



WinDENDRO™ 2019

Image Analysis System For Tree-Ring and Wood Density Measurement

WinDENDRO has been specifically designed for dendrometrists and dendrochronologists looking for a precise and efficient way to measure annual tree-ring widths and other related parameters such as minimum, maximum and average density, earlywood width and more.

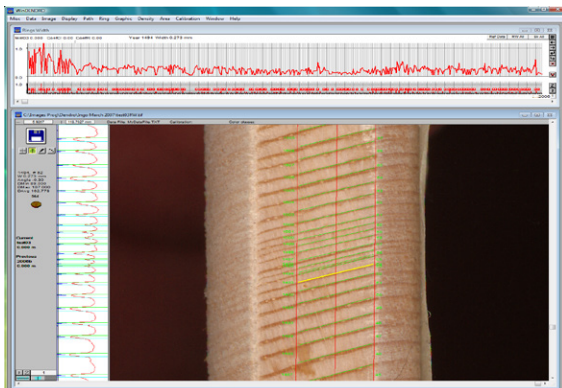


WinDENDRO analyses tree rings from wood disks, cores, X-Ray films and digital (filmless) X-Ray systems.

*Scanners shown on the left are for illustration purpose and do not correspond to models sold with **WinDENDRO**.

WinDENDRO is offered as a complete system or software alone. Its hardware components go from low cost, but precise, to faster and more precise high-end models. The software on its side is offered in four versions differing in functionality and costs. **WinDENDRO** runs on Windows operating systems including Windows 10.

In comparison to manual measurement systems, **WinDENDRO** offers advantages from different points of view. Productivity gain, operator comfort, images archiving with or without their analysis, a working method that encourages and facilitates verifications such as comparison with master series during measurements and easy commands to move back and forth along an analysed sample without mechanical delays or backlash.



Since 1991, **WinDENDRO** has been updated regularly, at least once a year, to make it on a par with technological advances in image acquisition hardware (scanners and digital cameras), computers, operating systems and image analysis. It also has evolved based on suggestions from its large base of experienced users. It is a mature and robust system that has made its proofs in many laboratories worldwide as can be seen from the hundreds of publications made with it (some are listed on www.regentinstruments.com).

Image Acquisition

The first step of tree-ring analysis is image acquisition.

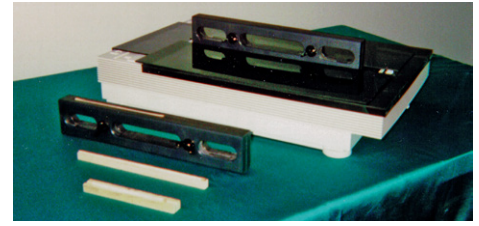
WinDENDRO is optimised for optical scanners but can also analyse images from cameras and digital filmless x-ray systems. It can open image files produced by these hardware manufacturers programs and saved in a standard format such as jpeg or tiff. However, most of the time **WinDENDRO** acquires images directly from such devices when they are TWAIN compatible*. Optical scanners are particularly well adapted for tree-ring analysis. They produce high quality images over large areas.

WinDENDRO deals with scanners in a very efficient way. It offers two methods to acquire images from them. One method is optimised for ease of use and requires just a mouse click to get an image. Time is saved in bypassing the standard "Preview" step and by using positioning accessories which allows to repetitively place the samples at the right place on the scanner. The other scanning method is more complex and powerful. It uses the *Preview* step to optimise the scanning parameters.

Disks are placed face down on the scanner for image acquisition. You can scan the whole disk, although this takes huge amounts of memory, or you can scan narrow paths, a few millimeters or centimeters in width, from pith to bark. A scan typically takes between 10 and 60 seconds to complete depending on the image size (scan area and resolution). Note that scanning whole disks or using very high dpi such as 2400 or more will need more time and

a fast computer with plenty of memory. Right after scanning, the image is displayed on screen.

Optional core holder and positioning system eases and accelerates core scanning. It allows the operator to rapidly position the samples at the same place on the scanner glass, thus eliminating the need to preview before a scan, and allows manipulation of cores during their preparation. This system can be rapidly added or removed at any time.



