Quantifying Biomass Feedstock Variability Using the DOE Bioenergy Feedstock Library

Rachel Emerson, Victor Walker, Amber Hoover, Marnie Cortez, Robert Kinoshita, Garold Gresham

Advanced Bioeconomy Feedstocks Conference

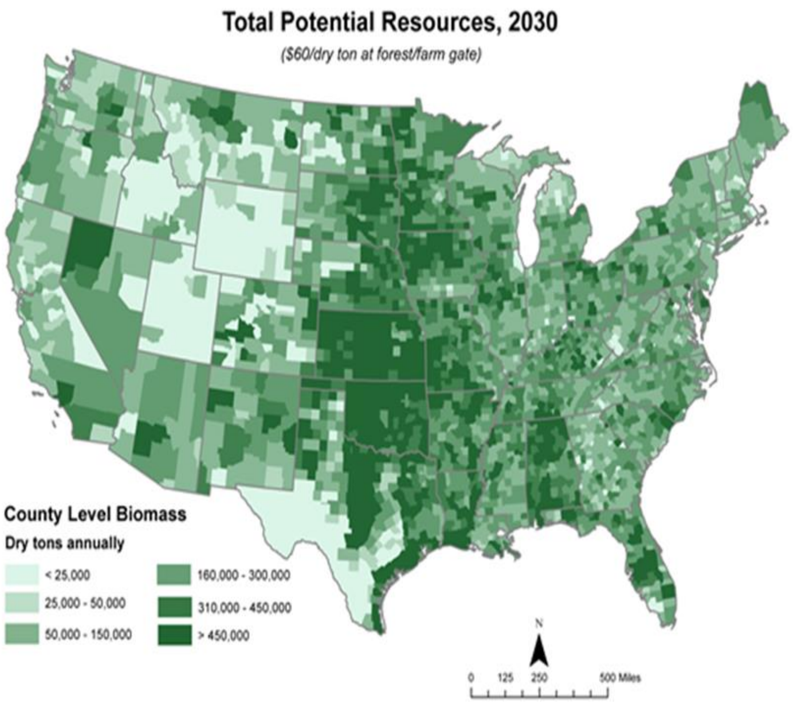
Miami, FL

June 7-8 2016

Billion Ton

Idaho National Laboratory

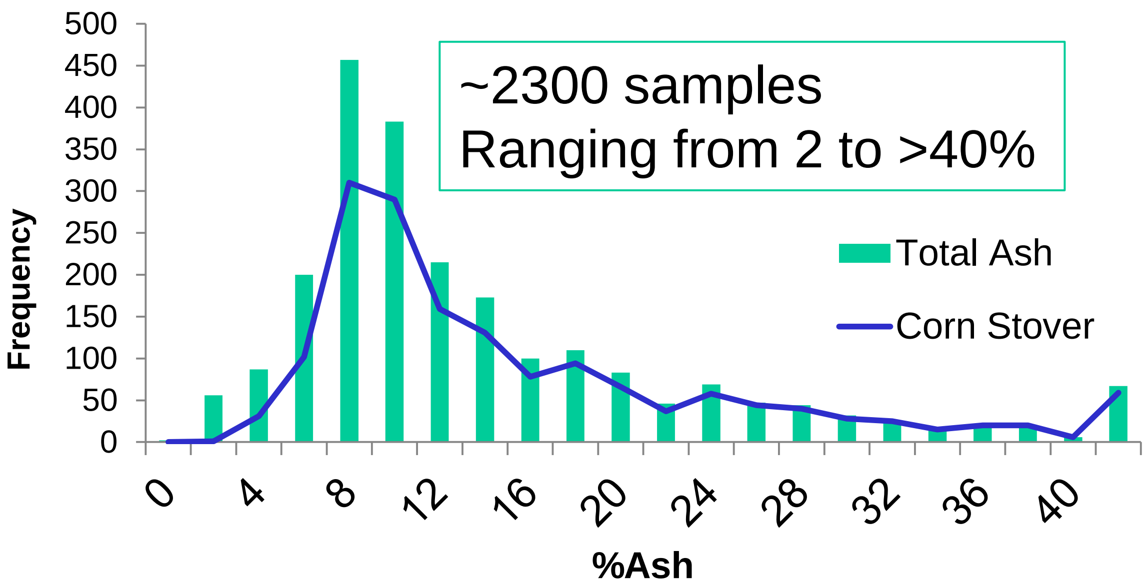
- DOE has recognized the importance of supporting expansion of the US bioenergy industry.
- Biomass resource assessments identified over 1 billion tons of potentially available biomass in contiguous US by 2030.
- The physical and chemical variability and the sources of that variability will have a huge impact on logistics.



