June 6, 2023

Rachel Emerson
Idaho National Laboratory
Senior Researcher

Feedstock Quality Variability

Deploying Purpose-Grown Energy Crops for Sustainable Aviation Fuel Workshop

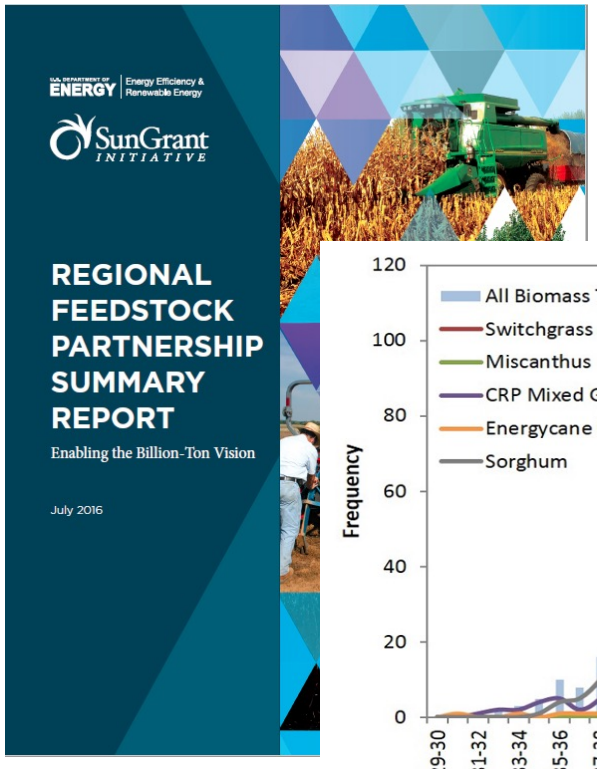
Resource Considerations

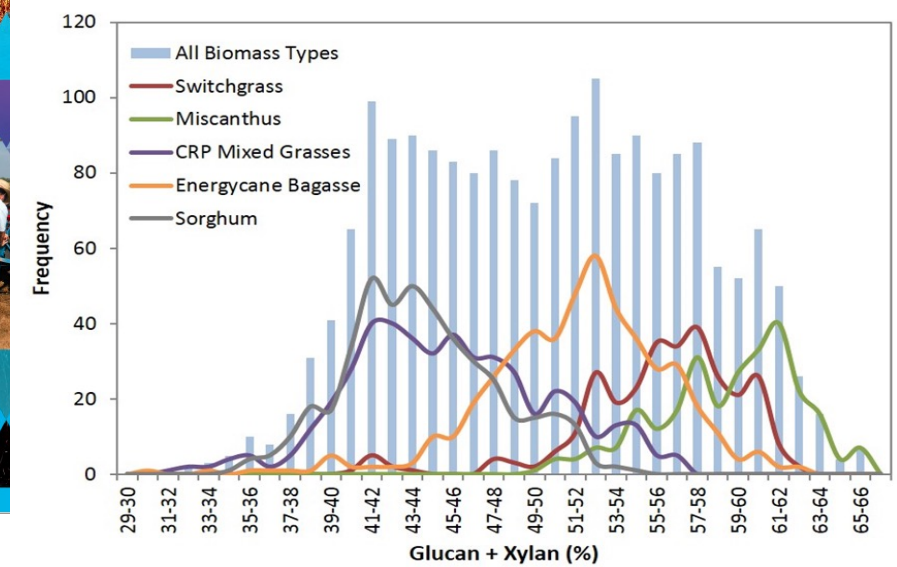
Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

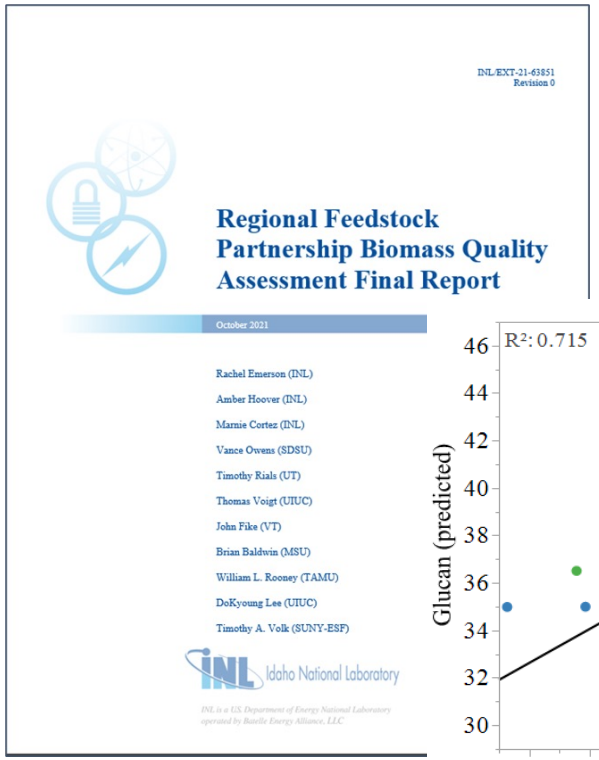
Idaho National Laboratory

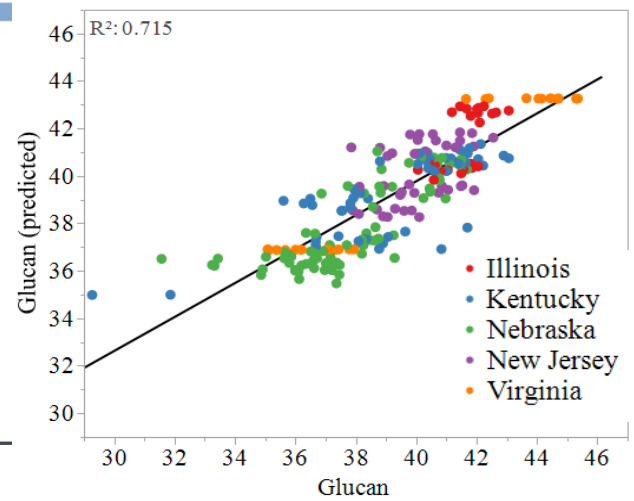
Introduction

- What we have learned about feedstock quality variability
- What gaps still need to be filled