Some of our scanners are particularly well adapted for disk or large samples scanning. They have their edges at the same level as the scan area glass which ensures that the sample is always in contact with the glass (important to have an image well focused).

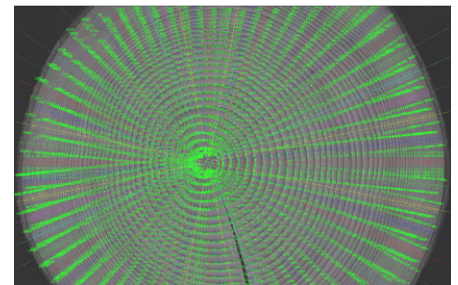
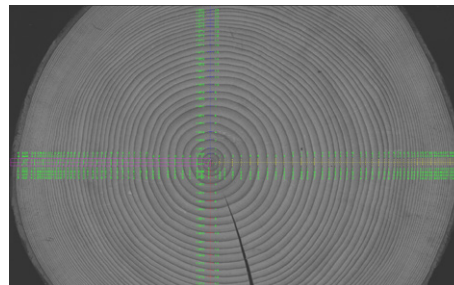
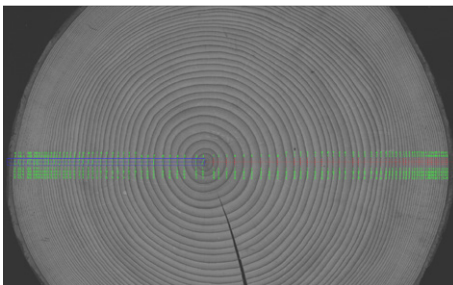
Most scanners on the market have their scan area glass lower than the plastic surrounding it. Large samples are not in contact with the glass everywhere.

*Although WinDENDRO can work with most TWAIN compatible scanners, we do not guarantee it will support all functionalities for all models. Our simple interface is guaranteed to work only with the models we sell. Our scanners also come with a calibration for higher precision. See the note regarding scanners on our web site.

** To learn more about sample preparation required for scanning and WinDENDRO see the [Regarding wood species, narrow rings and ring contrasts](#) note on next page.

Rings Detection

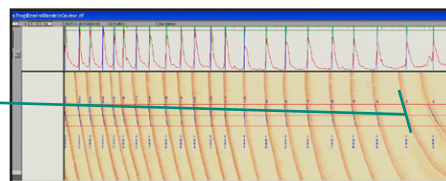
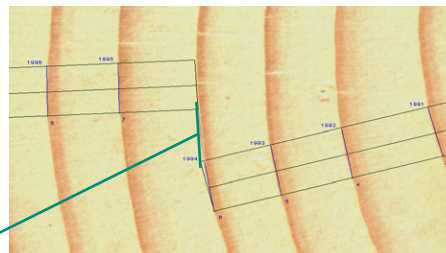
After image acquisition, you indicate **WinDENDRO** where to measure rings in the image. This is done by tracing paths interactively. Straight line paths such as those extending from a disk pith to bark can be created automatically with a single mouse click (up to a few hundreds in a single click). More complex shape paths (see below) are created manually by clicking at different places.



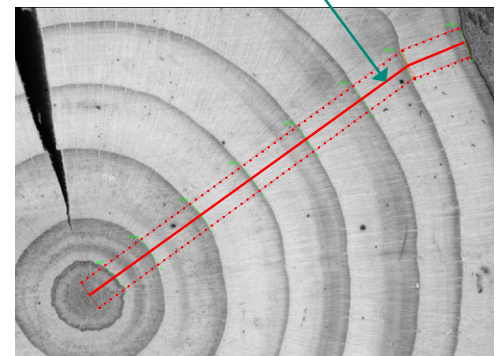
In its simplest form, a path can run across a sample (core or disk radius) on a straight line. Hundreds of paths can be created with a single mouse click in pre-defined directions around the clicked position. Paths can also be created by clicking at their beginning and ending points.

