion (in 5 percent classes) of the total live crown area, including the estimated dieback area.

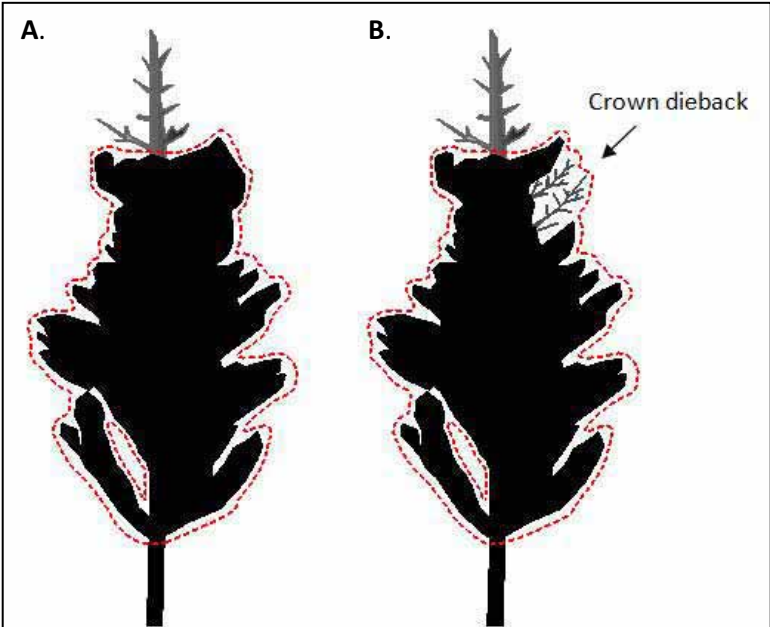


Figure 10. A. Crown with no dieback = 0%. B. Crown with some dieback = 10%.

#### 4.9.4 Crown Depth

The depth of green foliage present in the crown can also be used as a measure of forest condition. Bulman L. S (2008), measured crown depth using a 1-4 scale where:

- 1 = green foliage present in the lowermost quarter of the unpruned crown;
- 2 = green foliage present in the second lower most quarter of the unpruned crown;
- 3 = green foliage present in the second upper most quarter of the unpruned crown;
- 4 = green foliage present in the uppermost quarter of the unpruned crown.