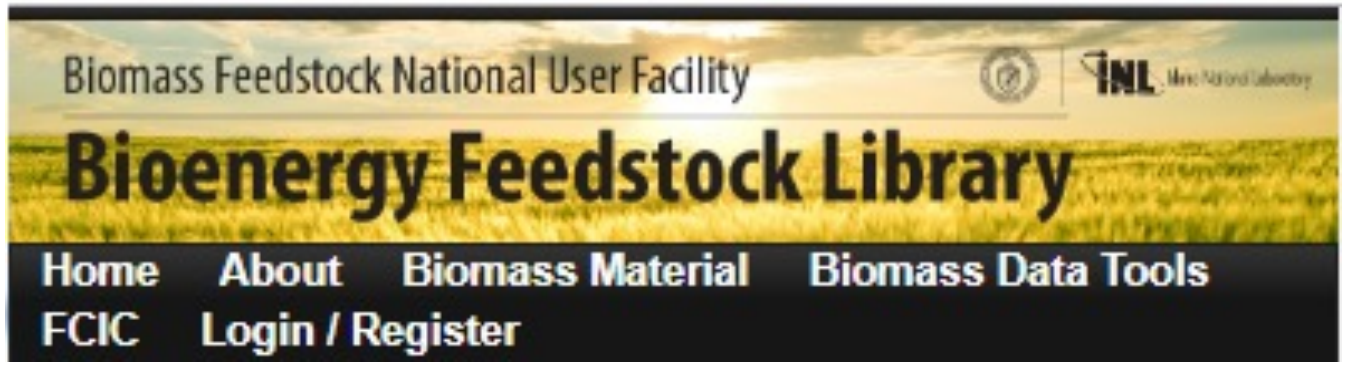




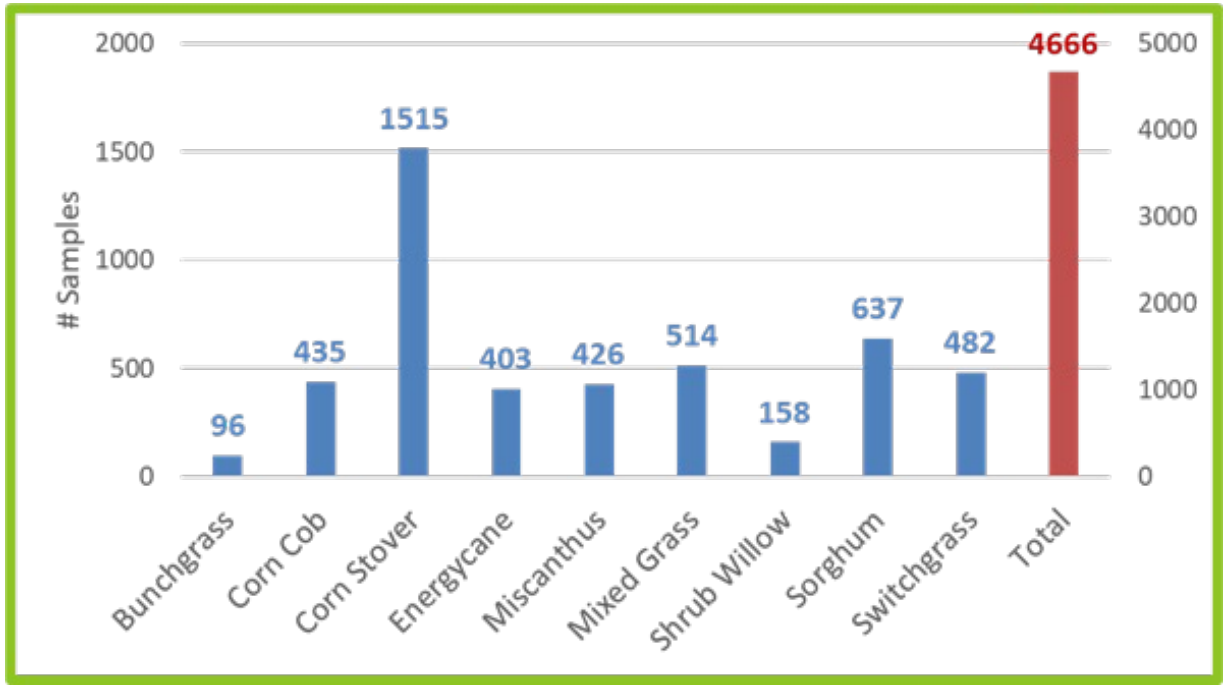


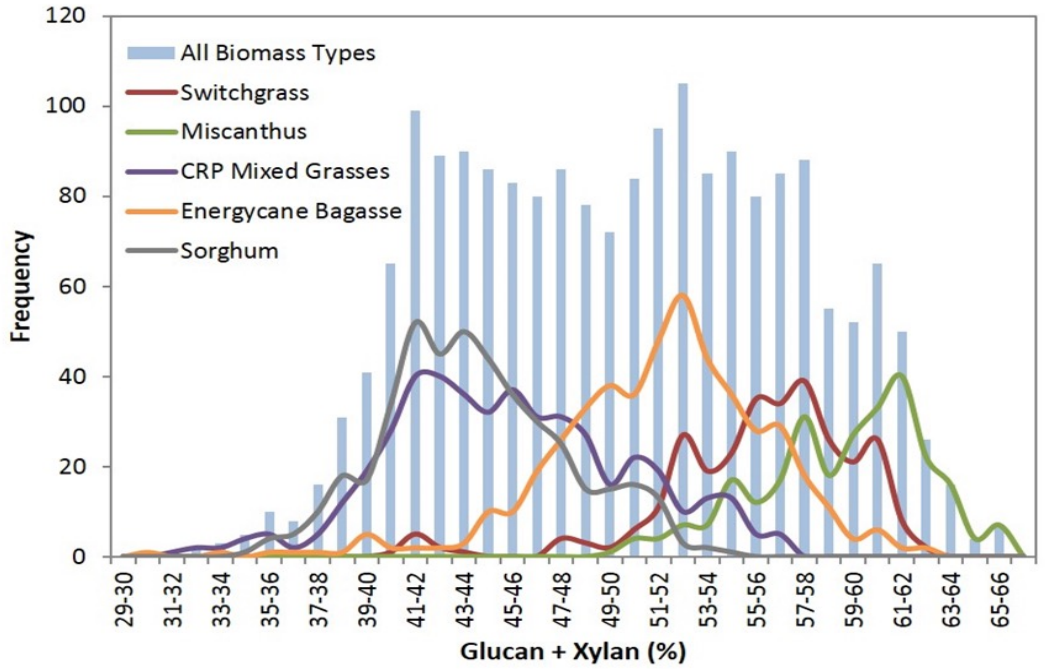
Increased understanding of feedstock quality variability