Paths can contain discontinuities to skip crack or missing wood areas on damaged samples or to continue measurements in another direction e.g. to move perpendicular to ring boundaries or avoid damaged areas.

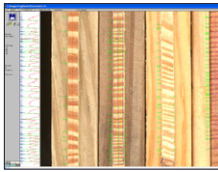
Ring-widths can be measured taking into account their boundary orientation relative to the path. This allows to increase the precision when using straight paths to achieve similar results as to path made perpendicular to ring widths.



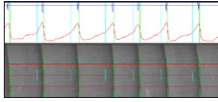
You can trace paths so that their trajectory is perpendicular to ring boundaries (as in manual dendrochronological measurement methods).



Rings Detection (continued)



One or more cores can be analysed per image. In this example, multiple cores have been scanned side by side to save time. They are then analysed in the same image by clicking their respective beginning and ending. For curved cores intermediary clicks are required.



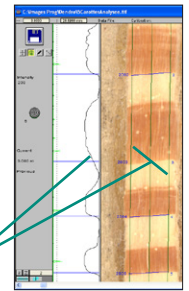
After paths have been created, rings are automatically detected by **WinDENDRO** and their presence is indicated over the image with lines and text. Lines indicate the rings boundary position and orientation and the text indicates the year and ring number. Earlywood width can also be displayed along with other ring features (explained next). Close to the image, a profile of the light variations inside the path is also displayed along with ring and earlywood widths. This region is also used to adjust the sensitivity of the automatic ring detection. The sensitivity of this initial detection can be adjusted in function of the rings appearance. Narrow and low contrasts rings require more attention.

One or two methods of ring detection are provided in function of the **WinDENDRO** software version. The first method is based on light

intensity differences. It is simple, efficient and works fine for contrasted rings like those of conifers. The other method is called Teach & Show. You show **WinDENDRO** a tree ring in the image and then it can automatically detect similar tree rings. This method is more computer intensive and is well adapted for low contrasted rings like those of deciduous trees. There are limits however and minimal contrast is required in order to get a good level of automatic detection. When contrast is too low, you can work in manual mode where you indicate the position of rings in the image by clicking them.

All the image content inside the path, not only the central line, is used to calculate the intensity profile displayed parallel to the path. The path width is adjustable so that you can choose what the profile is made of. Paths should only contain valid tree-rings information, they should not encompass the core holder for example. **WinDENDRO** Density version also uses ring orientation to produce more precise profiles. Each time a ring is moved or reoriented, the intensity profile is recalculated using a virtual slit that matches the rings boundary.

Light variations transitions are less sharp for rings with a wrong orientation.



Regarding wood species, narrow rings and ring contrasts

When rings are well contrasted, such as medium to large rings (0.5 mm and over) of coniferous species, the automatic detection rate ranges from 85 to 100% requiring little modifications from the operator, so the productivity gain over manual methods is very high. Rings with lower contrasts such as those from deciduous (hardwood) species or narrow rings, require more attention to preparation, scanning and analysis settings. The more time is spent on obtaining a good image, the less time is spent on their analysis. This is true for manual methods also. Low contrast samples can be analysed with **WinDENDRO** but the productivity gain over manual methods is lower than with conifers because more operator corrections are needed. Low contrasted rings requires paying attention to:

1) Sample preparation. It affects greatly the automatic detection rate. As rings get narrower, the finer the preparation has to be: 0.01 mm rings require a finer method than 1.0 cm rings. Visible mechanical marks like scratches should be avoided as they tend to be amplified

in digitized images. They can trigger false ring detections or wrong orientations. There is no universal method accepted for preparation, but sanding is very popular for dry samples.

2) Scanning. Contrast enhancements done during scanning or after in **WinDENDRO** make rings more visible. Narrow rings require higher resolution (DPI) than large rings. As a rule, the practical minimum number of pixels per ring is four and this number increases up to ten typically as ring contrast lower. A good quality scanner is also mandatory. Quality is not only related to the theoretical dpi claimed by its manufacturer. It is also a matter of good optics and electronics. Regent Instruments test and compare all scanner models they sell. They also ensure compatibility with **WinDENDRO** and its accessories.

