Modeling for wood chemistry, stiffness, and disease resistance: an update

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Outline

- Introduction & Problem Identification
- Objectives
- Materials and Methods
- Results and Discussion
- Future Work
- Conclusions

Introduction

When Breeding for Chemistry and Disease, What about Stiffness?

Problem Identification

Forest Products

- Important for us to know the ***chemical composition*** and ***stiffness*** of these genetically superior families.
- Important to pick families that have a combination of good forest product and tree health characteristics.

Forest Health

- Pine Decline/Disease has been on the rise.
- There is a need to rapidly screen trees for disease resistance
- There is a need to identify genetic families with superior disease resistance.

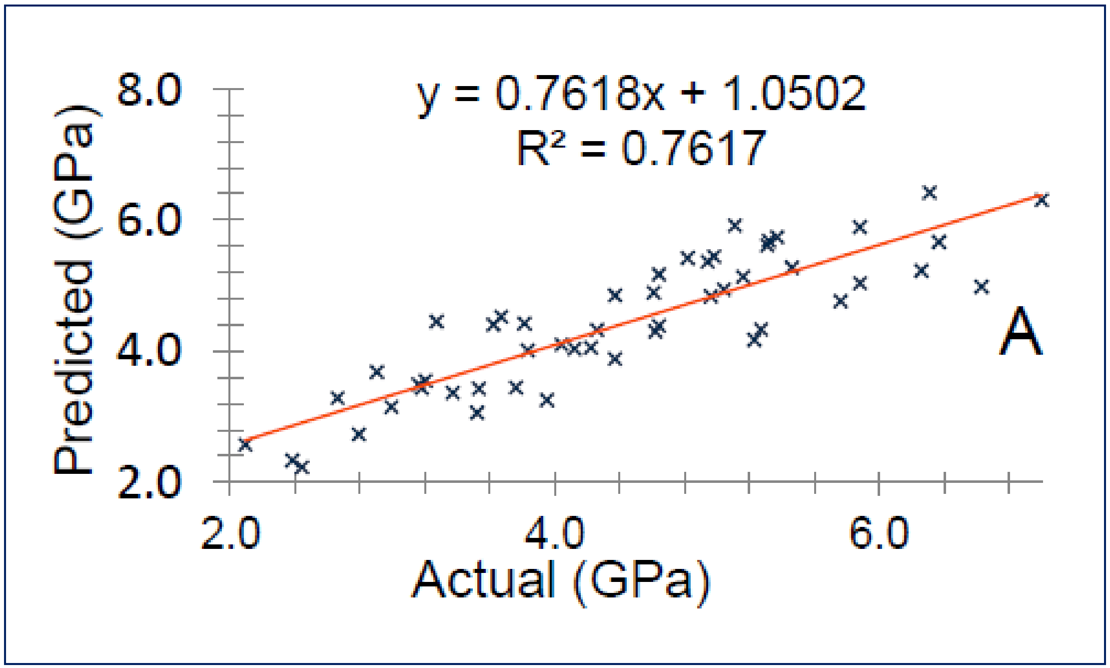
Problem Identification

Forest Products

Forest Health

Rational and Possible Solutions

NIR Spectroscopy Modeling of Small Clear Wood Stiffness based on Underlying Chemistry



Stiffness models like that from Kohan et al. 2012 can be leveraged to these 14 families. While the primary objective of this study is to relate chemistry to disease resistance, we need to avoid families that possess lower potential stiffness which is important for lumber.

Kohan, N. J., Via, B. K., & Taylor, S. E. (2012). Prediction of Strand Feedstock Mechanical Properties with Near Infrared Spectroscopy. *BioResources*, *7*(3), 2996-3007.

Rational and Possible Solutions

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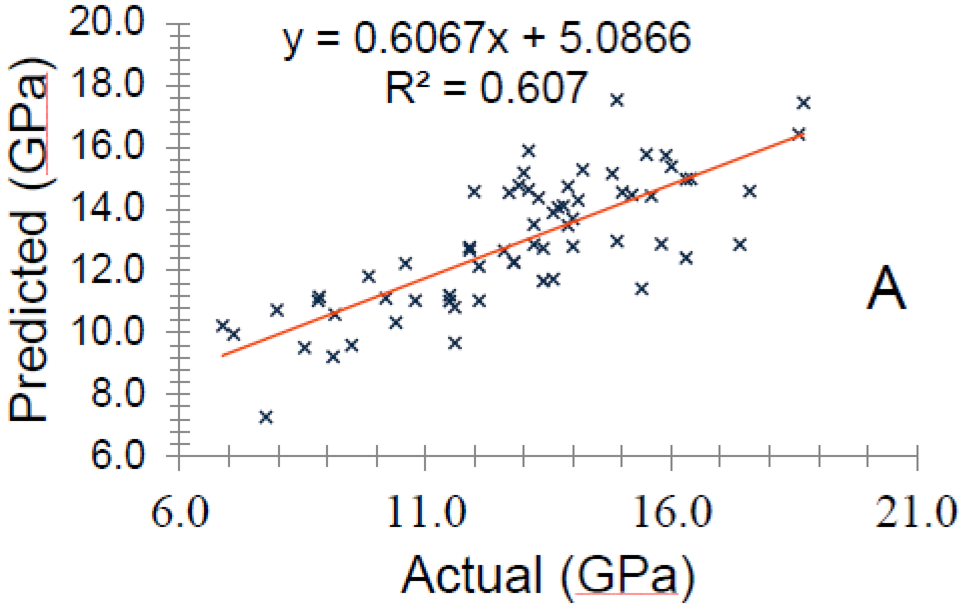