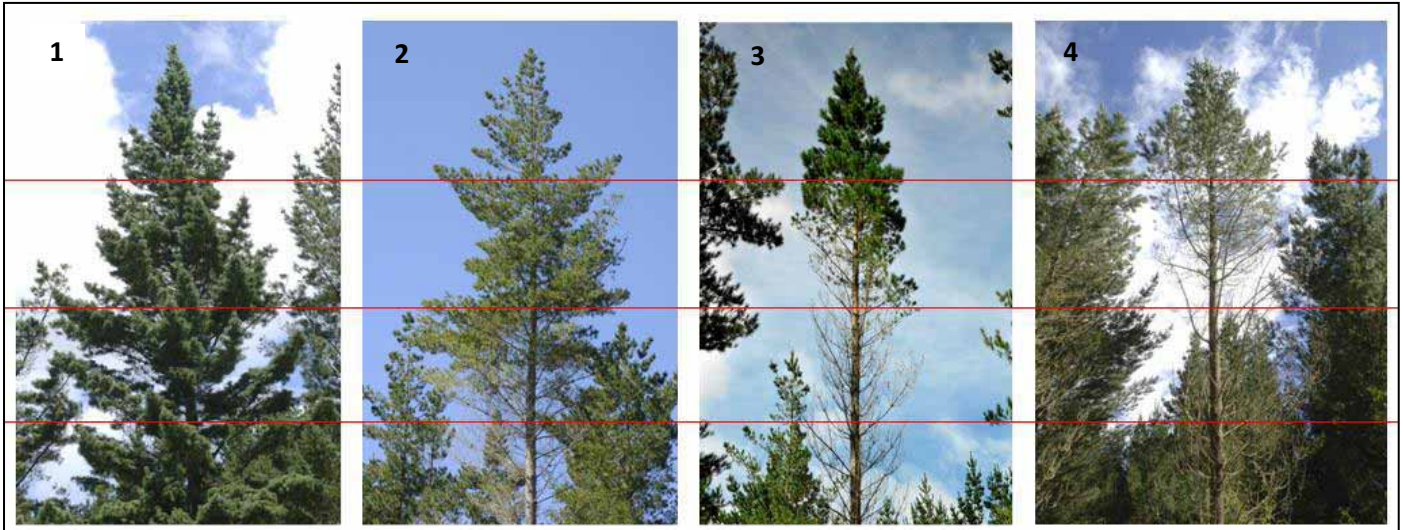


Figure 11. A visual guide to the assessment of crown depth

#### 4.9.5 Dothistroma

*Dothistroma septosporum* (dothistroma) causes needles to turn brown with red bands. Incidence is recorded in 5% increment classes up to 100% which would be used where a tree is completely diseased.



Figure 12. *Dothistroma septosporum* causes needles to turn red/brown (from Chapman, 1999)

#### 4.9.6 Cyclaneusma

*Cyclaneusma minus* (cyclaneusma) causes needles to turn yellow. Incidence is recorded in 5% increment classes up to 100% which would be used where a tree is completely diseased.



Figure 13. *Cyclaneusma minus* causes needles to turn yellow-brown (from Chapman, 1999)

#### 4.9.7 Resin Bleeding

Resin on the outside of the stem can be assessed on all trees which have been pruned. Using the standard field guide for assessing resin bleeding in Radiata pine in New Zealand<sup>1</sup> the following codes should be applied:

- 0 - Not assessed;
- 1 – Nil / Light resin;
- 2 – Moderate resin;
- 3 – Severe resin.

A graphical representation of the resin bleeding classes is given below.

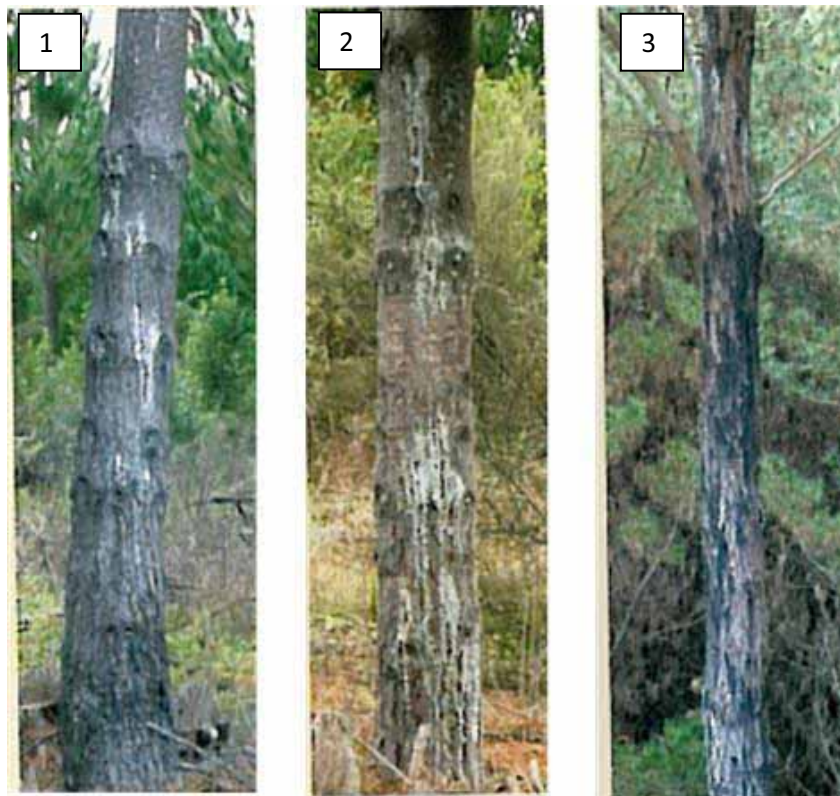


Figure 14. A graphical representation of the resin bleeding assessment scale.