Original Regional Feedstock Partnership



https://bioenergylibrary.inl.gov/Home/Home.aspx



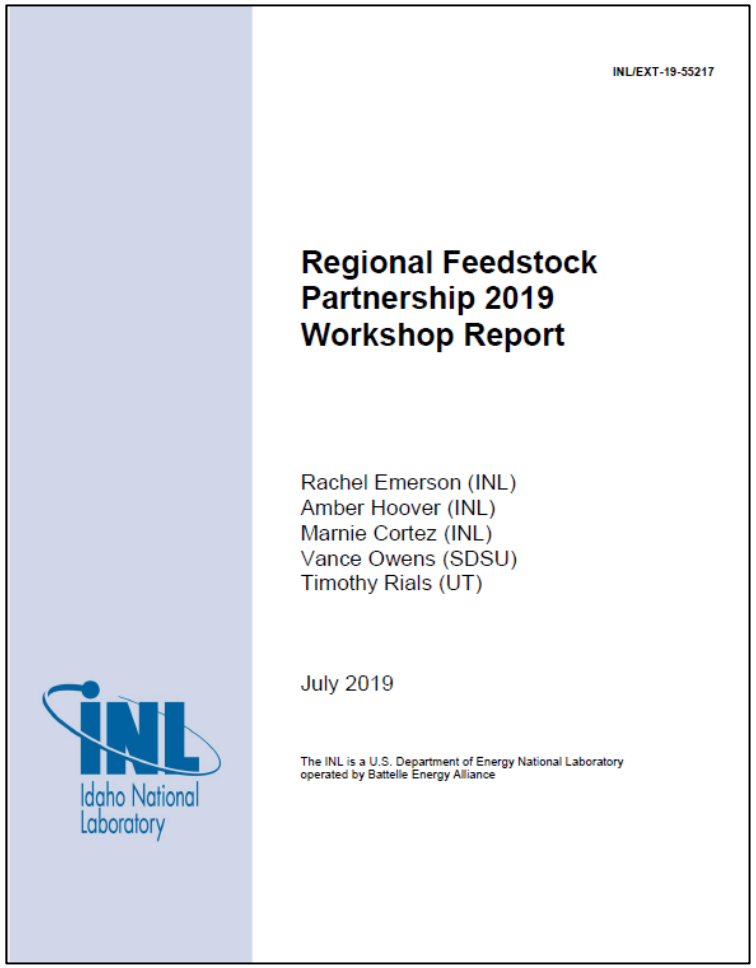


- Sample and meta data archival
- Collecting quality data
- Identifying ranges of variability

Quality Variability Workshop

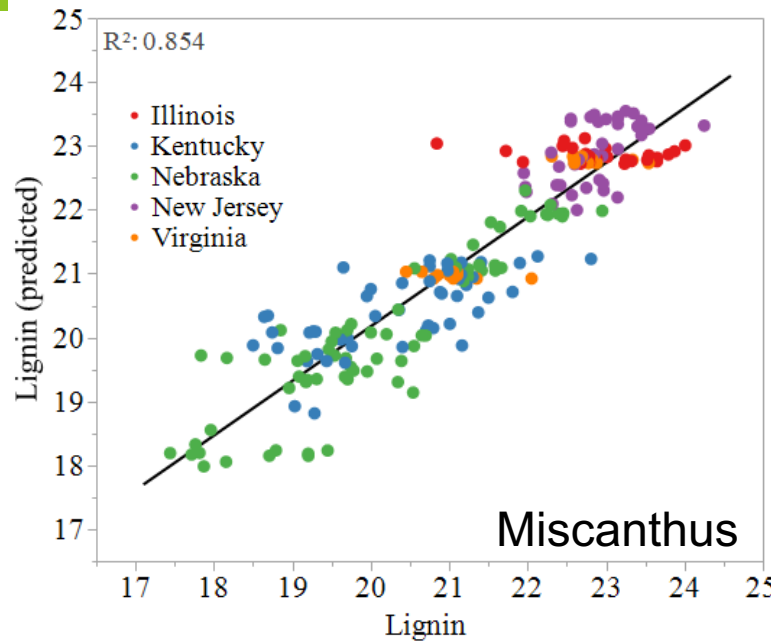
The objectives of the workshop included the following:

- Enable face-to-face interactions with field trial experts
- Fill in metadata and analytical gaps from the RFP for future analyses
- Share results from analysis of RFP biomass properties
- **Discuss the potential to develop biomass quality maps**
- Discuss preparation of peer-reviewed publications for each species
- Discuss outlines for a comprehensive summary

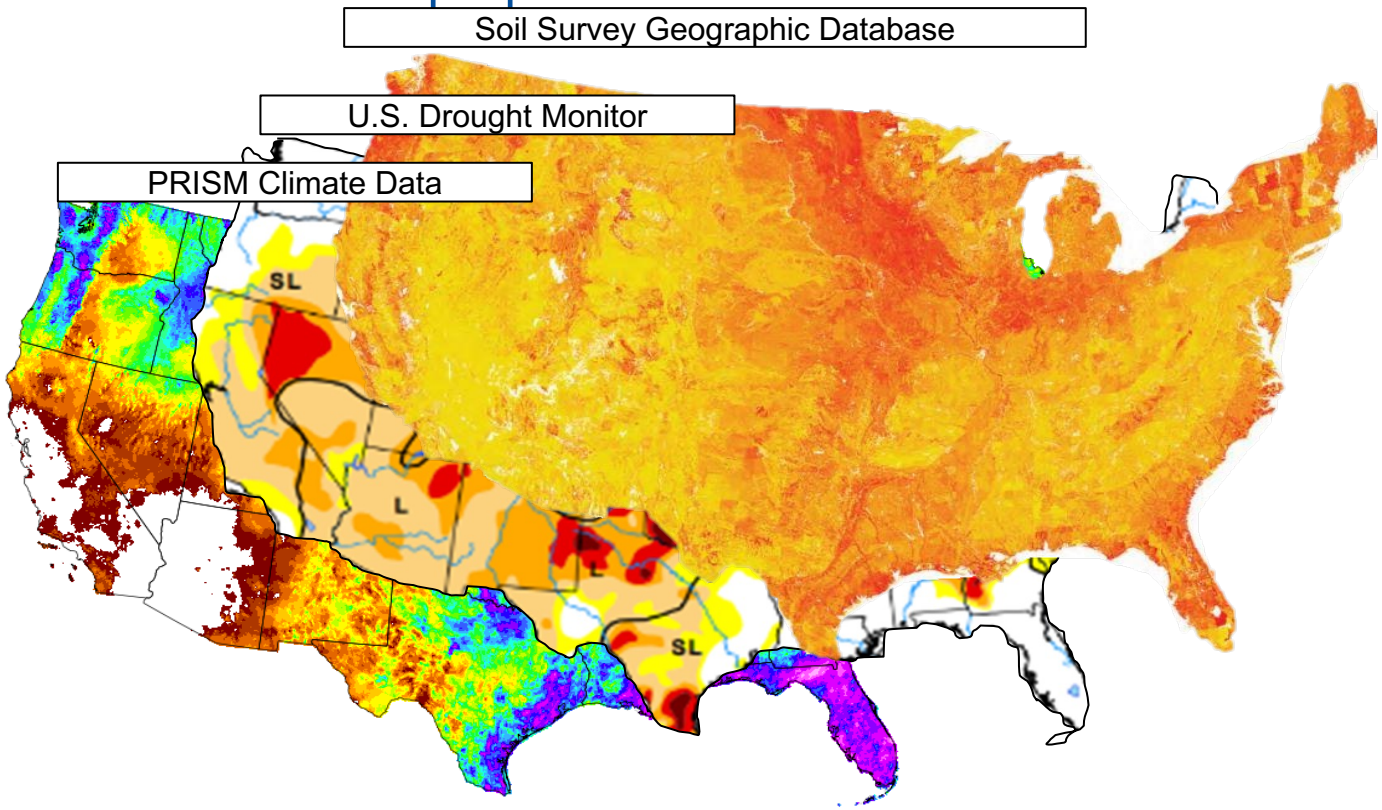


Regional Feedstock Partnership 2019 Workshop Report https://www.osti.gov/biblio/1558410

