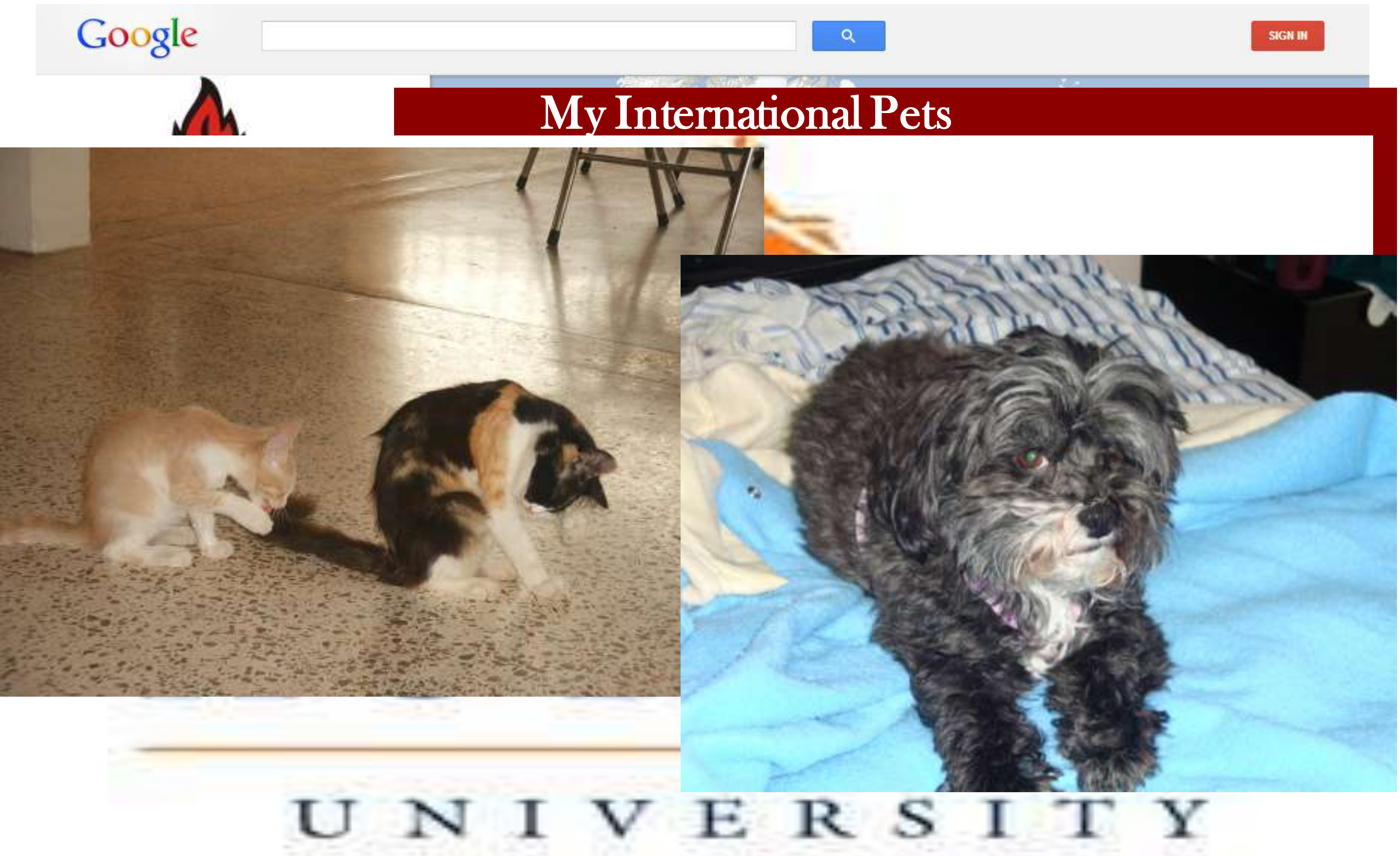
Screening Loblolly Pine Families for Chemistry and Stiffness

Gifty E. Acquah[1], Brian K. Via[1], Lori G. Eckhardt[2]

[1]Forest Products Development Center, School of Forestry and Wildlife Sciences, Auburn University, Auburn Alabama, USA
[2] Forest Health Cooperative, Forest Health Dynamics Laboratory, School of Forestry and Wildlife Sciences, Auburn University, Auburn Alabama, USA

About Myself



Outline

- Background
- Problem Statement
- Objectives
- Materials and Methods
- Preliminary Results
- Future Work
- Conclusions

Background

Loblolly Pine: Introduction

- Loblolly pine is the most important tree species in the USA
- Found in 14 states; from New Jersey to Central Florida, and west to Texas
- About 30 million acres in plantations in the south
- Serves as a habitat for diverse wildlife
- Provides an array of marketable products
  - ✓Contributes approximately $30 billion to the economy of the Southeastern US

Forest Products Development Center

Background

Loblolly Pine: Decline and Resolution

- Reduced growth, tree decline and mortality.