<sup>1</sup> As prepared for the Wood Quality Initiative and Forest and Farm Plantation Management Cooperative, Don McConchie – Wood Quality Focus – WQI Report No. APP 12

## 5 PHOTOGRAPHIC GUIDE

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The following section contains a photographic guide for assigning defoliation and crown transparency for radiata pine in New Zealand. Each photograph has been assessed by leading experts who have assigned a score for defoliation and crown transparency of 100% of the crown and of the top 50%. The assessable crown definitions used are outlined in Section 4.5. The photographic reference trees have been segregated according to their age into:

- **Young crop** – age 0-9 years old;
- **Mid rotation** – age 10- 18 years old;
- **Old crop** – older than 18 years old.

100% crown transparency: 0%

50% crown transparency: 0%

Defoliation class: 0%

21



Young crop

100% crown transparency: 5%

50% crown transparency: 5%

Defoliation class: 0%



100% crown transparency: 10%

50% crown transparency: 5%

Defoliation class: 0%



100% crown transparency: **15%**

50% crown transparency: **10%**

Defoliation class: **5%**

24

Young crop



100% crown transparency: 20%

50% crown transparency: 15%

Defoliation class: 5%



100% crown transparency: 20%

50% crown transparency: 5%

Defoliation class: 20%



100% crown transparency: **30%**

50% crown transparency: **20%**

Defoliation class: **20%**



100% crown transparency: 30%

50% crown transparency: 20%

Defoliation class: 10%

28

Young crop



100% crown transparency: 40%

50% crown transparency: 25%

Defoliation class: 5%

29

Young crop



100% crown transparency: 55%

50% crown transparency: 65%

Defoliation class: 5%

30

Young crop



100% crown transparency: 60%

50% crown transparency: 60%

Defoliation class: 5%

31

Young crop



100% crown transparency: **65%**

50% crown transparency: **70%**

Defoliation class: **5%**



100% crown transparency: 75%

50% crown transparency: 65%

Defoliation class: 5%



100% crown transparency: 5%

50% crown transparency: 5%

Defoliation class: 0%

34



Mid-Rotation

100% crown transparency: **20%**

50% crown transparency: **10%**

Defoliation class: **0%**



100% crown transparency: **35%**

50% crown transparency: **35%**

Defoliation class: **5%**



100% crown transparency: 50%

50% crown transparency: 25%

Defoliation class: 10%

37



Mid-Rotation

100% crown transparency: **60%**

50% crown transparency: **35%**

Defoliation class: **20%**