Quality Map Development



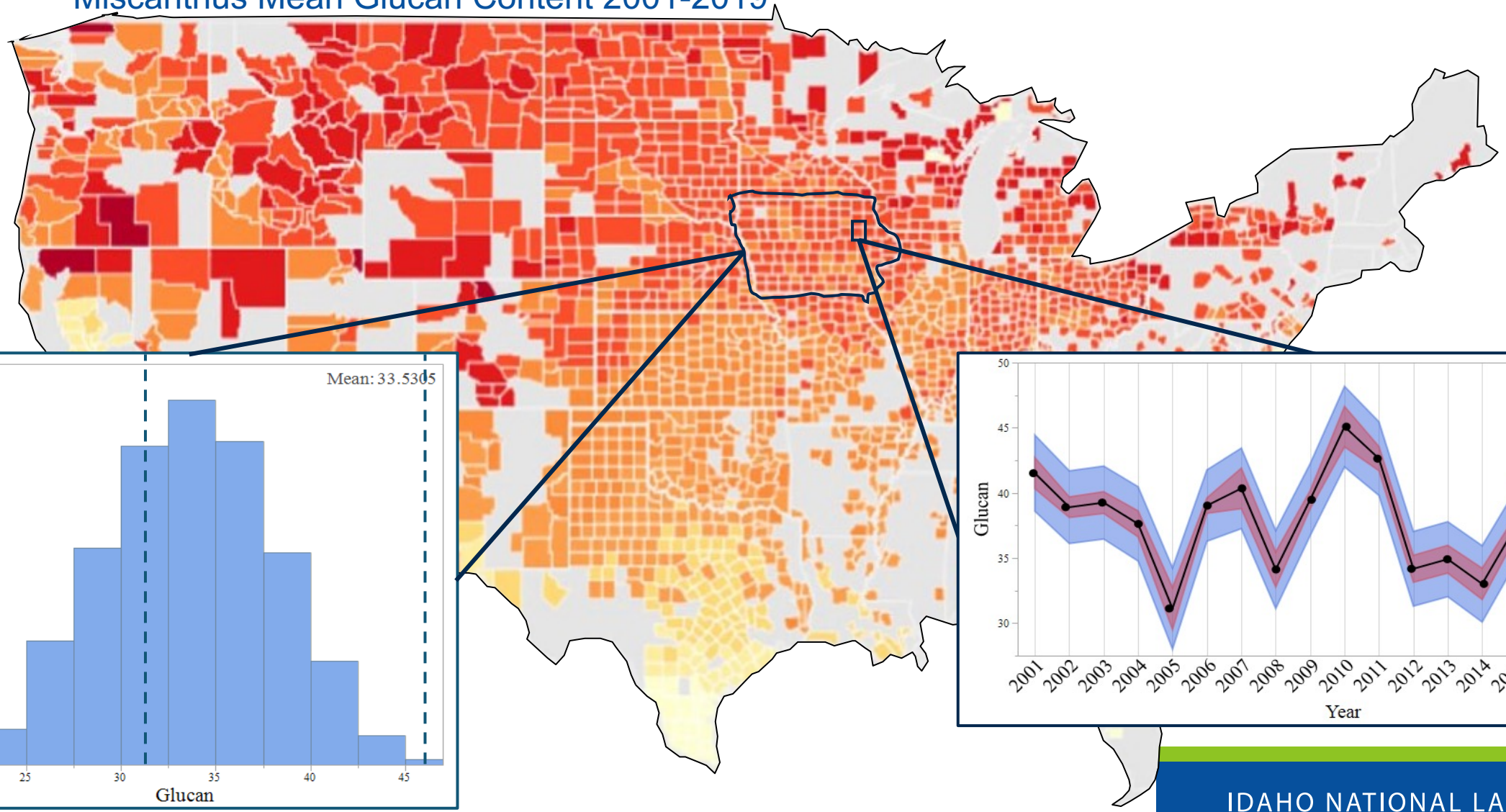
- Predictive model extrapolation using nationwide publicly available databases for environmental and agronomic factors.
- Spatial (U.S.) and temporal (20-year) variability in biorefinery specific critical material properties