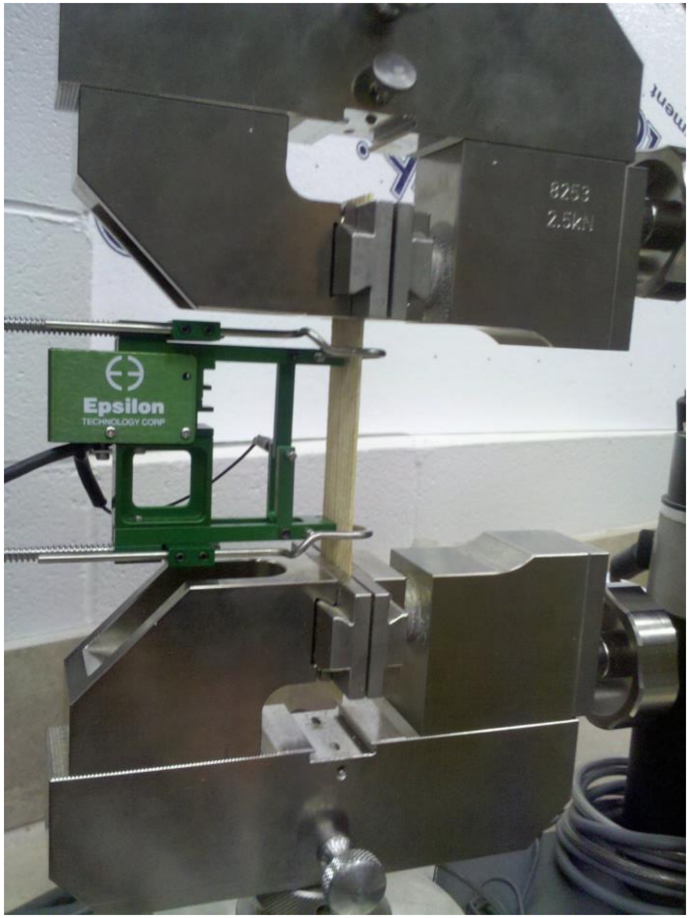

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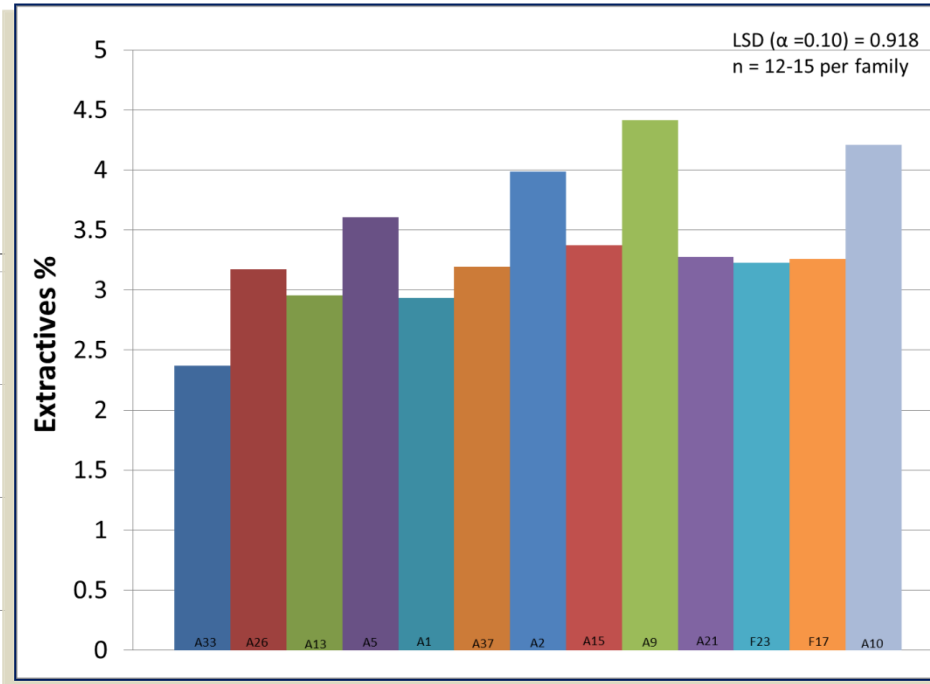
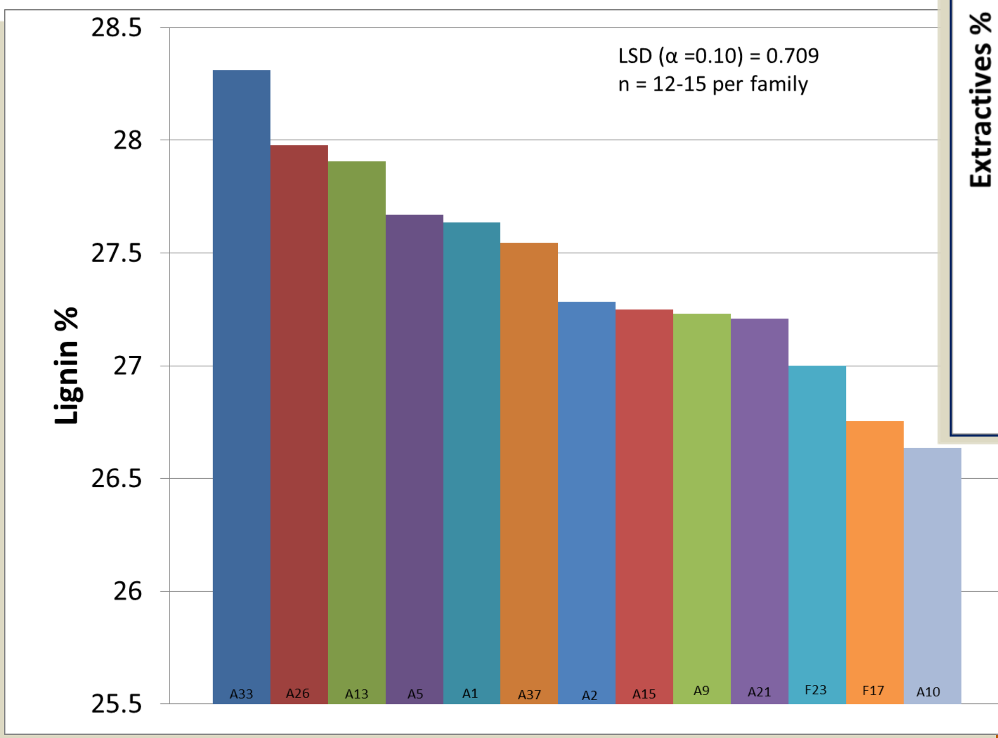
Rational and Possible Solutions

NIR Spectroscopy *Simultaneous* Modeling of Wood Chemistry, Disease, & Stiffness





Rational and Possible Solutions

NIR Spectroscopy *Simultaneous* Modeling of Wood Chemistry, Disease, & Stiffness

Family	Lignin	Cellulose	Extractives	Predicted Disease Resistance	NIR Predicted Stiffness	Ultrasonic Predicted Stiffness
A1	Low	Medium	Medium			
A21	Low	Medium-Low	High	Best Preliminary		
A13	Low	High	Low			
A34	Low	Medium-Low	Medium-Low			
F17	High	Medium	High			
A33	High	Low	High			
A37	High	Low	High			
A10	Medium-Low	High	High			

Continue to update database on extractives vs. disease relationship

Develop models relating wood stiffness to spectra

1. **FPDC**
2. **This project?**

Outline

- ➢Introduction & Problem Identification
- ➢Objectives
- ➢Materials and Methods
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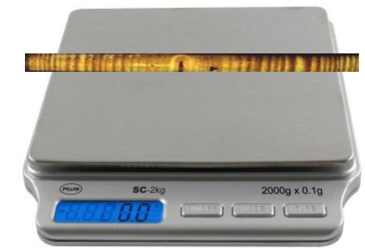
- ➢Future Work
- ➢Conclusions

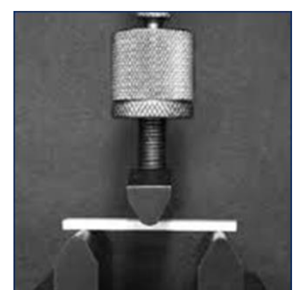
Experimental Plan & Approach

Cellulose, Extractives,
Lignin, Hemicellulose

Experimental Plan & Approach



Cellulose, Extractives,
Lignin, Hemicellulose



Singh, A. 2012. Thesis: Variation in resistance of loblolly pine (Pinus taeda L.) and slash pine (P. elliottii Englem.) families against Leptographium and Grosmannia root fungi. Auburn University.

Outline

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Objectives for 2014-15

- Develop NIR calibrations for wood chemistry of loblolly pine (*Pinus taeda*).
- Take these NIR calibrations and screen 14 genetic families from 2 sites for differences in:
  - Lignin, Cellulose, Hemicellulose, Extractives
- Relate wood chemistry to disease resistance and small clear wood stiffness.
- Pick families forecasted to have good disease resistance and small clear wood stiffness.
- Validate the "forecast" works!

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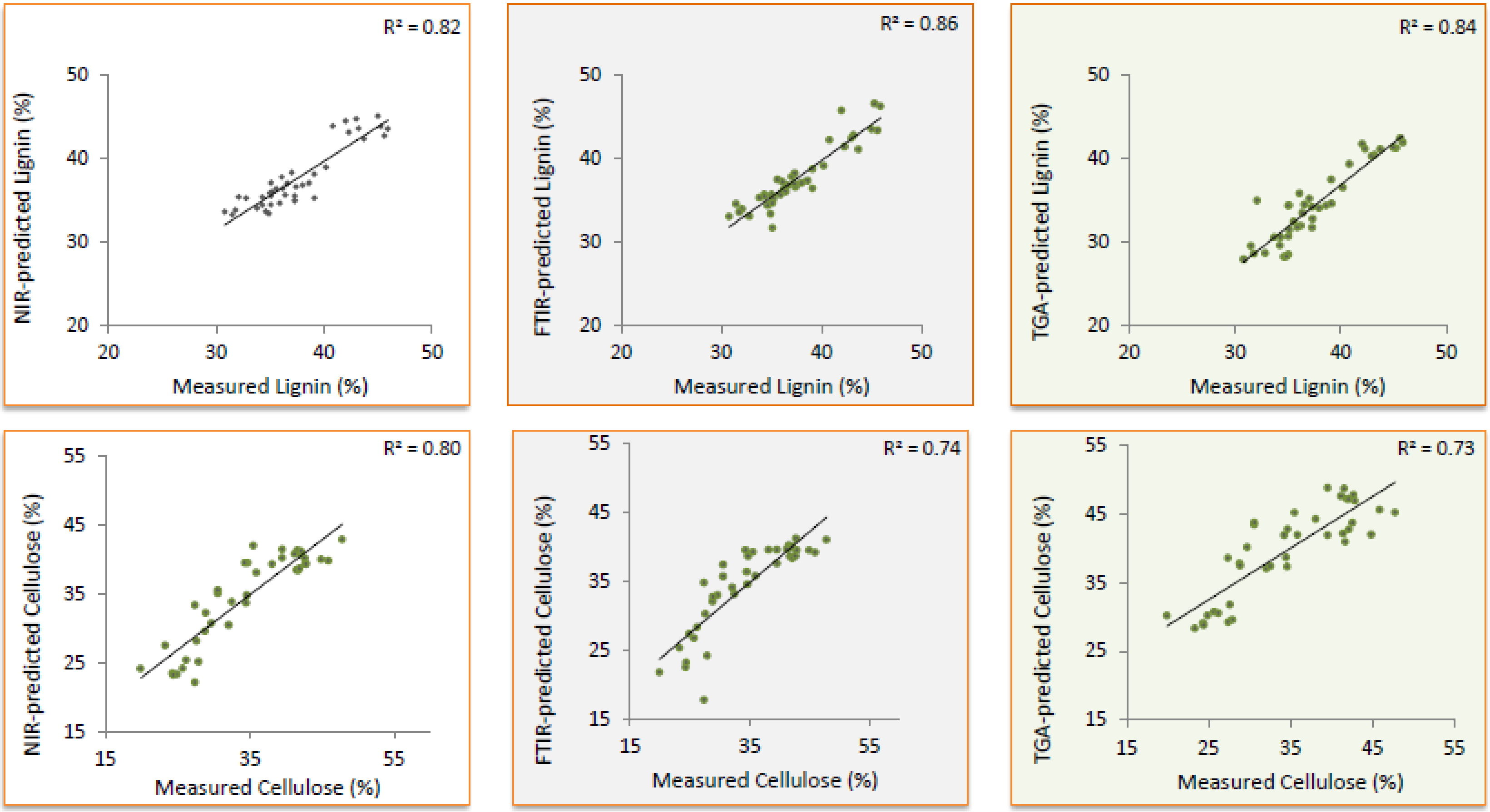
Development of NIR for Wood Chemistry

Property	Range	PCs	SEC	Bias	SEP	R^2
Extractives	1.2 – 13.1	2	0.93	0.197	1.40	0.93
Lignin	30.8 - 45.9	2	1.58	0.064	2.02	0.86
Cellulose	7.7 - 19.9	2	3.89	-0.139	5.10	0.74
Hemicelluloses	13.7 - 28.3	3	1.32	-0.116	3.58	0.82
Holocellulose	40.0 – 68.1	2	3.92	0.014	5.05	0.73

- Higher R-Square models are being developed.
- These models were developed from solid pine, bark, and needles.
  - The more biomass types included decreases precision.

Comparison of NIR to FTIR and TGA?



Validation of Stiffness Modeling – Spring 2014

- 7 families from Plum Creek
- 7 families from Rayonier
- Wide variance in diameter
- 14 year old stands
- Two sites from lower gulf elite population trials: Georgia & Florida

Validation of Stiffness Modeling – Spring 2014

Validation of Stiffness Modeling – Spring 2014

- Paint edges to slow down moisture loss to minimize checking.