Raw biomass is NOT a biorefinery feedstock!

Variability Impacts Cost

- Variability in feedstock quality can be extreme.
- Understanding variability is necessary to establish a valuation system for bioenergy feedstocks.
- Feedstock variability impacts financial risk



- Variability exists due to a number of confounding factors.
- Each 1% increase in ash increases cost ~$2.25/ton
  - Replacement
  - Disposal
  - Wear and tear
  - Buffering capacity

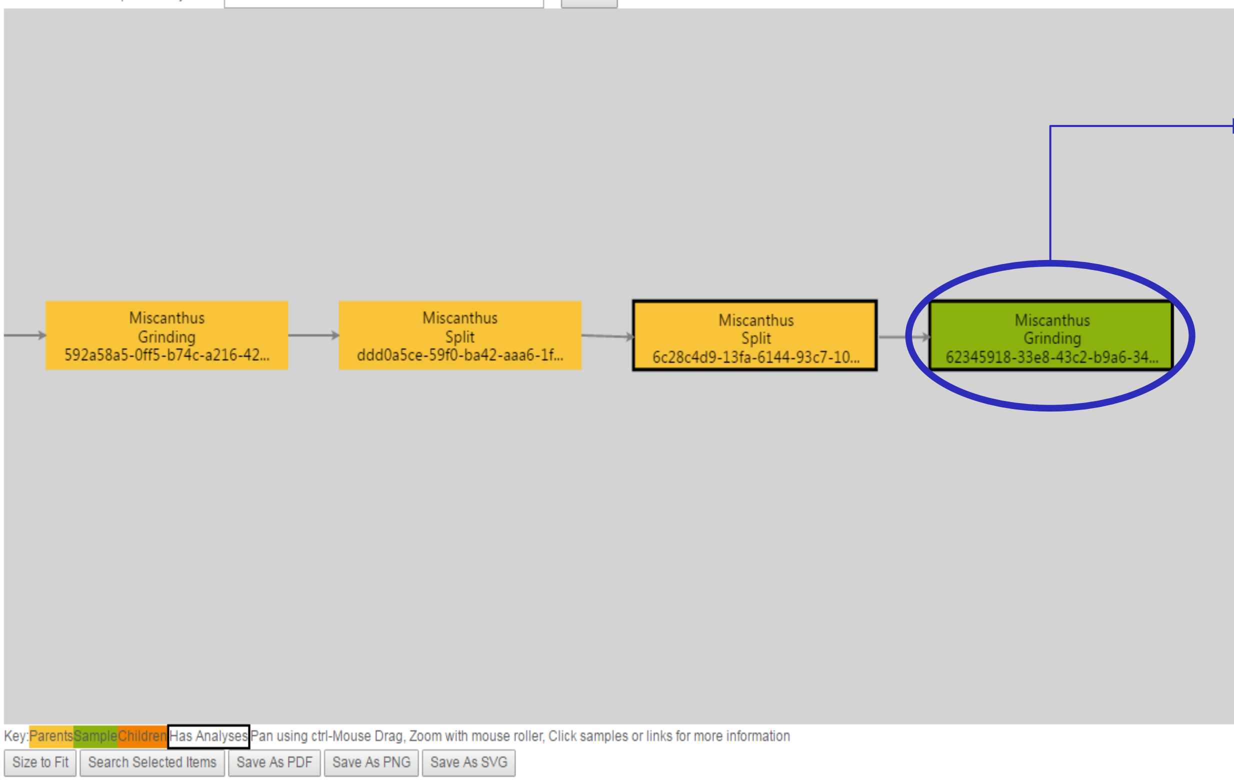
$0 → **$90**

Added feedstock cost ($/ton)

