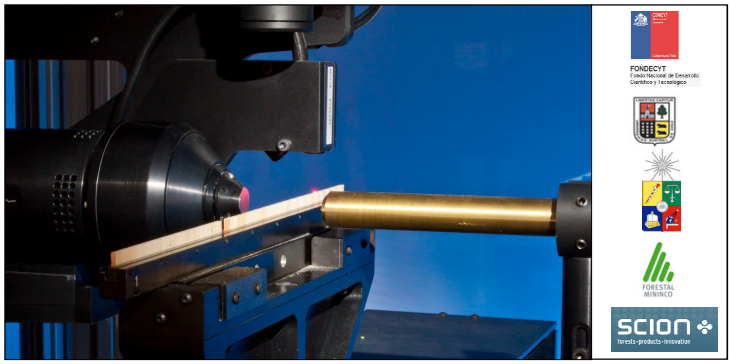
Wood properties of *Pinus radiata* D. Don trees growing on three contrasting sites in Chile

Alonso Barrios and Guillermo Trincado

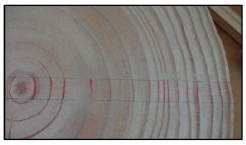


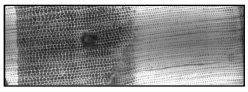
Valdivia, 5th November 2015.

Why to study wood and fiber properties?

- Knowledge about wood and fiber properties is a prerequisite for the proper utilization of forest resources.
- The variability of the forest resource has a high impact on the final result of the industrial production process.
- Consequently, some inefficiencies might occur in the transformation process of the raw material to end products.

Level of variation in wood properties





- Between-site variation (environmental variation).
- Between-tree variation (genetic variation).
- Within-tree variation (radial and longitudinal).
- Within-growth ring variation (seasonal variation).

Past Research at Regional Level

- **Delmastro, R., Diaz-Vaz, J.E., and Schlatter, J.E.** "Variability of inherited technological characteristics of *Pinus radiata* (D. Don)" (**1980 – 1981**). CONAF/PNUD/FAO.
- **Meneses, M.** "Determining site, silvicultural and genetic factors that affect the wood quality of radiata pine and development of analytical and operational tools for stand classification and logs segregation aimed to increase the yield of structural quality lumber and appearance wood products" (**2004 – 2007**). FONDEF D03I1128.
- **Meneses, M.** "Systematization of knowledge for the construction of a decision tool for supporting the increase of value recovery from radiata pine plantations during its transformation into end products" (**2007 – 2010**). FONDEF D06I1010.

Current Research at UACh

Financial Support from the National Fund for the Scientific & Technological Development (FONDECYT):

- "Evaluating and modeling the impact of environmental conditions on radiata pine wood and fiber properties" (**2012-2014**). Budget: M$ 83.8
- "Modeling at the regional scale the impact of climate change on juvenile wood properties for radiata pine" (**2015-2017**). Budget: M$ 135.5

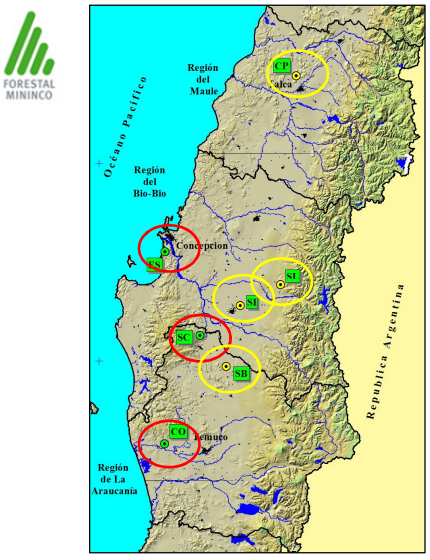
Study Sites : First Project (2012-2014)

Trials were established in 1995:

- Escuadrón (ES)
- Santa Lucía (SL)
- Santa Isabel (SI)
- Santa Candelaria (SC)
- Santa Balbina (SB)
- Copihual (CO)
- Capellanía (CP)

All sites were planted with the same spacing (3.5m x 2.0m) and same genetic stock.

Destructive tree measurements were made at the age of 17 years old (2012).