Validation of Stiffness Modeling – Spring 2014

- Label Family Number and position in tree.

Validation of Stiffness Modeling – Spring 2014

Validation of Stiffness Modeling – Spring 2014

Validation of Stiffness Modeling – Spring 2014

- Which group did more work?

Validation of Stiffness Modeling – Spring 2014

Validation of Stiffness Modeling – Spring 2014

- The Chain Gang.

Validation of Stiffness Modeling – Spring 2014

- Trees processed into bolts for stiffness testing.
- Other bolts dissected into cookies for chemistry testing.

Validation of Stiffness Modeling – Spring 2014

- Bolts further processed into slabs. They will then be processed into small clears for stiffness testing.
- Conditioning chamber for humidity and temperature control.

Conclusions

- Rapid Chemistry Models Developed for NIR. Fine tuning will continue.
  - Lignin, cellulose, hemicellulose, extractives.
- TGA and FT-IR models for cellulose and lignin developed.
- Samples collected from Plum Creek and Rayonier for stiffness validation.

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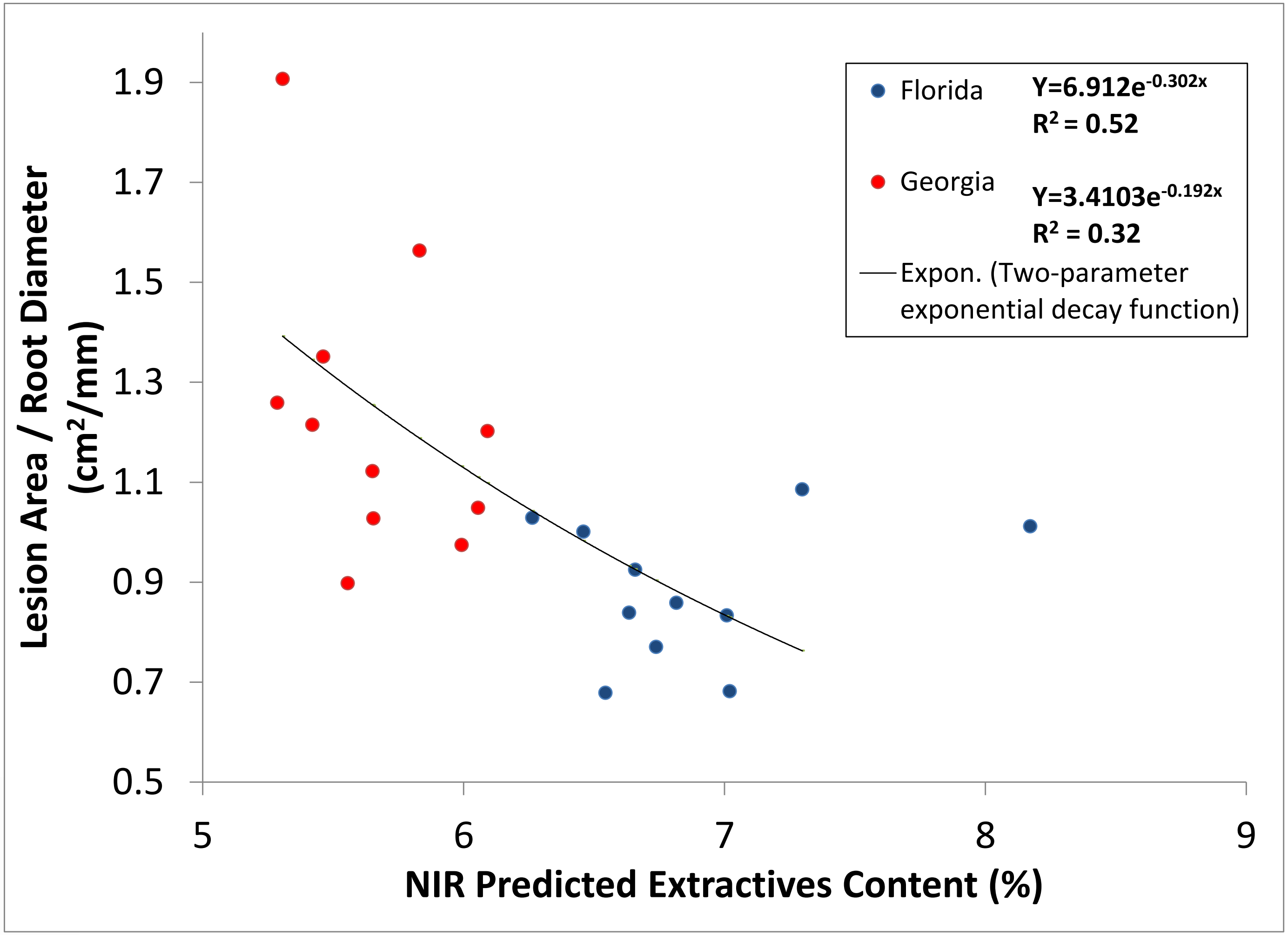
Future Work


Lesion Area / Root Diameter (cm²/mm)
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
5
6
7
8
9
NIR Predicted Extractives Content (%)
Florida
Y=6.912e-0.302x
R² = 0.52
Georgia
Y=3.4103e-0.192x
R² = 0.32
Expon. (Two-parameter exponential decay function)

Future Work

Pine Decline/Disease

- Determine the critical amount of extractives necessary to fight pine decline/disease.
- Target specific trees/families to fill in the gaps to better define the relationship between pine decline/disease and extractives content.
- Determine best family for Pine Decline.

Future Work

Forest Products

- Develop and validate models relating wood chemistry to strength and stiffness.
  - For NIR
  - For TGA
  - For FTIR
- Determine best families for Pine Decline & strength/stiffness.
- What about Ultrasonics?

Acknowledgements

Alabama Agricultural Experiment Station

AAES – Hatch - $40,000 – "Rapid Assessment Tools for the Genetic Improvement of Forest Products and Bioenergy"

NSF

AUBURN IGERT

NSF IGERT – $60,000 – "Integrated Biorefining for Sustainable Production of Fuels and Chemicals"

AFRI-CAP-IBSS – $110,000 – "Southeast Partnership for Integrated Biomass Supply Systems"

IBSS

FOREST HEALTH COOPERATIVE

Tessa Bauman

Jeff Cheippa

Potential of Acoustic Techniques for Standing Tree Stiffness of Different Genetic Families

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520 Devall Dr., Auburn, AL 36849

Outline

- What Is an Acoustic Technique?
- How It Works?
- Objectives
- Methods
- Primary Results
- $ Value Estimate
- Summary
- Acknowledgements

Introduction to Acoustics

- Speed of sound to assess the quality (mechanical and physical properties).
- Nondestructive Evaluation of Wood.
- Robust
- Rapid
- Cost Effective
- Sensitive to modulus of elasticity (MOE) of standing trees, logs, wood products.

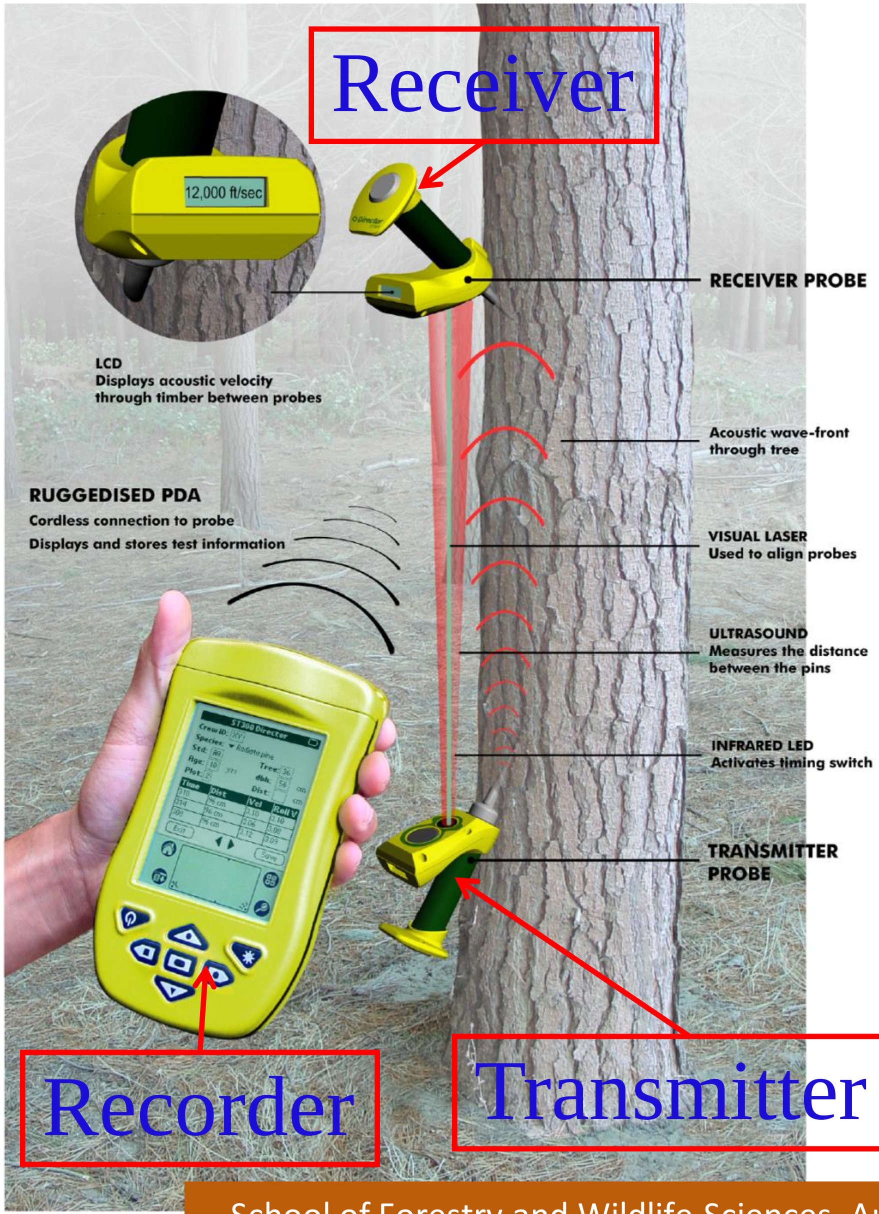
How it works?