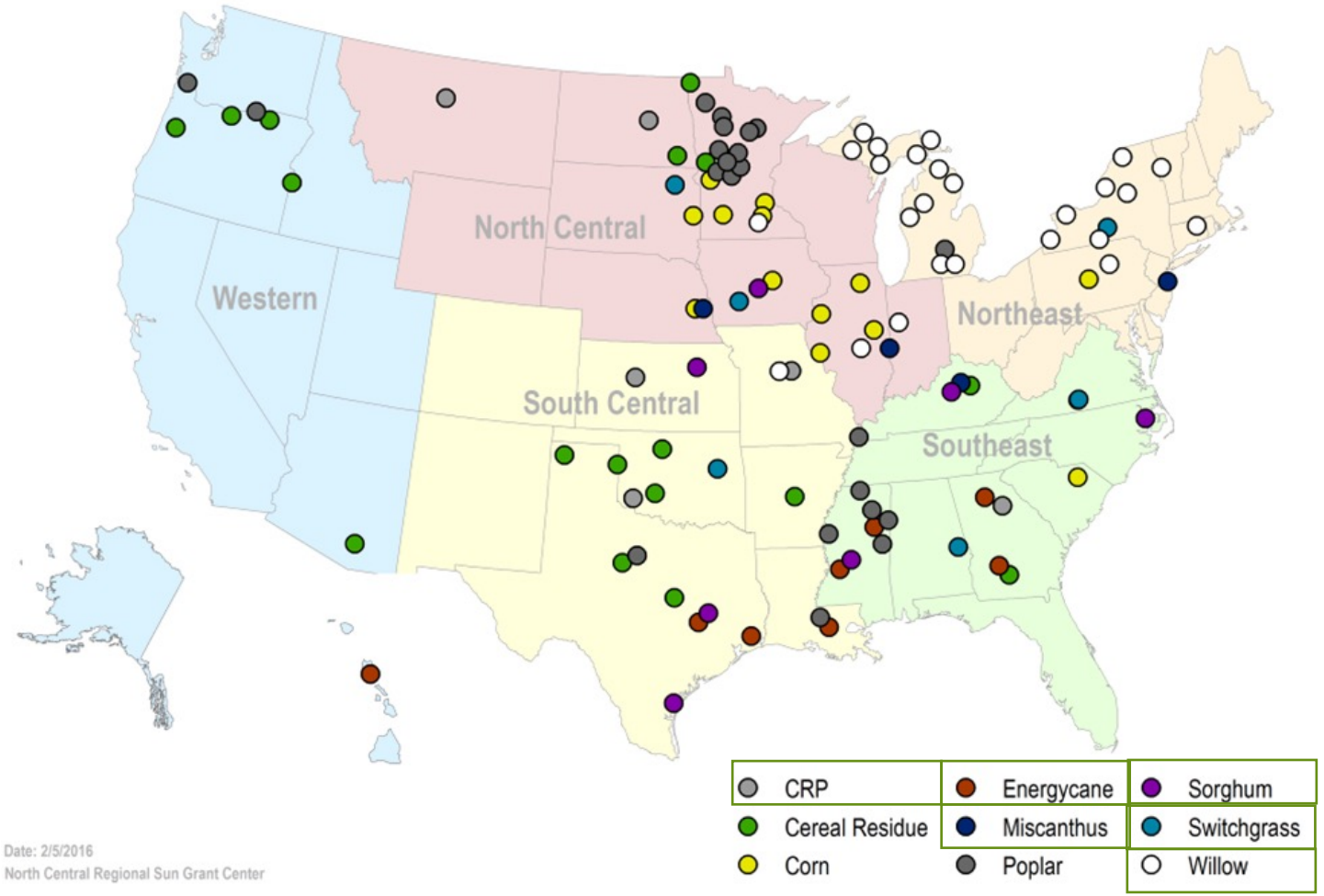
- Long term field studies use to develop relationships between environmental/agronomic factors:
  - Precipitation
  - Temperature
  - **Drought**
  - Soil properties
- Identified critical properties
  - Cellulose carb., lignin, etc.

Quality Map (Miscanthus)

Miscanthus Mean Glucan Content 2001-2019



Final Quality Technical Report



Key outcomes:

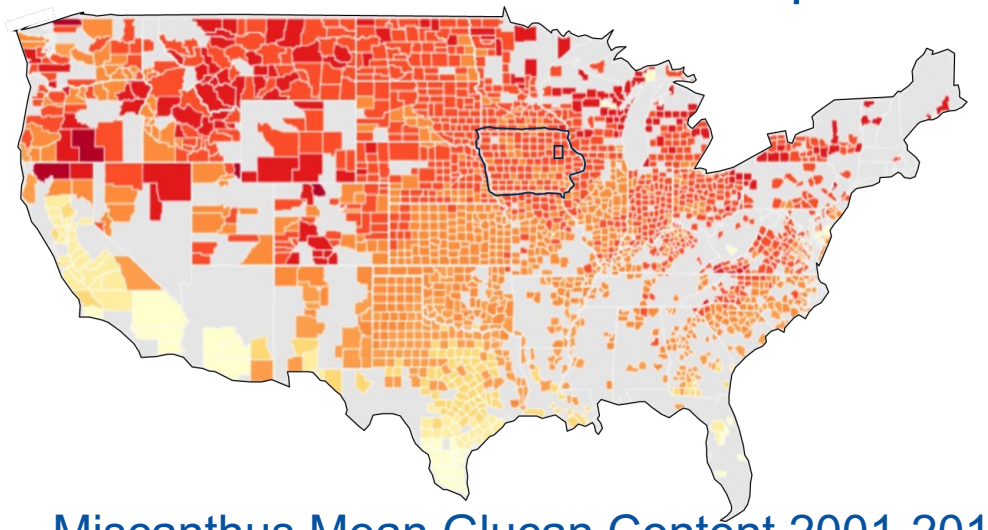
- Complete evaluation of the impacts of agronomic designs, genetics, and environmental conditions on chemical properties
- **Over 30 peer review publications** and technical reports focused on variability in quality data.
- Development of **spatial and temporal environmental quality prediction maps** for Miscanthus and switchgrass
- **Identification of future work**

Regional Feedstock Partnership Biomass Quality Assessment Final Report
https://doi.org/10.2172/1862678

Miscanthus

Success

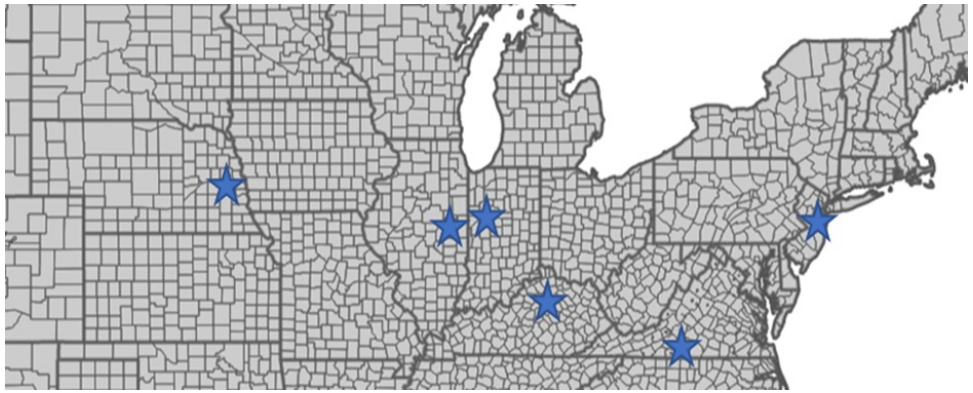
- Location and year had the largest effect on chemical attribute data compared to nitrogen
- Location-specific soil nutrient composition significantly impacted the inorganic speciation composition of the plants
- Quality map demonstrated
- 5 Peer Reviewed Manuscripts



Miscanthus Mean Glucan Content 2001-2019

Future Work and Gaps

- Single genotype
- Fertilization methods/levels
- Harvest timing
- Lack of soil data for prediction models