- The Forest Health Cooperative (FHC) is using the selection and deployment of genetically superior families that are disease-resistant as a management strategy to prevent pine decline.

- Important that we do not compromise other important properties (for example chemical composition and stiffness) while breeding for disease resistance.

Background

Importance of Chemistry and Stiffness

- Chemical Composition

  -Determines the optimum utilization pathway.

  - Change will impact the yield and quality of products.

- Stiffness

  -If compromised, mortality could occur due to reasons other than forest disease such as wind failure.

Problem Statement

- Important for us to know the chemical composition and stiffness of these genetically superior families.

- Conventional methods used to determine these properties of biomass are however time consuming, destructive, and mostly expensive.

- The need for alternative analytical tools that are easy to use and fast; non-destructive and cost-effective.

Problem Statement

Potential of NIR and FTIR spectroscopy

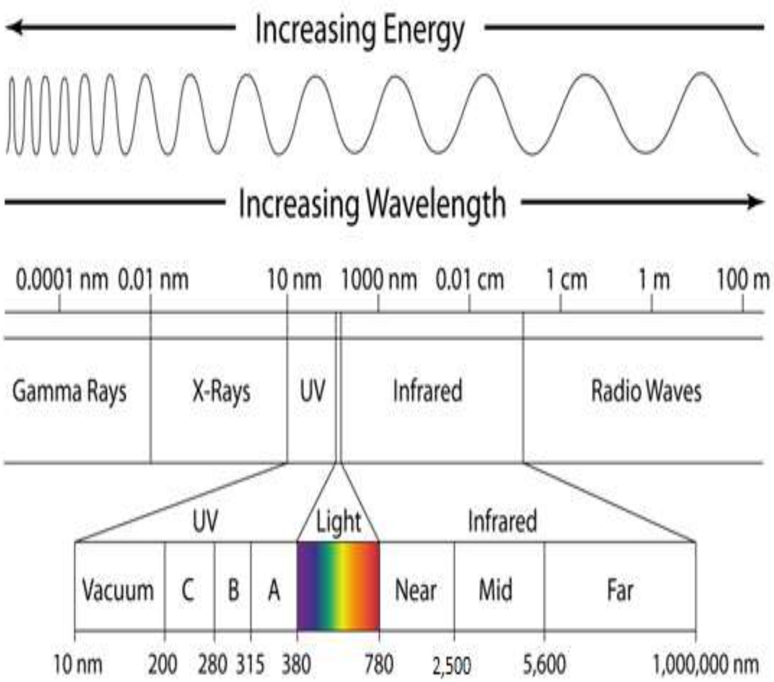


Fig.1: Infrared in the electromagnetic spectrum

- Underlying Principle: Measurements of the wavelength and intensities of the absorption and transmittance or reflectance of infrared light by a sample.
- In other words, the chemical finger print (in the form of a spectrum) of a sample is taken by NIR/FTIR at a specific point in time.
- NIR: 780 – 2500 nm; detects overtones and combinational vibrations
- FTIR : 2500 – 5600 nm; detects functional and fundamental vibrations

Forest Products Development Center

Objectives

Objective 1

Predict the chemical composition (i.e. extractives, cellulose, hemicelluloses and lignin) of select loblolly pine families using NIRS and FTIRS

Objective 2

Predict the stiffness (Modulus of elasticity) of select loblolly pine families using NIRS and FTIRS

Material and Methods

Materials: Objective 1 - Chemical composition

- 4 treatments of loblolly pine forest biomass based on plant part components
  - clean wood chips; wood and bark; whole tree chips and harvest slash
  - 10 biomass sets sampled from each treatment
- 14 treatments of solid pine wood based on families
  - 1 tree per family
  - 20 increment cores per tree

Material and Methods

Materials: Objective 2 - Stiffness

Materials:

- 14 treatments of solid pine wood based on families
  - 1 tree per family
  - 4 disks (40 cm thick) sampled from each tree

