FRI Project Record

No. 5907

PROTOTYPE BRANCH GROWTH MODEL
DEMONSTRATION PROGRAM
USER GUIDE

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REPORT No. 56 Sept 1997

EXECUTIVE SUMMARY

The Branch Growth Model (BGM) Demo program is intended to demonstrate the detailed predictions of the size and location of branches of *Pinus radiata* that can be produced by the BGM. The structure of the BGM, as a set of mathematical functions, allows the model to be used for different applications and different levels of detail as required.

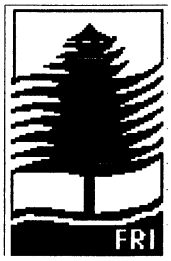
This program is used for visualisation of the model and will allow the prototype model to be demonstrated by Coop representatives within their respective organisations, and the output of the model to be examined visually. The stem model can be viewed from the whole tree level, where overall patterns can be seen, down to the shape of individual knots formed by branch growth within the stem.

The first part of this report describes how to use the program to interact with the 3 dimensional stem model created. The program incorporates a built in sequence which allows the features of the branch model to be demonstrated easily. The second part of this report contains a set of notes to accompany the demonstration, providing a supporting explanation of each of the graphical views of the branch model presented in the sequence. Views are provided starting from a whole stem perspective, down to individual branches.

Prototype Branch Growth Model

Demonstration Program

Stand Growth Modelling Cooperative



NEW ZEALAND
FOREST RESEARCH INSTITUTE
LIMITED

First Printed September 1997

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Introduction

Branch Growth Model

A detailed Branch Growth Model for *Pinus radiata* is being developed for the Stand Growth Modelling Cooperative (SGMC) as part of a fourth generation of growth models.

The objective of the model is to be able to predict the location, size and growth of branches encased within the stem. One use will be to grow MARVL data forward in time. It will also be able to provide detailed branch descriptions for sawing simulators.

Software implementations of a prototype version of the Branch Growth Model (BGM) have allowed issues relevant to practical applications of the model to be explored. One application provides a detailed graphical rendering of branching patterns on a single tree. This program is used for visualisation of the model and is now available to members of the SGMC. This will allow the prototype model to be demonstrated by Coop representatives within their respective organisations, and the output of the model to be examined visually.

The *BGMDemo* program is intended to demonstrate the detailed predictions of the size and location of branches that can be produced by the BGM. The various controls provided allow considerable flexibility in viewing the stem model. The stem model can be viewed from the whole tree level, where overall patterns can be seen, down to the shape of individual knots formed by branch growth within the stem.

The *BGMDemo* program implements the full detail possible with the BGM, to demonstrate its capabilities. It should be noted that the structure of the BGM, as a set of mathematical functions, allows the model to be used for different applications and different levels of detail as required. The program incorporates a built in sequence which allow the features of the branch model to be demonstrated easily.

Installation

System requirements

The *BGMDemo* program runs under Windows 95 or Windows NT. There is a 16-bit version for Windows 3.x, called BGMDem16. The installation procedure for the two versions is slightly different, and this is described later in this section.

In order to correctly view the Wood Properties feature of the *BGMDemo* program your computer must be able to display 32768 colours with a display resolution 800 by 600 pixels. These settings are also desirable for general use of the program. Use the Display item in the Control Panel (under Start | Settings in Windows 95) to view and change the display settings.

BGMDemo is distributed on 1.44Mb double-sided high-density disks. If this is unsuitable please contact the Software Manager, FRI.

Windows 95 and Windows NT 4

To install *BGMDemo* under Windows 95 or Windows NT 4:

1. Insert the distribution disk in the floppy drive.
2. Start the Explorer and browse to the floppy drive.
3. Double click on SETUP.EXE and follow the instructions.

The program is installed in a directory called BGMDemo, and an icon to start it is placed in your Start menu.

Windows 3.x

Follow the instructions for Windows 95 and Windows NT 4. If SETUP.EXE runs successfully you must have support for 32-bit programs installed in Windows. If not follow these instructions to install the 16-bit version of the program:

1. Insert the distribution disk in the floppy drive.
2. Start the File Manager and browse to the floppy drive.
3. Double click on SETUP16.EXE and follow the instructions.

