


This is a cross-section of a wood core of a ring-porous wood species and the white dots are the water conducting cells. As probably some of you already know, the year to year variability in the early wood vessel size can, in some cases, encode some valuable ecological information. Now let us suppose that in the area where you are coming from there is a very old oak stand and that you would like to know if also these vessels are able to encode some valuable information. What is the best approach? It is better to measure earlywood vessel highly precisely, but only on a very limited sampling, since the measurement is very time consuming, or is better to use a fast and automated measurement procedure which allows to measure a large sample but has the disadvantage of not being very accurate?



Expeditious building of vessel size chronologies

# Precision vs. efficiency: how much information do we lose in an automated measurement of earlywood vessels?

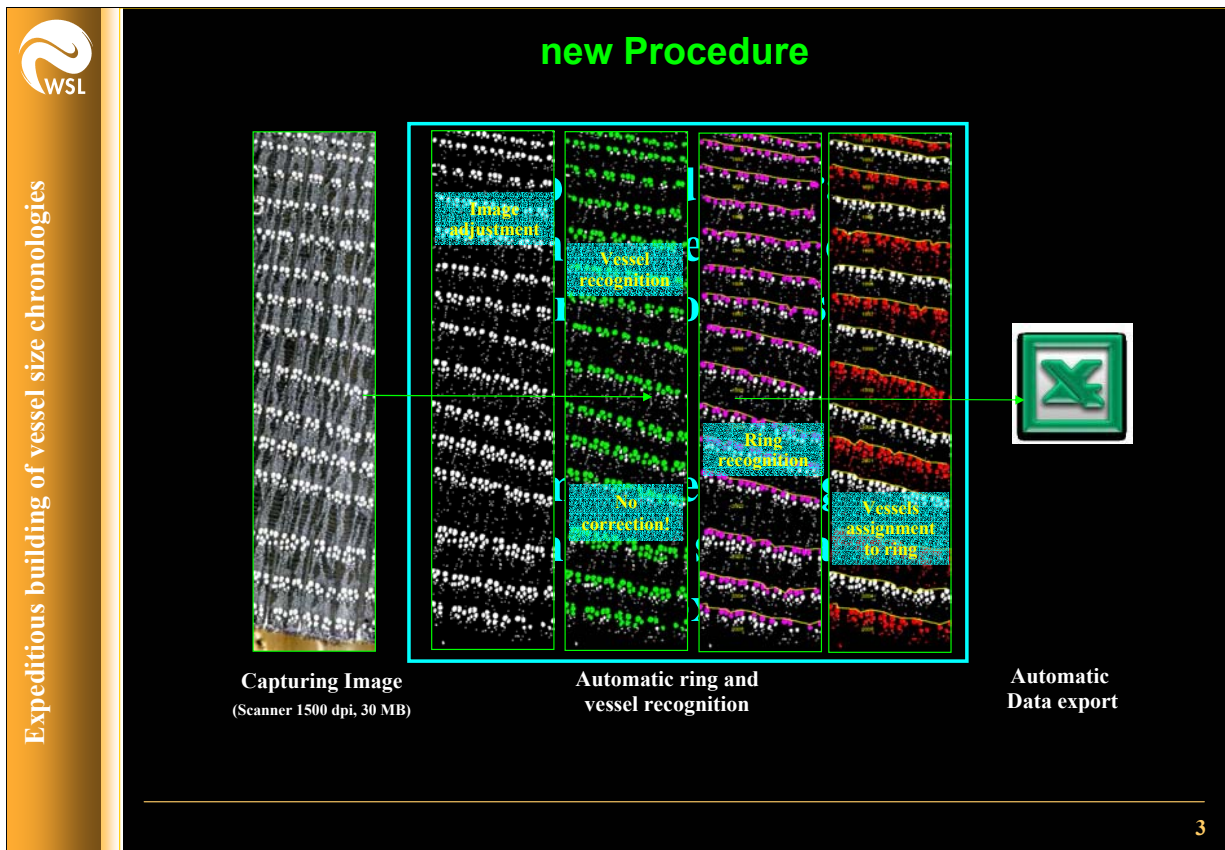
P. Fonti<sup>1</sup>, B. Eilmann<sup>1</sup>, I. Garcia-Gonzalez<sup>2</sup>, G. von Arx<sup>3</sup>