Material and Methods

Methods Flowchart

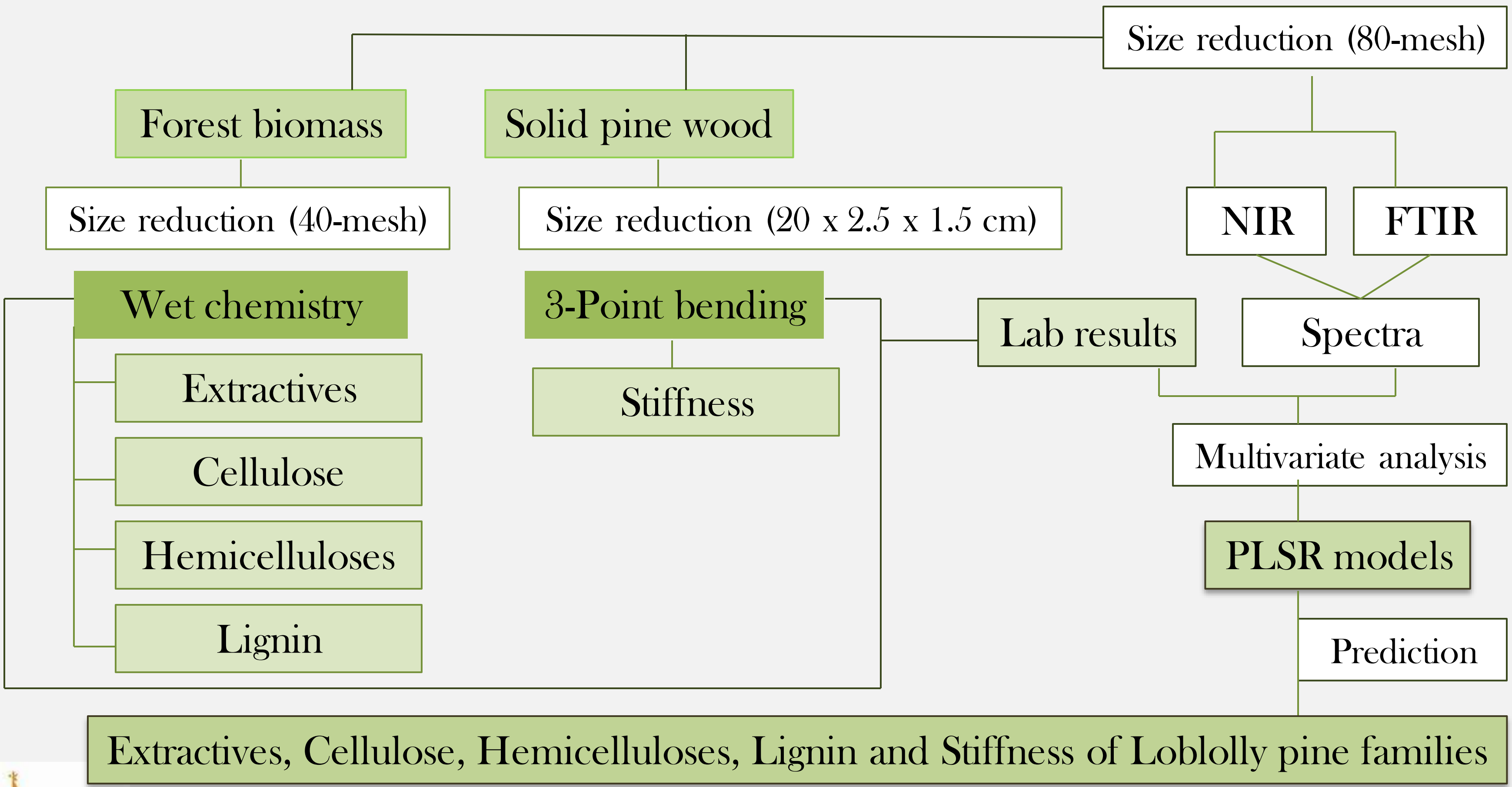
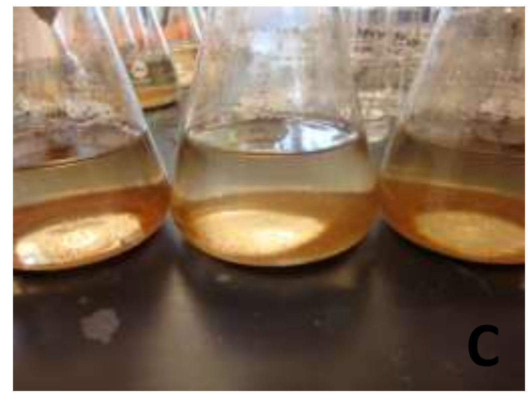


Fig.2: Schematic diagram of methods

Material and Methods

Methods

- Conventional Wet Chemistry
  - Extractives: NREL/TP-510-42619 and TAPPI T- 204
  - Cellulose, Hemicelluloses and Lignin: NREL/TP-510-42618