The program BGMDEM16.EXE is installed in a directory called BGMDemo, and an icon to start it is placed in a new program group, also named BGMDemo.

Using the Program

Program Controls

BGMDemo has a single screen window with no menus or extra forms. All controls used to manipulate the stem model are visible on the screen at all times. Those controls are grouped on the right hand side of the *BGMDemo* screen. The remainder of the screen is occupied by an area containing a number of pages, each presenting a different graphical view of the 3D stem model.

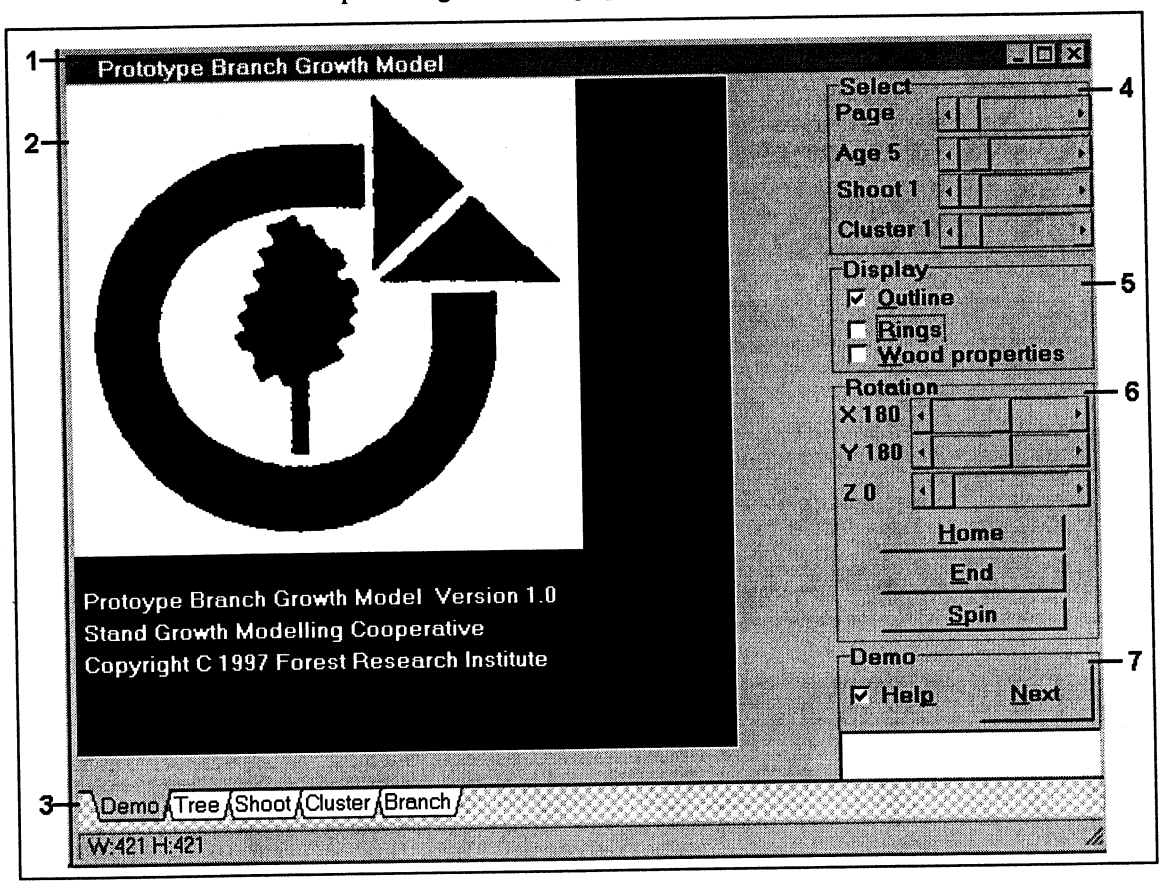

Figure 1. BGMDemo screen.

The main screen components are numbered in Figure 1 and each is described separately.

1. Title Bar

The title bar contains the program control menu in the left hand corner and the program title. At the right hand end are the window buttons to minimise, toggle full screen and close the program window (from left to right respectively). The program can be exited using the controls in the Title Bar as follows:

- double click the program control menu
- click the program control menu and select Close
- click the Close Window button
- press Alt-F4

2. Page View Area

The *BGMDemo* screen contains five view pages, arranged in the form of a tabbed notebook. Each page contains a view area used to display graphical images of a 3D stem model.