Bioenergy Feedstock Library

- Collaboration with DOE Regional Feedstock Partnership
  - Store, Track, and Analyze samples

Enter GUID to look up hierarchy for: Submit



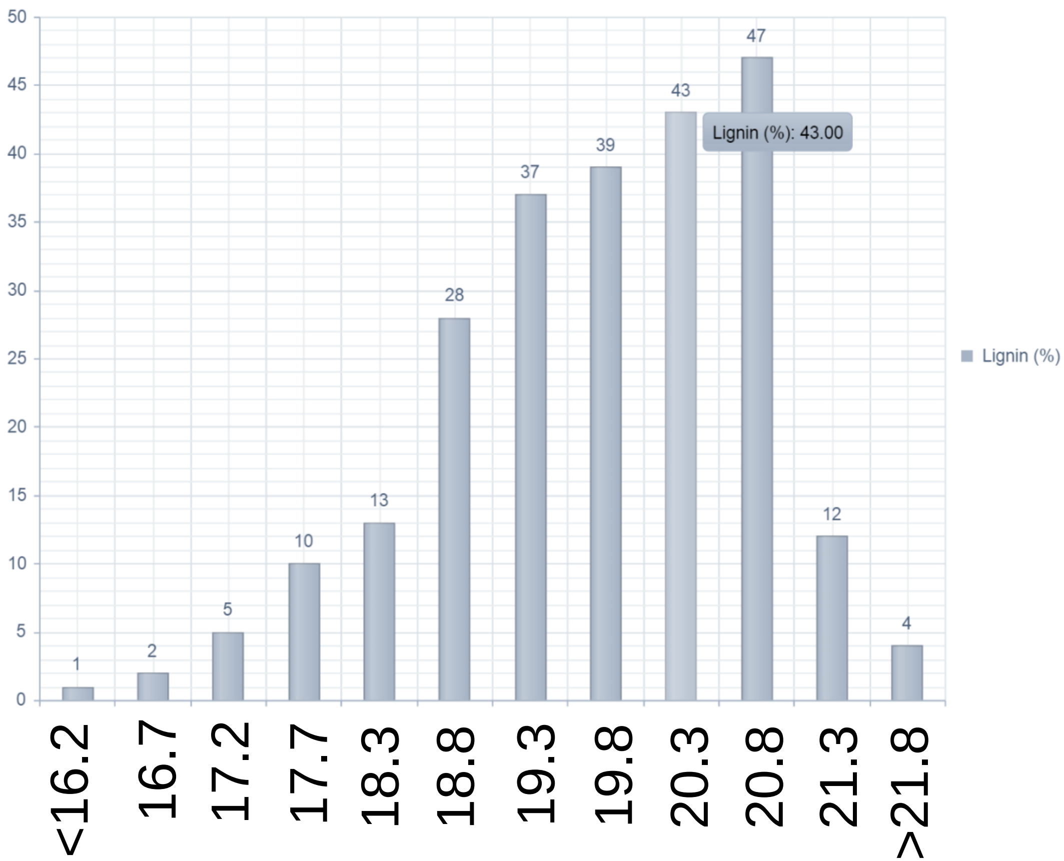
Name	Value
GUID	62345918-33e8-43c2-b9a6-348360f11d23
Project	FY15 Reference Materials
Date Collected	2/25/2015 12:00:00 AM
Collector	Not Specified
Consumed	Not Specified
Operation	Grinding
Location	ESL-B110 Bench C---
Current Amount	26.00 g
City	Tifton
Collector	Gary Gresham
Comments	8 way split
Container	1 gallon Ziplock
Crop Year	2014
CropType	Miscanthus
Cultivar	Mxg
Date of Sample	2/25/2015 12:00:00 AM
Format	0.2 mm
GUIDBarcode	62345918-33e8-43c2-b9a6-348360f11d23
Harvest Date	1/21/2014 12:00:00 AM
INL Contact	Gary Gresham
Organization/Institution	Repreve Renewables
Parent GUID	62345918-33e8-43c2-b9a6-348360f11d23
Project	2014 Reference Materials
Sample #	2 mm Split-1
State	Georgia
Type	Centrifugal Splitter
Elemental Analysis	**Elements in Ash (% oxides;ASTM D3174,D3682, D6349)**
% Al2O3	0.2900
% CaO	18.3400
% Fe2O3	1.2000
% K2O	6.4400
% MgO	9.0300
% NA2O	0.1800
% P2O5	3.5800