Management Conditions

General Objective

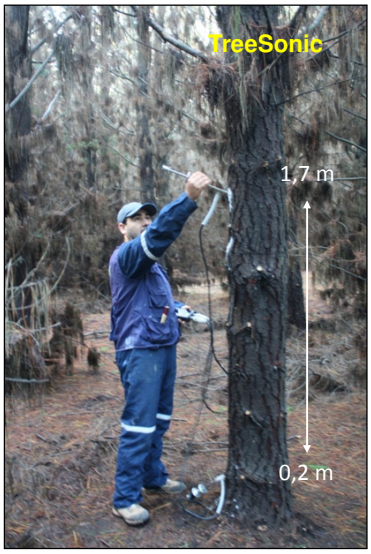
To bring out with unexisting empirical knowledge for radiata pine plantations “growing in Chile” on the effects of environmental conditions (site) on wood formation, and fibre and wood properties.

Data

In each trial, measurements and destructive sampling at tree, log, disc and growth ring levels were made.

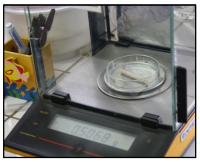
1. Measurement of basic density (5mm cores) and stiffness on standing trees.
2. Measurement of stem profiles.
3. Measurement of stiffness in logs (3 m length).
4. Sampling of discs at DBH and along the stem (every 3 m).
5. Green density measurement in discs.
6. Measurement of wood properties in growth rings (SilviScan 3).

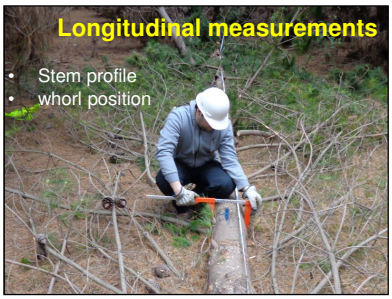
Tree-level measurements

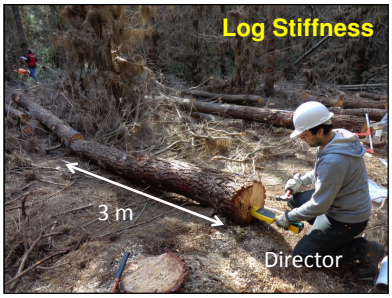


Cores

Basic density

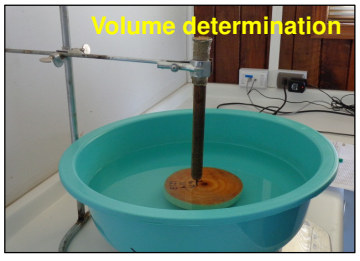






Disc sampling

Green and Basic Density



Preparation of wood samples for SilviScan

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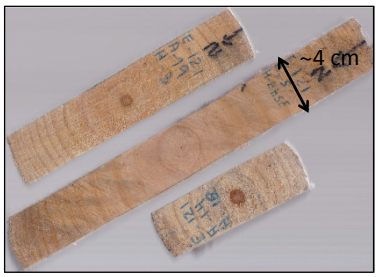
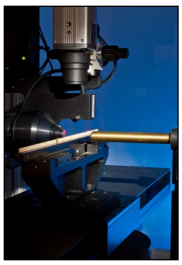
PAPRICAN





First Study

Wood properties of *Pinus radiata* D. Don trees growing on three contrasting sites in Chile

Goals

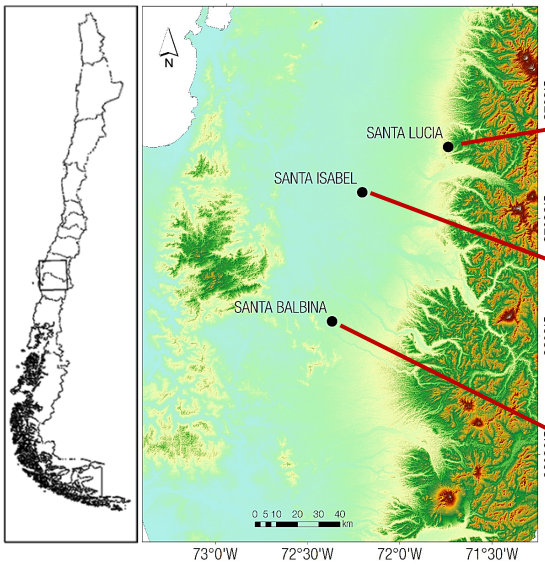
(i) to quantify between site differences in wood properties for juvenile and mature wood.