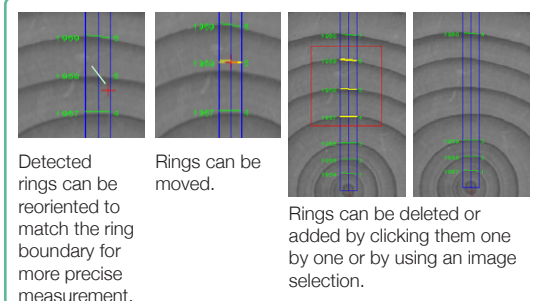
3) Analysis settings. They must also be fine tuned for low contrast rings. You can experiment with the two methods of ring detection provided and adjust their parameters to optimise the automatic detection. Some samples are better done in the complete manual mode.

Rings can be tagged with observations that you define. You choose their name, meaning and the symbol used to indicate their presence close to a ring. For example, you could define two features called narrow and frost and select which rings have these characteristics. These ring features are then displayed on the graphic and in the image close to rings which have these features.

No modifications are made to the original image which is always available for future reference or analyses. The images can also be exported to other software programs to create a report for example. They can also be saved with their analyses and later be retrieved and edited or validated by **WinDENDRO**.

Rings Validation

After the initial automatic ring detection, a validation must be done to consider the possibility of the presence of false, frost, locally absent rings or simply misclassifications done by **WinDENDRO**. In this regard, we say **WinDENDRO** is a semi-automatic rather than an automatic system. This is done by browsing the image and looking for missing or false rings. Contrary to systems based on positioning tables, you can switch back and forth along the ring paths without precision loss due to gears backlash. Previously identified rings can be reviewed at any moment even years later. Adding or deleting rings is easily done interactively. When the mouse is held over a ring, the latter is highlighted in yellow as illustrated. Clicking it deletes the ring, clicking at a place there is no ring adds one. Rings can be deleted in groups, moved or reoriented. Earlywood-latewood boundaries position can also be overridden. As modifications are done, the rings' number and year are automatically updated in the image and the ring-width graphic.



The Ring-Width Graphic & Cross-Dating

A graphic of ring-widths in function of the year is displayed during the analysis and is automatically updated as rings are edited during the validation phase (Reg and Density versions). This graphic is also used for visual and numerical cross-dating. It can display simultaneously master chronologies and the ring widths of the sample under analysis and correlate some of them to help find mistakes in the analysis. Ring-width series can be detrended, i.e. converted to indices, using the smoothing spline method.

The smoothing spline can be displayed to help determine its filtering strength.

Skeleton plots can be displayed during the measurements of one or more series simultaneously with master chronologies. These are used by dendrochronologists to identify rings that are smaller or larger than their neighbors for visual cross-dating.