Tracking all information associated at every step in sample life cycle

Bioenergy Feedstock Library

Attribute	#Entries	Min Value	Max Value	Mean	Standard Deviation
Lignin (%)	242	15.72	21.79	19.46	1.08

Frequency Graph:



Library Overview

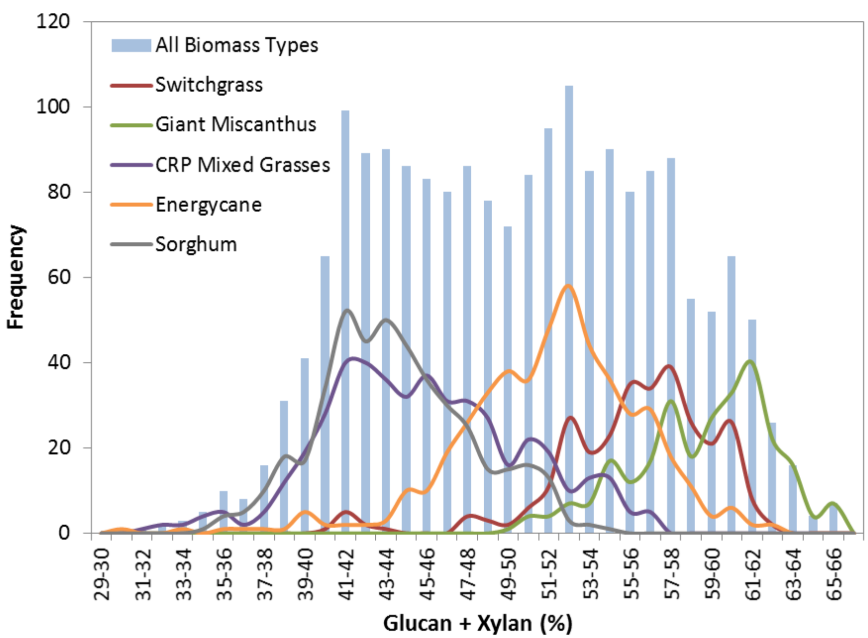
- 35,000 unique sample
  - 90 feedstock types
  - 38 states in US
  - 3 countries
- >100 collaborating universities, feedstock supplier, National labs, and industrial partners
- 3321 samples with analytical data publically available.
  - Chemical
  - Physical
  - Conversion

