Waves propagation as a tool to ranking structural quality of *Eucalyptus globulus* Labill. beams

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Eucalyptus globulus Labill.

- Eucalyptus globulus, cover around 700.000 ha in Spain located in Galicia, Asturias, Cantabria and Huelva.
- Although the current main use is to obtain pulp and fiber boards, its mechanical properties provide great potential for structural applications.
- Spanish standard visual grading assigned Strength grade D40 (EN1912) for small dimensions

Context

- Timber for structural applications requires grading

- Strength, stiffness and density properties need to be know for the structures design.

- Methods for the strength grading of the timber are necessary to be associated with the Visual grading

  - based on bending principle or other principles such as ultrasound, vibration, radiation, or combination of these principles

Context

- There are a lot of techniques and equipments proposed to be applied with this objective (grading) and it is important to know if the results are equivalent or correlated.

Objective

To compare the results of different nondestructive equipments, based on the wave propagation, as a tool to ranking structural quality of *Eucalyptus globulus* Labill. beams .

Material

The tests were performed on 50 beams in green conditions (68% moisture content) with 100 mm width, 150 mm high and 3000 mm length. The tests were performed in in green conditions.

three longitudinal points on transversal sections for each beam

Grading tools

- **Ultrasound**
  - Sylvatest (CBT, Swiss)
  - USLab (AGRICEF, Brazil)
- **Stress wave**
  - Microsecond Timer (Fakopp, Hungary)
  - Electronic-Hammer (Instrument Mechanic Labor GmbH, German)
- **Resonance**
  - HM200 (Fibre-Gen, New Zealand).

Ultrasound tools

Sylvatest (CBT, Swiss)

USLab (AGRICEF, Brazil)

Stress wave tools

Electronic-Hammer (Instrumenta Mechanic Labor GmbH, German)

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Resonance tool

HM200 (Fibre-Gen, New Zealand).

Bending test

Non destructive bending test

Destructive bending test

50 beams

MOE

5 beams (representing velocity variability)

MOR

Summary Statistics Velocities

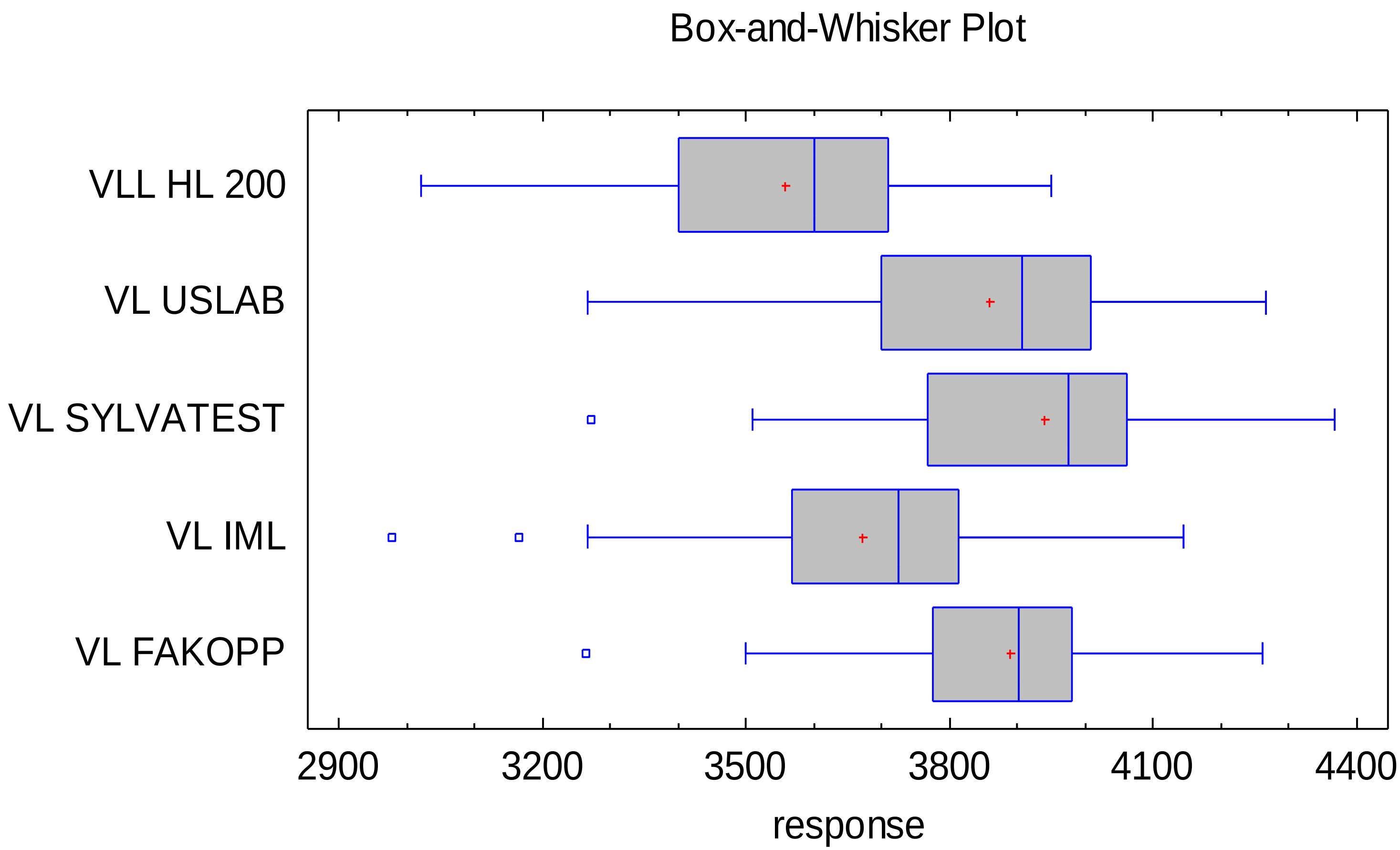
	Average m.s^{-1}	*CV %*	*Minimum m.s^{-1}*	*Maximum m.s^{-1}*	*skewness*	*kurtosis*
HM 200	3558	6,18	3020	3950	-1,31	-0,53
USLAB	3858	6,01	3268	4267	-1,48	-0,33
SYLVATEST	3939	5,96	3273	4369	-1,34	0,23
IML	3671	6,68	2977	4146	-1,60	0,58
FAKOPP	3888	5,15	3264	4262	-1,38	1,36