1 WSL, Birmensdorf, Switzerland.  
2 University Santiago de Compostela, Spain  
3 LTRR, USA

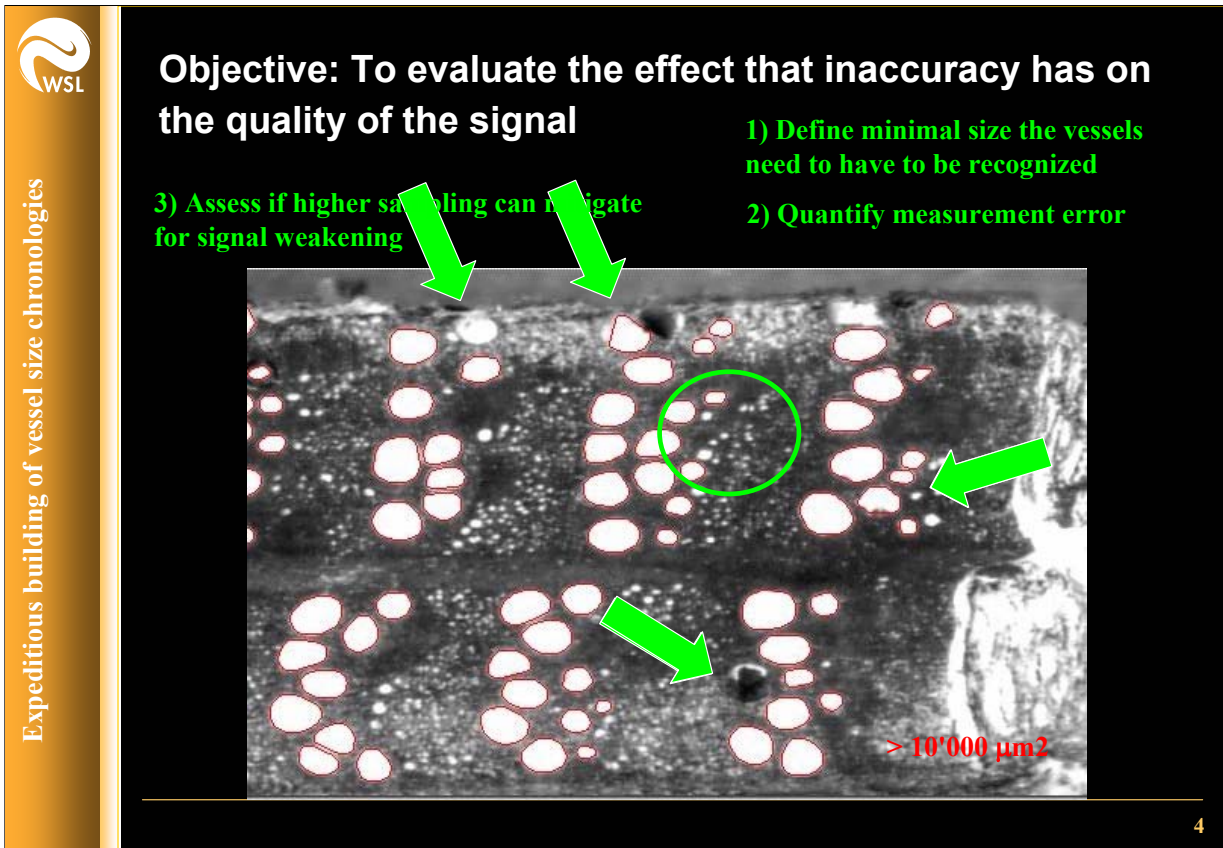
---

2

Exactly this question, precision versus efficiency in measurement, is the topic of this presentation. This is a pure methodological study that I've performed together with Britta, Ignacio and Georg.



This question, precision versus efficiency in measurement, has become relevant since we developed a new procedure for a rapid and automatic measurement of the earlywood vessels of ring porous wood species. This is possible thanks to an improved image analysis device that we called "ROXAS". This procedure consists in measuring vessels directly from digital scan images of previously prepared wood core surfaces. Roxas can then adjust the images, recognize the vessels and then recognize the rings based on vessels distribution and finally assign the vessel measurement to the correspondent rings. All this data are then stored in an output file. This procedure is very efficient since it allows to measure a whole core in a short time, but it also entails some inaccuracy.