Ring widths can be displayed unmodified as measured in millimeters

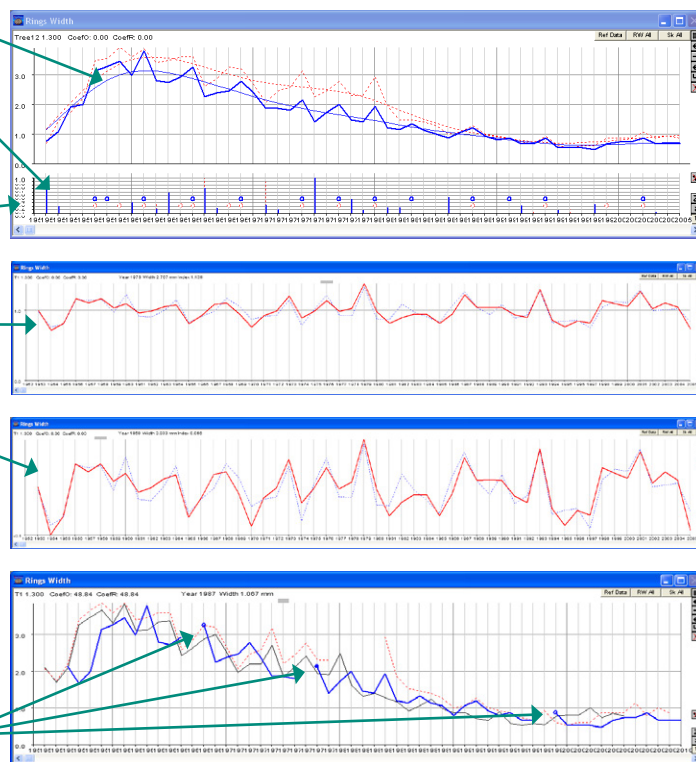
or

as index values, i.e. ring widths for which long term non-climatic variations such as those due to tree aging have been removed.

Ring widths can also be converted to a logarithm scale to increase the effects of narrow rings variations.

There are many interactive commands associated with the graphic. For example, when you click on a year in the graphic, the image is scrolled to display the part of the image containing that ring. The ring-width series can be splitted and shifted at different places (and the correlation updated) to help find missing or false rings. Modifications done by adding rings at splits points can be ported to the analysed sample by activating a command.

Three split points where the data series can be independantly shifted. More points can be added or removed.



Density Analysis

WinDENDRO is available with or without density analysis capability. The principles behind **WinDENDRO**'s density analyses are well known and have been applied for years in tree-ring analysis. Different methods can be applied to perform density analysis in **WinDENDRO**:

• The conventional film-based method

This method is the oldest and most widely used for tree-ring density analysis by dendrochronologists. It is well documented in Dr. Schweingruber book "Basic and Applications of Dendrochronology". Wood samples are cut into thin slices, i.e. 1 to 2 mm thick, brought to a predetermined humidity level and exposed to x-rays over a film. The film is then developed. In **WinDENDRO**, the conventional analog densitometer is replaced by a digital method that consists of scanning the x-ray film and then measuring light that passes through a virtual slit scanned over the rings. Unlike the analog densitometer, parameters such as slit size can easily be changed. When computing density, **WinDENDRO** automatically sets the slit angle tangent to the ring boundary in order to produce accurate measurements. The slit angle linearly changes its orientation gradually between rings so that it is tangent to all ring boundaries. The operator can interactively override the slit angle estimated by **WinDENDRO**.

• The "Blue Intensity" reflected-light method

Well described by R. Campbell et al. (Tree-Ring Research, Vol. 67(2), 2011, pp.127-134), this method does not produce true

density measurement. Nevertheless, it has been demonstrated that used with **WinDENDRO**, it provides an inexpensive and reliable surrogate for conventional x-ray densitometry. The blue intensity method uses the blue channel of color images produced on a flat-bed scanner. A strong correlation has been demonstrated between blue intensity measurements and maximum latewood density when wood surface is carefully prepared. A special calibration procedure permits results obtained by different laboratories, or using different scanners, to be compared. One major advantage of this method is that it does not require costly radiation equipment.

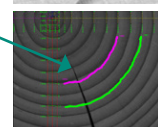
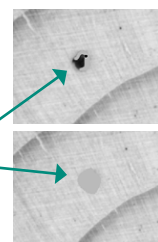
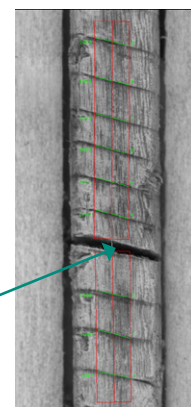
• The filmless digital x-ray imaging method

It is possible to use the newest filmless digital x-ray cameras or scanners (not sold by Regent) to acquire x-ray images of pieces of wood and then measure their density. Some systems require that the pieces of wood still be prepared as described above. Density is measured in **WinDENDRO** from these images exactly as it is from digitized films except for calibration.

Multiple density measurements can be saved on a ring or pixel basis. Available per ring: ring width, earlywood and latewood width in mm or percentage of ring width, ring maximum density, ring minimum density, ring mean density, earlywood mean density, latewood mean density and ring boundary orientation. Available per pixel along a ring path: pixel density or light intensity (calibrated or not) and slit orientation.

