Specialty Wood Products
Research Partnership

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Theme: Specialty Wood Products (SWP)

Technical Report

Sapwood Depth Tool – Proof of Principle

Authors:

Nurzhan Nursultanov, Bill Heffernan

Research Provider:

University of Canterbury

Date: June 2018

Report: SWP-T054

FOREST GROWERS RESEARCH

supported by forestgrowers commodity levy

TABLE OF CONTENTS

INTRODUCTION 1

Prototype Design of the Sapwood Tool 1

METHODS 2

Sapwood Tool 2

Measuring Procedure 2

Determination of SW/HW Interface 4

Electrical Conductivity of *Eucalyptus globoidea* 5

RESULTS 6

Sapwood Tool 6

Electric Current Variation in Logs 6

Sapwood Thicknesses 6

Electrical Conductivity of *E. globoidea* 8

CONCLUSIONS AND FUTURE WORK 8

ACKNOWLEDGEMENTS 9

REFERENCES 10

INTRODUCTION

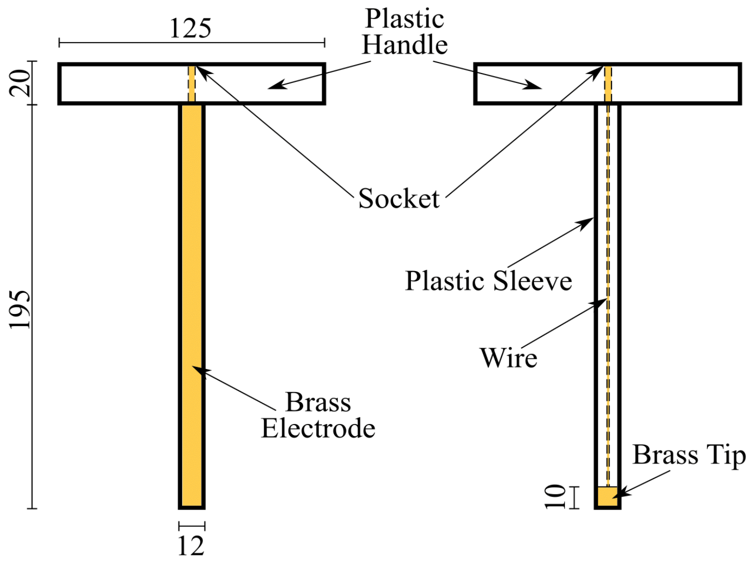
In the past, the size of sapwood and/or heartwood was determined by a length measuring device on a crosscut of the stem; this is a destructive method which requires a whole tree to be cut down. Currently available methods, such as coring, sap flow measurement, and electrical resistance measurement, allow differentiation of sapwood and heartwood on standing trees. The coring method is fast, but requires an appropriate dye if the colours of sapwood and heartwood are similar (Guyot, Ostergaard, Lenkopane, Fan, & Lockington, 2013). Less invasive than coring, the sap flow measurement method is time-consuming and expensive. Electrical resistance measurement is independent of wood colour, and it can be fast, as the measurement of electrical resistance is almost instantaneous. However, commercial devices such as Picus TreeTronic (Argus Electronic GmbH, Rostock, Germany) with its numerous sensors require a long set-up time, making this method time consuming.

This research aims to develop a sapwood tool that can determine the sapwood/heartwood interface based on electrical resistance measurements with minimised set-up time. This report shows the first developed lab-based prototype of the sapwood tool, and describes its main operational principles, including the algorithm of sapwood depth identification. To prove the proposed concept, the sapwood tool was tested on four logs, including specimens of *Pinus radiata*, *Pseuodtsuga menziesii*, and *Sequoia sempervirens.* In addition, electrical conductivity of *Eucalyptus globoidea* is presented in this report.

Prototype Design of the Sapwood Tool

The bottleneck of Picus TreeTronic and of similar tomographs is their long set-up time due to the installation of numerous sensors around a tree. Such an arrangement is required for tomography but is unnecessary for a single point determination of the sapwood/heartwood interface. Therefore, it was decided to use one sensor. Furthermore, as the sapwood tool will be used under field conditions, potentially on hundreds of trees per day, we wanted the tool to be robust, user-friendly and lightweight. These criteria governed the design of the sapwood tool (**Fig. 1**).

