DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

Sustainable Herbaceous Energy Crop Production in the Southeast United States

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Feedstock Technologies Program

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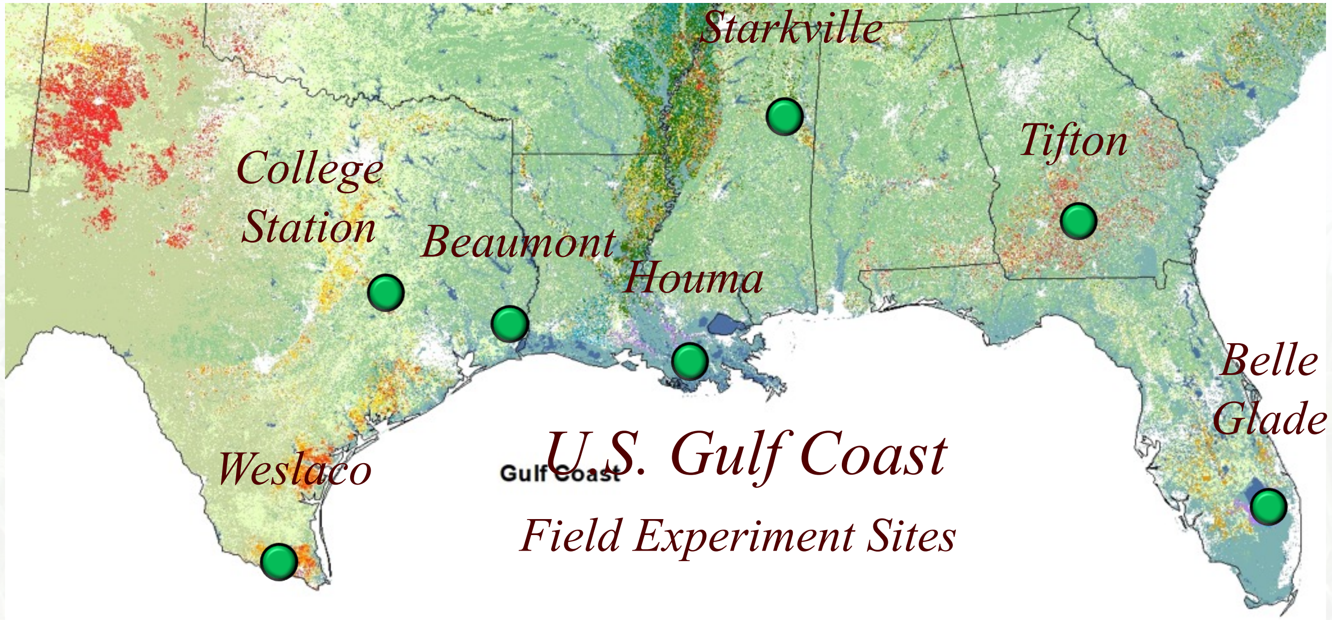
Project Overview

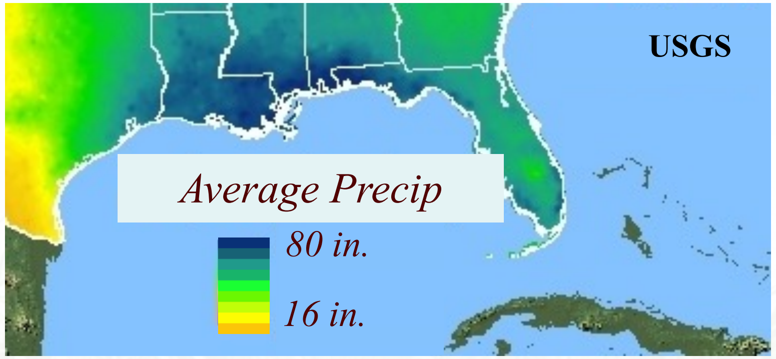
***Over-riding goal** is to assess the economic viability and environmental sustainability of energycane and biomass sorghum production in the southeast U.S.*

- ***What is the potential for cellulosic bioenergy crop production?***
  - *Cellulosic bioenergy crop production is a nascent industry in the U.S. and has the potential to supply 5% of U.S. energy demand while achieving increased carbon reduction*
  - *The southeast U.S. is ideally suited for a cellulosic industry due to plentiful land, ample rainfall, and a pressing need for agricultural diversification*

- ***What does the project expect to achieve?***
  - *To characterize the seasonal dynamics of biomass production of two cellulosic energy crops*
  - *To assess the economic viability and environmental sustainability of energy crop production and potential impact of competition with conventional crop production*
  - *To develop site-specific best management practices and operational plans to optimize biomass production, harvest and storage*