100% crown transparency: **60%**

50% crown transparency: **30%**

Defoliation class: **15%**

39



Mid-Rotation

100% crown transparency: 70%

50% crown transparency: 40%

Defoliation class: 25%

40



Mid-Rotation

100% crown transparency: 80%

50% crown transparency: 50%

Defoliation class: 5%



100% crown transparency: **85%**

50% crown transparency: **60%**

Defoliation class: **35%**



100% crown transparency: **95%**

50% crown transparency: **80%**

Defoliation class: **80%**



100% crown transparency: **15%**

50% crown transparency: **15%**

Defoliation class: **15%**



100% crown transparency: **25%**

50% crown transparency: **10%**

Defoliation class: **10%**



100% crown transparency: **45%**

50% crown transparency: **20%**

Defoliation class: **30%**



100% crown transparency: **55%**

50% crown transparency: **30%**

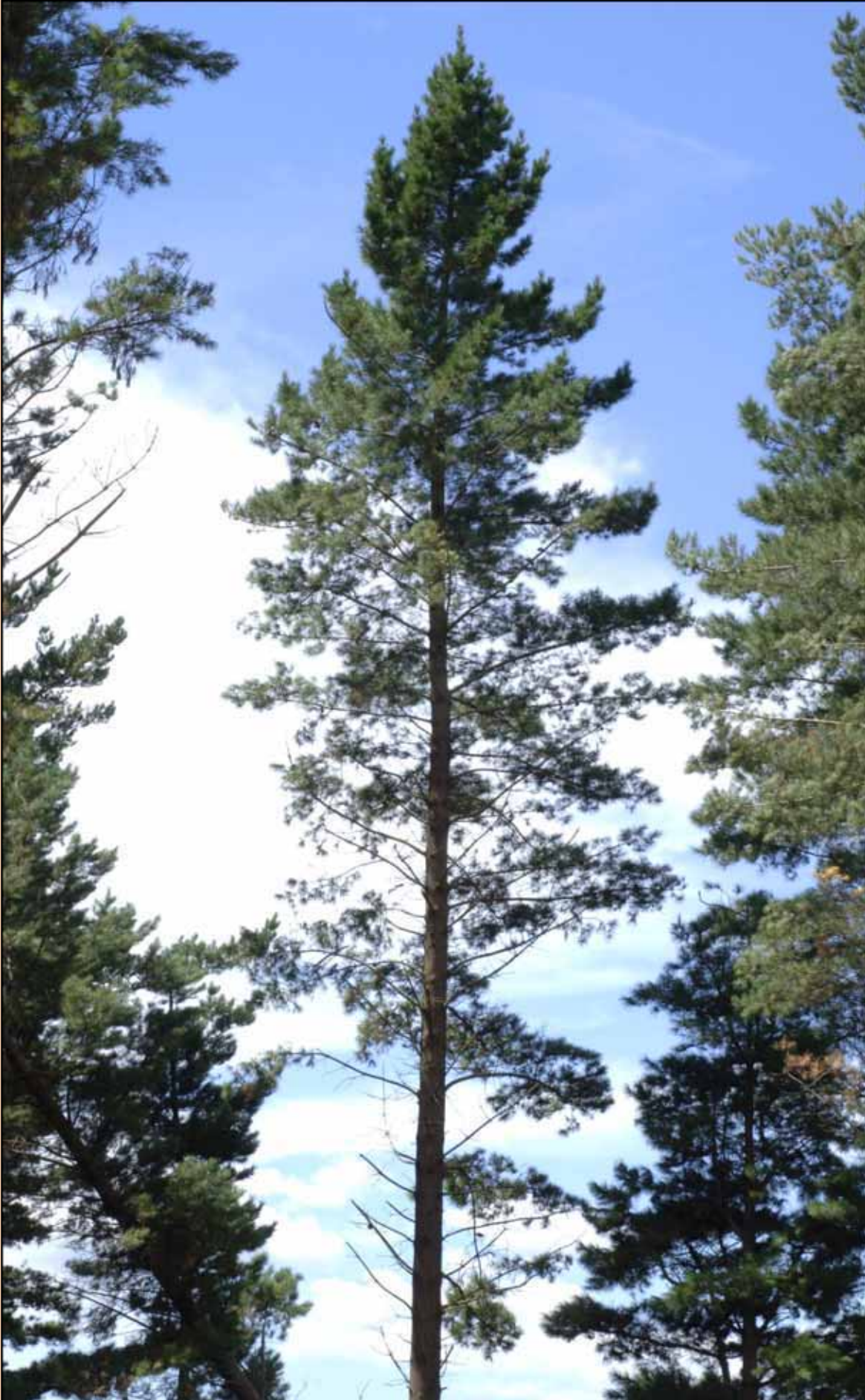
Defoliation class: **45%**



100% crown transparency: 65%

50% crown transparency: 35%

Defoliation class: 5%



100% crown transparency: **80%**

50% crown transparency: **40%**

Defoliation class: **45%**

49



Old Crop

100% crown transparency: **85%**

50% crown transparency: **60%**

Defoliation class: **40%**

50



Old Crop

100% crown transparency: 90%

50% crown transparency: 45%

Defoliation class: 35%



## 6 QUALITY CONTROL PROCEDURES

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Quality control (QC) is the system of routine technical activities that ensures the quality of the inventory that is being developed, in this case the provision of reliable datasets for the long term monitoring of forest condition. While it is intended that a proportion of the sites will be revisited and the accuracy of measurements blindly assessed, the main means of ensuring high quality data is the diligence of the field crews. The following procedures should be followed:

Prior to the commencement of fieldwork:

- Check that all equipment required is present and is in good working order.
- Ensure that adequate spare batteries are available for all electronic equipment.
- Ensure that crew members have the best available information to locate/re-locate the plot.
- Ensure that crew members are fully informed of all plot measurement methodologies.

Before all crew members leave the site, check that:

- Data sheets are completed legibly and that there are no obvious anomalies.
- The team leader has completed a count of all trees assessed for condition and equals the number of trees electronically captured.
- All equipment is accounted for.