The sapwood tool consists of the <u>measuring</u> and <u>return</u> probes, each of 12 mm diameter. Such a diameter provides structural strength, preventing the probes from excessive bending, and allows an operator to use a domestic battery drill, with the maximum drill bit diameter of 13 mm. Each probe has a plastic handle and socket at the top, to connect the probe to a power source. The return probe is made of brass, while the measuring probe consists of a brass tip connected to a socket by a wire, inside a plastic sleeve.



(a)

(b)

Fig. 1. (a) A schematic diagram of the sapwood tool, with the return (*left*) and measuring (*right*) probes. The yellow and white colours denote the metal and plastic parts, respectively. **(b)** A photo of the sapwood tool. *Note:* All values are in millimetres. The measuring probe has 1 cm depth indicators.

METHODS

Sapwood Tool

Measuring Procedure

To identify the sapwood thickness in a standing tree using the developed sapwood tool, four logs of three wood species were selected. Two logs were *P. radiata*, one log was *P. menziesii*, and the other log was *S. sempervirens* (**Fig. 2**). Their heartwood and sapwood were identified by visual means. The sapwood (SW) thicknesses – the distance from the log's external surface to the sapwood's internal border – was measured by the sapwood tool and by a ruler on the crosscuts of the logs.

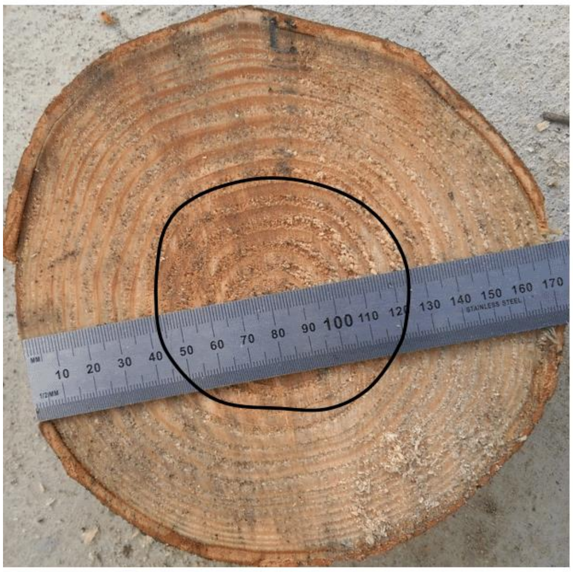
To measure sapwood thickness using the sapwood tool, the following steps were carried out:

Step 1. Two holes were drilled, one on top the other, in parallel to the stem, using a drill guiding bush. To avoid the probes jamming inside the holes and to ensure a good contact with the timber, the drill bit diameter was chosen to be one millimetre larger than that of the probes, (13 mm).

Step 2. The probes were connected to a power source.

Log 1: *P. radiata*

Log 2: *P. radiata*



Log 3: *P. menziessii*

Log 4: *S. sempervirens*

Fig. 2. Four logs used in the experiment. The position of the ruler shows the direction along which the sapwood tool was inserted. The black solid lines denote the heartwood contours determined by visual means during the experiment.

Step 3. The return probe was fully inserted into one of the predrilled holes.

Step 4. The brass tip of the measuring probe was inserted into the other hole.

Step 5. The power source was activated.

Step 6. Electrical parameters: voltage and electric current were recorded.

Step 7. The power source was turned off.

Step 8. The measuring probe was inserted by a 1 cm step into the stem and Steps 5-7 were repeated.

Step 9. Steps 5-8 were repeated until the measuring probe was inserted 8 cm into the logs. (Maximum insertion depth is 13 cm).

The schematic diagram of the set-up is shown in **Fig. 3**.