- Acoustic system includes three principal components:

Transmitter

Receiver

Recorder



How it works?

Acoustic system :

Director ST300 (Fibre-Gen)

- Transmitter (Tx)
- Receiver (Rx)
- Recorder (Data logger)

Fig 2. Rx and Tx Probes

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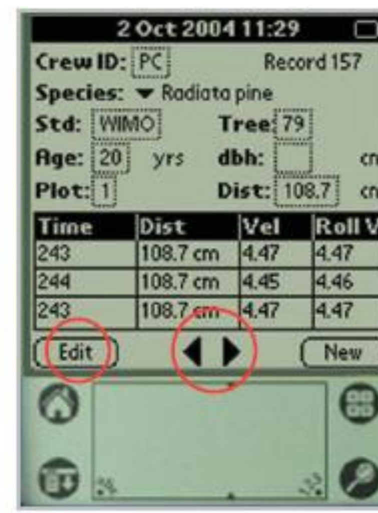
Methods for Acoustic Collection

5. Tapping the Tx Probe to record a Reading (8 hits to get on average data)

4. Press the laser alignment button on the Rx and release it, The Distance will be shown the Rx LCD and recorded by the Recorder



Methods for Acoustic Collection

1. Hammer the Tx into the tree between knee and hip height at 45°

2. Hammer the Rx Pin into the tree approximately ~0.8-1.5m above the Tx Probe

3. Slot the Rx Probe onto the Rx pin

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How it works?

- The two probes (Tx & Rx) are positioned at a distance (~0.8-1.5 meters apart)
- The **distance** is measured using a visible laser
- The stress wave is induced with a hammer on one end and detected by the receiver on the other end.
- The time of flight (**TOF**) between the two probes is captured.
- Then velocity=Distance/TOF

How it works?

The dynamic modulus of elasticity (MOE) of standing tree is calculated based on green wood density and the velocity.

$$E_D = V_{ToF}^2 \times \rho_g$$

E_D: dynamic modulus of elasticity (lb/in^2 (Pa))

V_{ToF}: velocity of the wave through the material (ft/s (m/s))

ρ_g: density of the material (lb/ft^3 (kg/m^3))

Objectives

- Establish equipment reliability
  - Compare old with a newly calibrated instrument.
  - Compare two operators
  - Check the effect of probe distance
    - Hammer force,
    - Time between hits
- Check the effect of wood density (in the field we can not measure).
- Evaluate loblolly pine trees planted at Nahunta Georgia and Yulee Florida in a genetics trial.
- Back of the envelope $ value estimation

Methods

Eight 14 years old trees were selected from the Plum creek research plot at Nahunta Georgia:

A21, F3, A15, F18, A34, A26, A33 and A 37

Seven 14 years old trees were selected from the Plum creek: A9, A2, A17, A5, A1, A10, and F23

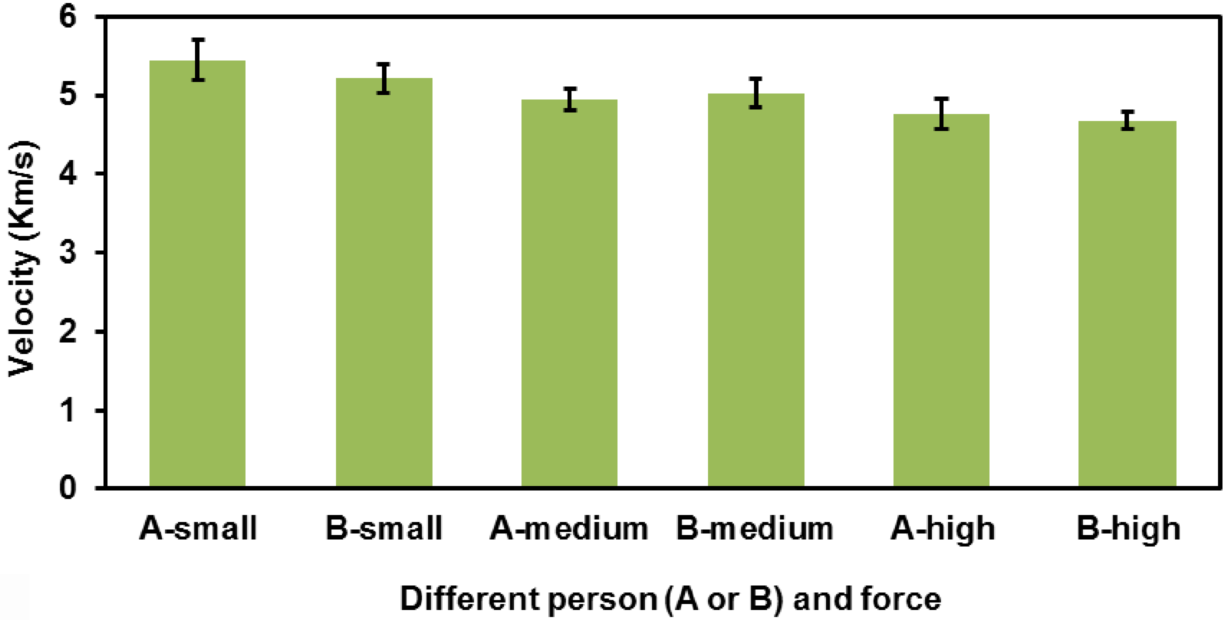
Standing tree

Harvested tree

Results

Operator effects:

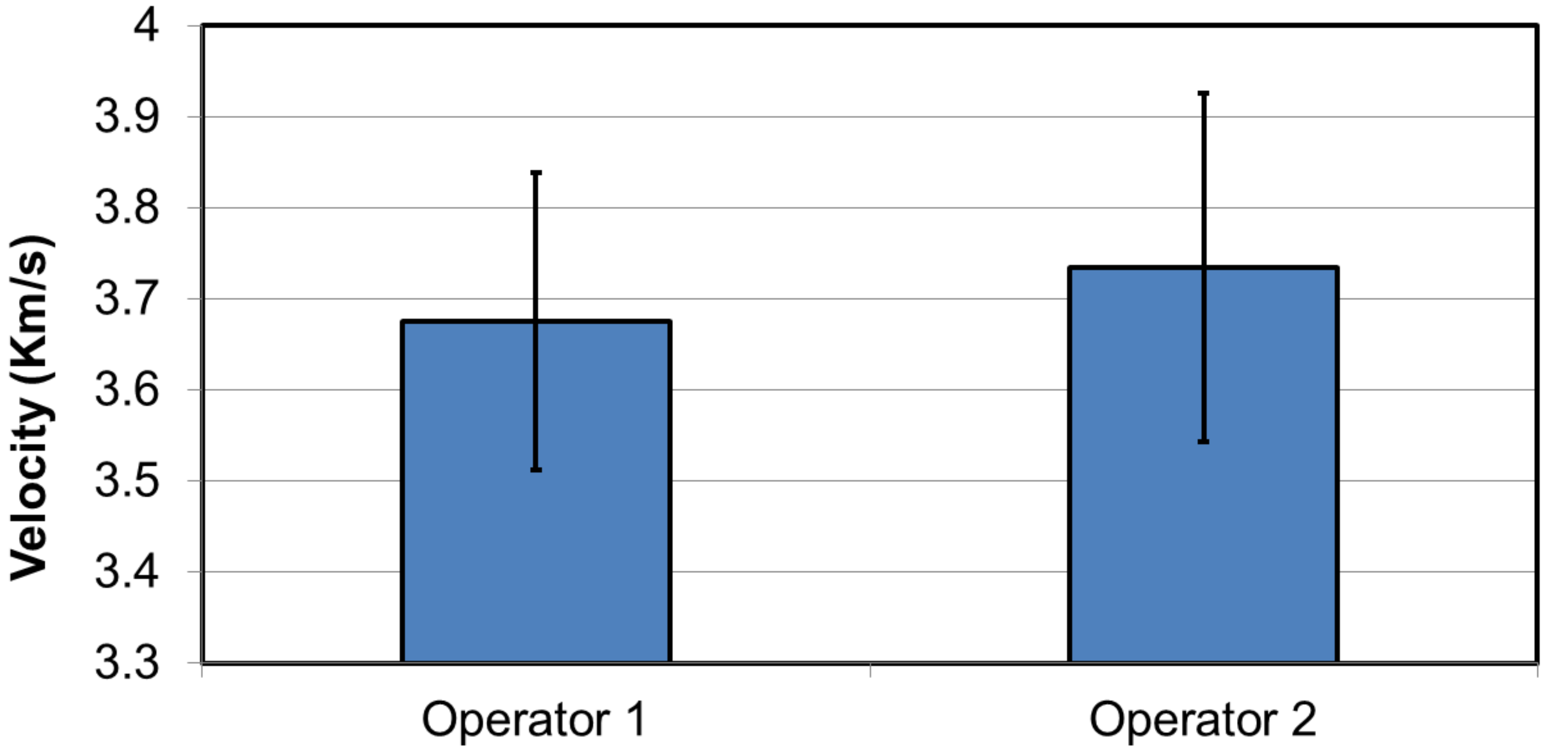
- Equipment operators can differ in hammer force.
- Equipment seems forgiving for different forces. But there is a small trend.