Summary Statistics MOE and Green Density

MOE (MPa)	
Average	13022
CV (%)	11.9
Minimum	7990
Maximum	15780
Stnd. skewness	-2,33
Stnd. kurtosis	1,98

Green density (kg.m^{-3})	
Average	1093
CV (%)	6.73
Minimum	926
Maximum	1226
Stnd. skewness	-0,05
Stnd. kurtosis	-1,08

Velocities in different tools



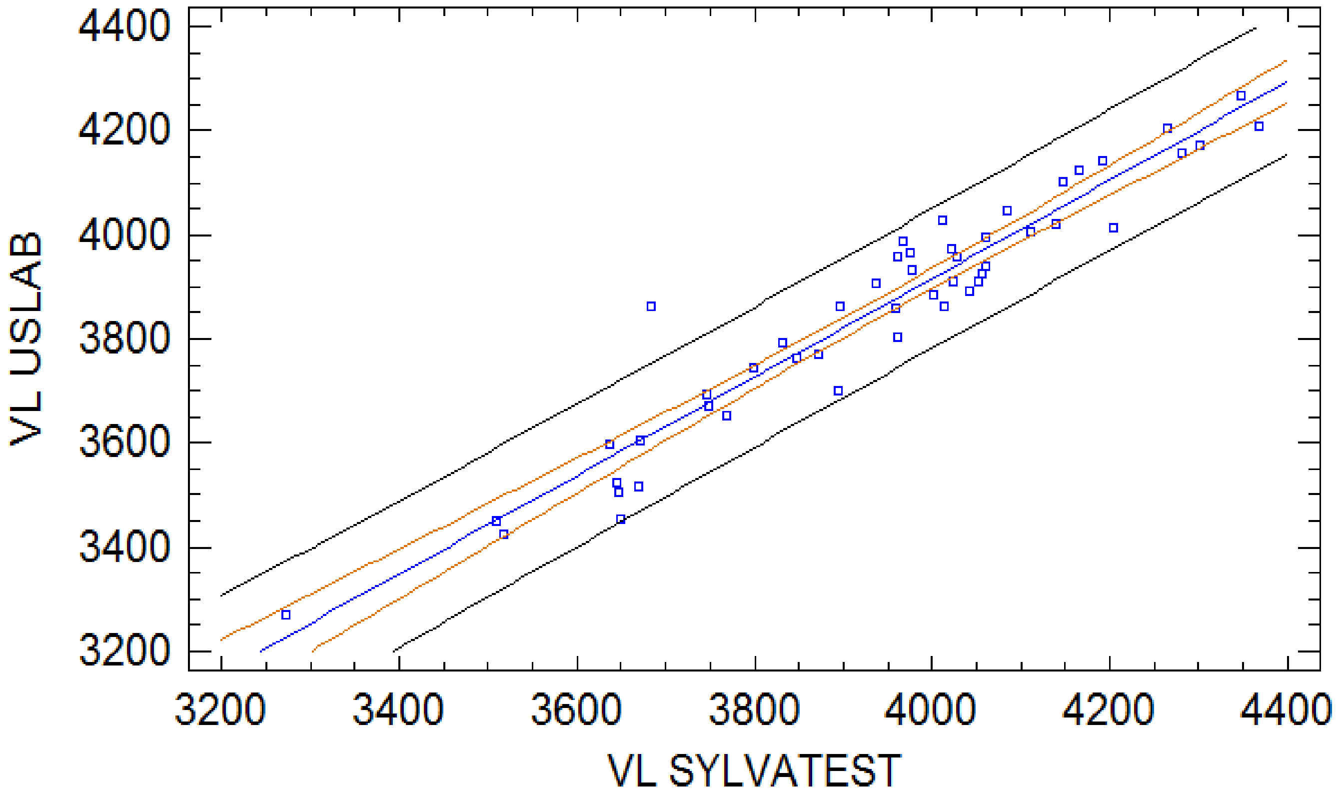
Method: 95,0 percent LSD

Velocity comparison

Tool	*Mean*	*Homogeneous Groups*		
HM 200	3558	X		
IML	3671		X	
USLAB	3858			X
FAKOPP	3888			X
SYLVATEST	3939			X