(ii) to investigate the pith-to-bark variation for wood properties.

(iii) to quantify relationships between wood properties.

(iv) to evaluate between-site differences in wood properties for earlywood and latewood.

Study sites



TUCAPEL
Altitude 716 m asl
P = 1641 mm
T = 11.0°C
SI = 34.8
Volcanic ash

LOS ANGELES
Altitude 184 m asl
P = 1001 mm
T = 13.1°C
SI = 34.2
Wet sands

COLLIPULLI
Altitude 283 m asl
P = 1262 mm
T = 12.7°C
SI = 31.4
Red clay

Soil Types

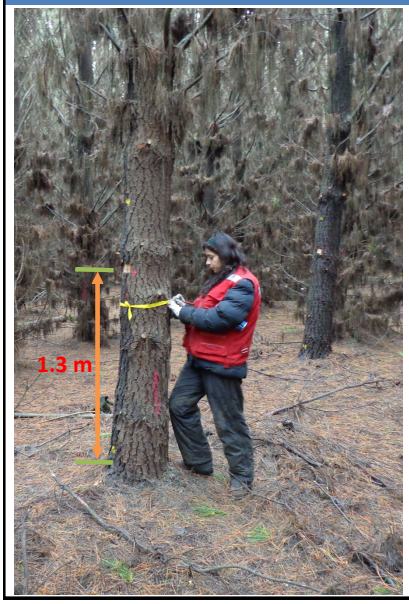
Laboratorio de Nutrición y Suelos Forestales

Santa Lucía (volcanic ash)
Water holding capacity
263 mm m^{-3}

Santa Balbina (red clay)
Water holding capacity
136 mm m^{-3}

Santa Isabel (wet sands)
Water holding capacity
104 mm m^{-3}

Sampling Procedure



- 20 sample trees were selected at each site.
- Tree Measurements.
  DBH (cm)
  TH (m)
- For each tree a 30 mm disk at DBH was sampled for studying wood properties.

Radial wood sample preparation

Extraction and drying with 100% ethanol

Extraction with acetone

Radial strip for SilviScan (2 x 7 mm)

SilviScan®-3 Measurements

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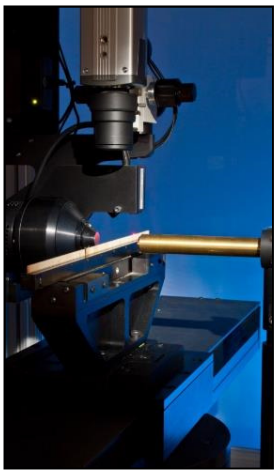
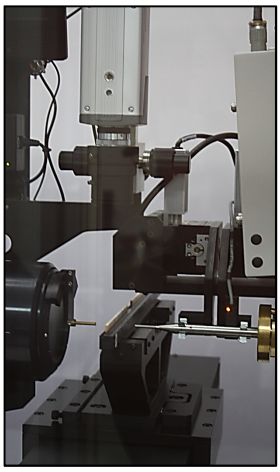
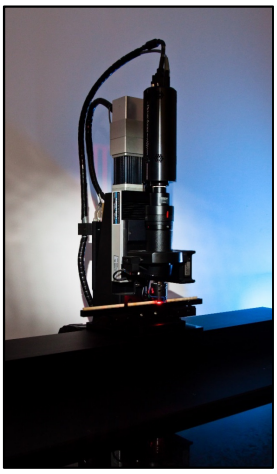


Densitometer (resolution 25 µm)