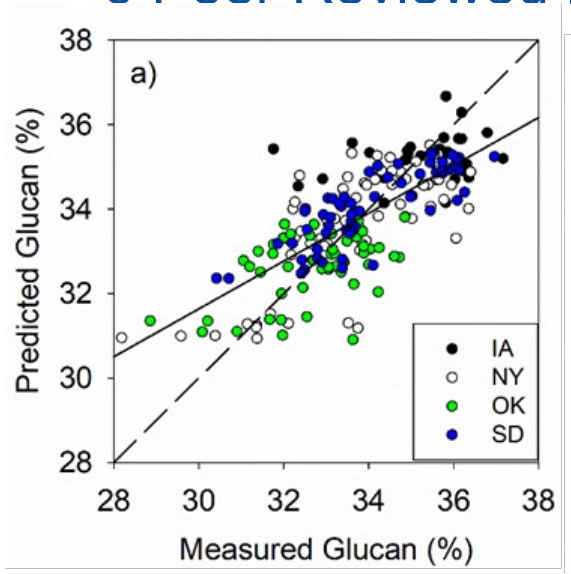


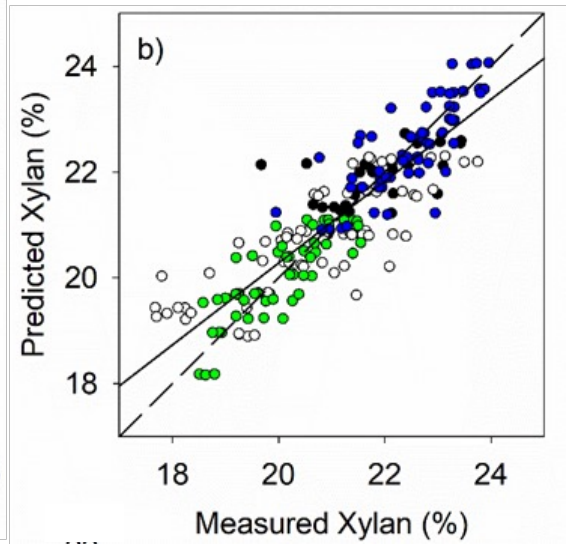
- **2008-2015**
- **5 locations**
- **3 N treatments**

Switchgrass

Findings and Success

- Location and year had the largest effect on chemical attributes
- Environmental variables strongly related to the chemical attributes
- Precipitation strongly impacted lowland switchgrass chemical attributes
- 6 Peer Reviewed Manuscripts





Future Work and Gaps

- More locations for lowland switchgrass
- Lack of soil information
- Location and cultivar information confounded

3 Levels N Treatment

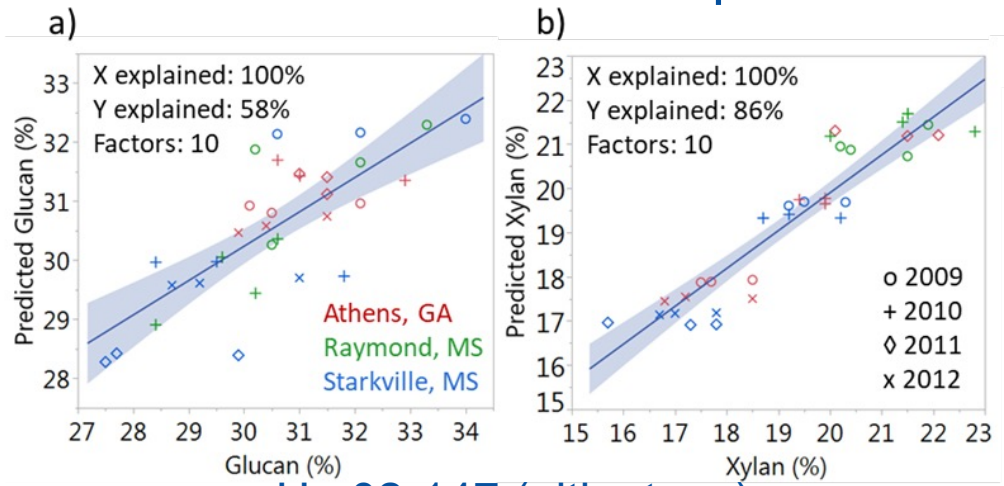
Location	Planting Year	Crop Years	Cultivar Type	Cultivar
Iowa	5/8/2009	2010-2015	Upland	Cave-In-Rock
New York	5/29/2008	2009-2015	Upland	Cave-In-Rock
Oklahoma	9/2/2008	2009-2015	Upland	Blackwell
South Dakota	5/17/2008	2009-2015	Upland	Sunburst
Virginia	7/1/2008	2009-2015	Lowland	Alamo

Hoover, A. Emerson, R., Cortez, M., Owens, V., Wolfrum, E., et al. (2022) GCB Bioenergy. https://doi.org/10.1111/gcbb.12942

Energycane

Findings and Success

- ºBrix was impacted by genotype, location, variety, weather, and time of year; Fiber percentage consistent across locations and genotypes.
- Optimized harvest timing dependent on genotypes for sugar content sugars
- Environmental factors and biomass yields could explain 40–87% of various chemical attributes
- 4 Peer Reviewed Manuscripts



Ho 02-147 (pithy type)

Future Work and Gaps

- Evaluate trends for genotypes along with broader categories
- Soluble sugar measurements not included
- Lack of soil information

5 genotypes

Location	Planting Year	Years with Quality Data
Athens, GA	2009	2009-2012
Tifton, GA	2008	2009-2011
Waimānalo, HI	2010	2011-2012
St. Gabriel, LA	2008	2011-2012
Raymond, MS	2008	2009-2010
Starkville, MS	2008	2009-2012
Bryan, TX	2008	2009-2011
Beaumont, TX	2008	2009-2012

Sorghum

Findings and Success

- All chemical attributes significantly impacted by location, harvest year, and genotype
- Inverse relationship between structural carb. And lignin with yield.
- Environmental models developed for sorghum types and genotypes but models not strong
- 5 Peer Reviewed Manuscripts

Factor	Glucan	Xylan	Lignin	Total Ash	Protein	Volatiles	Ash	Carbon	Nitrogen
Genotype		H	H	H	S	H	H	H	H
Location									
Year								H	
Block [Location x year]									
Year x Genotype									
Genotype x Location								S	S
Year x Location	S			S	S	S		H	S
Year x Location x Genotype	H	H	H	H	H	H	H	H	H
R^2	0.85	0.90	0.90	0.89	0.89	0.96	0.95	0.91	0.89