Approach – Experiment Sites and Characteristics





Location	Soil Type	Energycane	Biomass Sorghum	Conventional Crop
Weslaco, TX	Sandy clay loam	Cultivars (3)	Cultivars (3)	Cotton
College Station, TX	Clay loam	same	same	Grain Sorghum
Beaumont, TX	Clay	same	same	Rice
Houma, LA	Clay loam	same	-	Sugarcane
Starkville, MS	Silty clay loam	same	same	Corn
Tifton, GA	Sandy	same	same	Corn
Belle Glade, FL	Organic	same*	same	Sugarcane

*Florida phytosanitation laws required planting energycane from existing genotypes from within the state

Approach - Project Team and Expertise

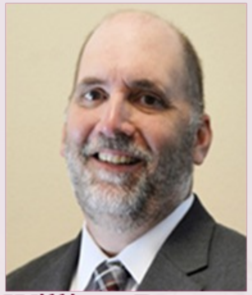
Project Director

Lloyd T. Wilson
Systems Integration

Texas A&M University

Yubin Yang
Agronomics

Fugen Dou
Soil & Sustainability



William Rooney
Breeding

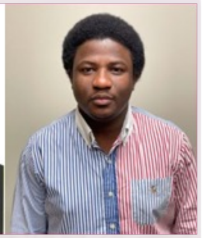
John Jifon
Agronomics

Jeffery Brady
Microbial Diversity

T. Bera

H. Araji

Soil & Water



O. Obayomi
Microbial Diversity

Mississippi Sate University

Brian Baldwin
Agronomics

Jesse Morrison
Agronomics

University of Florida

Alan Wright
Soil & Water

Calvin Odero
Weed Science

Hardev Sandhu
Agronomics

USDA-ARS: Tifton and Houma

Joseph Knoll

Anna Hale

Genetics & Breeding

H. Mula-Michel
Microbial Diversity

Tennessee State University

Prabodh Illiukpitiya
Agricultural Economics

Approach - Team Communications

Team Communications

- *Frequent emails, phone calls and video conferences on emerging issues*
- *Monthly progress updates and activities tracking with project site leaders and with DOE Project Officer and Technology Manager*
- *Quarterly project reports to DOE*
- *Annual project review and planning meetings to discuss progress, review milestones, planned research tasks, and timelines*

Team Communications and Collaborations with related Projects

- *Linkage with the University of Illinois Center for Advanced Bioenergy and Bioproducts Innovation (CABBI)*
- *Memberships on previously funded DOE SunGrant Herbaceous Feedstock Project and three USDA NIFA projects to develop economic thresholds and sampling methods for pests of sugarcane and cellulosic bioenergy crops*
- *Provide biomass samples to the Idaho National Laboratory feedstock collection*
- *Partner with Verd Company to test feedstock using ethanol-ensiled technology*

Approach: Risk Identification and Mitigation to Ensure Success

Key Risks that have been identified and mitigations taken to ensure success

Organizational

- *Frequently assess each component of the project's research schedule to stay on top of all land operations*
- *Cross-train project personnel to mitigate any effects of possible changes in personnel*

Operational

- *Production of excess biomass sorghum hybrid seed/energycane stalks to ensure sufficient biomass sorghum seed and energycane seed cane to plant the research plots*
- *Ensure seedbed forming is higher at research sites with heavier soils and greater rainfall to provide an aerobic environment for root health*

Approach: Technology Development Chart

- Sustainable Biomass from Herbaceous Energy Crops
  - Agronomics Data Collection
    - Biomass growth & quality
      - Growing season
      - Post-Maturity & Harvesting
    - Biomass change in storage
      - Aerobic storage
      - Anaerobic storage
  - Sustainability Data Collection
    - Carbon & greenhouse gas
      - Soil carbon sequestration
      - Greenhouse gas emissions
    - Soil, nutrients and water
      - Water and nutrient runoff
      - Nutrient leaching
      - Soil erosion
    - Biodiversity
      - Soil microbes
      - Ground-active invertebrates
  - Data Integration & Analysis
    - Economic analysis
    - Life cycle analysis
    - Ecosystem services
    - Best management practices
    - Year-round biomass plans