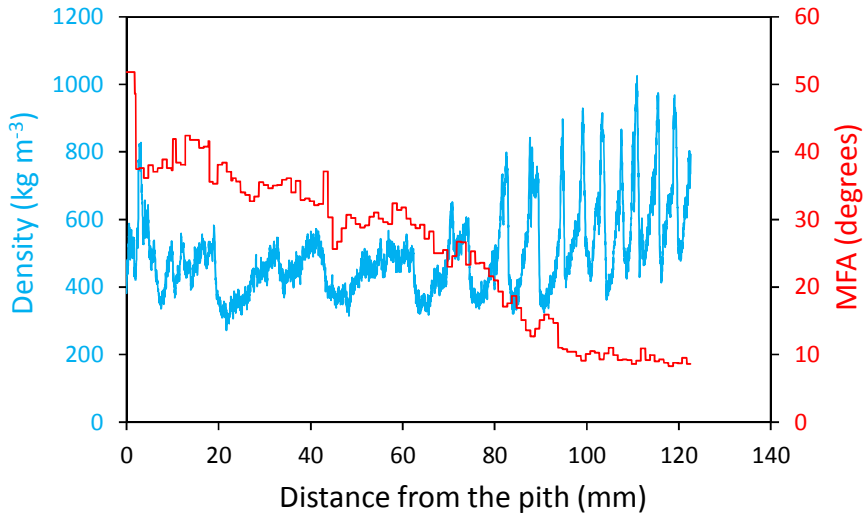


Diffractometer (resolution 1 mm)

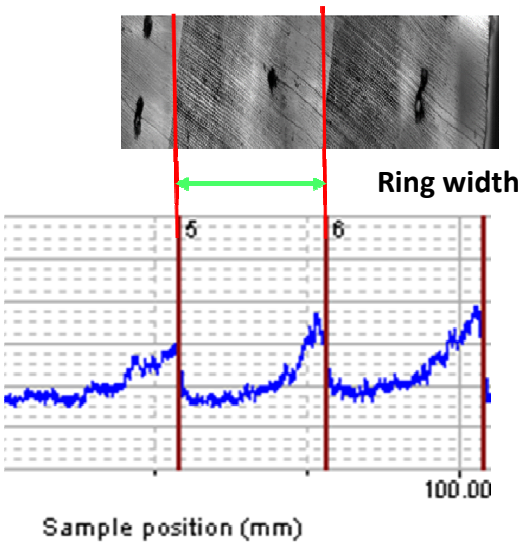


Cell scanner (resolution 25 µm)

Ring-level measurements (SilviScan)



Growth rings demarcation



Target Variables

- ✓ Ring width (RW)
- ✓ Basic density (WD)
- ✓ Modulus of elasticity (MOE)
- ✓ Microfibril angle (MFA)
- ✓ Cell wall thickness (CWT)
- ✓ Latewood proportion (LWP)

Between-site comparisons

Analysis of variance by juvenile and mature wood

$$Y_{ij} = u + S_i + e_{ij}$$

For between-site comparisons we considered:

- Juvenile wood: **3-10 growth rings**
- Mature wood: **11-17 growth rings**

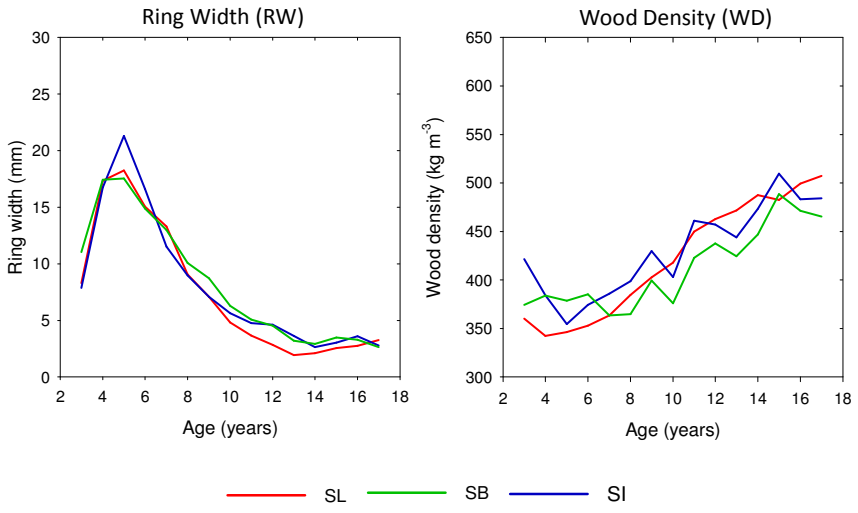
Values of tree-level wood properties where obtained weighting by the area of the growth rings.