But of course, there are also some disadvantages. This images shows how Roxas recognize the vessels and we can see that the software does not work really properly. There are some vessels that are not recognized or only recognized. So, the main objective of our study was to evaluate how much these inaccuracies can affect the the quality of the ecological signal we are looking for.

In particular we wanted:

To define the minimal vessel size that the vessels need to have in order to be consistently recognized

To quantify the measurement error, and

To asses if a larger sampling that we can get thanks to the faster measurement can compenassate for the signal weakening that we iduce by the more approximative measurement



Expedition building of vessel size chronologies

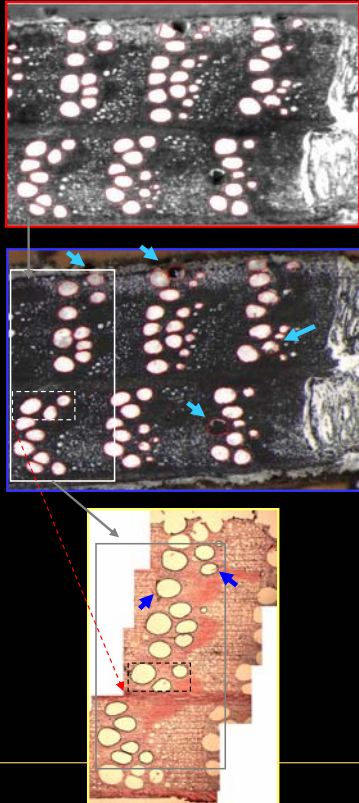
## Method

MVA (>1000  $\mu\text{m}^2$ )  
 period 1956-2006  
 2 cores of sessile oak  
 (*Quercus petraea*)

**SCANNER**  
 2,000 dpi

**STEREO**  
 12.5× objective  
 9,100 dpi

**MICRO**  
 40× objective  
 29,900 dpi



**Auto**

**Auto**

**Manual**

**Manual**

5

What we did was to measure the mean vessel area considering all the vessels larger than 1000  $\mu\text{m}^2$  for every ring from 56 to 06 of two oak. These measurement have been performed 3 times by using three different procedures. The first procedures that we called SCANNER is the one I just explained before.

Then we measured exactly the same vessels on the same core, but this time using images of the core surface captured with a stereo microscope with a 12.5 time magnification. These measurement have been performed ring by ring and twice: once purely automatically, which means we just let the software decide what is a vessel or not, and then we measured the same but this time performing manual correction when the software was misrecognizing the vessels.

The third procedure was our reference. Here the vessels were measured very precisely by using images of thin section captured with a microscope with a 40 time magnification. The measurement obtained were than used to compare the precision in measurement between the procedures.

