Near Infrared (NIR) & Freeze Damage

Team: Tom Starkey, Scott Enebak, Ryan Nadel, Brian K. Via

My Background

Education:

LOUISIANA STATE UNIVERSITY

PH.D. - Wood Quality/Chemistry Characterization

VirginiaTech

MS – Wood Engineering
BS – Forest Products

Industrial Experience:

INTERNATIONAL PAPER – Wood Quality Project Leader – Forestry/Lumber and Pulp/Paper

LOUISIANA PACIFIC – Scientist - Building Products

Auburn Experience:

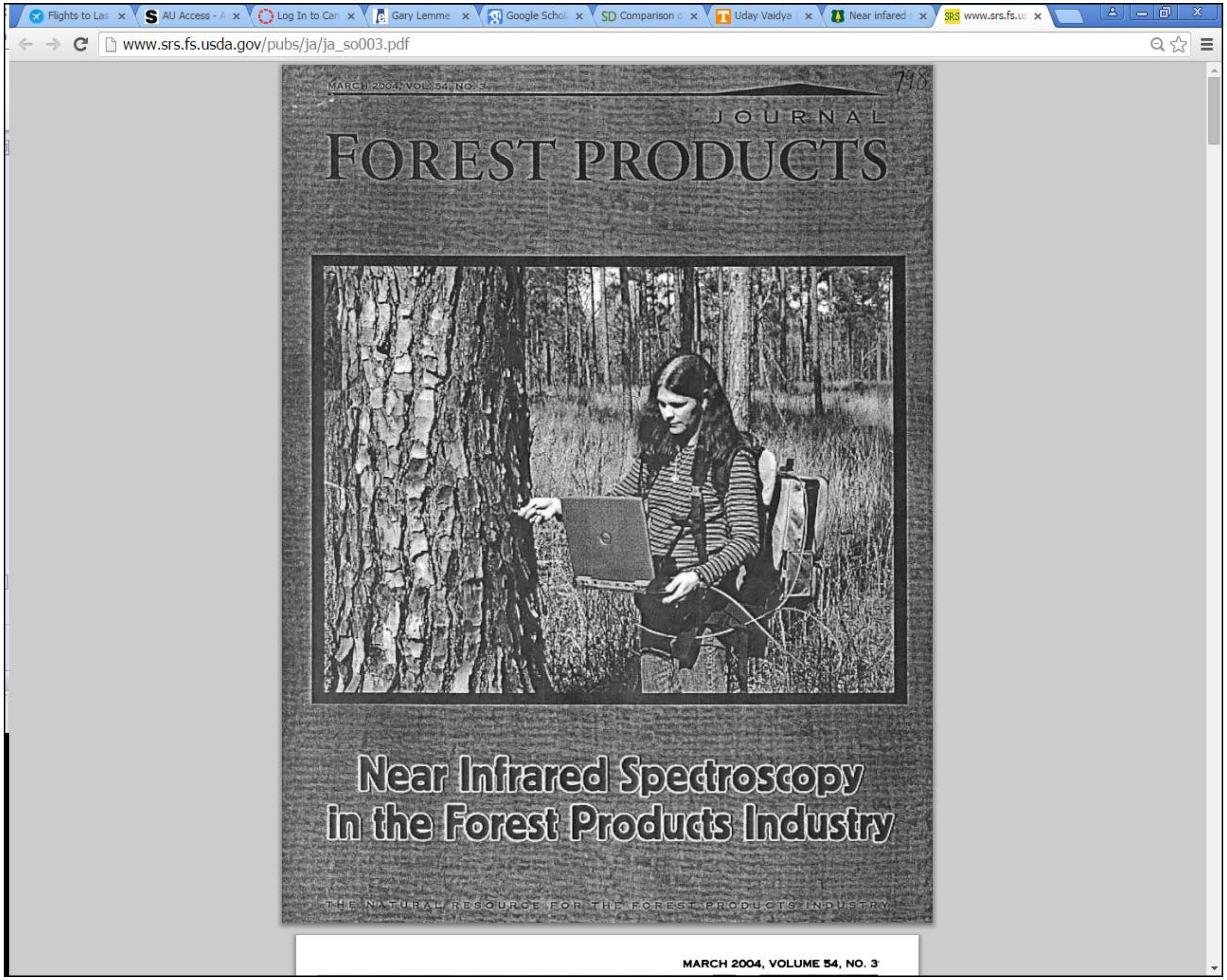
7 years experience
Director Forest Products Development Center