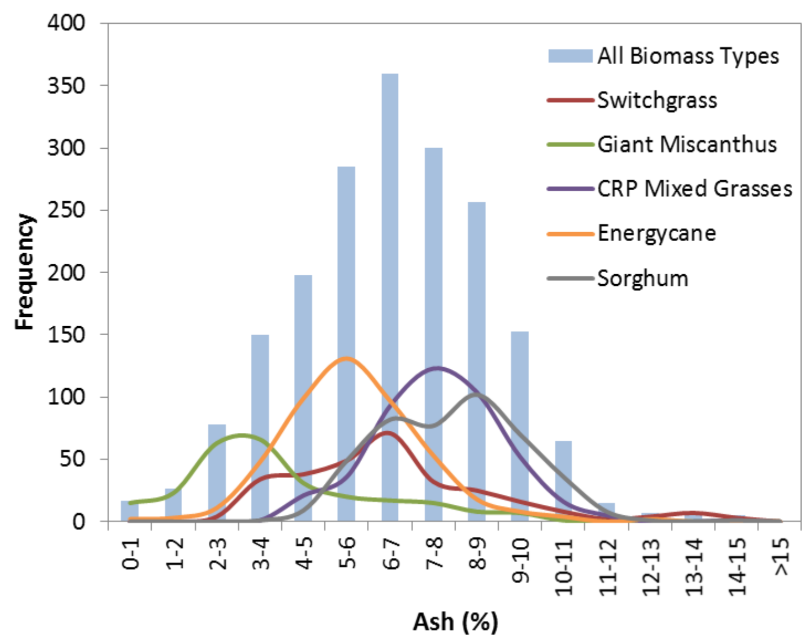
bioenergylibrary.inl.gov

Application of Library Variability

- Regional Feedstock Partnership quality parameter data.
- Sources of Variability
  - Crop years
  - Feedstocks
  - Harvesting conditions
  - Field Treatments
- How does this help us answer large scale questions about feedstock variability?

	#'s
Crop Years	5
Feedstocks	5
States	21
Samples	1937

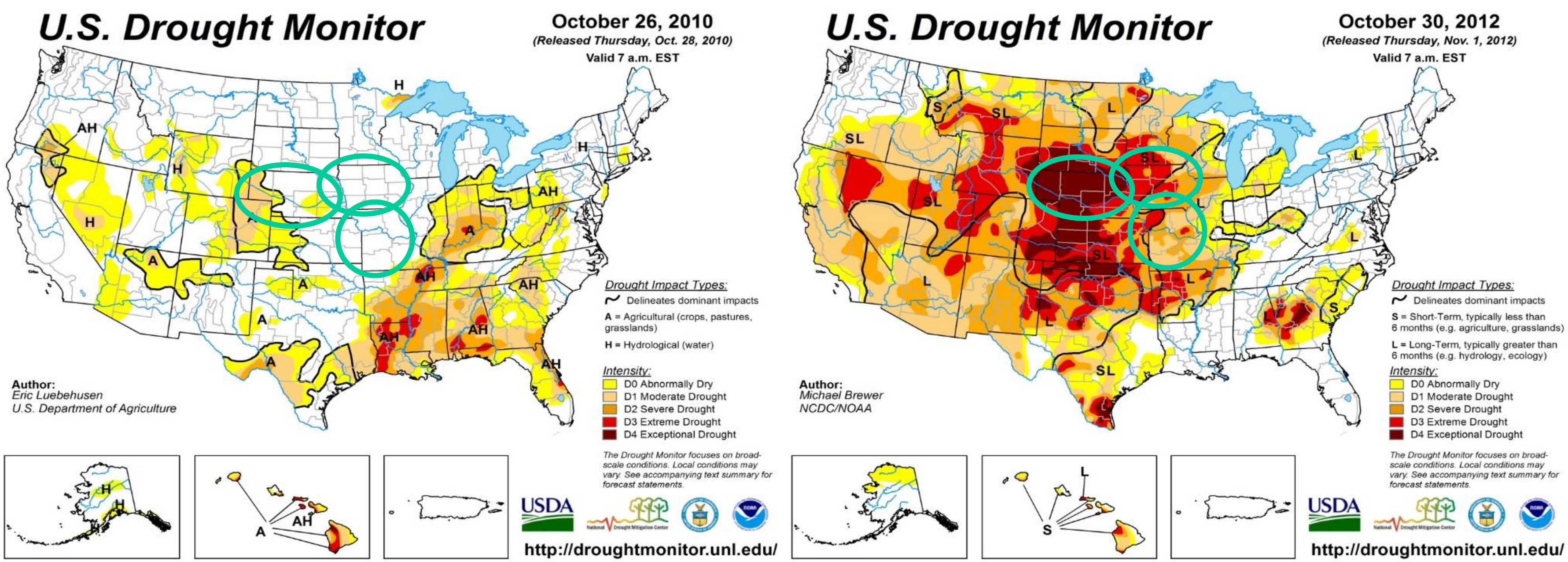




Drought Study

- 3 Feedstocks
  - Corn Stover
  - Native Mixed Grass
  - *Miscanthus x giganteus*
- 3 Locations
  - Iowa
  - Missouri
  - Nebraska

Drought effects on Physical Yields and Quality Measurements.