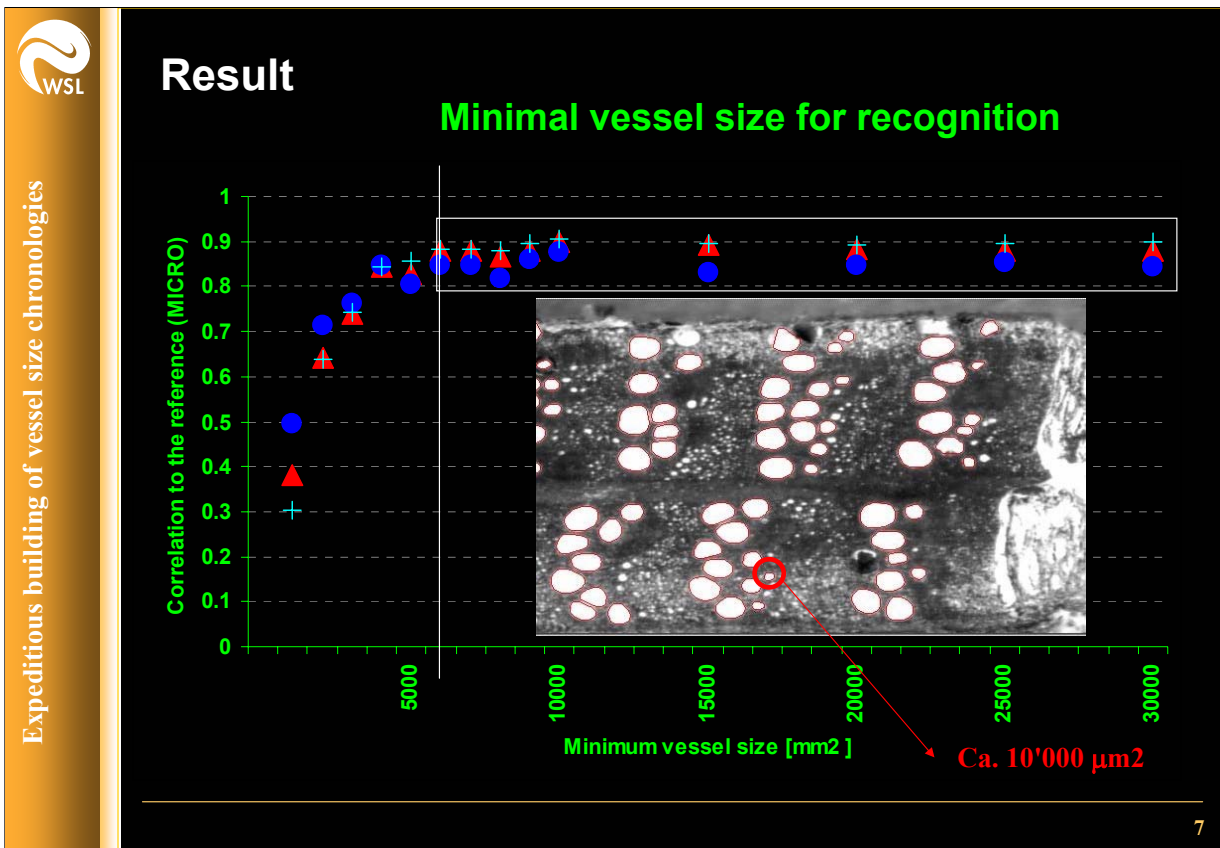
**Result**

**Time effort for 1 core with 50 rings**

	Procedures	Fast		Reference	
		SCANNER	STEREO		MICRO
<b>Preparation</b>	Processes time	sanding, cleaning, dying black and chalk filling 20'			piecing, thin-sectioning, staining and fixing 8 h
<b>Images acquisition</b>	# images magnification resolution disk space time	1 for the whole core 1x 2,000 dpi 6-8 MB 10'	1 per ring 12.5x 9,100 dpi 350 MB 50'		1 to 8 per ring 40x 29,900 dpi 500 MB 6 h
<b>Measurement</b>	Step unit Mode time	whole core Automatic 20'	ring by ring Automatic 1h	ring by ring with manual correction 2h	ring by ring with manual correction 6h
	<b>Total time</b>	50'	2h 10'	3h 10'	20h

6

The first result a would like to show you is about the time we need for the measurement of 1 core with 50 rings. If we consider all the processes from the preparation of the wood core surface, to the images acquisition, to the measurement of these vessels on the images, we can see that there is a large difference between the procedures. So, if we need something like 50 minutes to measure 1 core with the SCANNER, we need 2 to 4 time the same amount if we do the same measurement with the STEREO, and if we want to have a very accurate measurement of thin section than we need to calculate 24 time this amount.