Progress and Outcomes: Biomass Sorghum Field Experiments

Beaumont

Belle Glade

College Station

Starkville

Tifton

Weslaco

Progress and Outcomes: Energycane Field Experiments

Beaumont

Belle Glade

College Station

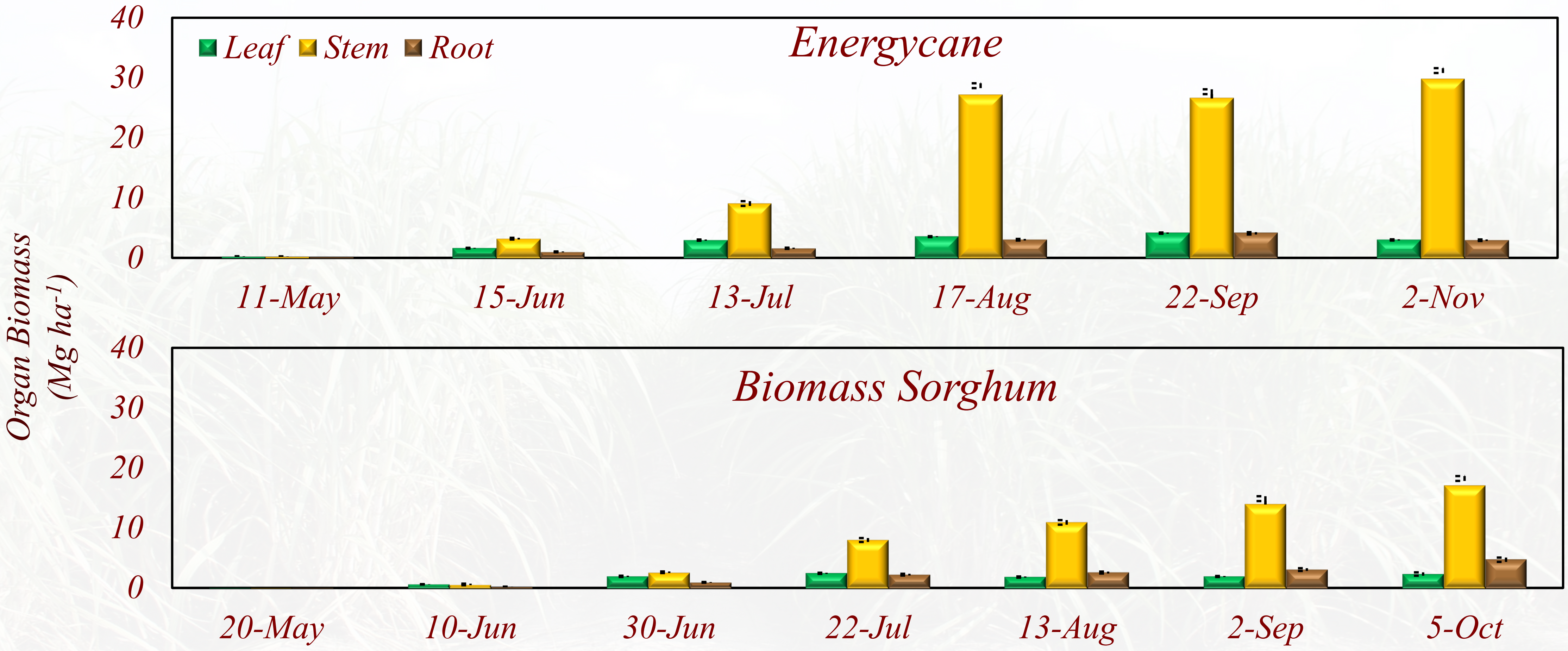
Houma

Starkville

Tifton

Weslaco

Progress and Outcomes: Agronomics Data (Seasonal Biomass Growth)