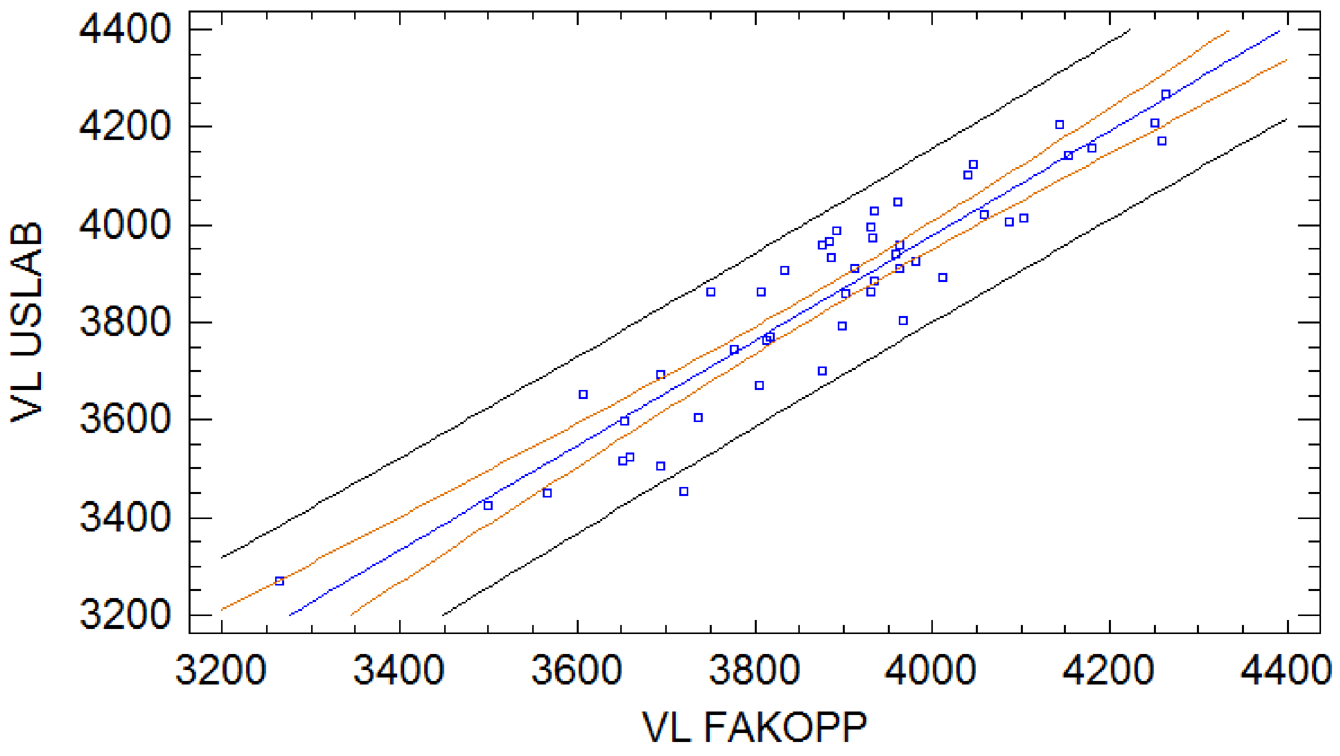
Velocity Correlations

VL USLAB = 126,7 + 0,95*VL SYLVATEST
R = 0,96
R^2 = 92%



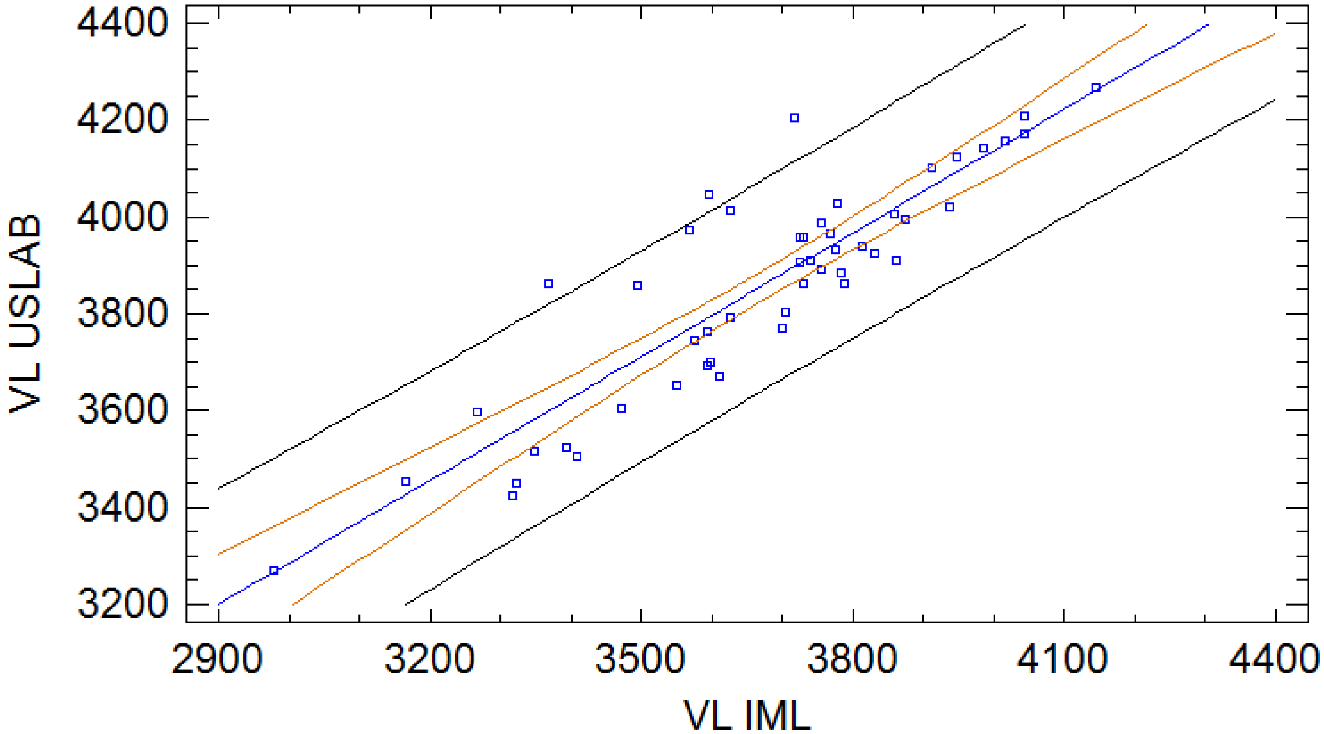
Velocity Correlations

VL USLAB = -320,1 + 1,07*VL FAKOPP
R = 0,93
R^2 = 86%



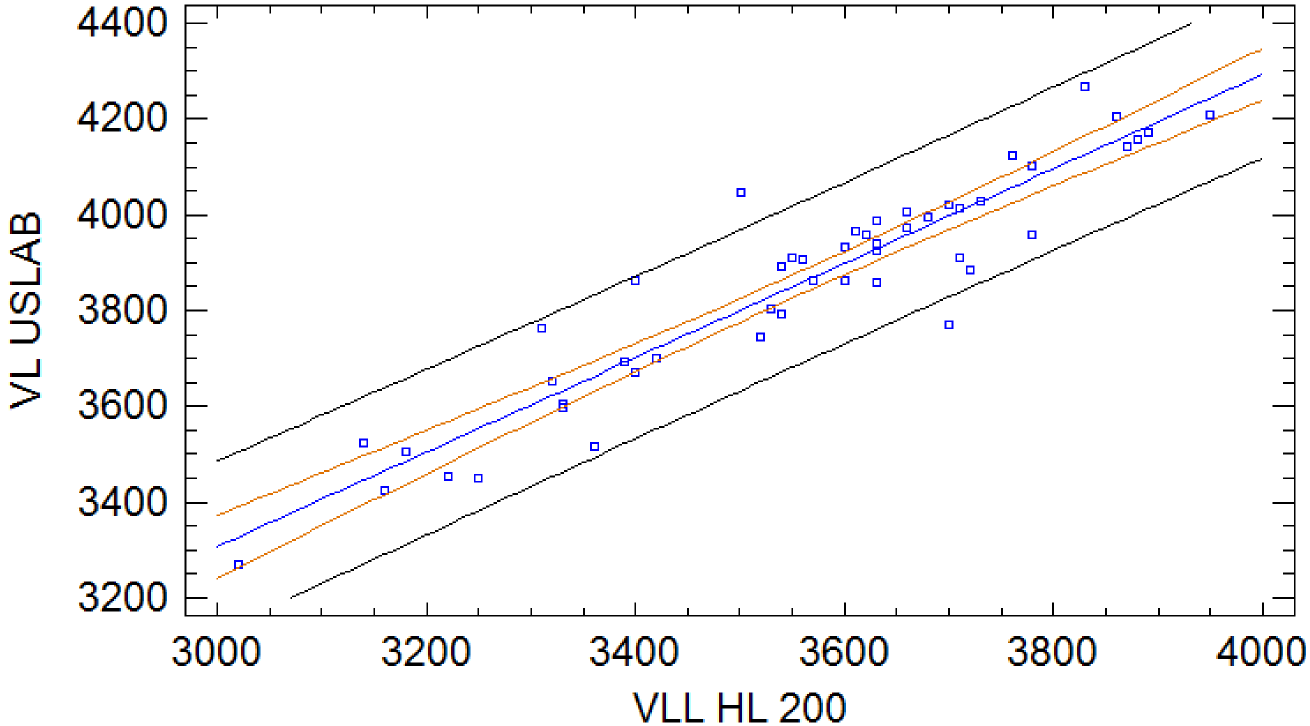
Velocity Correlations

VL USLAB = 727 + 0,85*VL IML