Results

Operator effects:

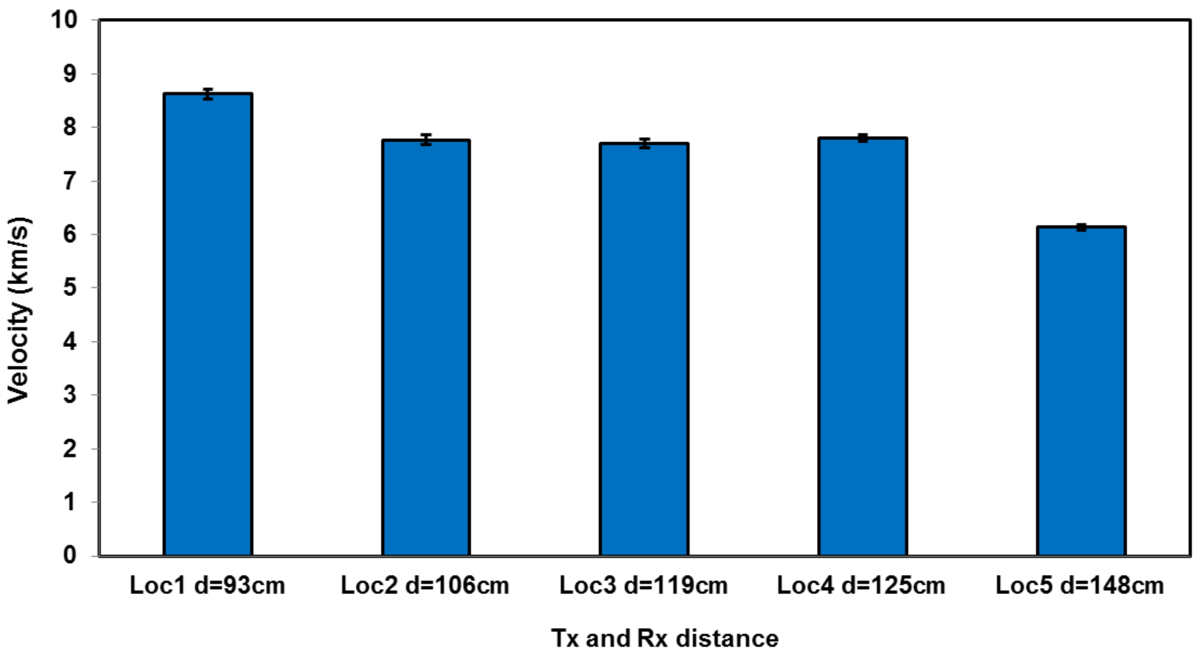
The equipment operators has no significant effects (*after training and practice*).



Results

Tx and Rx probes distance effects:

The distance could influence the velocity although it could be 0.8 to 1.5 m. A 1.2 m (≈4 feet) is recommended.



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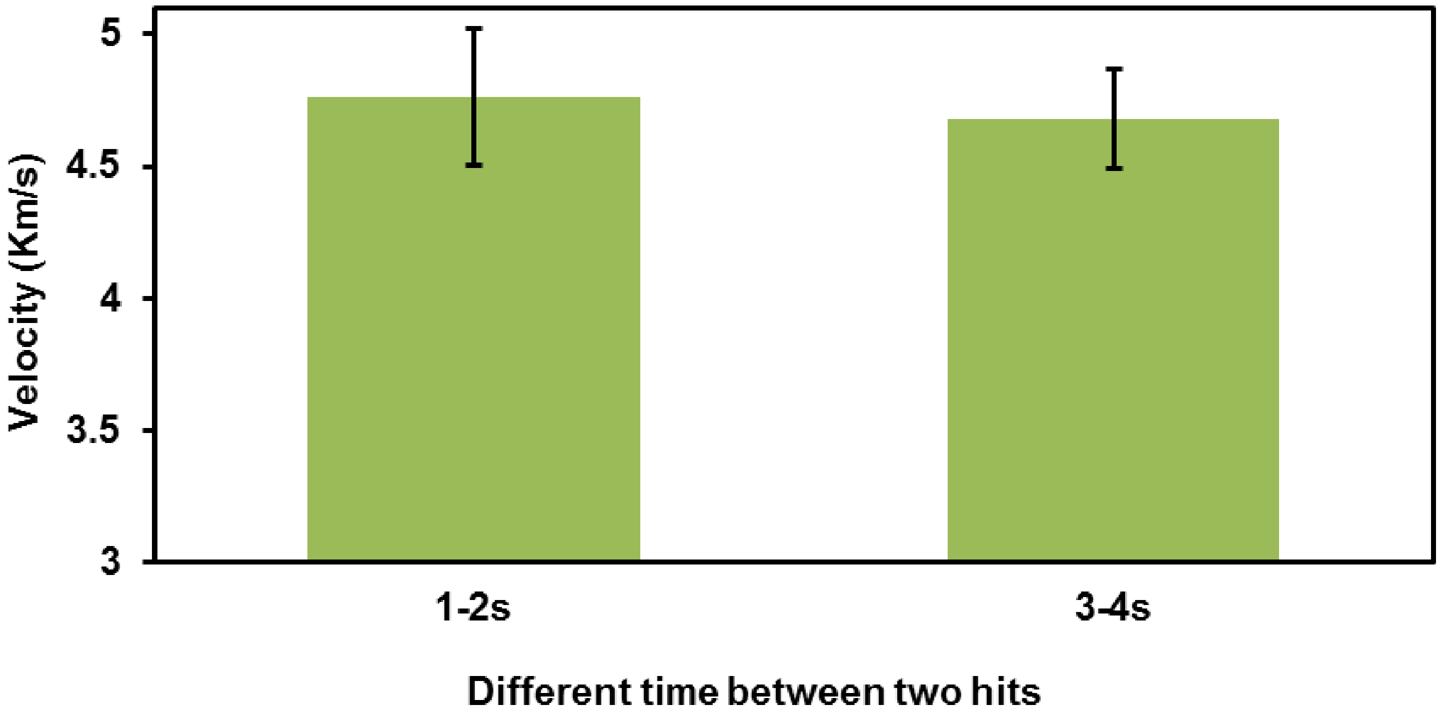
Results

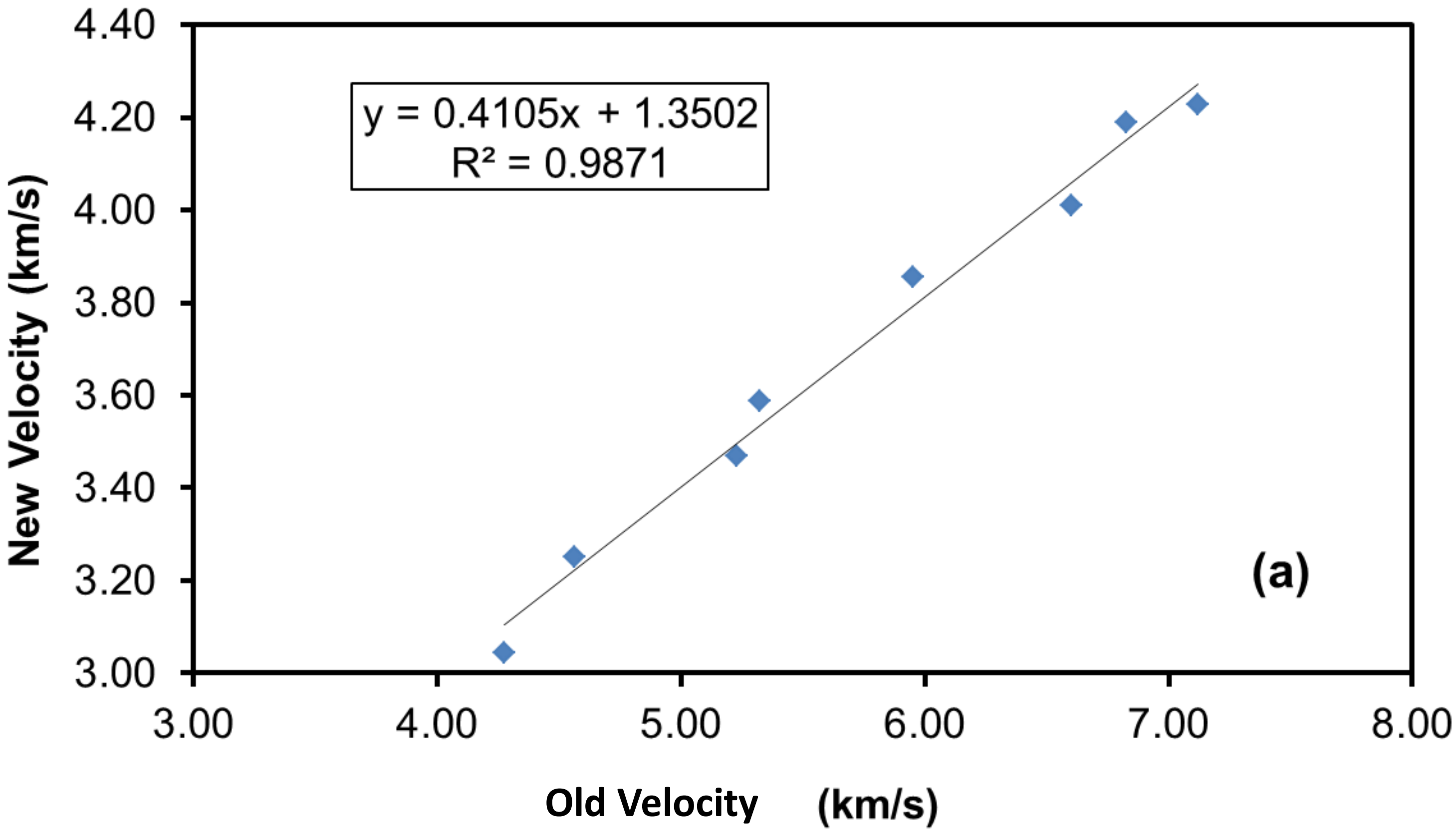
The effect of Time between hits.