The first page displays the demonstration sequence. The other four pages provide graphical views of the 3D stem model at different levels of detail, based on obvious levels of tree structure. The pages are:

Demo. A slide-show sequence of images demonstrating the BGM can be viewed. Refer to the Model Demonstration section for more information on this.

Tree. The whole stem and all the branches are displayed. This shows the overall pattern of branching on the tree.

Shoot. A selected annual shoot is shown, with its branches. The relative placement of branch clusters along the annual shoot can be seen.

Cluster. A selected branch cluster is displayed. This view shows the spatial arrangement of branches and stem cones the cluster.

Branch. The largest branch in the selected cluster is shown in detail. The diameter growth of the branch through time, and the onset of bark encasement, can be seen in this view. The bark encased part of a branch is coloured red, to contrast with the green used for the live part of the branch.

3. Page Tabs

Each of the five *BGMDemo* view pages can be selected by clicking on the labelled set of tabs below the page view area.

4. View Select

The View Select panel contains four slider controls which are used to select the item to be viewed:

Page. This can be used as an alternative to the page tabs for changing the current view page.

Age. The tree and branches are grown forward in time with this control. Clicking the right hand arrow grows one year, while clicking to the right of the slider between the arrows grows five years. Growing backwards is not currently supported.

Shoot. Each annual shoot can be selected with this control. Clicking the arrows moves up or down one shoot, while clicking between the slider and the arrows moves five annual shoots along the stem.

Cluster. This control allows each cluster within the current annual shoot to be selected. Clicking the arrows moves up or down one cluster.

5. Display Options

The Display panel contains three check boxes which are used to control the display of specific features of the stem model:

Outline. If growth rings are not displayed the stem profile can be represented by displaying the outer growth ring only. This option is useful to reveal branching patterns which can be obscured when growth rings are displayed.

Rings. This enables the display of stem growth rings. The growth rings are displayed as vertical lines along the stem, in a single plane, and as concentric rings in a horizontal plane at the base of each annual shoot or cluster. The rings are useful to examine the annual stages of growth.

Wood properties. The *BGMDemo* program incorporates two wood properties models: basic wood density and spiral grain. Selecting this option allows these wood properties to be overlaid on the view of branches. This allows a combined view of the spatial arrangement of these three important determinants of wood quality. Density is represented as a range of colour on the growth rings. Spiral grain is shown in the Cluster view by extending the growth ring lines below the cluster, angled to the degree predicted by the model. Note that the correct display of wood density requires a computer with a high quality display. Refer to the Wood Properties section for more information.

6. 3D Rotation controls

The various graphical views display a 2 dimensional projection of the complete 3 dimensional (3D) stem model. To allow the 3D model to be examined the graphical view can be rotated interactively. This enhances the ability to visualise the spatial arrangement of branches within the stem.

The rotation panel contains three horizontal sliders for the rotation of the X, Y and Z axes of the 3D model. The Z axis is perpendicular to the screen. Clicking the slider arrow rotates by a single degree, allowing fine control. Clicking between the slider and the arrow rotates by ten degrees. Dragging the slider causes continuous rotation.

To allow a more 'natural' rotation the mouse can be used directly by dragging in the view area to rotate around the X and Y axes. The left mouse button is held down anywhere in the view area and the mouse moved, 'dragging' the image and allowing a continuous rotation around both axes. Movement to the left or right rotates around the Y axis, while vertical movement rotates around the X axis. The mouse can be thought of as 'grabbing' the near side of the 3D image and the movement causing it to rotate around the two axes.

The rotation panel also contains three buttons which perform specific rotational actions:

Home. Returns the image to the "home" position with the stem vertical, in a side view.

End. Displays the stem end on, from a "birds-eye view".

Spin. Rotates the image continuously around the X axis. Click this button again to stop the rotation.

7. Demonstration panel

The demonstration panel contains a button labelled Next which is used to step through the demonstration sequence. Below this is a small text window used to show the title of each demonstration view. Refer to the Model Demonstration section for information on this.