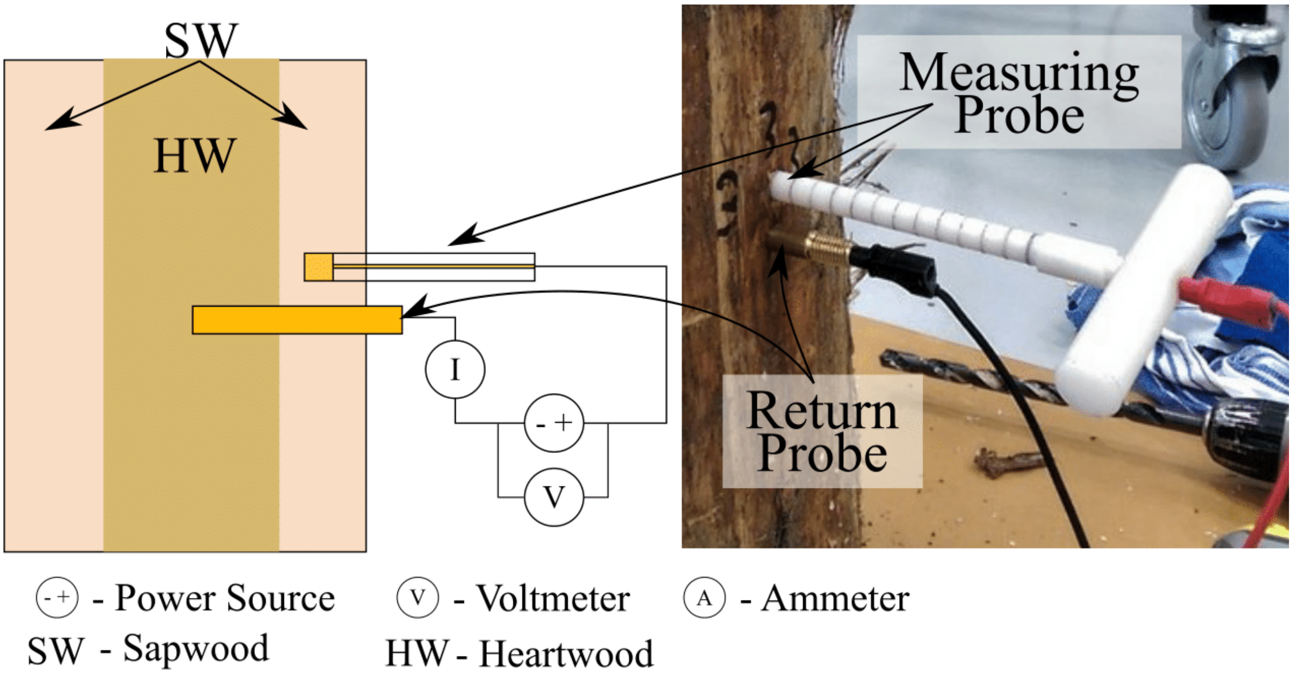


Fig. 3. The experimental lab set-up of the sapwood tool: the schematic diagram *(left)* and the photo of the fully inserted return and partially inserted measuring probes *(right)*.

Determination of SW/HW Interface

Electrical conductivity, a property that defines how well a conducting material passes an electric current, is linked to electric current by the following equation:

$$I = \frac{\sigma A V}{l},$$

where I is the electric current in amps [A]; V is the voltage in volts [V]; A is the cross-sectional area, through which the electric current flows [m^2]; σ is the electrical conductivity in siemens per meter [S/m]. The higher the conductivity, the higher the electric current for a given voltage.

According to prior research by Nursultanov (2018), at the University of Canterbury, sapwood is more electrically conductive than heartwood. The ratio of sapwood's electrical conductivity to heartwood's electrical conductivity depends on wood species. For example, in *P. radiata*, sapwood was found to be 40 times as conductive, and in *S. sempervirens* twice as conductive, as heartwood. In addition, Nursultanov (2018) observed a transitional zone in *S. sempervirens* (**Fig. 4**), which was about 1.5 times less conductive than the sapwood. Furthermore, according to Nursultanov (2018), variation of electrical conductivity within sapwood or heartwood is negligible. This led to an assumption that electric current will decrease noticeably only when the measuring probe passes the SW internal border interface, from the outside.