Results

Different ST300 units effects:

The the correlations between the old and new ST 300 for velocity were very high

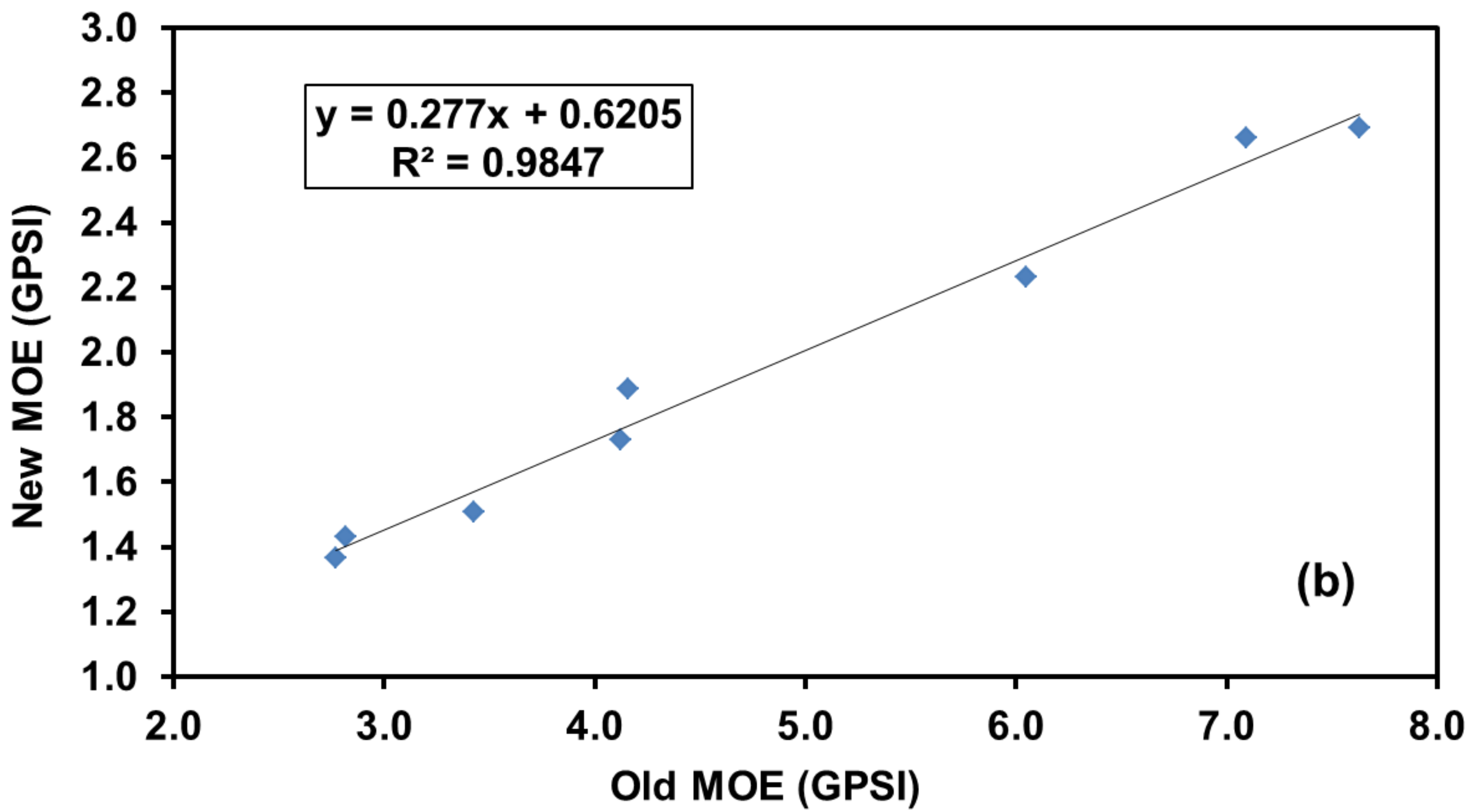


Results

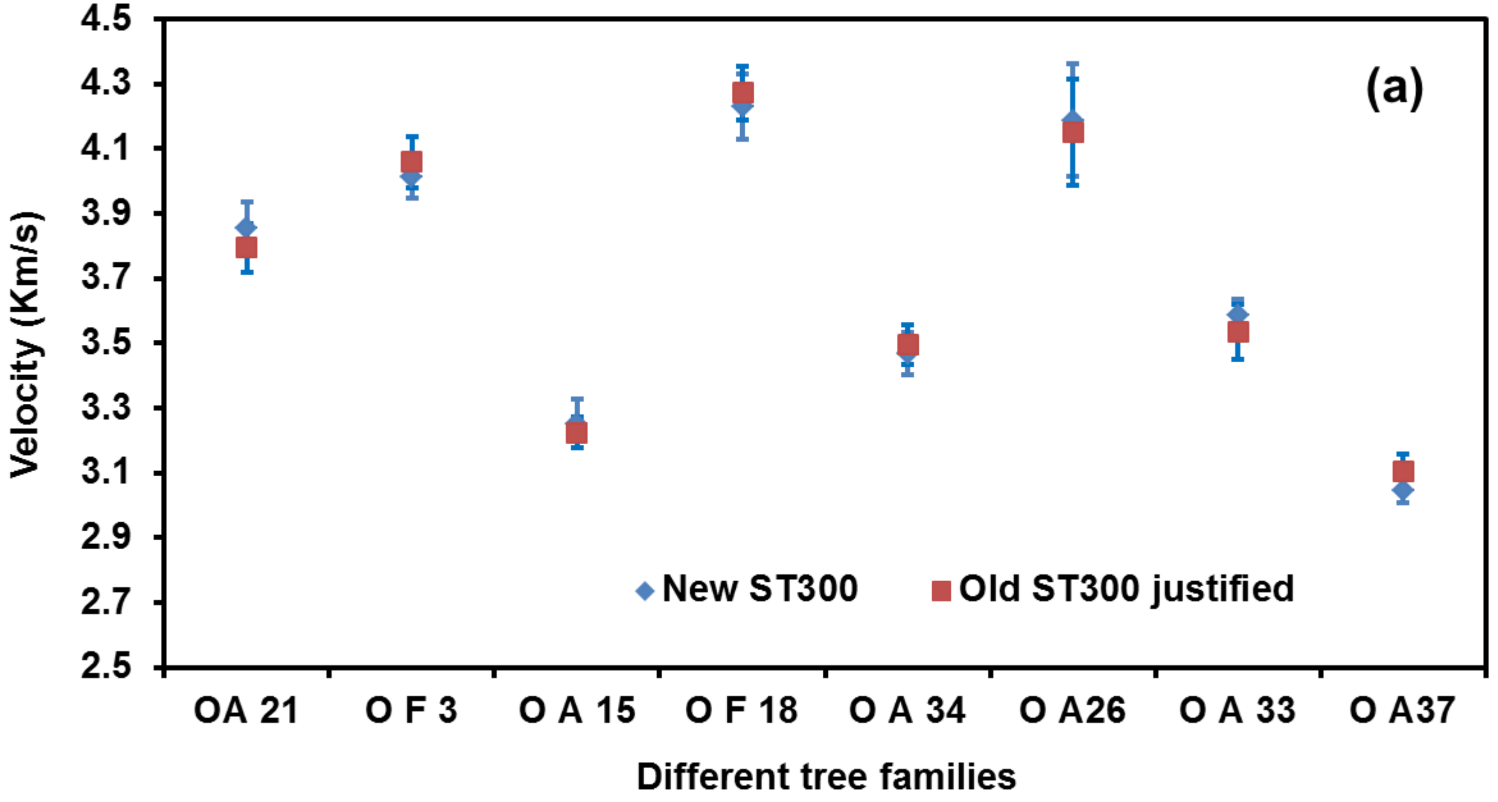
Different ST300 units effects:

The the correlations between the old and new ST 300 for MOE were also very high. But they were not reading the same thing.