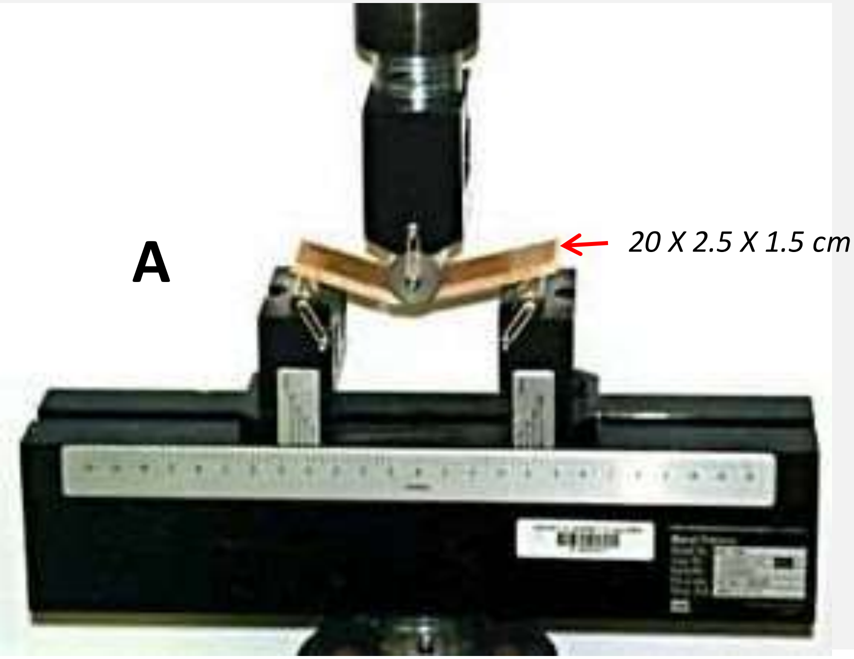


Forest Products
Development Center

Material and Methods

Methods

- Conventional 3-Point Bending
  - Stiffness: ASTM D 1037-99



Material and Methods

Methods

- NIR and FTIR spectra acquisition and analysis
  - ASTM E1655-05 and ASTM E1790-04

A

80-mesh

B

C

Preliminary Results (Objective 1)

Chemical composition determined conventionally

Table 1: Measured Properties of forest logging residues

	Extractives (%)	Glucose (%)	Mannose (%)	Cellulose (%)	Hemicelluloses (%)	Lignin (%)
Whole tree	4.2 (0.7)	33.7 (2.4)	8.2 (1.5)	31.0 (2.4)	**24.1 (2.2)**	37.3 (1.6)
Wood & Bark	**2.1 (1.2)**	41.3 (3.6)	7.2 (1.9)	38.9 (3.8)	22.9 (2.9)	35.9 (2.0)
Harvest Slash	**10.1 (1.9)**	27.2 (2.4)	6.1 (1.2)	**25.2 (2.4)**	22.1 (4.2)	**43.7 (1.7)**
Wood	3.1 (0.3)	45.3 (2.5)	7.3 (0.3)	**42.7 (2.4)**	**20.3 (0.9)**	**33.5 (1.6)**

Comparable results from literature

Wood: Extractives 0 – 21
Cellulose 32 – 55
Hemicelluloses 21 – 27
Lignin 21 - 40

Needles: Extractives 20
Lignin 33
Holocellulose 46

Bark: Extractives 2 – 5
Lignin 40 – 55
Holocellulose 30 – 43

Litterfall: Extractives 5.8 – 23.1
Lignin 32.6 – 48.3
Holocellulose 20.9 – 43.0

Forest Products Development Center

Preliminary Results (Objective 1)