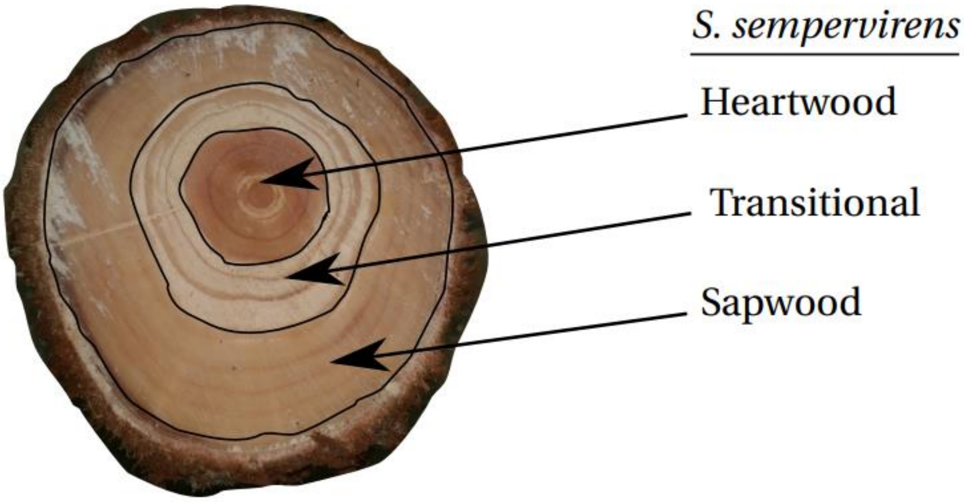


Fig. 4. The crosscut of *S. sempervirens* used in Nursultanov's (2018) study.

To determine this border, it was proposed to analyse the data based on the gradient of electric current (m), recorded at every centimetre of depth into the tree. This gradient can be expressed as:

$$m = \frac{I_j - I_{j+1}}{d_j - d_{j+1}},$$

where I_j and I_{j+1} are the electric current measured at the depth d_j and d_{j+1}, respectively. The highest gradient value would appear on the interface, located between d_j and d_{j+1}. The higher the resolution of electric current measurement, the more precise the proposed method. Currently, with the 1 cm resolution, the physical depth precision of this method is ±0.5 cm.

Electrical Conductivity of *Eucalyptus globoidea*

Prior to using the sapwood tool on *Eucalyptus globoidea*, electrical conductivity of its sapwood and heartwood should be known. The information about electrical conductivity of *E. globoidea* was limited to a single study done by Nursultanov (2018); however, the results were not consistent, potentially caused by partial drying of the samples. Therefore, electrical conductivity of *E. globoidea* was remeasured in this study. The main objective of this study was to determine longitudinal electrical conductivity difference between sapwood and heartwood based on a single log from a 14 year old tree. In this study, 8 cubes of sapwood and 8 of heartwood (16 in total) were randomly selected.

This study followed the experimental methods used by Nursultanov, Altaner, and Heffernan (2017), with key aspects described as:

- The log was cut into cubes of 2 cm side-length. Only the cubes with straight grain were selected.
- Each cube was sealed inside a testing rig.
- Electrical conductivity was measured from room temperature (about 23^{o}C) to 90^{o}C, with a temperature step of 10^{o}C.