En-route to home base, ensure:

- Secure storage of data sheets at the field base. If possible electronic data should be downloaded to a laptop computer and a back-up copy made.
- Where field crews are in the field for periods of more than 2 weeks, data should be returned to home base by tracked mail or equivalent courier service.

At home base, check that:

- Data sheets are updated
- Electronic data entry and checking routines have been completed and data sheets archived in the appropriate field data database.

## 7 DATA STORAGE

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Routine archiving of data is an essential part of any monitoring system. Field data are expensive to collect and because data from previous sampling periods form part of a time-series, it is not possible to recover data that have been lost. For these reasons it is important that all data and information collected (e.g. plot sheets, maps, aerial photographs, computer data files etc) are archived in designated facilities.

Daily backups take place in the field by creating a duplicate copy of the “DATA” folder within DataPlus and copying to an external memory card.

### 7.1 ELECTRONIC RECORD NAMING CONVENTIONS

All records are to be converted to electronic formats using the following naming and conversion guidelines.

- *Photos* – Named with Site ID and Photo ID suffix of “\_PhotoXXXXX” where XXXXX refers to the photo ID reference number. Preferred images formats are standard \*.jpg, \*.bmp or \*.gif files.  
e.g. AB123\_PhotoS2343001.jpg
- *Paper Forms* – Converted to PDF (Adobe Portable Document Format V.9), and combined into a single document including any relevant maps or aerials photos used.
- File to be named with Site ID and Date  
e.g. AB123\_070101.pdf
- *GPS Co-ordinate files* – these are left in original file formats and provided with the following naming convention.
- Site ID, date and GPS suffix  
e.g. AB123\_070101\_GPSXXXXX.XXX

## 8 BIBLIOGRAPHY AND SUGGESTED READING

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- Bauer, A., Dammann, I., Gawehn, P., Schrock, H. W., Wendland, J., & Ziegler, C. (2007). *Waldbaeume*, 2.
- Beets, P. N., Bulman, L. S., & Pearce, S. H. (2009). *Forest Health Assessments and their Relationship with Volume Increment and LiDAR*. New Zealand Forest Owners Association.
- Beets, P. N., Bulman, L. S., & Pearce, S. H. (2008). *Relationships between leaf area, growth, tree health attributes and LiDAR*. New Zealand Forest Owners Association.
- Beets, P., & Oliver, G. (1998). *Field guide to scoring upper mid-crown yellowing (UMCY) symptoms in radiata pine*. Rotorua: Forest Research Bulletin No.208.
- Bulman, L. S. (2003). *Crown health assessments of sustainably monitoring plots for Fletcher Challenge Forest*. Rotorua: New Zealand Forest Research Institute.
- Bulman, L. S. (2008). *Development of criteria used to estimate forest health - with reference to New Zealand conditions*. Rotorua: SCION.
- Bulman, L. S. (1997). *Tree Health Suvey - Rotokawa field*. Rotorua: New Zealand Forest Research Institute.
- Bulman, L. S., & Kimberley, M. O. (2005). *A revised forest health survey surveillance system*. Forest Research.
- Bulman, L., Gadgil, P., Kershaw, D., & Ray, J. (2004). Assessment and control of Dothistroma needle-blight. *Forest Research Bulletin No. 229*, p. 48.
- Chapman, S. (1999). Field guide to common pests, diseases, and other disorders of radiata pine in New Zealand. *Forest Research Bulletin 207 (revised edition)*, p. 57.
- Dunlop, J. D. (1995). *Permanent Sample Plot System User Manual*. FRI.
- Forests, I. (2006). *Part 2 Visual Assessment of Crown Condition*.
- Hendry, S. J., Poole, E. J., Craig, I., & Proudfoot, J. C. (2005). *Forest Condition 2004*. Edinburgh: Forestry Commission .
- ICP Forests. (2006). *ICP Forests: Part 2 Visual Assessment of Crown Condition* (<http://www.icp-forests.org/Manual.htm>).
- Innes, J. L. (1990). *Assessment of Tree Condition*. London: HMSO.
- Innes, J. L. (1993). *Forest Health: Its assessment and status*. Wallingford, UK: CAB International.
- Innes, J. L., Boswell, R., Binns, W. O., & Redfern, D. B. (1986). *Forest Health and Air Pollution*. London: HMSO.
- Payton, I. M. (2010). *Land Use and Carbon Analysis System Planted Forest Data Collection Manual*. Wellington, New Zealand: Ministry for the Environment.
- Payton, I. N. (2004). *New Zealand Carbon Monitoring System Indigenous Forest and Shrubland Data Collection Manual*. Christchurch, New Zealand.: Printed by The Caxton Press.
- Schomaker, M. E., Zarnoch, S. J., Bechtold, W. A., Latelle, D. J., Burkman, W. G., & Cox, S. M. (2007). *Crown-Condition Classification: A Guide to Data Collection and Analysis*. Asheville: Southern Research Station.
- United States Department of Agriculture. (2005). *Analyzing Forest Health Data*. General Technical Report SRS-77.
- United States Department of Agriculture. (2007). *Crown-Condition: A guide to data collection and analysis*. General Technical Report SRS-102, Forest Service.
- United States Department of Agriculture. (2005). *The Enhanced Forest Inventory and Analysis Program - National Sampling Design and Estimation Procedures*. General Technical SRS-80, Forest Service.