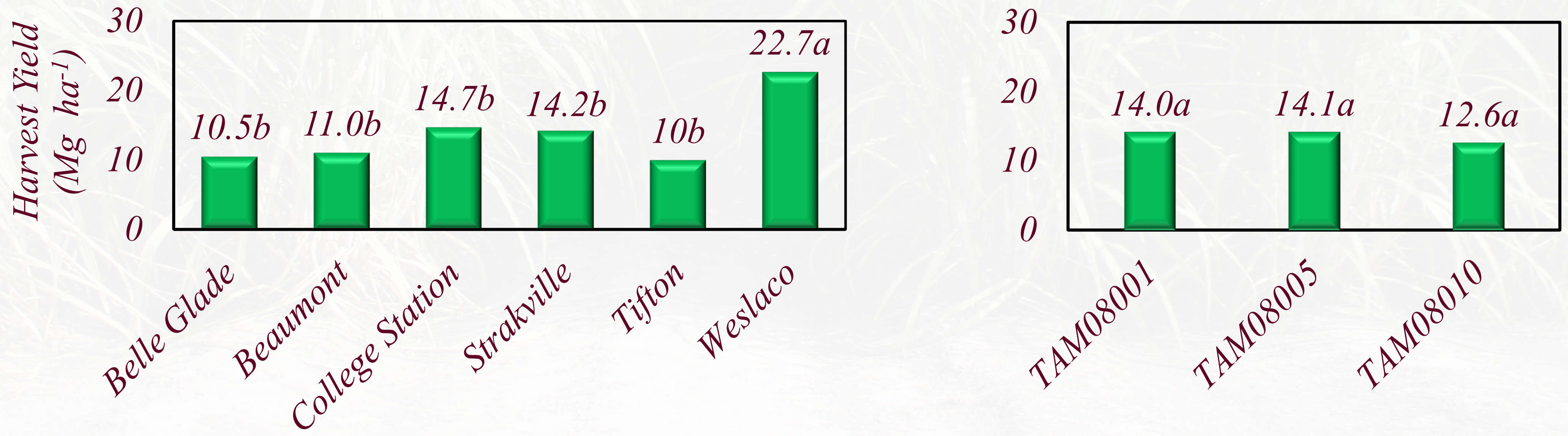


- *Stem and root biomass show an increasing trend through the season*
- *Leaf biomass tends to decrease near the middle of the season*

Progress and Outcomes: Agronomics Data (Biomass Yield)

Impact of Genotype and Site on Yield (Biomass Sorghum)

Source	DF	Sum of Squares	F Ratio	Prob
Model	17	1531.32	3.33	0.0001*
Genotype (G)	2	50.14	0.93	0.3998
Site (S)	5	143.59	10.64	<.0001*
G × S	10	43.59	0.16	0.9983
Error	78	2108.26		
C. Total	95	3639.57		

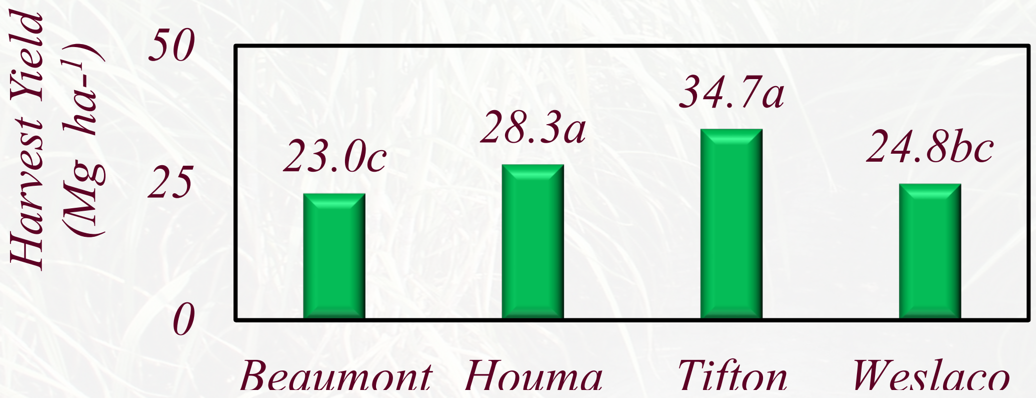


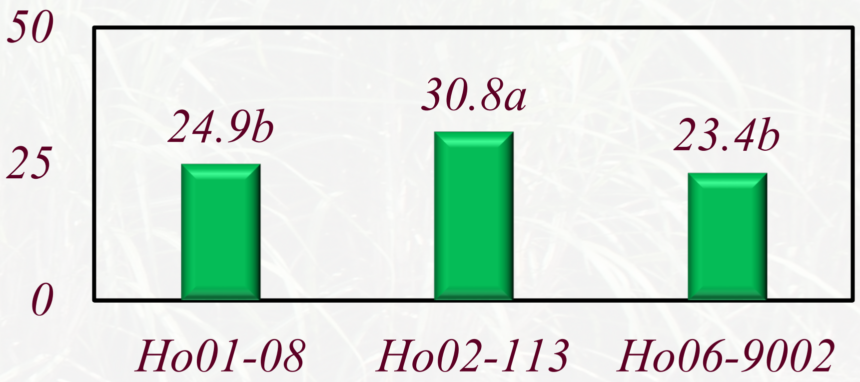
- Biomass yield significantly impacted only by site
- Weslaco had the greatest yield among the sites

Progress and Outcomes: Agronomics Data (Biomass Yield)

Impact of Genotype and Site on Yield (Energycane)