Emerson, Hoover, Ray, et al. "Drought effects on compostion and yield for corn stover, mixed grasses, and Miscanthus as bioenergy feedstocks" Biofuels, 2014, 5(3), pp 275-291.

Drought Study Cont.

Feedstock	Location	Year	n	TEY (L Mg^{-1})	Dry Biomass ($Mg\ ha^{-1}$)	TEY (L ha^{-1})
Corn Stover	Iowa	2010	11	334 (7)	3.0 (1.4)	990 (471)
Corn Stover	Iowa	2012	11	300 (8)	3.7 (1.1)	1125 (325)
Mixed Grasses	Missouri	2010	18	250 (12)	2.5 (0.6)	635 (146)
Mixed Grasses	Missouri	2012	14	216 (17)	1.2 (0.6)	259 (119)
Miscanthus	Nebraska	2010	12	342 (5)	27.7 (3.2)	9495 (1159)
Miscanthus	Nebraska	2012	12	292 (5)	23.7 (1.8)	6912 (545)

59%

26%

Conclusions:

-Corn Stover yields not affected by drought but quality was impacted.

-Mixed grasses and Miscanthus decreased significantly both yield and quality.

-Miscanthus affects of drought were much more significant than field nitrogen treatments.

Summary

- Quality variability is an important factor in the success of the bioeconomy.
- Library is a useful sample tracking and management tool for project level management.
- The ubiquitous data collected across multiple projects can be used in aggregation to help understand scope and sources of feedstock variability.
- Publically available tool meant to help not only INL research but bioenergy researchers everywhere.

Acknowledgements

- Other Library team members: Brad Thomas, Ross Hays, Chenlin Li, Rachel Colby.
- Those who were authors or contributed to data:

INL: Allison Ray, Jeffrey Lacey, Garold Gresham, Dave Muth Jr., Nathanael Kilburg, James Mahoney, Cole Glass, Sabrina Morgan, Matthew Bryant, Karen Delezene-Briggs, Sergio Hernandez

NREL: Courtney Payne, Amie Sluiter, Edward Wolfrum, Stefanie Maletich

ARS-USDA: Doug Karlen, Larry Pellack, Gary Radke

Iowa State University: Stuart Birrell, David Laird

University of Missouri: Robert Kallenbach

University of Georgia: Josh Egenolf, Carl Jordan

University of Nebraska-Lincoln: Matthew Sousek, Roch Gaussoin

University of Illinois: Thomas Voight, Emily Thomas, Andy Wycislo, DoKyoung Lee

- Collaborators mentioned: Krystel Castillo (University of Texas at San Antonio), Emily Heaton (Iowa State University), and Danielle Wilson (Iowa State University), Oakridge National Laboratory.

This work is supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Bioenergy Technologies Office, under DOE Idaho Operations Office Contract DE-AC07-05ID14517