R = 0.89
R^2 = 79%



Velocity Correlations

VL USLAB = 346 + 0,99*VLL HM 200
R = 0,94
R^2 = 87%



Prediction of the MOE from the velocity

Device	Model	P-Value	R	R^2 (%)	Standard error
USLab (2^+)	MoE static = -8113+ 4,74*Vel USLab	0,000	0,80	65,1	945
Sylvatest (2^+)	MoE static = -9204,73 + 5,62*Vel Sylvatest	0,000	0,84	70,9	862
HM200 (2^+)	MoE static = -7871+ 5,84*Vel Hitman	0,000	0,82	67,2	915
IML (2^+)	MoE static = -5219 + 4,94*Vel IML	0,000	0,76	58,1	1035
Fakopp (2^+)	MoE static = -13021 +6,6*Vel Fakopp	0,000	0,85	72,7	834

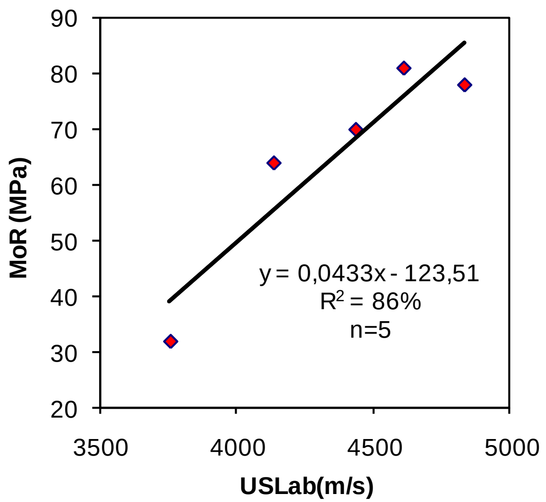
Comparison of stiffness coefficient (CLL= ρV^2) and static MOE