Forest Products Development Center

Rational & Problem Identification

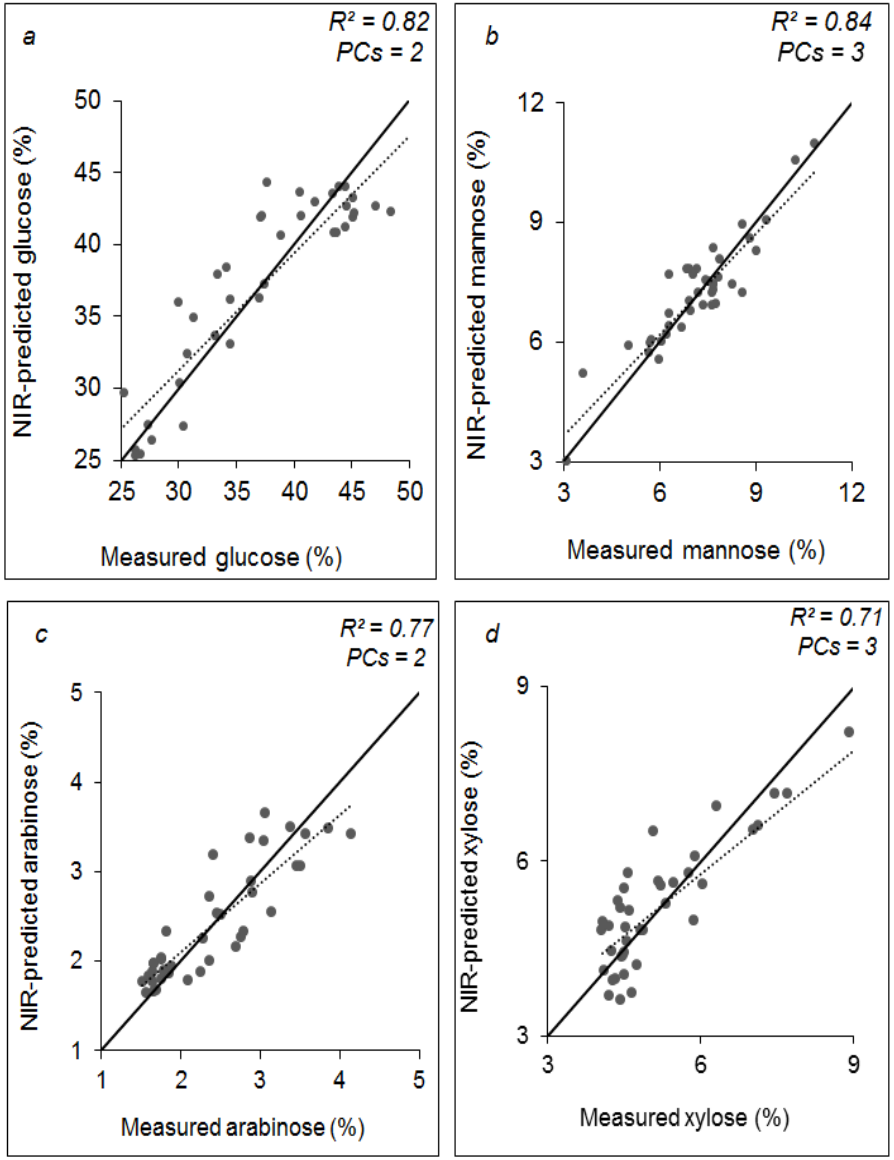
- Frost damage takes 1-2 weeks for visible symptoms.
- Large sample sizes of seedlings necessary for statistical certainty.
- Other methods are expensive, destructive, labor intensive
  - such as electrolyte leakage.
- Near Infrared Reflectance (NIR) Spectroscopy has been shown to be sensitive to freeze damage in Norway spruce and Scots pine.
- NIR is a rapid light reflectance method that can be calibrated for traits sensitive to wood chemistry.