WinDENDRO Features Per Software Model

Feature	WinDENDRO Software Model			Description
Analysis (Paths)	Basic	Reg	Density	
Number of automatic ring detection methods	1	2	2	All versions have the intensity differences method. The Reg and Density versions have an alternative method called Teach&Show method which is sometimes better for deciduous (but can also work with conifers). Two methods give more options for low contrasted rings.
Paths per image (max)	4	256	256	The mini version only works with one path at a time. The Basic can work with 1 to 4
Vertical or horizontal paths	Y	Y	Y	Paths in the same direction as the image edges.
Paths in any direction	N	Y	Y	Paths in directions other than horizontal and vertical
Multi-segments paths	N	Y	Y	Paths that have more than one segment and can change direction between segments
Brother paths	N	Y	Y	Possibility to add paths to existing ones sharing the same origin (such as a disk pith).
Tangent to ring boundary	Y	Y	Y	Ring widths are more precise when they are oriented to follow the ring boundary direction.
Skip gaps (cracks, void)	Y	Y	Y	To exclude areas such as cracks due to wood drying from the ring widths measurements.
Batch ReAnalysis	N	Y	Y	Possibility to reanalyse images previously analysed under different analysis parameters. To change the calibration or the earlywood definition for example.
Measurements				
Earlywood, latewood width measurement	N	Y*	Y*	* The density version will produce more precise earlywood width measurement when density analysis is turned on (even if no light calibration is done). This version is strongly recommended for this measurement.
Sapwood width	Y	Y	Y	Must be indicated manually by the operator.
Ring features	N	Y	Y	For each ring, you can set up to five features or observations that you define (frost ring, wide, missing...) plus add textual comments. Features are displayed in the image, the ring-widths graphic and are saved with the analysis data.
Log/Area module	N	N	Y	This module is optional and can be added to any version of WinDENDRO. It adds the following: <ul style="list-style-type: none"> • Compression (reaction) wood and voids (cracks) areas measurement. This is done manually by tracing them in the image. • Disk area, shape (form coefficient), perimeter, average radius, ring density per inch or cm in function of distance to pith. This is done semi-automatically.
Light reflection analysis	N	Y*	Y*	Export the path intensity profile to text files (on a pixel basis). The density version will produce more precise measurements when density analysis is turned on (even if no light calibration is done). This version is strongly recommended for this measurement.
Density analysis	N	N	Y	From x-ray films or images from digital filmless x-ray systems. Measurements per ring include; minimum density, maximum density, average ring density, average earlywood density, average latewood density and ring orientation.
Image Sources				
Analyse tiff, jpeg or bmp files	Y	Y	Y	Tiff uncompressed is recommended for precision.
Acquire images from TWAIN compatible scanners and cameras	Y	Y	Y	The Mini version can only open tiff, bmp and jpeg files.
Calibration for images which come from a camera	Y	Y	Y	Calibration of images from a camera can be done with a single mouse click when Regent's new calibration targets are included in the image.
Image Processing And Analysis				
9 to 16 bits per pixel grey levels	N	N	Y	Grey levels images with more than 8 bits per pixels of information (typically 10, 12 or 16 bits/pixel) produce greater precision density analyses.
Color channel selection	N	N	Y	Color images can be visualized and analysed on one of its three color channels (Red, Green, or Blue) or using the three of them (a regular color image). If the color channel is changed while an analysis is displayed, the paths intensity profile and density values for each ring (min, max, average) are recalculated automatically.
Image edition	N	Y	Y	You can edit the image (modify its content) with any color present in it (by picking it up interactively) or by defining your own colors. This allows to remove defects that prevent ring analysis from being done accurately. It can also be used to remove artefacts for density analysis (on x-ray films or wood). Any modifications done to the image are permanent and are saved with it (if you save the image after edition).
Image Temporary Markers	N	Y	Y	You can draw temporary markers over the image (to help you keep track of rings along a disk to find missing ones for example). Markers appearance (thickness, color) can be changed after they have been created and can have an identification name.
Graphic				
Ring-width graphic, cross-dating, skeleton plots, detrending	N	Y	Y	Refer to the Graphic section of this brochure.
Misc.				
Save data in ascending/descending order	Y/N	Y/Y	Y/Y	From pith to bark or bark to pith.
Possibility to save only the last few rings of a path	N	Y	Y	For stem analysis mostly. To study growth of only some years of interests.
Customisable sample identification	N	Y	Y	Choose the meaning and type of some variables that identify a sample before its analysis. This information is saved with the data.
WinCELL Regular included	N	Y	Y	A program for wood cell anatomical analysis (lumen area, length, cell length, earlywood width...).