Between-site comparisons
Tree dimensions

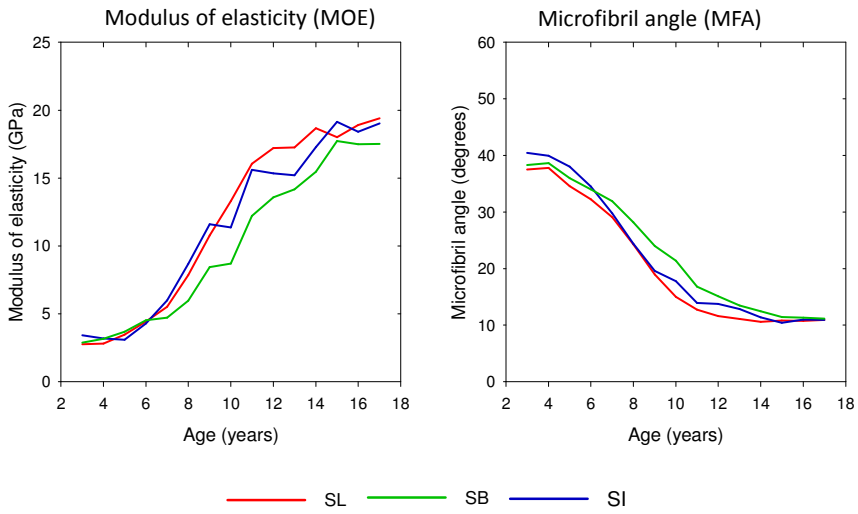
Variable	Site			
	F-value	SL	SB	SI
DBH (cm)	1.79^{ns}	26.7	29.0	26.9
TH (m)	3.02^{ns}	27.5	25.9	27.6
Stem slenderness (m m^{-1})	9.41^{***}	104.7^{a}	90.4^{b}	104.1^{a}

Note: Means followed by different letter are significant at $p < 0.05$. *** is significant at p=0.001, and ^{ns} is non-significant at p=0.05.

Mean Radial Profiles



Mean Radial Profiles



Mean Radial Profiles

Between-site comparisons:
Juvenile and mature wood properties

Wood property	Juvenile wood				Mature wood			
	F-value	SL	SB	SI	*F*-value	SL	SB	SI
RW (mm)	1.25^{ns}	13.4	12.8	13.6	1.28^{ns}	3.1	3.9	3.9
WD (kg m^{-3})	3.45^{*}	367.8^{b}	$378.8^{a,b}$	385.9^{a}	3.70^{*}	476.8^{a}	448.4^{b}	470.5^{a}
MOE (GPa)	3.61^{*}	$6.2^{a,b}$	5.6^{b}	6.5^{a}	4.65^{*}	17.6^{a}	15.1^{b}	16.8^{a}
MFA (degrees)	2.57^{ns}	28.2	30.6	29.6	2.42^{ns}	11.6	13.5	12.4
CWT (µm)	1.44^{ns}	2.4	2.4	2.5	1.63^{ns}	3.2	3.1	3.3
LWP (%)	14.93^{***}	19.0^{a}	14.2^{b}	21.2^{a}	53.56^{***}	37.6^{a}	20.5^{c}	25.8^{b}

Note: Means followed by different letter are significant at $p < 0.05$. *** is significant at p=0.001, * is significant at p=0.05 and ^{ns} is non-significant at p=0.05.

Correlations between wood properties

	Juvenile wood						Mature wood					
	RW	WD	MOE	MFA	CWT	LWP	RW	WD	MOE	MFA	CWT	LWP
RW	1	0.09^{ns}	–0.19^{ns}	0.21^{ns}	–0.09^{ns}	0.21^{ns}	1	–0.52***	–0.70***	0.68***	–0.28^{ns}	–0.37**
WD		1	0.37**	0.12^{ns}	0.81***	0.07^{ns}		1	0.90***	–0.67***	0.91***	0.43***
MOE			1	–0.81***	0.68***	0.20^{ns}			1	–0.90***	0.83***	0.52***
MFA				1	–0.26^{ns}	–0.07^{ns}				1	–0.68***	–0.49***
CWT					1	–0.06^{ns}					1	0.30^{ns}
LWP						1						1

Note: *** is significant at p=0.001, ** is significant at p=0.01 and ^{ns} is non-significant at p=0.05.