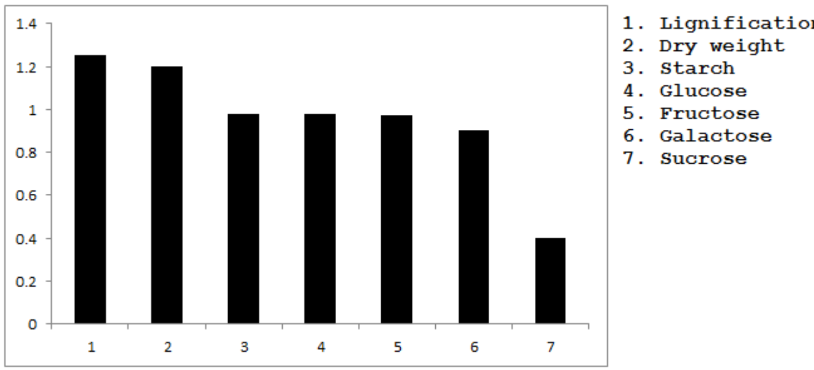
Rational & Problem Identification



So, C. L., Via, B. K., Groom, L. H., Schimleck, L. R., Shupe, T. F., Kelley, S. S., & Rials, T. G. (2004). Near infrared spectroscopy in the forest products industry.*Forest Products Journal*, *54*(3), 6-16.

NIR Sensitivity to Sugar Content





Sundblad, L. G., Andersson, M., Geladi, P., Salomonson, A., & Sjöström, M. (2001). Fast, nondestructive measurement of frost hardiness in conifer seedlings by VIS+ NIR spectroscopy. *Tree physiology*, *21*(11), 751-757.

Acquah, G. E., Via, B. K., Fasina, O. O., & Eckhardt, L. G. (2015). Nondestructive prediction of the properties of forest biomass for bio energy, fuel and chemical applications using near infrared spectroscopy (NIRS). *Journal of Near Infrared Spectroscopy*, *23*, In Press (Online First).

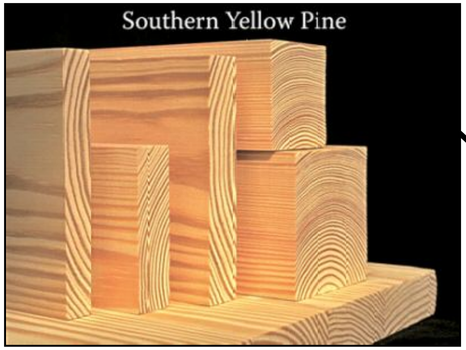
NIR Sensitivity to General Chemistry

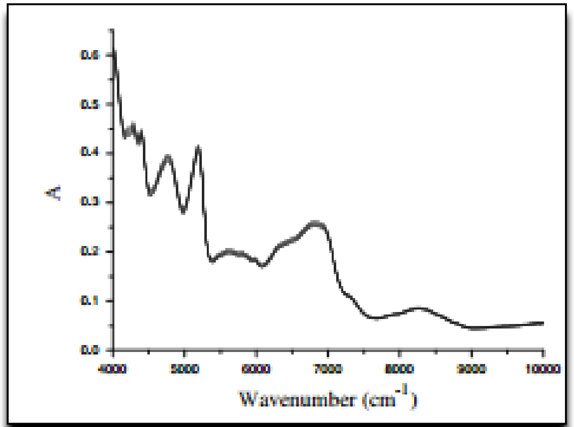
Table: PLS1 model statistics for the chemical properties of forest biomass using raw spectra