NIR Spectra

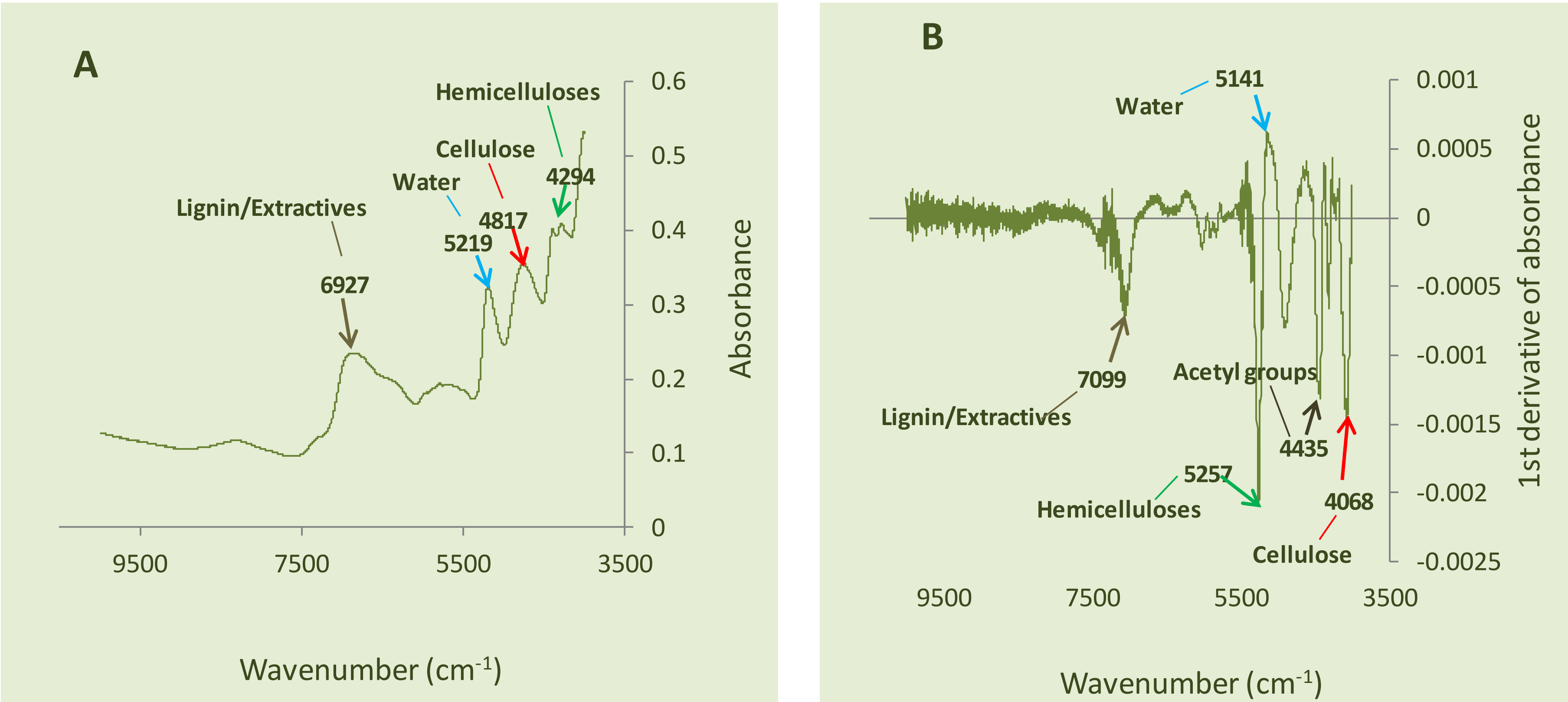


Fig.3: Raw (A) and 1st derivative – treated (B) NIR spectra of forest logging residues showing important wavenumbers corresponding to chemical components

Preliminary Results (Objective 1)

Calibration model statistics for property prediction

Table 2: Fit statistics of PLSR calibration models for the prediction of chemical composition of logging residues

	PCs	SEC	SEP	R^2	RPD	Bias
Extractives (%)	4	1.08	1.23	0.91	2.70	-0.043
Glucose (%)	4	3.34	3.74	0.82	2.01	0.103
Mannose (%)	8	1.00	1.44	0.65	1.05	-0.022
Cellulose (%)	4	3.45	3.87	0.81	1.92	0.103
Hemicelluloses (%)	8	2.61	3.66	0.41	0.83	0.134
Lignin (%)	4	1.55	1.75	0.88	2.39	0.073

Definition of Model Statistics

PCs – Principal components: Factors (wavenumbers) used to develop models; the lesser the number, the better.

R^2 - Coefficient of calibration: Measures the strength of the correlation between the measured and predicted property; the closer to 1, the better.

SEC – Standard error of calibration: Determines how well model fits data; should not be more than 1/10th the range of lab results.

SEP – Standard error of prediction: Measures model's predictive ability; should be close to the SEC but greater.

RPD - Ratio of performance to deviation: Evaluates SEP in terms of SD (Standard deviation) of the reference data; the greater the value, the better.

Bias - Detects any systematic difference between calibration set and the prediction set; the closer to zero, the better.

Forest Products Development Center

Preliminary Results (Objective 1)