# 9 APPENDICES

## 9.1 APPENDIX 1 FOREST CONDITION ASSESSMENT FORM

SITE ID: \_\_\_\_\_ MEASURER 1: \_\_\_\_\_

DATE: \_\_\_\_\_ MEASURER 2: \_\_\_\_\_

SITE COMMENTS:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Record measurements for individual tree condition on this sheet.

Tree No.	Tree Position, Bearing (mag)	Tree Position, Slope Distance (m)	Compass Point (e.g. N, W)	1 <sup>st</sup> Bearing (mag)	1 <sup>st</sup> Slope Distance (m)	2 <sup>nd</sup> Bearing (mag)	2 <sup>nd</sup> Slope Distance (m)	Entire Crown Transparency	Top 50% Crown Transparency
Tree No.	Defoliation	Stem Visibility	Needle Retention	Crown Dieback	Crown Depth	<i>Dothistroma</i>	<i>Cyclaneusma</i>	Resin Bleeding	Comments

Notes: 1<sup>st</sup> and 2<sup>nd</sup> bearing and distance refers to position of each crew member in relation to the tree being assessed. **Entire Crown Transparency:** 0-100% in 5% increments. **Top 50% Crown Transparency:** 0-100% in 5% increments. **Defoliation:** 0-100%. **Stem Visibility:** 1 Less than 25% of the stem is visible through the unpruned crown, 2. 25-50% of the stem is visible through the unpruned crown. 3. 50-75% of the stem is visible through the unpruned crown, 4. 75% + of the stem is visible through the unpruned crown; . **Needle Retention:** 0 = mature 1 yr needles absent; 1 = 1 yr, 2 = 2 yr, 3 = 3 yr mature needles present. **Crown Dieback:** 0-100% in 5% increments. **Crown Depth:** 1 Green foliage present in the lowermost quarter → 4 Green foliage present in the uppermost quarter of the unpruned crown. **Dothistroma:** 0-100% in 5% increments. **Cyclaneusma:** 0-100% in 5% increments. **Resin Bleeding:** 1 Absent or rare → 4 Over 50% covered.

**APPENDIX 2 DATAPLUS APPLICATION HELP NOTES (XXX WIP)**

**Data Entry Fields and Screens**

The following additional fields have been added to the CMS\_PF Data capture application to record FCM data

**9.1.1 Forest Condition Monitoring Fields**

Prompt	Description
T100CT	Crown Transparency across 100% of the tree crown
T50CT	Crown Transparency for the top 50% of tree crown
DEF	Defoliation of tree crown
CrD	Drown Depth
StV	Stem Visibility
CDi	Crown Dieback
N	NeedleRetention
DO	Proportion of crown infected with dothistroma
R	Resin bleeding

Level Notes:

- Where appropriate a drop down list can be accessed by pressing the F2 key
- All fields are "U - not assessed" by default