Property	Pretreatment	SEC	Bias	PCs	SECV	R^2
Extractives	1st derivative	0.99	0.03	2	1.23	0.92
Lignin	Raw	1.55	0.07	4	1.75	0.87
Glucose	1st derivative	3.30	-0.12	2	3.95	0.82
Mannose	1st derivative	0.63	-0.10	3	1.60	0.84
Galactose	1st derivative	0.97	0.00	3	2.05	0.71
Arabinose	1st derivative	0.36	0.00	2	0.42	0.77
Xylose	1st derivative	0.73	0.05	3	1.23	0.71
Cellulose	1st derivative	3.40	-0.14	2	4.09	0.80
Hemicelluloses	1st derivative	1.78	0.00	3	3.40	0.68
Holocellulose	1st derivative	3.73	-0.15	2	4.44	0.75

Acquah, G. E., Via, B. K., Fasina, O. O., & Eckhardt, L. G. (2015). Nondestructive prediction of the properties of forest biomass for bio energy, fuel and chemical applications using near infrared spectroscopy (NIRS). *Journal of Near Infrared Spectroscopy*, *23*, In Press (Online First).

Collaboration with FPDC: NIR Predicting Multiple Traits from One Measurement





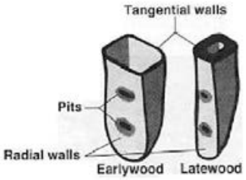
Seedling Freeze Tolerance

Forest Health

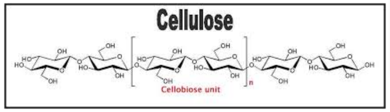
Microfibril Angle?

Build Models

Solid R^2=0.9

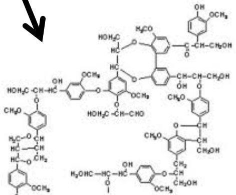


Powder R^2=0.9 – 0.96



Solid R^2=0.76 to 0.9

Powder R^2=0.96-0.99



Lignin

Powder

Volatiles (R^2=0.92),

HHV (R^2=0.7), Ash (R^2=0.7)

Preliminary Study: Methodology

Freezing Process:

a) 3 treatments (freeze times) for two seedlots (7-56 and Piedmont)

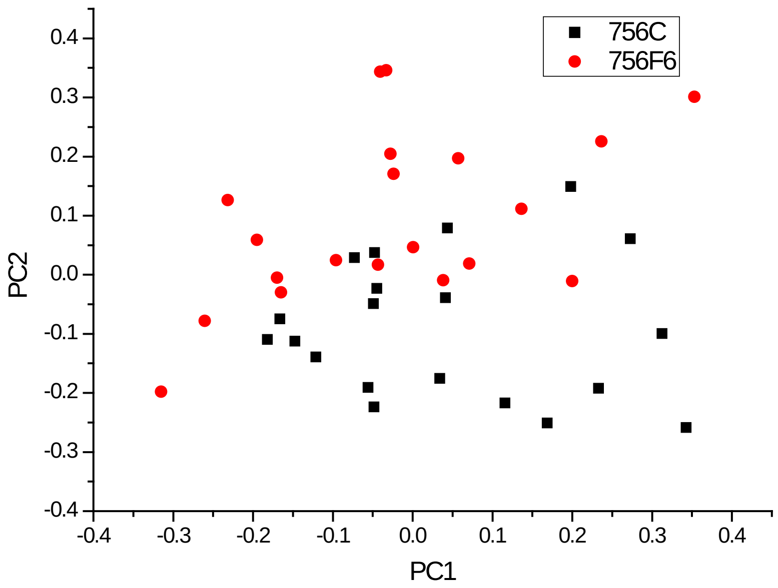
b) 50 seedlings per treatment (total of 300 seedlings)