Data

When an analysed image is saved to a file, the analysis is automatically saved with it. This analysis can later be retrieved, validated or modified simply by loading the image in **WinDENDRO**. The analysis data such as ring width, minimum density etc, are also saved to standard text files that can be read by many programs including spreadsheet style software like Microsoft's Excel. **WinDENDRO** has its own format, documented in its user guide, to store these data but can also convert files to the decadal (Tucson) format used by dendrochronologists at 1/100 or 1/1000 of a mm precision. Unlike the decadal format, the **WinDENDRO** format allows to store the analysis settings, date and time, image information along with the ring measurements.

Stem Analysis

XLSTEM is an optional stem analysis program that runs within Microsoft Excel. It allows to visualize data produced by **WinDENDRO** and to do standard stem analysis such as reconstituting tree growth as function of age, measuring tree volume... Calculations can be done interactively on selected trees or in batch.

XLSTEM calculates the following information from ring width data produced by **WinDENDRO**:

- Mean radius (quadratic method), diameter and area per disk (cumulative or incremental)
- Tree height and volume as a function of age or year (cumulative or incremental)
- Basal and summary information about the tree

It has three height interpolation methods: Linear, Carmean and Newberry.

Misc.

WinDENDRO comes with a printed color illustrated manual, and prompt and competent technical support via e-mail. Our technical support team is close to and can rely on **WinDENDRO** programmers for technical advices.

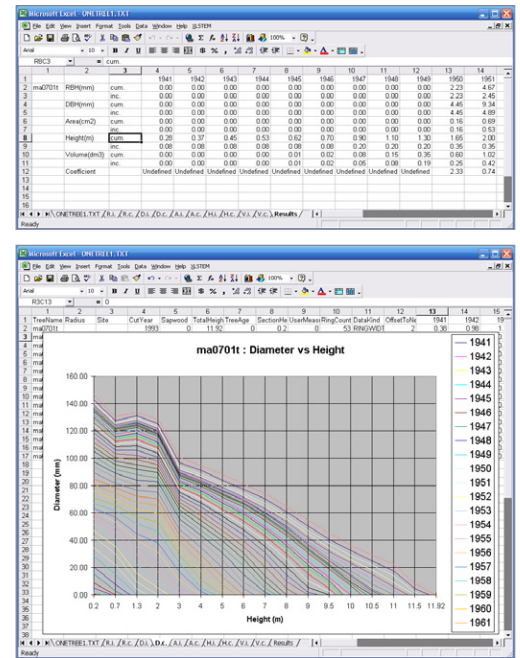
A Free **WinCELL** Regular software comes with **WinDENDRO** Regular & Density Software Models

WinDENDRO is a member of a product family for plant science research and production. Visit our web site for more details!

What's New About WinDENDRO?

- Several improvements for **WinDENDRO** Regular and Density versions include Improved automatic ring detection for hardwood species, new driverless software protection keys, and the new 64-bit software version can load images larger than 3GBytes.
- Calibration Targets to use with **WinDENDRO**'s implementation of the blue reflectance density surrogate method
- Images analysed with version 2019 can be saved in older formats 2009, 2012, 2014, 2016, 2017, and 2018 providing features specific to 2019 are not used. This allows exchange of analysed files with these previous versions.

WinDENDRO™ has been designed in collaboration with Dr. Rejean Gagnon and Dr. Hubert Morin at the Dendroecology Laboratory at Université du Québec à Chicoutimi (Canada).



Tree height as a function of diameter

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