Pr

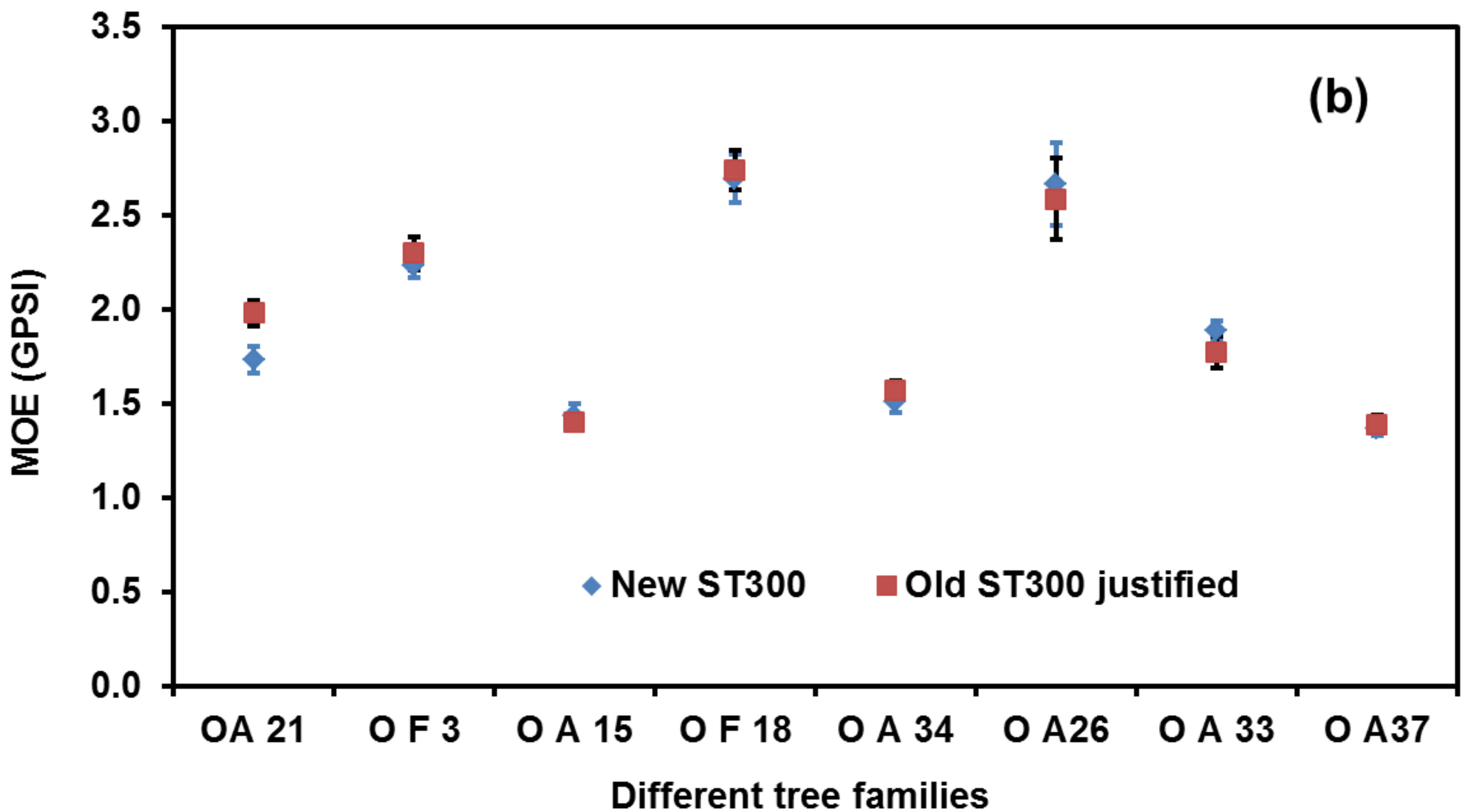


Results (8 trees from GA)



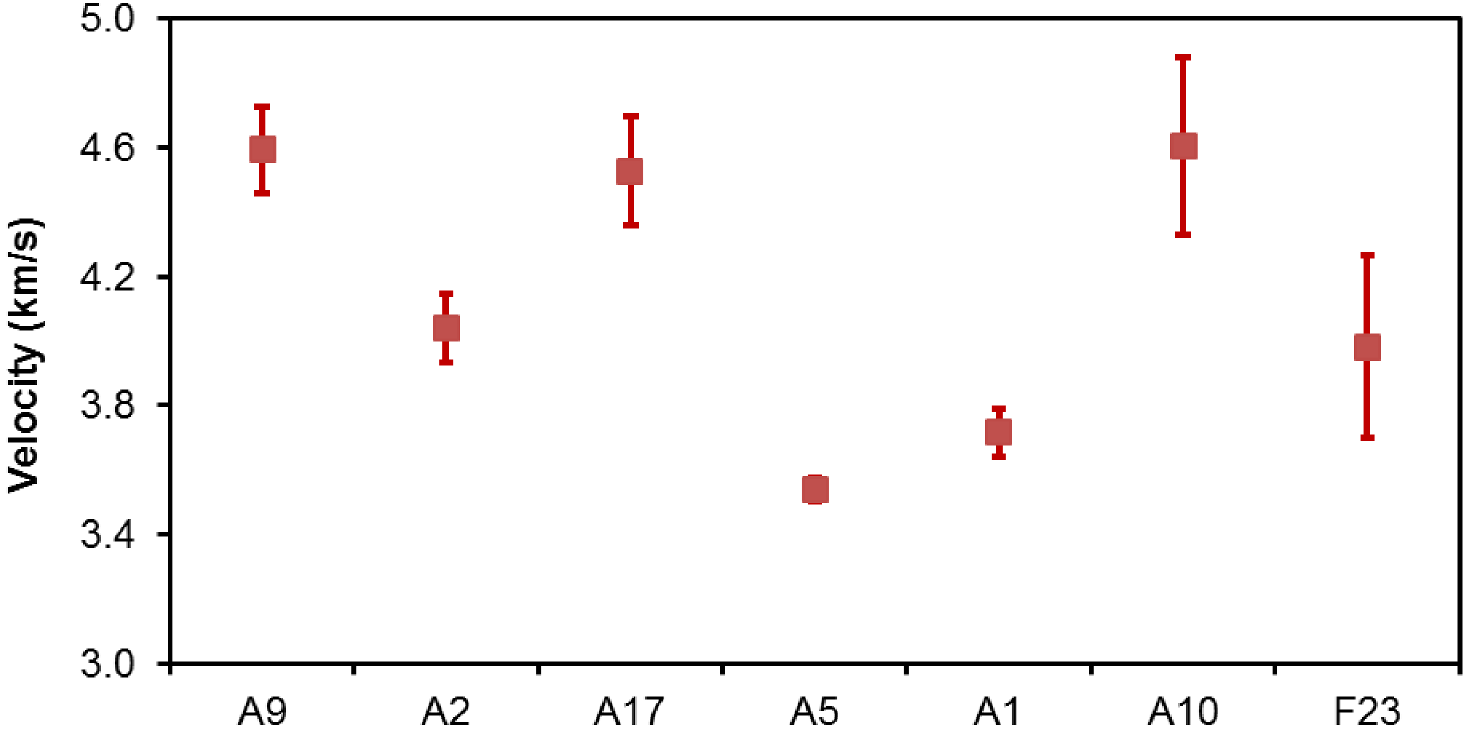
- **The velocity of the eight families trees measured by the old (after modification) and new ST300 units were matched very well <u>AFTER ADJUSTMENT</u>**

Results (8 trees from GA)



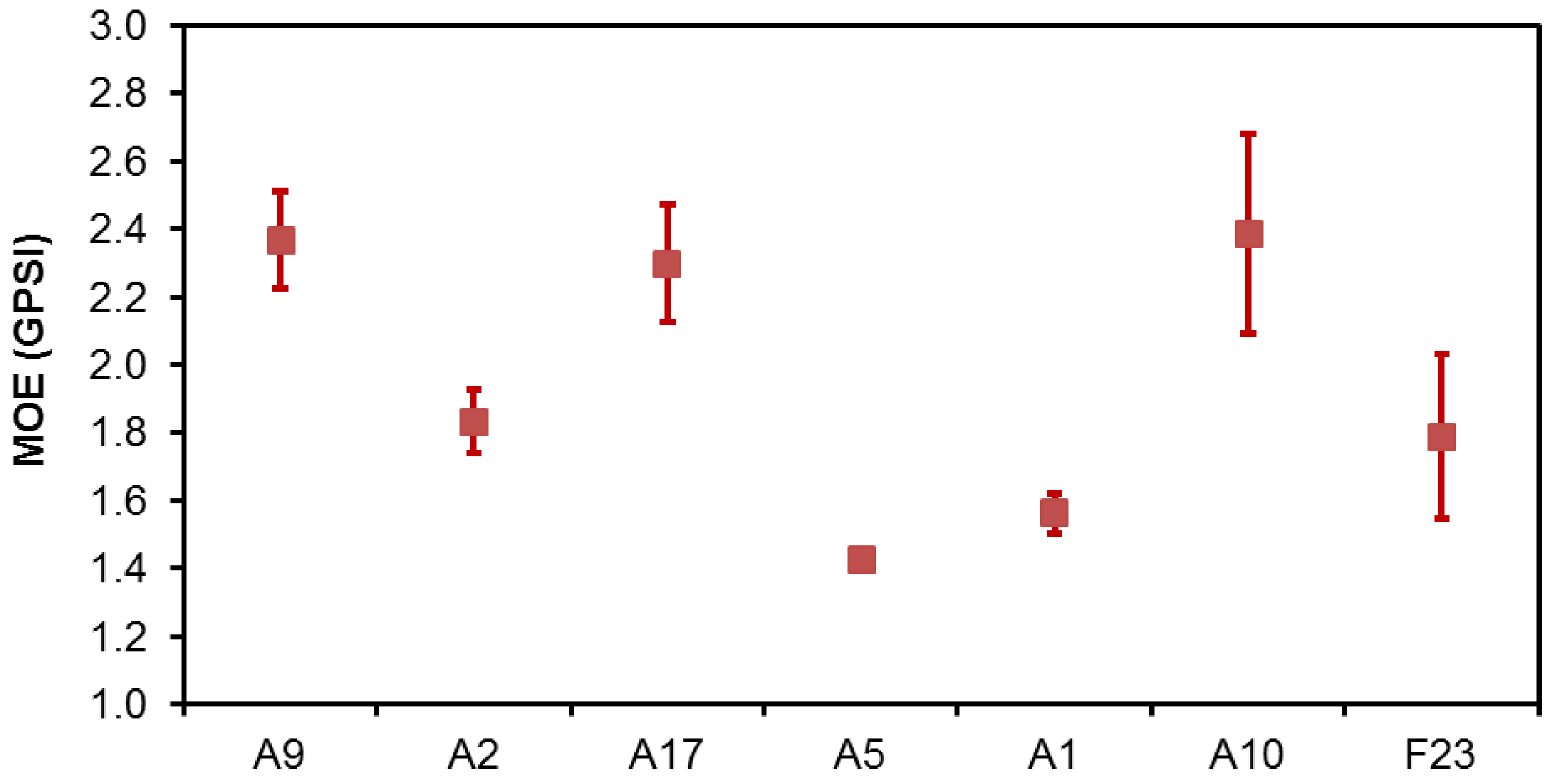
- The MOE of the eight families trees measured by the old (after modification) and new ST300 units were matched very well
- Loblolly pine trees form different genetic families may have different dynamic MOE