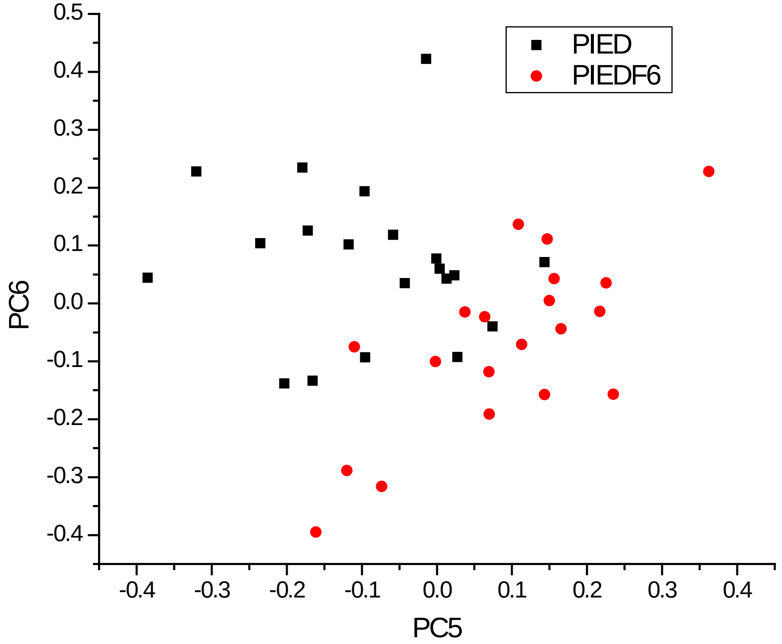
c) 3 freeze times are 1 hour, 3 hours and 6 hours