Regression Plots

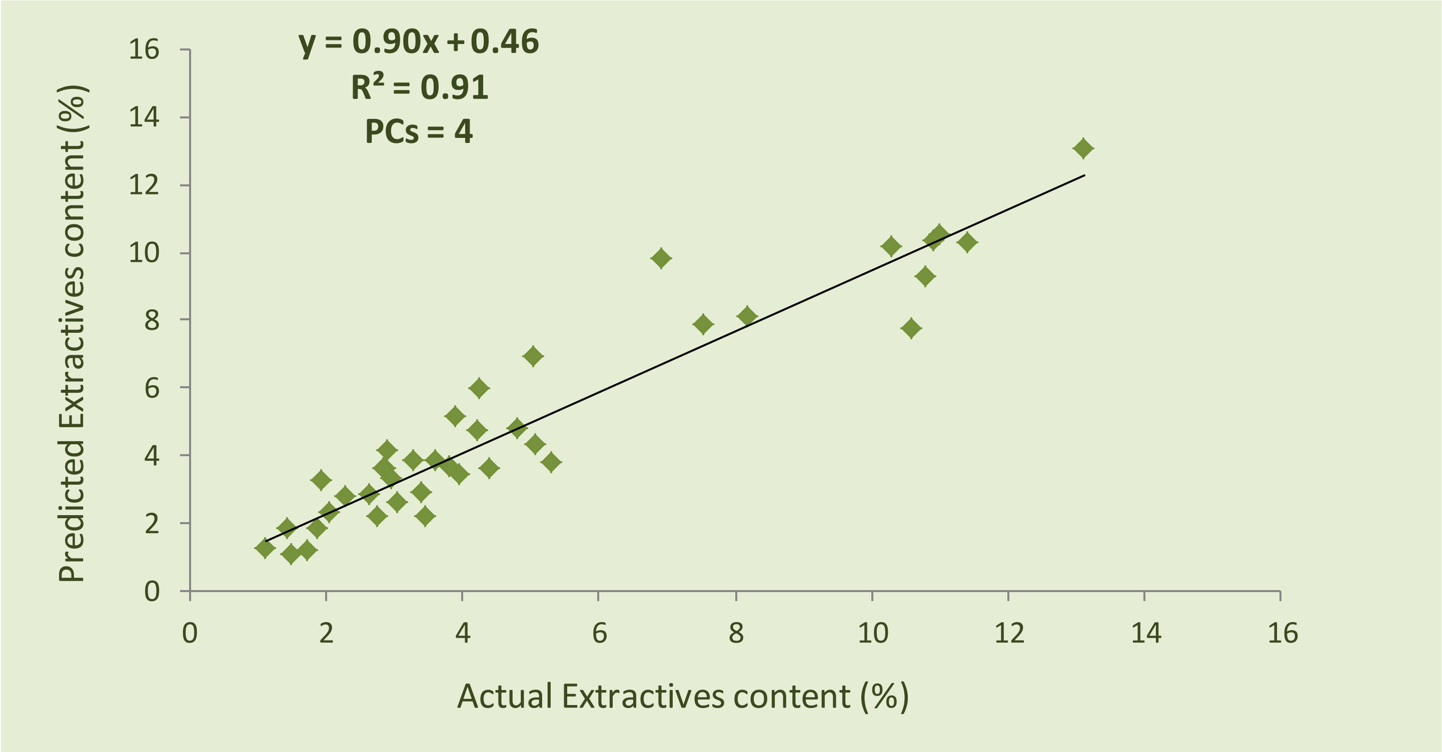


Fig.4: Linear regression plot between conventionally measured extractives content and NIR-predicted extractives content

Preliminary Results (Objective 1)

Regression Plots

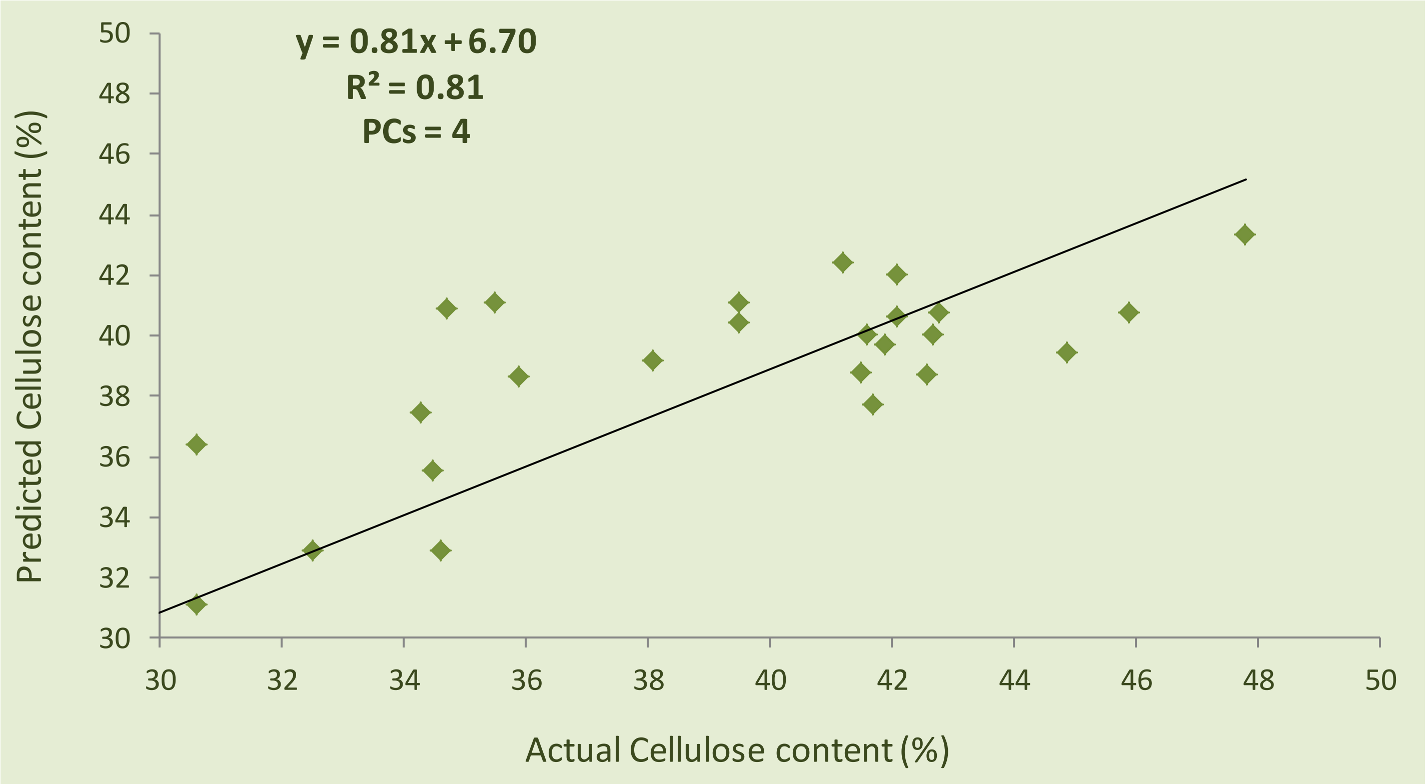


Fig.5: Linear regression plot between conventionally measured cellulose content and NIR-predicted cellulose content