RESULTS

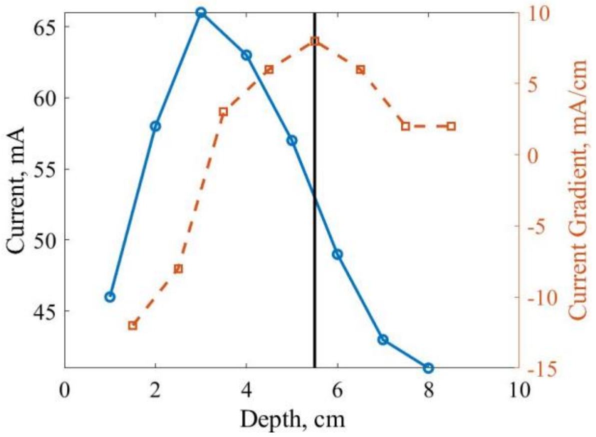
Sapwood Tool

Electric Current Variation in Logs

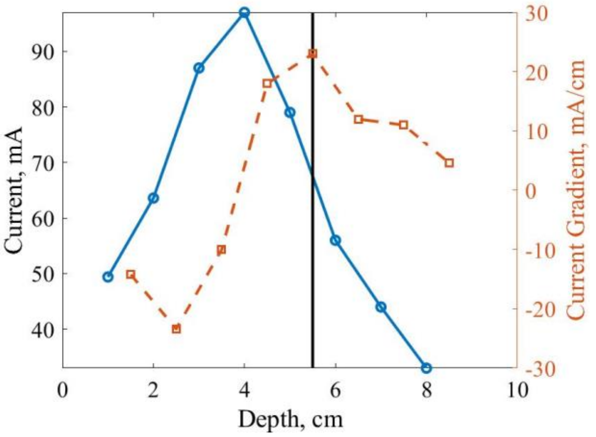
Fig. 5 shows the logs' variation of electric current, the current gradient and the position of the sapwood's internal border. All the logs showed similar behaviour, electric current increased initially and then gradually decreased closer to the centre. The first increase of electric current can be due to the existence of an external dry annulus in the logs, particularly observed in *P. radiata* logs (**Fig. 2**). Deeper into the sapwood, the moisture content increased, resulting in higher electrical conductivity and hence the electric current values rose. The consequent decrease of electric current was caused by an approached low conductive zone, represented by either heartwood or a transitional zone.

Sapwood Thicknesses

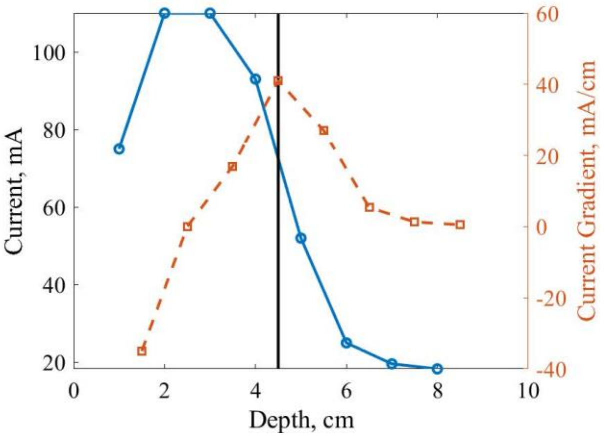
Tab. 1 shows the sapwood thicknesses measured with a ruler and the sapwood tool. The agreement between the methods demonstrates the feasibility of such a sapwood tool.



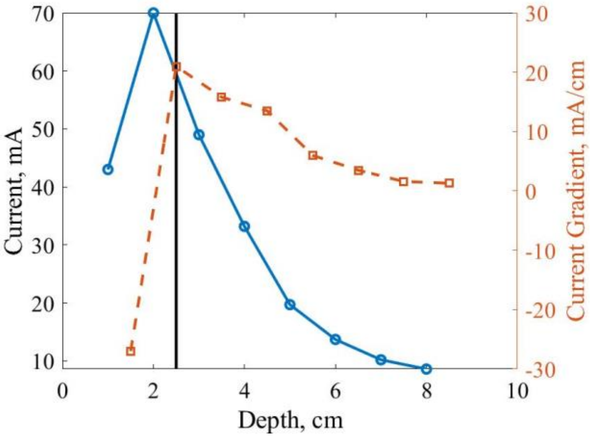
(a) *P. radiata*



(b) *P. radiata*



(c) *P. menziesii*



(d) *S. sempervirens*

Fig. 5. The variation of electric current with depth (blue solid line) and the internal border of the sapwood (black solid line). The red dashed line denotes the gradient of electric current.