Results (7 trees from FL)



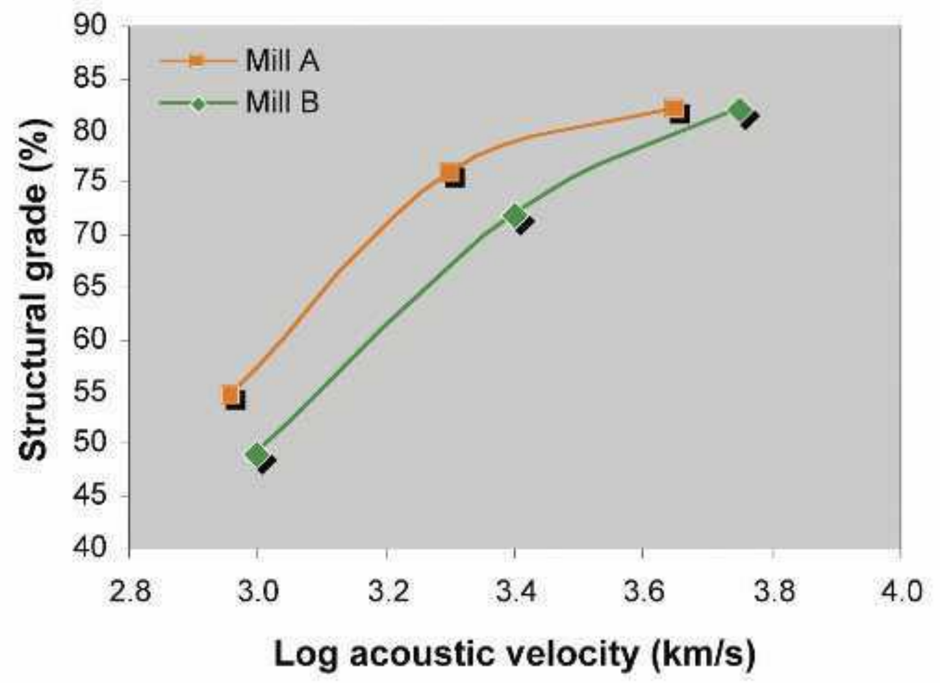
- **Only one machine was available for this site.**

Results (7 trees from FL)



Dollar Value Potential

- *"Assuming a price differential of NZ$200/m³ between structural and nonstructural lumber, an increase in average log acoustic velocity of 0.1 km/s produces an increase in structural lumber yield of about 5 percentage points.* ***<u>This translates into a gain of about NZ$6/m³ on log volume or about NZ$1.8 million (\$1.5 mill U.S.) for a mill processing 300,000 m³ of logs per</u>***



Wang, et al. (2007). Forest products journal. Vol, 57(5), 6-14.

Dollar Value Potential

- <u>**Common Grades of MSR Lumber**</u>

The machine grading process sorts dimension lumber by strength and stiffness to improve consistency. The table below shows four common MSR grades and design

Grade Designation	Bending Fb	Tension parallel to grain Ft	Compression parallel to grain Fc//	Modulus of Elasticity E
1650f-1.5E	1650	1020	1700	1,500,000
1800f-1.6E	1800	1175	1750	1,600,000
2100f-1.8E	2100	1575	1875	1,800,000
2400f-2.0E	2400	1925	1975	2,000,000

http://www.msrlumber.org/designmsrlumber.htm

If Dollars Per Thousand Board Feet

2x4 2400f	545
2x4 1800f	485

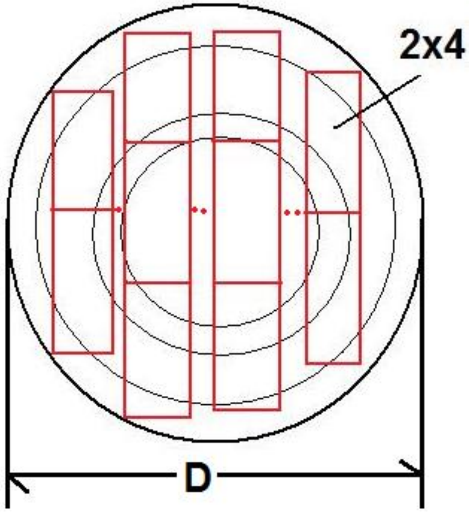
RANDOM LENGTHS

$60 more Per Thousand Board Feet

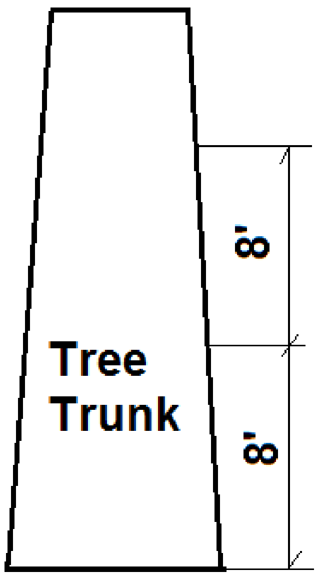
If a tree is identified as 2400f (MOE=2.0x10^6 psi)
From 1800f (MOE=1.6x10^6 psi)

Dollar Value Potential

- **Assume one tree can be cut to 0.51 (D=30", 2 logs with 8' length) Thousand Board Feet (TBF) 2"x 4" 2400f grade lumbers, instead of 1800f grade lumbers, ~$30? more can be sold for only one tree with higher grade.**

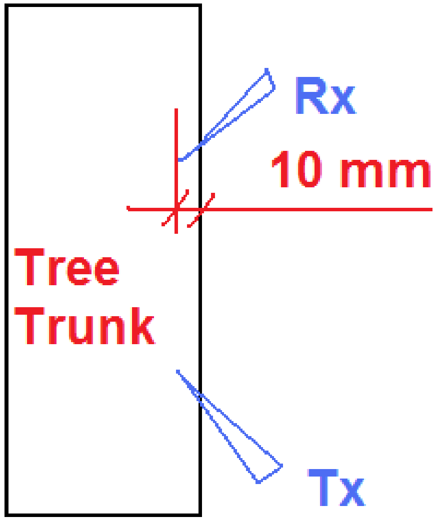


Tree Diameter (in)0	Possible TBF	$ more may Be sold with higher grade
25	0.39	23.4
20	0.23	13.8
15	0.14	8.4



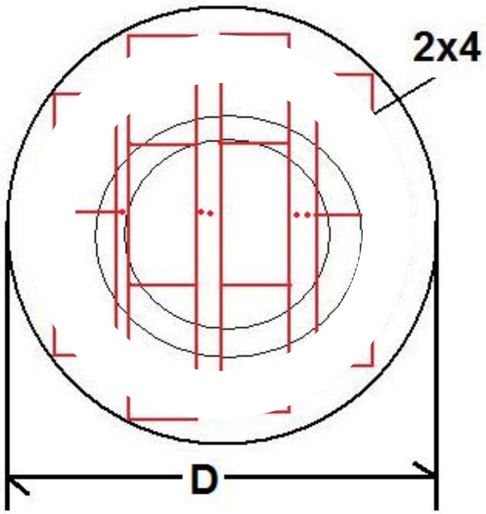
Dollar Value Potential

- **Other assumptions: the lumbers cut from the log core have the same MOE value compared with edge lumbers because the ST300 measured the edge of the tree.**
- **Further study is needed to invest the difference between the core and edge of the log using ST300.**



- **If only edge part (~50%) can be identified:**

Tree Diameter (in)	Possible TBF	Edge part TBF (~50%)	$ more may Be sold with higher grade
25	0.39	0.20	**12**
20	0.23	0.12	**7.2**
15	0.14	0.07	**4.2**



Summary

- **With training, equipment operators had no effect.**
- **The proper distance was determined.**
- **Differences in force had a small effect. We still recommend training for consistency.**
- **Wait Time (T) between each hit did not matter.**
- **Old machine was precise but not accurate. But we were able to adjust to a calibrated machine.**
- **A preliminary analysis suggests that \$4 to \$12 a tree might be possible if trees could be classified into 1.6 and $2.0x10^6$ psi groups.**

Future Work and Key Questions

- **Forest Products Development Cooperative**
  - **We hired Dr. George Cheng in December. We have a potential Volunteer for Sawmill processing.**
  - **Will test ability of acoustics to measure tree and log stiffness. $ values will be checked for opportunities.**
- **The modulus of elasticity of a 15 year old stand seemed high compared to the literature. We need to validate by testing small clears and lumber.**
- **How well does this thing really measure when density is not available as an input? Can we even do it?**

Future Work and Key Questions

- **Can we just measure the stiffness from the edge of the tree or can we estimate the entire whole cross section?**
- **How does a measurement at the bottom reflect the entire tree? Note: the higher MSR grades would come from the bottom and from the edge.**
- **Do we want to test the same Genetic Families as tested for differences in the Forest Health Coop.?**

Acknowledgements

Dr. Xiping Wang at USDA Forest Products Laboratory, Madison, WI, for the ST300 acoustic tools help.

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Adam Trautwig

Forest Products Development Center

Thank You!

Any Questions?