d) Measure stem (after cutting) and collect spectra

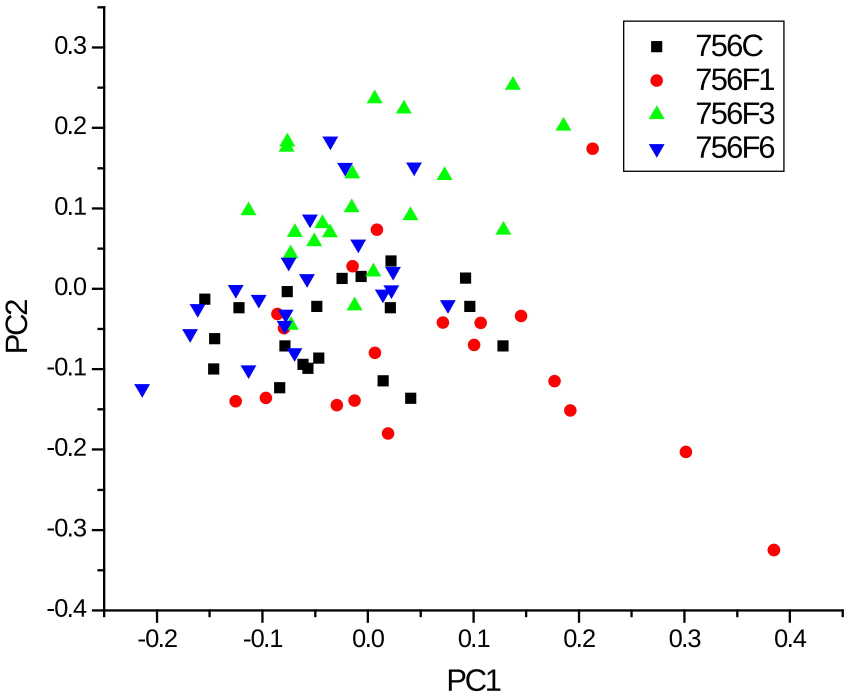
e) Run sensitivity analysis

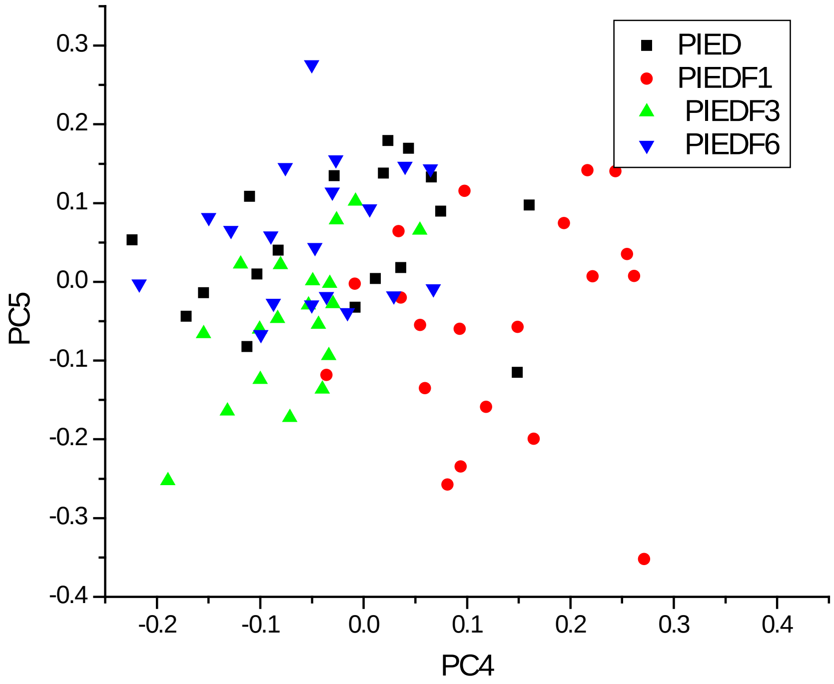
Preliminary Study: Results



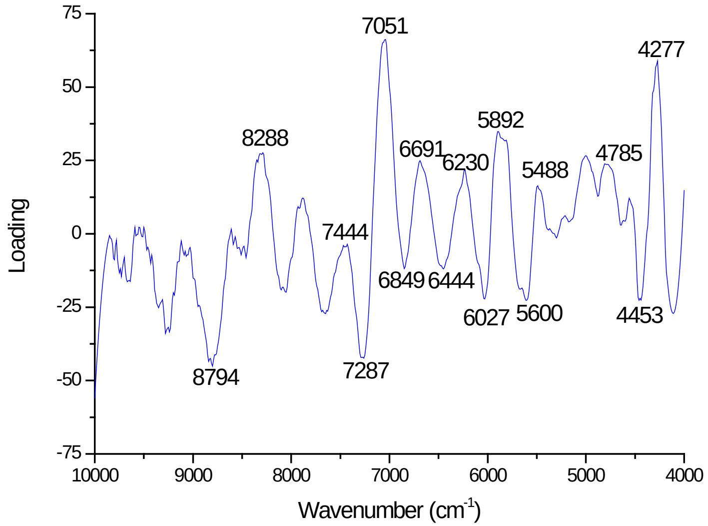


Preliminary Study: Results





Preliminary Study: Results



Smoothed loading

Band location wavenumber (cm^{-1})		Component	Bond vibration
PLS	**Literature**		
4277	4277	Cellulose	C-H str.+C-H_2 def.
4453	4435	All	O-H str.+ C-O str.
4785	4795	Cellulose/Hemicellulose	O-H and C-H def. + O-H str.
5488	5495	Cellulose	O-H str. + 2nd OT C-O str.
5600	5593	Cellulose	1st OT C-H str.
5892	5890	Lignin	1st OT C-H str.
6027	6003	Hemicellulose	1st OT C-H str.
6230	6257	Cellulose	1st OT O-H str.
6444	6460	Cellulose	1st OT O-H str.
6691	6700	Hemicellulose	1st OT O-H str.
6849	6874	Lignin	1st OT O-H str.
7051	7057	Lignin	1st OT C-H str. +C-H bend.
7287	7300	Hemicellulose/all	1st OT C-H str. +C-H def.
7444	7410	Hemicellulose/all	1st OT C-H str. +C-H def.
8288	8250-8160	Cellulose	2nd OT C-H str.
8794	8749	Lignin	2nd OT C_{ar}-H str., 2nd OT C-H str. of CH_3 groups

Next Steps

1. Hire a student
2. Perform studies understanding which chemistry changes with freeze damage
    1. FTIR
    2. HPLC
    3. 2D Correlation Spectroscopy
    4. NIR
3. Calibrate NIR spectroscopy to identify freeze damage pine seedlings
4. Work on Field method that could be used by members