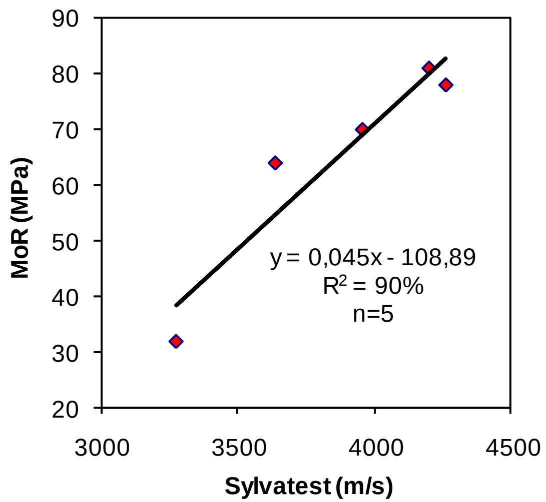
	MOE	CLL USLAB	CLL Sylvatest	CLL HM200	CLL IML	CLL Fakopp
Average MPa	12955	16286	16979	13863	14893	16542
CV (%)	12,9	11,8	12,2	12,1	13,3	11,6
Difference (%)	-	25,7	31,1	7,0	15,0	27.7

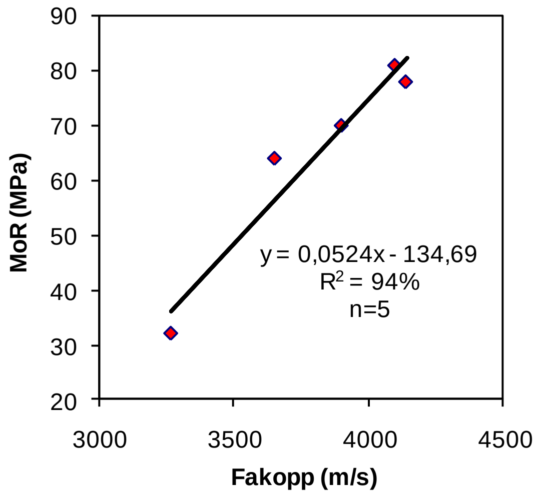
Prediction of the MOE from the CLL (stiffness coefficient)

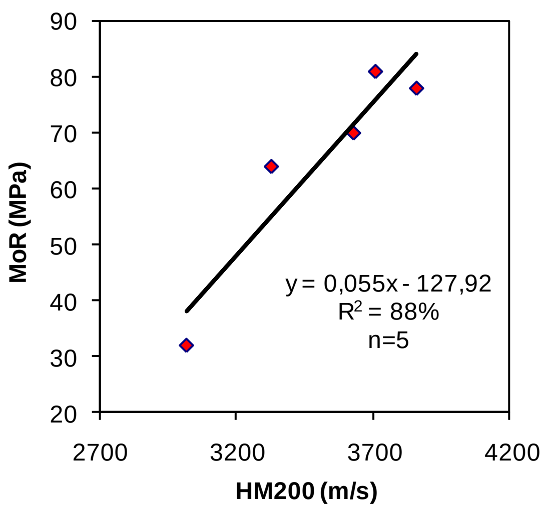
Device	Model	P-Value	R	R^2 (%)	Standard error of estimation
USLab (2)+	MoE static = 1724 + 0,51*CLL	0,000	0,85	72,9	636
Sylvatest (2)+	MoE static = 2209 + 0,62*CLL	0,000	0,84	71,1	778
HM200 (2)+	MoE static = 1776 + 0,80*CLL	0,000	0,87	75,7	607
IML (2)++	MoE static = 3245 + 0,64*CLL	0,000	0,83	68,5	890
Fakopp -1	MoE static = 2639 + 0,61*CLL	0,000	0,77	60,4	998
Density (1)***	MoE static = 9350+2,73*Density	0,339 (ns)	0,14	2,1	1325