Future Work and Gaps

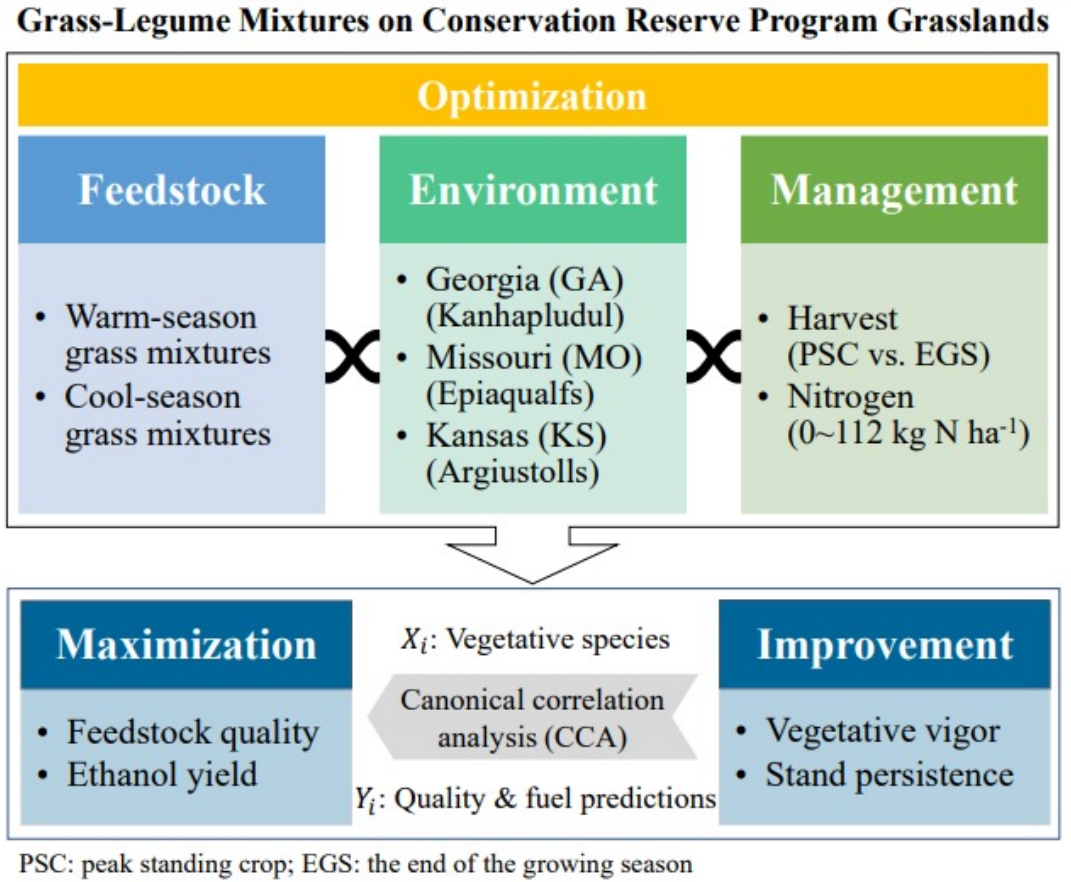
- Agronomic factors such as anthesis not evaluated
- Soluble sugar measurements not included
- Lack of soil information

- 6 genotypes
- 2008-2012
- 7 locations

Mixed Perennial Grasses

Findings and Success

- No fertilization supported healthy legume populations while higher nitrogen inputs increased grass, particularly cool-season grasses.
- Kill frost harvests impacted ash, nitrogen content, cell wall components, and theoretical ethanol yields.
- Precipitation highest environmental impact factor for yield and chemical variability
- 7 Peer Reviewed Manuscripts



Lin, C.-H., Namoi, N., Hoover, A., Emerson, R., Cortez, M., et al. (2023). GCB Bioenergy, https://doi.org/10.1111/gcbb.12980

Future Work and Gaps

- Impact species transitions
- Understand chemical variability of individual species
- Lack of soil information