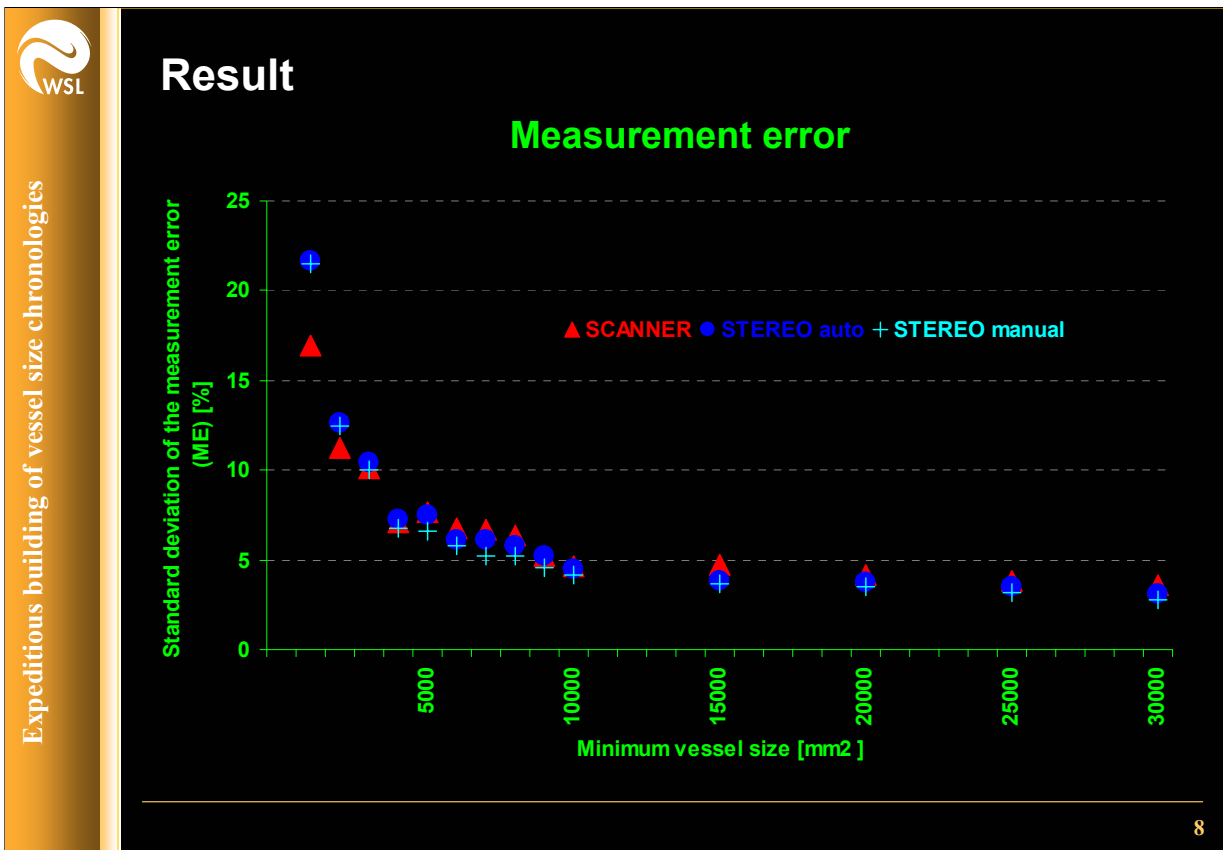


Another results I wanted to show you is related to the size that the vessels have to have in order to be consistently recognized by the new procedures.

What we did here it was to correlate the MVA series measured with the very precise procedure based on the thin micro-section with that of the other fast procedures. Calculation of correlation have been repeated by progressively increasing the minimal size of recognizable vessel from 1000 to 30'000.

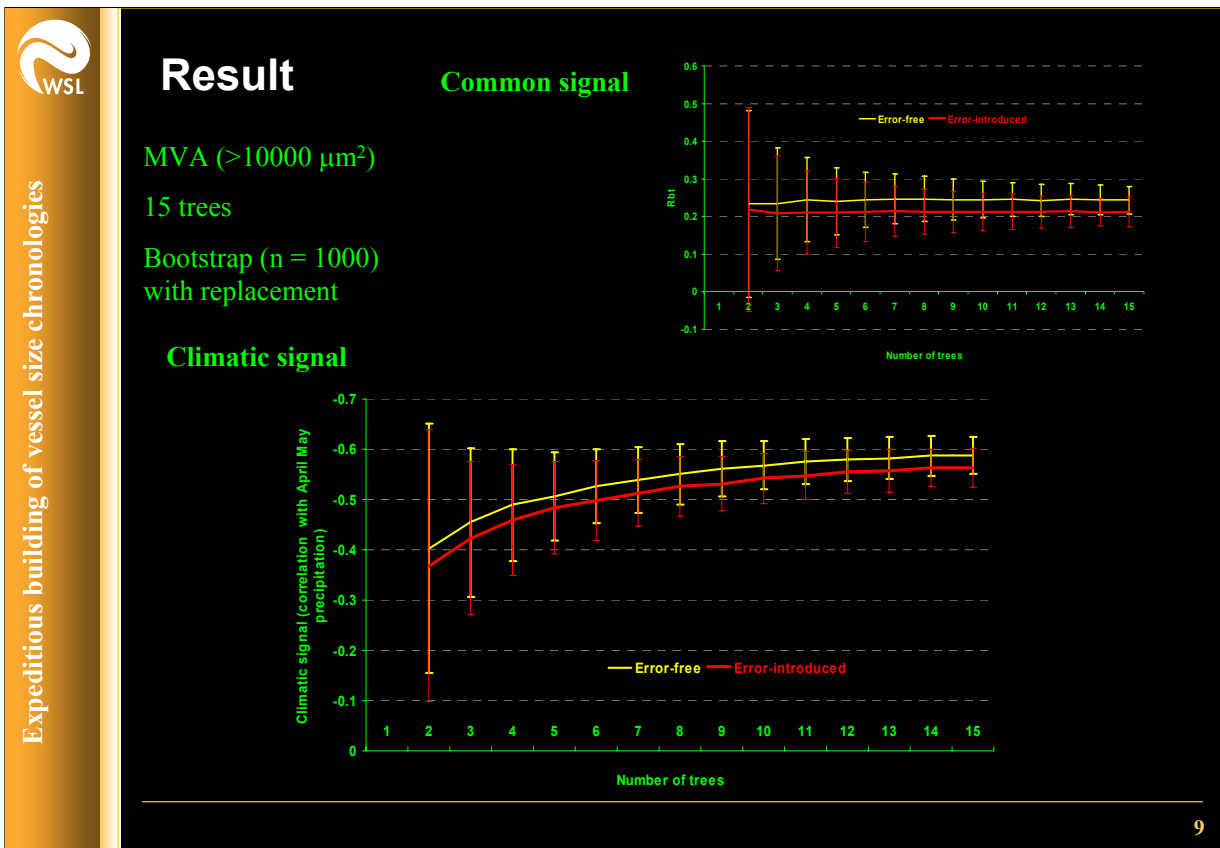
So for example this point correspond to the correlation between MICRO and SCANNER MVA-series when only vessel larger than 10000 are considered. When correlation stabilizes at higher values, this means that the similarities between both measurement procedures can not further be improved, even if only larger vessels are considered. In this specific case this means that correlation stabilizes when only vessels larger than 6000 are considered. This 6000 therefore correspond to the lower limit for an consistent vessel recognition.