Model Demonstration

1. Getting started

Allow 10 minutes for a quick pass through the demonstration, longer if discussion is added. Note that the demonstration should be run from beginning to end, immediately after starting the program. To re-run the demonstration sequence you must exit the program and start again, you can not step back through the sequence.

The program starts on the Demo page, and the demonstration sequence is stepped through by clicking the "Next" button in the Demonstration panel at the right of the screen, or by pressing *Alt-N*.

If the Help item in the Demonstration panel is checked the program automatically opens the help file BGMDEMO.HLP at the appropriate topic when the demonstration is started. At each step in the demonstration sequence the Help page is advanced to stay in step with the program screen. The Help window can be moved and re-sized so that it does not obscure the Next button, or too much of the Demo page. Clicking anywhere on the program screen will bring it to the foreground, obscuring the Help, but it will reappear when you click Next again.

If you do not want the Help, click the Help check box in the Demonstration panel, or press *Alt-P*.

Each step in the demonstration sequence has a numbered heading displayed on the Next button. Those numbered headings correspond to the items in the following section, and in the Help.

2. Introduction

Knots are a major determinant of log grade and the quality of wood products. For this reason an important component of the 4th generation of growth models is a Branch Growth Model (BGM) for *Pinus radiata*. The purpose of the model is to predict the location, size and growth of branches within the stem. The whole crown is not modelled, simplifying data collection and modelling, while delivering the required information about stem defects.

The demonstration consists of two phases: an outline of the functions contained in the Branch Growth Model (BGM); and a "visual tour" of the predicted patterns of branching on a single tree.

3. Model functions

The BGM consists of several mathematical functions. Those functions will now be described briefly to give an outline of the structure of the model.

4. Annual shoot

The BGM is based around the annual shoot, which is the height growth in a single growing season. The tree height in mid-winter marks the end of each annual shoot.

In this first view the second annual shoot is shown at age 5. The pith can be seen in the centre, surrounded by the annual growth rings.

5. Number of clusters

For each annual shoot the model predicts the number of branch clusters. The number of clusters varies from 1 to 6.

6. Cluster positions

Each cluster is located within the annual shoot. The last cluster is located at the top of the annual shoot. If there are 2 clusters a long and short internode are formed, otherwise they are more evenly distributed along the shoot.

In this view the position of each cluster has been indicated by a horizontal line across the stem.

7. Number of branches

For each branch cluster the number of branches is predicted. A number from 5 to 8 branches per cluster is typical.

8. Number of cones

Reproductive maturity is not reached until age 8 in *Pinus radiata*. After this age stem cones may be formed on some clusters. One function predicts the presence of cones on a cluster, and a second predicts the number of cones.

Because the tree is currently at age 5, and we are in the second annual shoot, there are no stem cones present.

9. Diameter of largest branch

Branch diameter prediction in the BGM is based on the largest branch in each cluster. The main reason for this is that the largest branch is more easily observed (for example in MARVL inventory or log grading) and also has a strong influence on the wood quality for that section of stem.

A circle representing the diameter of the end of the branch at the surface of the stem is shown in this view.

10. Relative branch diameters

The diameters for the other branches in a cluster are predicted relative to the largest branch.

The diameters of the other branches in the cluster are also shown in this view.

11. Branch angles

The insertion angle of each branch into the stem is predicted next.

In this view a line is shown representing the pith of the branch from the stem pith to the surface of the stem.

Because this is a two dimensional representation of a three dimensional branch cluster the diameter circles can appear as ellipses, and some branch angles appear steeper.

12. Branch azimuth

Branch azimuth is the "compass" angle of each branch, locating it around the circumference of the stem.

This is a "birds-eye view" of a branch cluster. The pith is located in the centre, surrounded by the annual growth rings. The pith of each branch is represented by a straight line extending from the stem pith to the surface of the stem, and its diameter by a circle at the end. The model predicts an interesting pattern of branching observed in *Pinus radiata* where branch size alternates from larger/smaller/larger... around the stem.

13. Cluster depth

The depth of a cluster delineates the region of defect in the stem. Given the geometry of the stem and branches, cluster depth is determined directly. However a separate function is provided in the BGM to predict cluster depth independently.