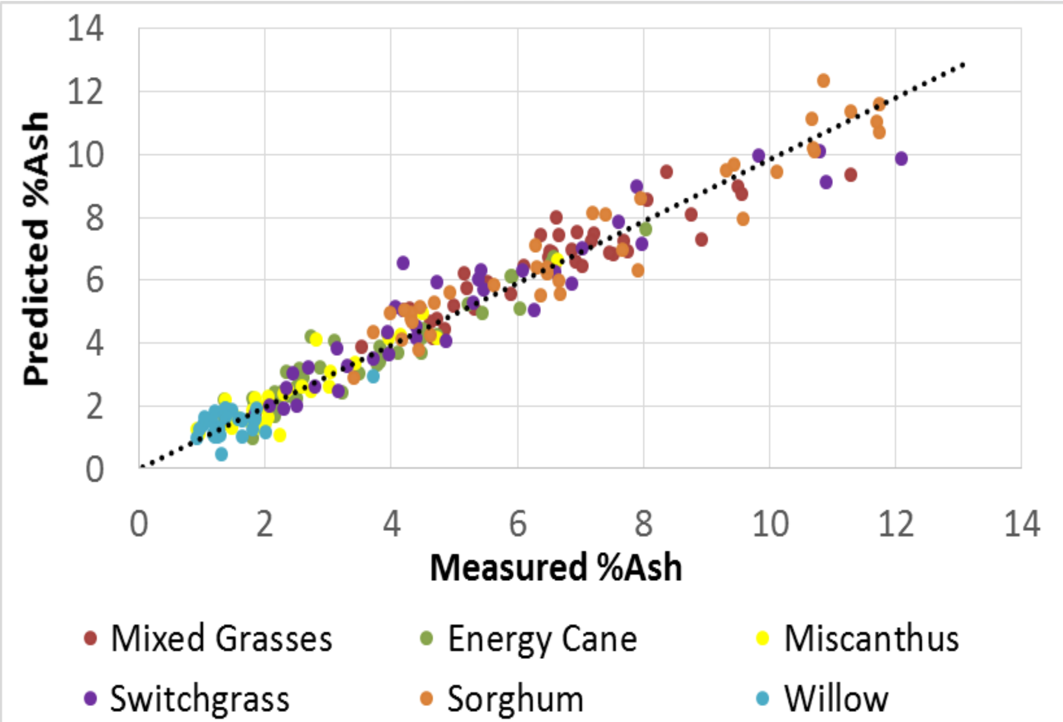
Questions?

NIR Model Development

- Proximate/Ultimate rapid characterization
- Development of NIR models that can handle variability:
  - Feedstock (including different cultivars)
  - Location
    - Matrix effects of different locations within one type of feedstock can affect analyte concentrations
  - Crop Year/ Harvest Season
    - As seen in the drought study harvest year can effect multiple physical and chemical components in feedstocks
- High throughput and rapid screening techniques are necessary to quickly characterize samples

Feedstock	# of States	# of Years	Total # Samples	Range: %Ash
Mixed Grasses	2	5	43	4- 11
MIS (*Miscanthus)*	5	5	30	1 – 7
SG (Switchgrass)	5	5	38	1 – 12
SOR (Sorghum)	7	5	40	3 – 12
EC (Energy Cane)	5	4	48	1 - 8
WIL (Willow)	1	1	32	1 – 4
Total	**18**	**6**	**233**	**1 - 12**

NIR Model Results



Model Merits	Common	Advanced
RMSEC	0.92	0.65
RMSECV	1.01	0.88
R^2 Cal	0.89	0.95
R^2 CV	0.84	0.91

Improved Models

Conclusions:

Using advanced spectral preprocessing techniques a PLS model was built to predict ash content that could handle feedstock, temporal, and spatial variabilities.

Collaboration Opportunities

- The goals of the Library team are to establish collaborations so that disparate data can be brought together in a single management framework to perform similar studies too large for a single institution.
- Examples:
  - University of Texas at San Antonio: Krystel Castillo
    - Using the publically available library data to answer nationwide questions about chemical and physical differences based on the feedstock type and storage conditions.
  - Iowa State University: Emily Heaton & Danielle Wilson
    - Biomass Crop Production Lab will be using our library to manage their own field experiments and track data
    - Collaboratively we will be analyzing the samples from these studies for chemical and physical properties.
  - INL: Logistical Supply Chain Model Inputs
    - As the data in the library grows it has become a resources for supplying real data for simulations for logistical supply chain modeling efforts.
    - Energy inputs for processing samples can be linked to quality properties of the samples for a larger picture.