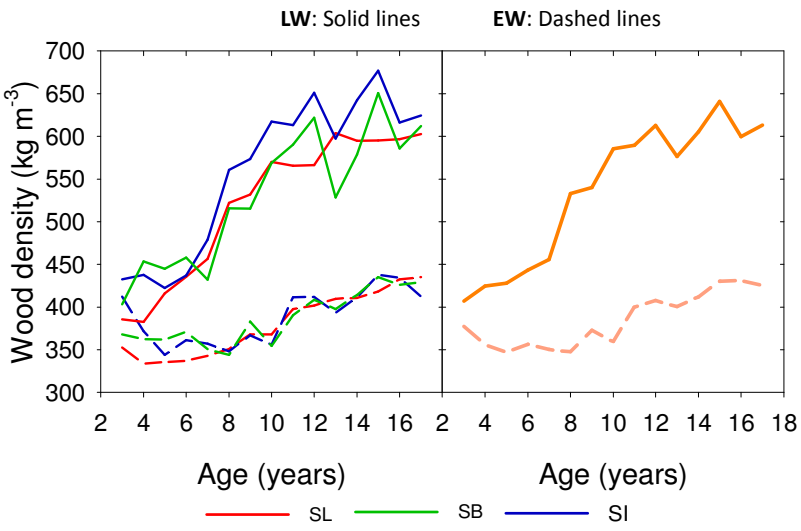
Between-site comparisons

Early-and latewood properties

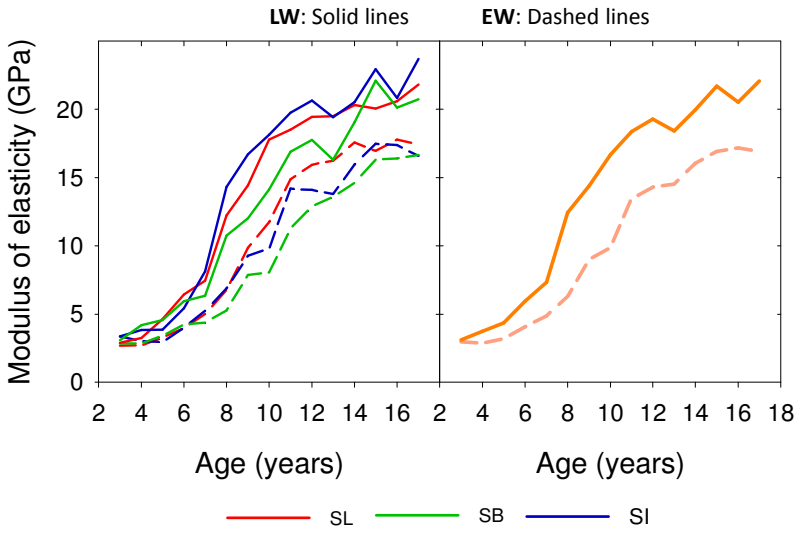
Wood property	Juvenile wood				Mature wood			
	F-value	SL	SB	SI	*F*-value	SL	SB	SI
WD (kg m^{-3})								
EW	3.61*	345.7^{b}	363.8^{a}	356.8^{a,b}	0.10^{ns}	410.8	412.9	415.8
LW	7.88***	475.2^{b}	487.2^{b}	510.7^{a}	8.21***	591.9^{b}	599.1^{b}	635.8^{a}
MOE (GPa)								
EW	0.59^{ns}	5.5	5.2	5.5	2.40^{ns}	16.1	14.1	15.2
LW	9.67***	9.4^{a}	7.9^{b}	10.5^{a}	5.11**	20.5^{a,b}	19.4^{b}	21.5^{a}

Note: Means followed by different letter are significant at $p < 0.05$. *** is significant at p=0.001, ** is significant at p=0.01, * is significant at p=0.05 and ^{ns} is non-significant at p=0.05.

Wood density (WD)
Radial profile early-and latewood



Modulus of elasticity (MOE)
Radial profile early-and latewood



Conclusions

- Although there were no differences between sites in growth rate, there were significant site differences in WD, MOE and LWP for juvenile and mature wood.
- We found that between-site differences in wood properties and correlations were more marked for mature wood in comparison to juvenile wood.
- Wood properties presented diverse pith-to-bark trends driven by tree age. WD, MOE, CWT and LWP showed an increasing and RW and MFA showed a decreasing pith-to-bark pattern.
- We found that RW was not related to any wood property for juvenile wood. However, RW showed a significant negative correlation with WD, MOE, and LWP and a significant positive correlation with MFA for mature wood. Consequently, high growth rates only had a negative impact on wood properties of mature wood.
- We found that between-site differences in WD, and MOE were higher in the latewood component for juvenile and mature wood. Our results suggest latewood to be more sensitive to site variations than earlywood.