This could be useful by allowing the model to be used at a simpler level, predicting the location and size of branch clusters. The computational cost of predicting information about individual branches can be avoided, while still providing useful information about wood quality.

14. Branch diameter growth

Finally the BGM predicts branch diameter growth. This was identified as one of the important requirements of the model, in order to project branch sizes from MARVL inventory forward in time.

In this view the stem pith is seen at the left hand side, to the right are the annual growth rings. The branch pith is represented by a line angled upward to the right, and the branch diameter by a line at each year of growth crossing the branch pith. The deviation of the annual growth rings is approximated below the branch.

15. Model output

This program uses the outputs from the model to create simple graphical views in the form of a "line sketch". These graphical views are a literal representation of the outputs of the model. The program provides views at the following levels: whole stem (tree), annual shoot, cluster, and branch. These views allow branching patterns to be observed at the various levels of structure within the tree.

This part of the demonstration takes a quick guided tour through these views, and through time, noting points of interest along the way. This will give you a feel for the behaviour of the model.

16. Whole stem

This view shows the whole stem at age 5. The pith and annual growth rings can be seen as earlier. It should be noted that diameter is enlarged by a factor of twenty in the "Tree" view. Each branch is represented by a single line.

17. Whole stem - branching

In this view of the tree the annual growth rings are removed. The variation in branching along the stem predicted by the model can be seen more clearly.

18. Birds-eye view

Looking straight down on the stem the arrangement of the branches around the stem can be seen.

19. Annual shoot

The tree has been grown to age 10, and this view shows the second annual shoot.

In the center is the pith, surrounded by the annual growth rings. Each branch cluster is shown, with the last at the top of the shoot.

Pruning has been simulated on this tree, so there is a sheath of clearwood surrounding a knotty core at the base of the tree.

20. Branch cluster

The tree has been grown to age 15. This view shows a cluster in the 6th annual shoot.

The stem pith is seen at the center, surrounded by the annual growth rings. Each branch is represented with a single central line for its pith, a line above and below that marking the outer profile of the branch. The circle at the end represents the branch diameter adjacent to the surface of the stem.

The next view shows a short "animation" sequence of this branch cluster.

21. 3D model

The graphical model of the tree and its branches is actually three dimensional. Any view can be rotated interactively, adding considerably to the power of the program for visualising the model.

In this step a simple rotation is shown as a short animation.

The next view shows a short "animation" sequence. To show the variation of branching the first cluster in each annual shoot is shown, moving up the stem.

22. Branching variation/Stem cones

The last cluster shown has stem cones. These can be seen at the base of the cluster as a horizontal defect from the pith to the stem surface.

It should be noted that stem cones leave a hole in the wood, which degrades the wood quality considerably.

23. Branch growth

The tree has been grown to age 20.

This view shows the largest branch in the first cluster of the sixth annual shoot. This cluster is above the pruned section of the stem.

In this view the stem pith is seen at the left hand side, to the right are the annual growth rings. The branch pith is represented by a line angled upward to the right, and the branch diameter by a line at each year of growth crossing the branch pith.

It can be seen that most of the branch growth occurs in the first three or four years. At a later age the branch stops growing, and after this the branch diameter reduces as the stem grows over the tapered branch.

The next view shows a short "animation" sequence of this branch.

24. Bark encasement

The outer part of the knot formed after the branch stopped growing is bark encased, which further degrades wood quality compared to the "live" part of the knot. A simple rotation is shown as a short animation, showing more clearly the shape of the knot formed by this branch, and the bark encased region at its outer end.

In summary it can be seen that the branch model predicts detailed and realistic patterns of branching, and this information will be a valuable input into the next generation of decision support systems for forest managers.

Wood Properties

Demonstration

The program incorporates two wood properties models: for basic wood density, and spiral grain, recently published in the New Zealand Journal of Forestry Science by the Wood Processing Division, FRI.

> Xin Tian, D. J. Cown, and M. J. F. Lausberg: Modelling of *Pinus radiata* wood properties. Part 1: Spiral Grain. *New Zealand Journal of Forestry Science 25(2):* 200-213.
>
> Xin Tian, D. J. Cown, and D. L. McConchie: Modelling of *Pinus radiata* wood properties. Part 2: Basic Density. *New Zealand Journal of Forestry Science 25(2):* 214-230.