Tab. 1. Logs' SW thicknesses measured on crosscut by a ruler and determined by the sapwood tool.

Logs	SW thickness (ruler), cm	SW thickness (sapwood tool), cm
Log 1	6.2	5.5±0.5
Log 2	6.3	5.5±0.5
Log 3	4.3	4.5±0.5
Log 4	3.0	2.5±0.5

Electrical Conductivity of *E. globoidea*

The effect of temperature on electrical conductivity of *E. globoidea's* sapwood and heartwood is shown in **Fig. 6**. At room temperature, the average electrical conductivity values of the sapwood and the heartwood were 0.095 S/m and 0.023 S/m. This difference would allow determination of sapwood in a living *E. globoidea* tree using the sapwood tool.

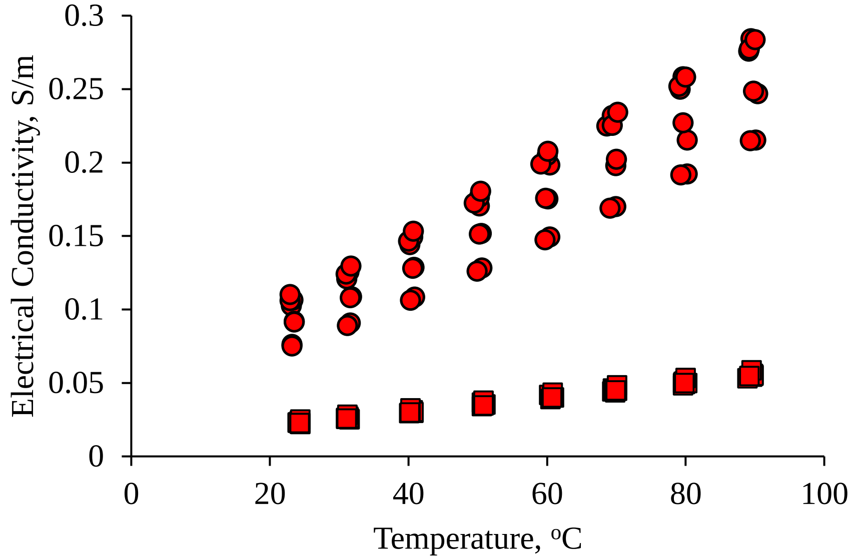


Fig. 6. The electrical conductivity of *E. globoidea's* sapwood (circles) and heartwood (squares).

CONCLUSIONS AND FUTURE WORK

The investigated method showed promising results on selected logs, including *S. sempervirens* with the relatively conductive transitional zone and heartwood. The developed prototype of the sapwood tool proved the concept. However, the resolution of the tool and its current design require further improvement. Ideally, to be used under field conditions, the sapwood tool should measure electric current, with higher accuracy, during drilling and log the electric current versus depth automatically. At present, concepts for such designs are being developed. Lastly, in future work, the sapwood thickness in *E. globoidea* logs, and other relevant species, should be measured using the sapwood tool.

ACKNOWLEDGEMENTS

The authors would like to thank Mr Nigel Pink, technician in the Forestry Work Shop, the University of Canterbury, for his help in cutting the samples, and to Paul Millen for providing *E. globoidea* samples.

The authors also would like to express their gratitude to the Electrical and Computer Engineering and Chemical and Process Engineering departments of the University of Canterbury for providing necessary equipment.

REFERENCES

Guyot, A., Ostergaard, K. T., Lenkopane, M., Fan, J., & Lockington, D. A. (2013). Using electrical resistivity tomography to differentiate sapwood from heartwood: application to conifers. *Tree physiology, 33*(2), 187-194.

Nursultanov, N. (2018). *Joule heating of green Pinus radiata logs for phytosanitary purposes: An in-depth investigation by experimentation and computational modelling.* (PhD), University of Canterbury.

Nursultanov, N., Altaner, C., & Heffernan, W. (2017). Effect of temperature on electrical conductivity of green sapwood of Pinus radiata (radiata pine). *Wood Science and Technology, 51*(4), 795-809.