Another interesting results that we can see in this graph is that up to this value of 6000 all procedures show quite high correlation to the reference and that a manual correction only slightly improve the correlation. So it does seems to be very important to perform these corrections.



Here I wanted to show you some results about the Measurement error. What we can see here is the variation of measurement inaccuracy by progressively increasing the minimal vessel size.

The measurement error is quantified for each single MVA values as the percentage differences with the references. Since the error varies around 0, here are only shown the standard deviation of this error. In other words this point indicate that if only vessels larger than 10000 are considered, 66% of the MVA values measured with SCANNER shown less than 5% difference that MVA of the reference. Here again we can therefore see that if we want to include very small vessels into the measurement than we are doing a bad job, since we have a very large measurement error. This error stabilize to lower values when only vessels larger than 9000-10000 mm<sup>2</sup> are considered.



The last results I want to show you is the most interesting one but also the most difficult to explain. This results contemporaneously show the loss in signal information due to measurement inaccuracy but also the gain that we can get if we increase sample size.


As indicators for signal information we considered two parameters, the common signal (i.e., the correlation between MVA-time series) and the climatic signal, which for this specific case is the correlation with April and may precipitation.

For this we measured the MVA on 15 trees, with the scanner procedure. Only vessels larger than 10'000 are considered into the calculation. Then, using a bootstrap procedure with 1000 repetition to randomly select the trees, we calculated the average and variation in common and climatic signal. This has been performed repeatedly by progressively increasing the number of trees considered into the calculation of the chronology.

Then we repeated exactly the same, but this time by adding in the measurements of MVA the measurement error we have calculated before.

The results are shown in these graphs. So what we can observe is:

- That increasing the number of trees does not improve RBT but it improve the climatic signal
- That in general the chronology calculated with the additional introduced measurement error weaken the signal, but only slightly
- That the lost in the common signal can be easily compensated by increasing the sample size.



Expeditious building of vessel size chronologies

## Take-home message

- Measurement can be (relatively) fast
- Above a vessel size threshold measurement is accurate
- Manual correction not strictly necessary
- Increased sample size improve strength and confidence in signal compensating weakening due to inaccuracy

10

So, in order to conclude. In this presentation we have seen that:

- It is nowadays possible to have method for a rapid and efficient measurement of earlywood vessels in ring-porous species
- Above a vessel size threshold the measurement are sufficiently accurate
- And it is not strictly necessary to perform manual corrections.
- Finally we have proved that an increased sample size that we can have thanks the more efficient way of measurement, we can improve the strength and the confidence in the signal and thus we can easily compensate for the weakening induced by the measurement inaccuracy.