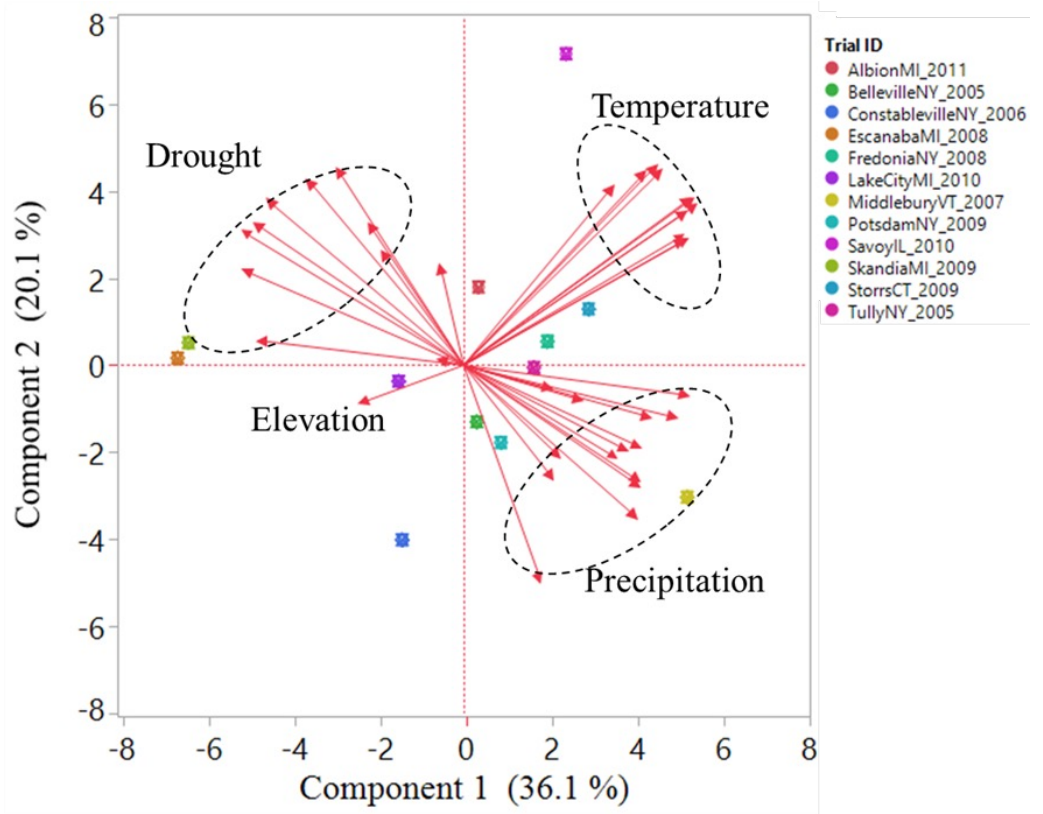
Willow

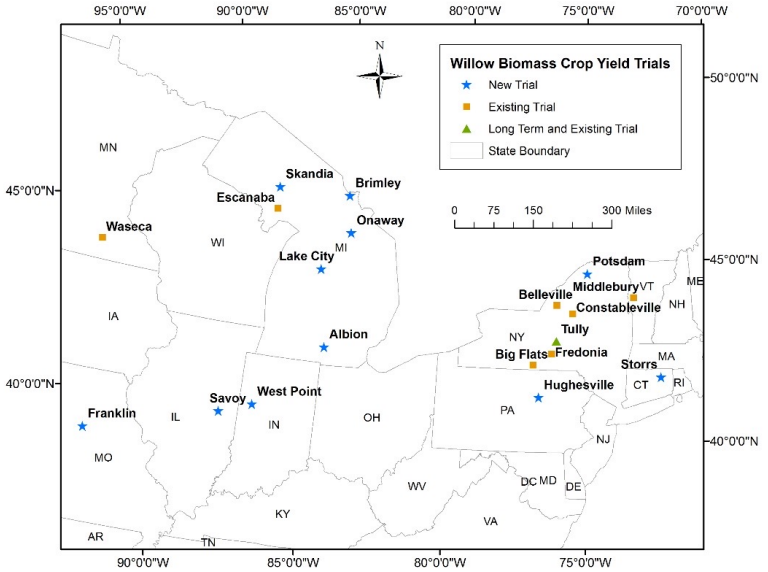
Findings and Success

- Environment and genotype impacted chemical attributes
- Diversity group trends of chemical variability evaluated
- Environmental variables accounted for 85% of chemical variability in some diversity groups
- 4 Peer Reviewed Manuscripts

Future Work and Gaps

- More evaluation on impact of rotations
- Generalize genotypes
- Lack of soil information





- 19 trials
- 1993-2010
- 94 genotypes

(4-30 genotypes/site)

Summary

- Demonstrated long-term quality variability
  - Gaps in quality factors assessed
  - Not all feedstocks evaluated
- Developed a more comprehensive understanding for the impacts of environmental factors on chemical variability
  - Soil factors identified as significant but not widely available
- Identified data gaps for potential next steps
  - What gaps does/will the ASEC and RACIPAC FOA studies fill?

Acknowledgements

The Sun Grant Regional Feedstock Partnership yield and additional quality assessment studies were made possible through funding from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy under Bioenergy Technologies Office award number DE-FC36-05GO85041 and DE-AC07-05ID14517.

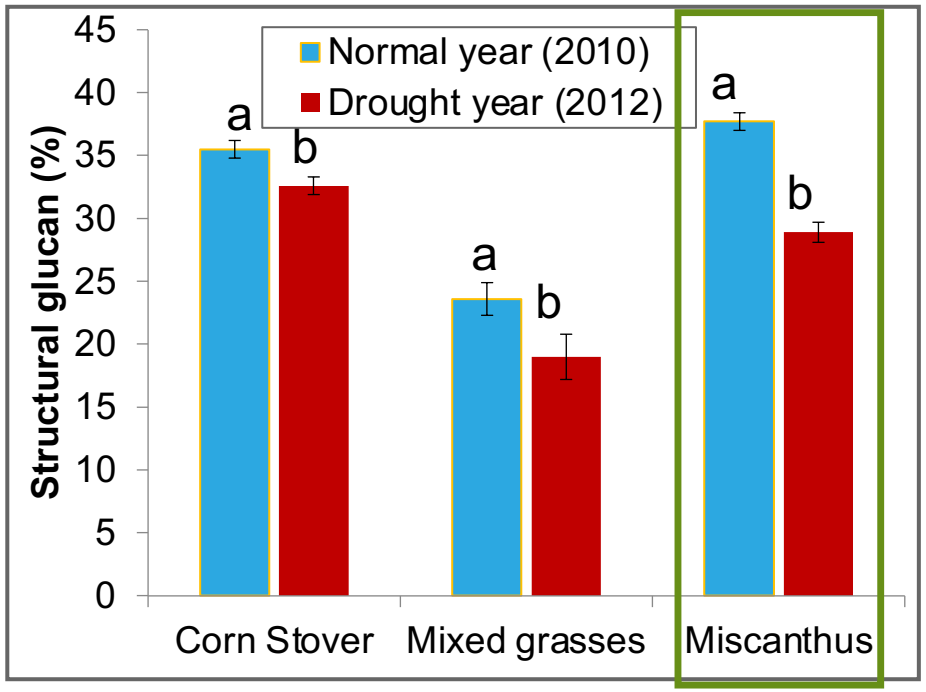
Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

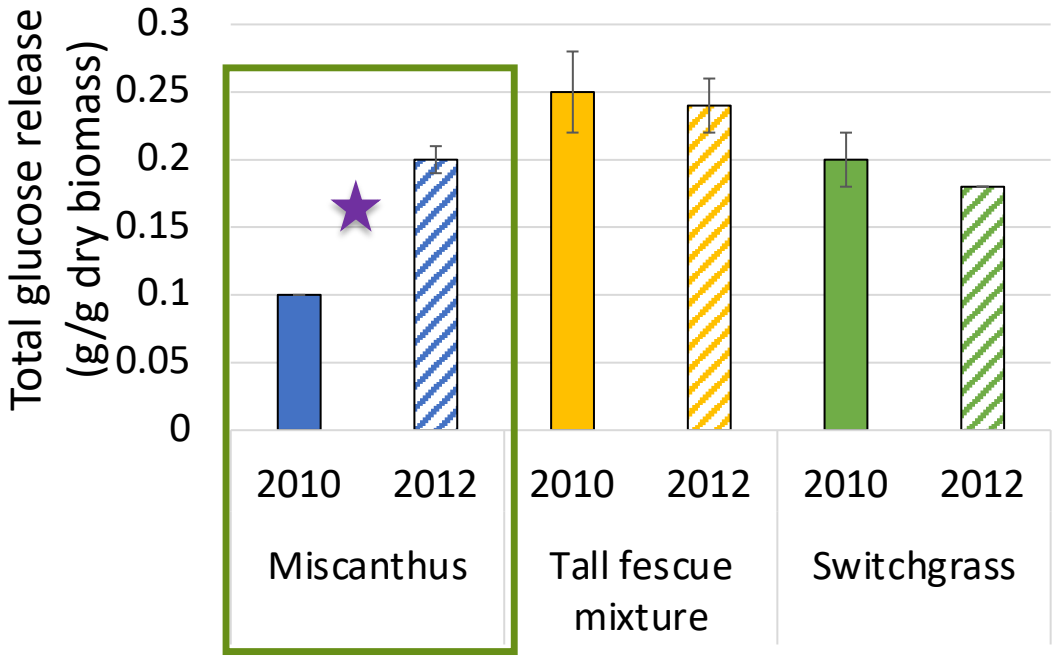
Highlights – Drought Impacts

Long duration of field studies allowed for assessment of environmental impacts

- Feedstock composition was significantly different
- Significant increase for Miscanthus glucose release



Emerson, R. M., A. N. Hoover, A. E. Ray, et al. (2014) Biofuels https://www.tandfonline.com/doi/full/10.1080/17597269.2014.913904



Hoover, A., R. Emerson, A. Ray, et al. (2018) . Frontiers in Energy Research, https://www.frontiersin.org/articles/10.3389/fenrg.2018.00054/full .