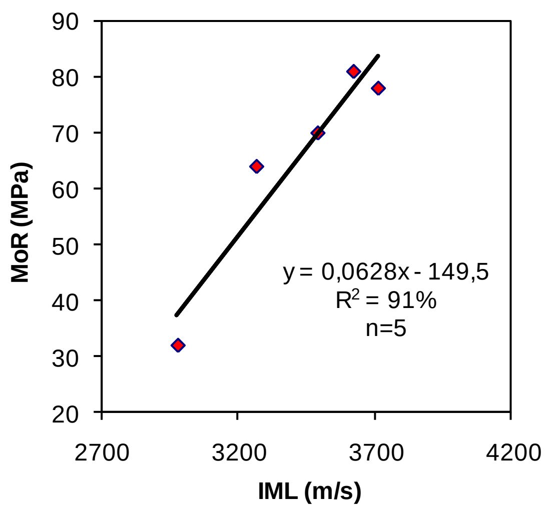
Correlation between MOR and wave velocity



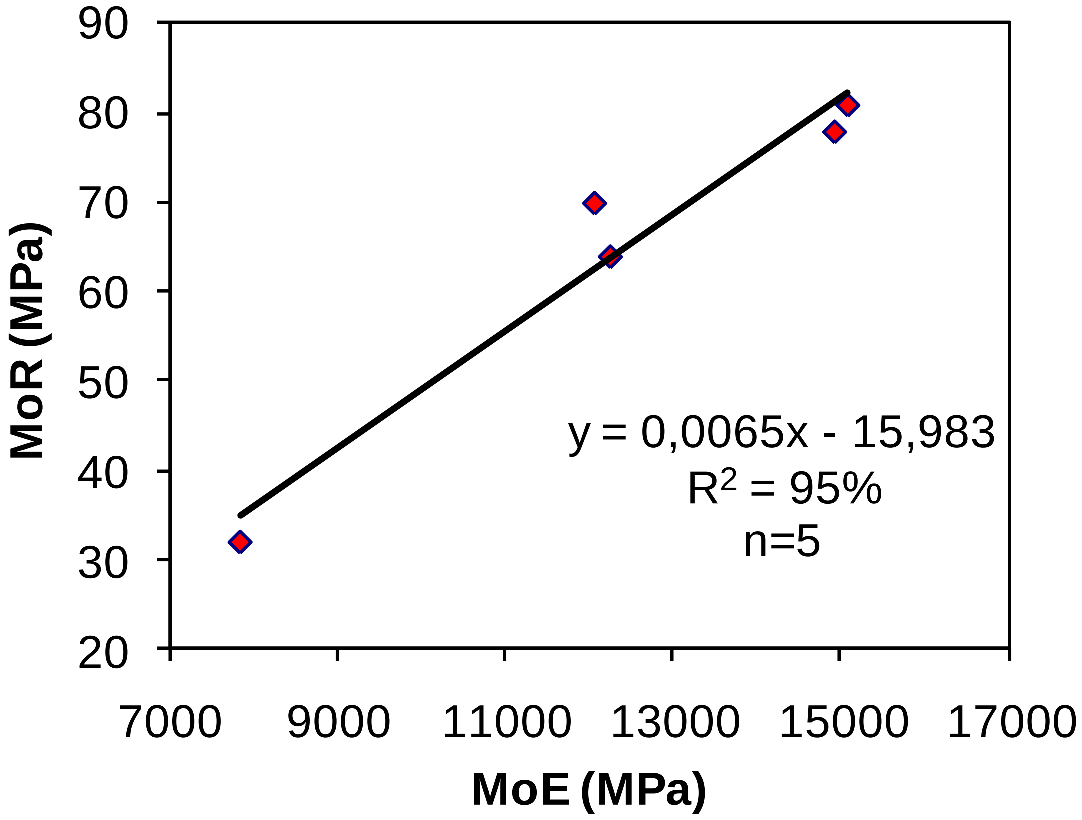




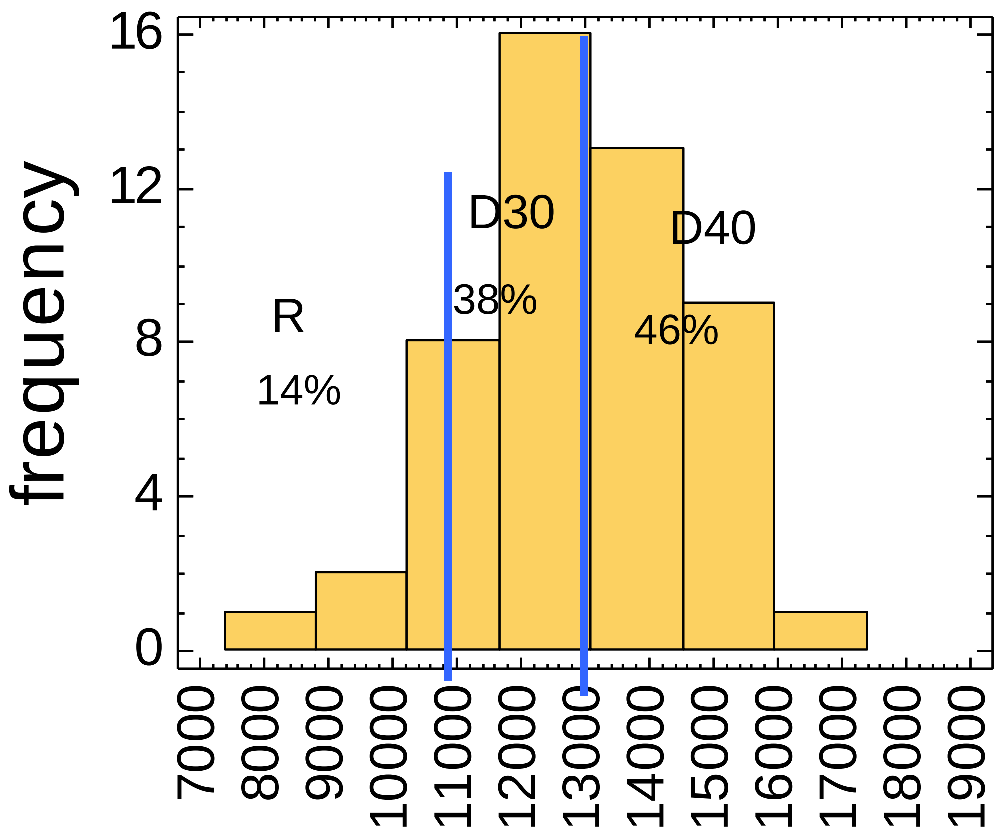




Correlation between Stiffness and Strength



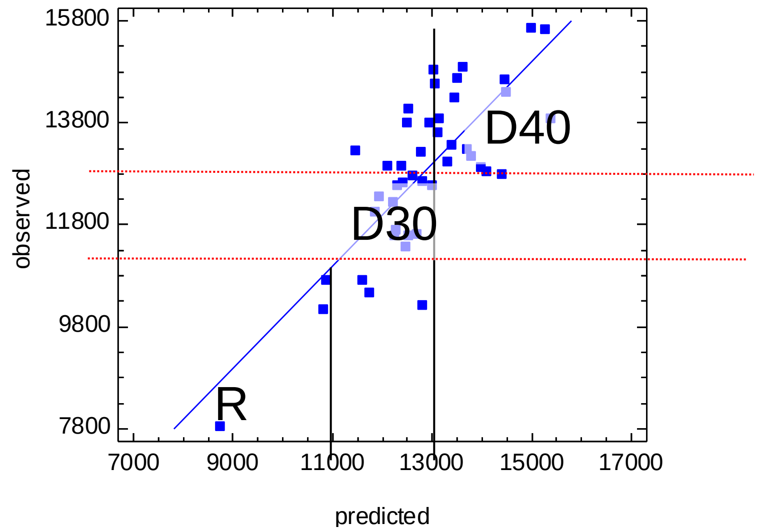
Potential strength class eucalyptus large section, acording stiffness



Strength grade according Stiffness to EN 338 and considering strenght>30 N/m2

Two potential strengh class will be proposed

Acoustic grading accuracy



MoE predicted

	USLab			Sylvatest			HM200			IML			Fakopp		
	R	**D 30**	**D 40**	**R**	**D 30**	**D 40**	**R**	**D 30**	**D 40**	**R**	**D 30**	**D 40**	**R**	**D 30**	**D 40**
Total	3	25	19	2	24	21	4	24	19	3	22	22	4	27	19
Ungraded	0	8 32%	0	0	6 25%	-	0	7 29%	-	2 66%	5 23%	-	1 25%	9 33%	-
Upgraded	-	3 12%	5 26%	0	4 16%	5 24%	-	2 8%	4 21%	-	5 23%	5 23%	-	3 11%	4 21%

Conclusions

- The velocities obtained with each tool are, in some cases, significantly different but they are all highly correlated.
- The predictive power of the modulus of elasticity with different sonic method is high and similar in all tools.
- The prediction model are, in general, better using the stiffness coefficient.

Thanks you!