The outputs of these models can be demonstrated by manually performing the steps outlined below, at the end of the automated *BGMDemo* demonstration sequence. You will need to familiarise yourself with the operation of the *BGMDemo* controls before demonstrating this aspect of the program. Refer to Using the Program for a description of using the various controls.

Selections to be made in the program are given in italics before each step. For example:

Page:Tree	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings:On*	*Wood properties: Off*	

means that you should select the Tree page, check the Rings box, and grow to age 25. Changes from the preceding view are in bold.

Start

Page:Tree	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings:On*	*Wood properties: Off*	

The annual growth rings are shown in this view in a uniform colour.

Density

Page:Tree	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings:On*	*Wood properties:* ***On***	

By selecting to view wood properties the growth rings are coloured to represent the predicted basic wood density at that point in the stem. A scale is displayed at the lower left of the View Page.

If density is observed near the pith it can be seen that there is a vertical trend of decreasing density as you move higher in the stem, from 350 to 300 kgm^3.

*Page:**Shoot***	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings:On*	*Wood properties: On*	

Here the predicted radial trend of density can be seen, increasing from 350 to over 400 kgm^3 with increasing ring number from the pith.

Spiral Grain

*Page:**Cluster***	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings:On*	*Wood properties: **Off***	

Drag (rotate) the cluster to show that the growth rings extending up through the cluster are simply represented by a series of lines in a flat plane.

Page:Cluster	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings:On*	*Wood properties: **On***	

Colour represents density as previously explained. In addition the growth rings are extended below the cluster, and the lines are angled by the degree predicted by the spiral grain model.

Page:Cluster	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings: **Off***	*Wood properties: On*	

Drag (rotate) the cluster again to show that there is a maximum grain angle near the pith, which decreases with increasing ring number from the pith.

Conclusion

*Page:**Tree***	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings: Off*	*Wood properties: On*	***Home***

Note the region of clearwood created by pruning at base of tree. This zone is of higher value as it is free of knots.

Page:Tree	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings: **On***	*Wood properties: On*	

This region also has higher density wood, and a lower grain angle. This view clearly shows how the higher value material is concentrated in the clearwood zone at the base of the tree.

Knots, wood density and spiral grain are 3 key determinants of wood quality. It is very useful to be able to visualise the spatial arrangement of these together.

Page:Tree	*Age:25*	*Shoot: 6*	*Cluster: 1*
Outline: Off	*Rings: **Off***	*Wood properties: On*	

Glossary of Terms

annual shoot

The vertical region of the main stem formed in a single growing season. The top of each annual shoot is marked by the position of the growing tip in mid-winter in the year it is produced.

azimuth

Azimuth is the angle of a branch in a horizontal plane. It can be represented as an angle in degrees from true North, and places branches around the circumference of the stem.

bark encased

After a branch dies the stem continues to grow past it. The knot formed has bark surrounding it.

BGM

Branch Growth Model. A component of the 4th generation of FRI growth models. A model for predicting the location, size and growth of branches within the stem for Pinus radiata.

clearwood

Wood free from knots. This is obtained in Pinus radiata by pruning of branches at the base of the tree.

cluster

Branch cluster. In Pinus radiata branches are formed in "whorls" or clusters. There may be up to six clusters in an annual shoot. The spaces between successive clusters are commonly referred to as internodes.

cluster depth

The vertical depth of the region of the stem completely containing the knots formed by the branches in a cluster.

growth rings

Where growth proceeds in annual steps, with a clear mid-winter rest annual growth rings are formed from bands of earlywood and latewood. The outer edge of the latewood band marks the outer edge of the growth ring.

knotty core

An inner zone of the stem containing knots and occlusion scars formed from pruning at the base of the tree.

MARVL

Method of Assessing Recoverable Volume by Log type. MARVL is a system of field inventory and computer based analysis used to predict grade recovery from a potential harvest area.

SGMC

FRI - Industry Stand Growth Modelling Cooperative

stem cones

Female cones can be formed on the main stem in Pinus radiata. As the objective of the Branch Growth Model is to model the stem defects caused by branching, stem cones must be included.