Forest Products Development Center

Preliminary Results (Objective 1)

Regression Plots

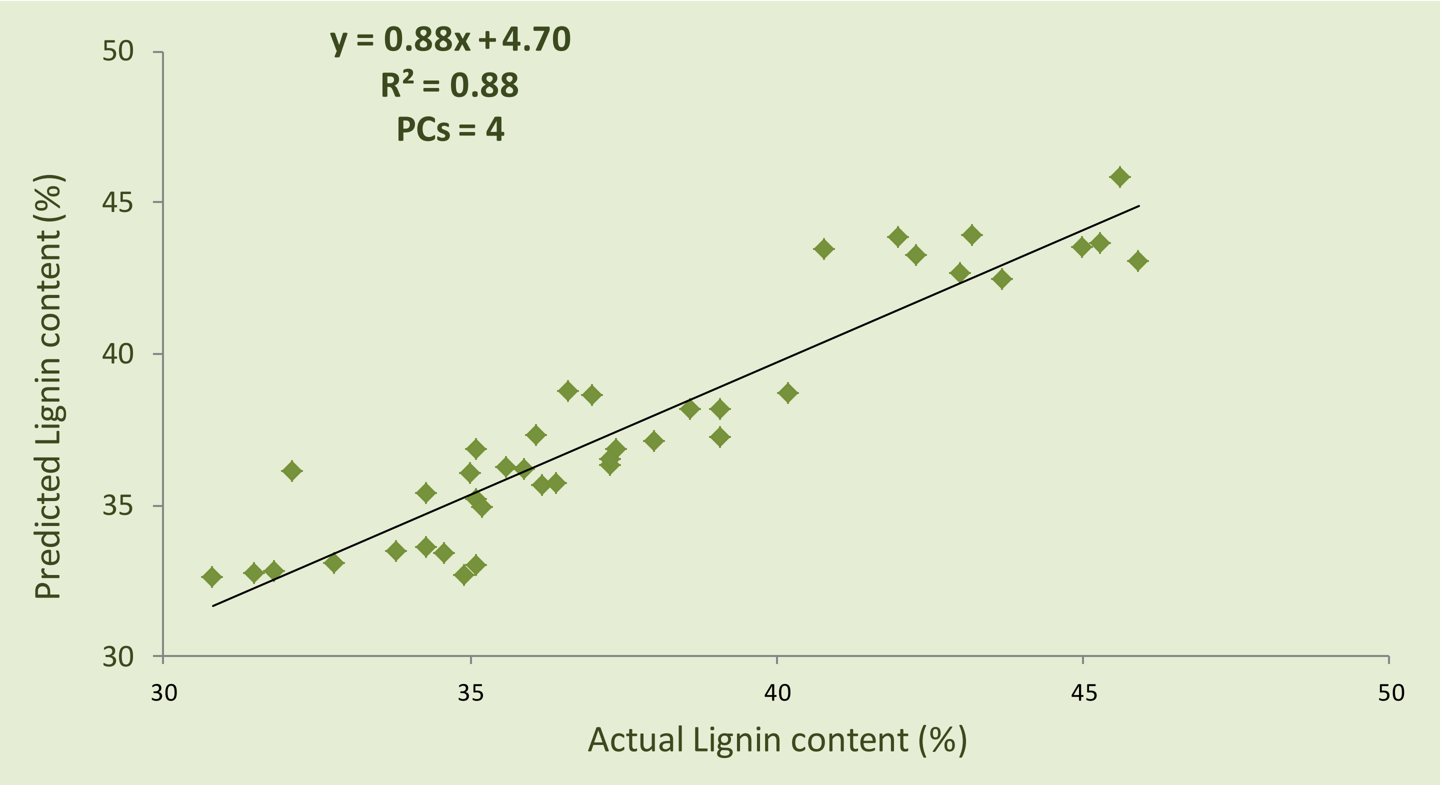


Fig.6: Linear regression plot between conventionally measured lignin content and NIR-predicted lignin content

Preliminary Results (Objective 1)

Pre-treatment with 1st Derivatives

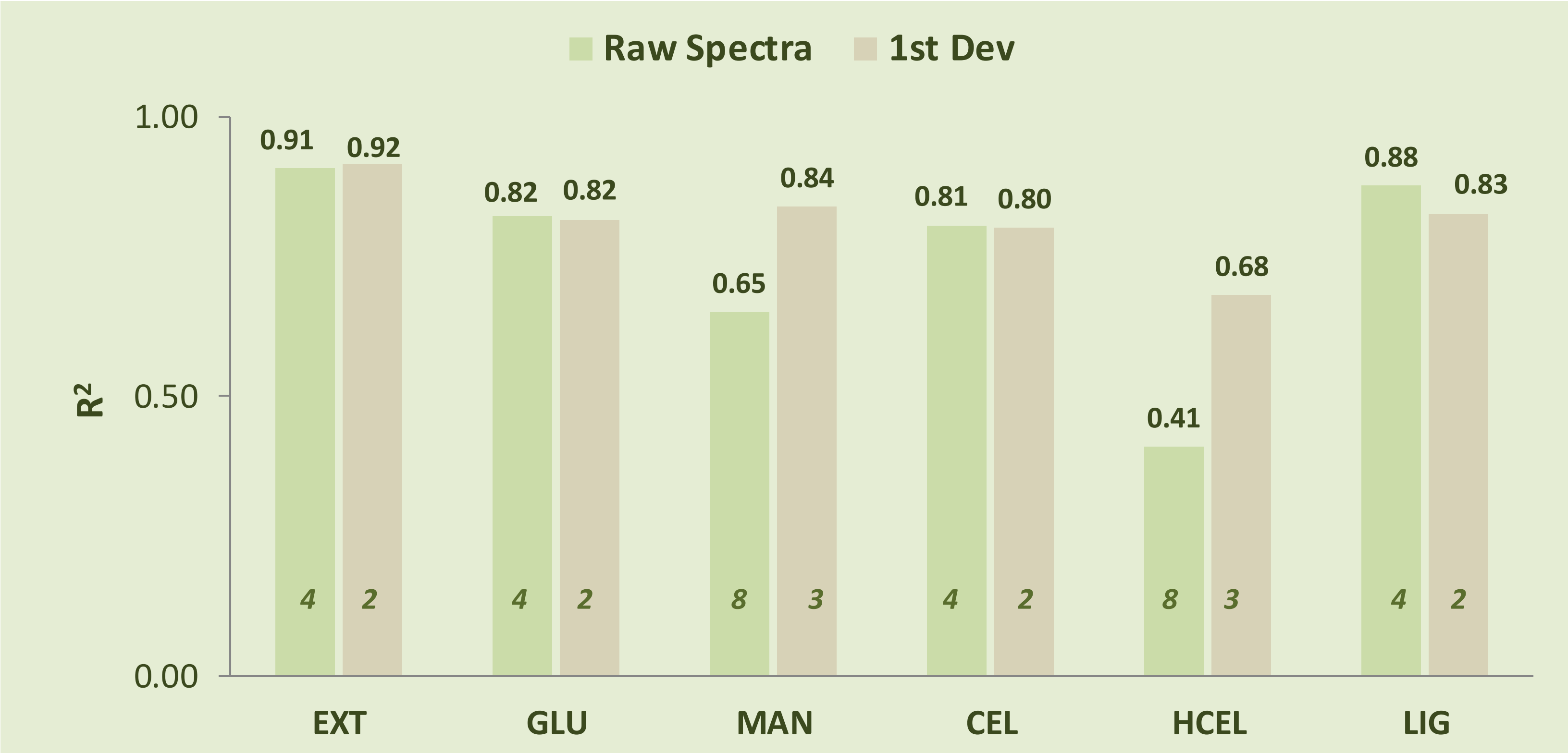


Fig.7: Linear regression plot between conventionally measured lignin content and NIR-predicted lignin content

Preliminary Results

Calibration model statistics for thermochemical properties

Table 3: Fit statistics of PLSR calibration models for the prediction of thermochemical properties of logging residues

	PCs	SEC	SEP	R^2	RPD	Bias
Calorific value (MJ/KG)	2	0.37	0.48	0.57	1.15	0.012
Volatile matter (%)	2	1.00	1.15	0.88	2.46	-0.024
Fixed carbon (%)	2	1.27	1.51	0.85	2.09	0.005
Ash (%)	3	0.61	0.97	0.68	1.07	0.004

Definition of Model Statistics

PCs – Principal components: Factors (wavenumbers) used to develop models; the lesser the number, the better.

R^2 - Coefficient of calibration: Measures the strength of the correlation between the measured and predicted property; the closer to 1, the better.

SEC – Standard error of calibration: Determines how well model fits data; should not be more than $1/10^{th}$ the range of lab results.

SEP – Standard error of prediction: Measures model's predictive ability; should be close to the SEC but greater.

RPD - Ratio of performance to deviation: Evaluates SEP in terms of SD (Standard deviation) of the reference data; the greater the value, the better.

Bias - Detects any systematic difference between calibration set and the prediction set; the closer to zero, the better.

Future Work

Objective 1

- Use samples from 14 families for external validation (i.e. Predict the chemical properties of the 14 families using calibration models developed with forest logging residues)

- Develop calibration models for property prediction using FTIR spectra of forest logging residues

Forest Products Development Center

Future Work

Objective 2

- Develop calibration models for the prediction of stiffness using NIR and FTIR spectra of select families.

Conclusions

Calibration models developed so far have good statistics and will be able to satisfactorily predict the chemical composition of select loblolly pine families.

In the long run, this study will enable us to identify and deploy families that are disease resistant and also optimized for chemical quality and stem strength.

Acknowledgement

- ✓My Advisor
- ✓My Committee Members
- ✓NSF-AUBURN IGERT
- ✓FHC

Thank you!

Questions?