Source	DF	Sum of Squares	F Ratio	Prob
Model	11	1902.69	13.30	<0.0001*
Genotype (G)	2	561.67	21.59	<0.0001*
Site (S)	3	1111.92	28.49	<0.0001*
G x S	6	229.09	2.94	0.0163*
Error	47	611.34		
C. Total	58	2514.03		

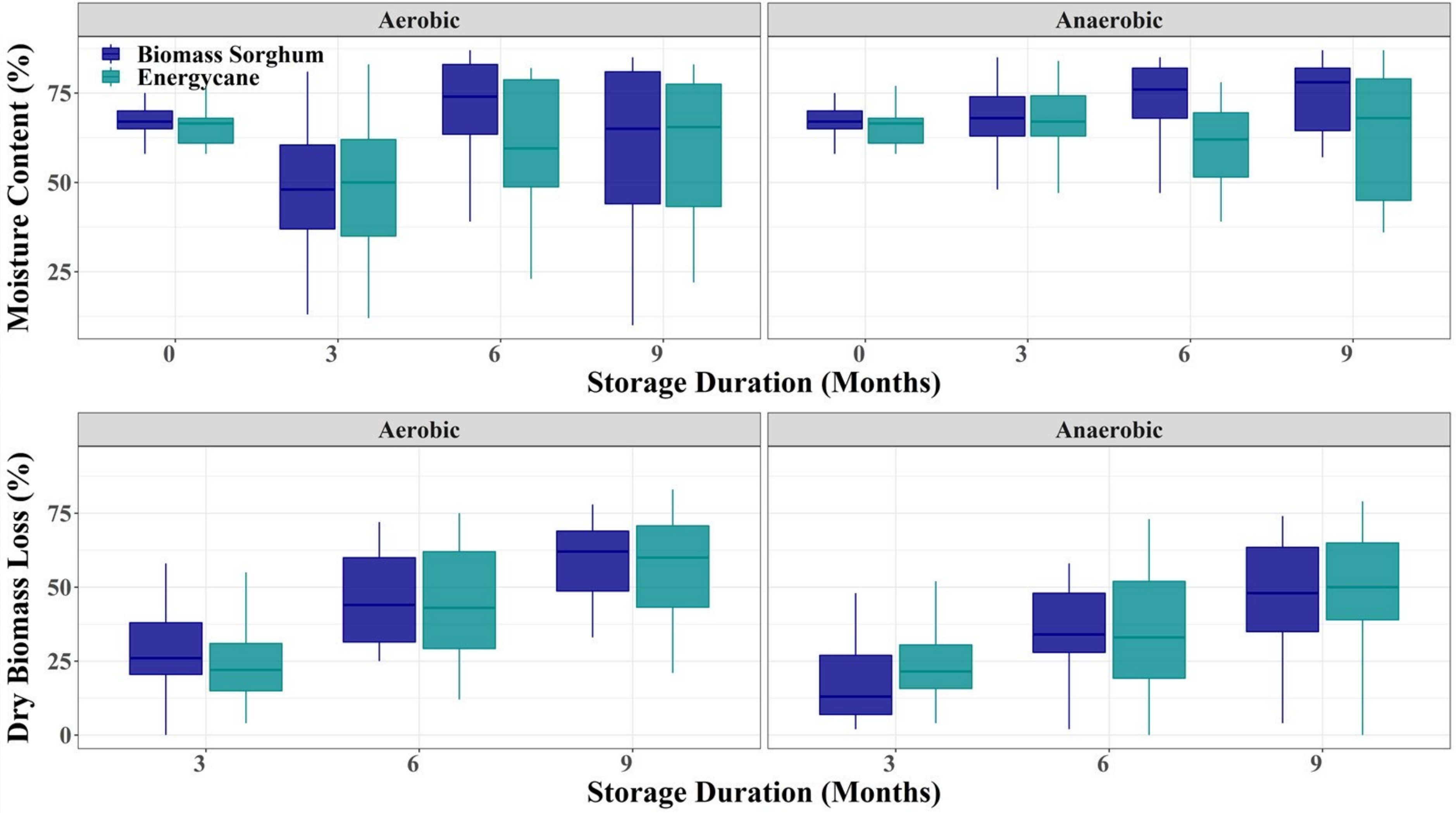




- *Biomass yield significantly impacted by site (S), genotype (G) and S × G interaction*
- *Tifton had higher yield than the other three sites*
- *Ho02-113 has the highest average yield, followed by Ho01-08 and Ho06-9002*

Progress and Outcomes: Agronomics Data (Biomass Storage)

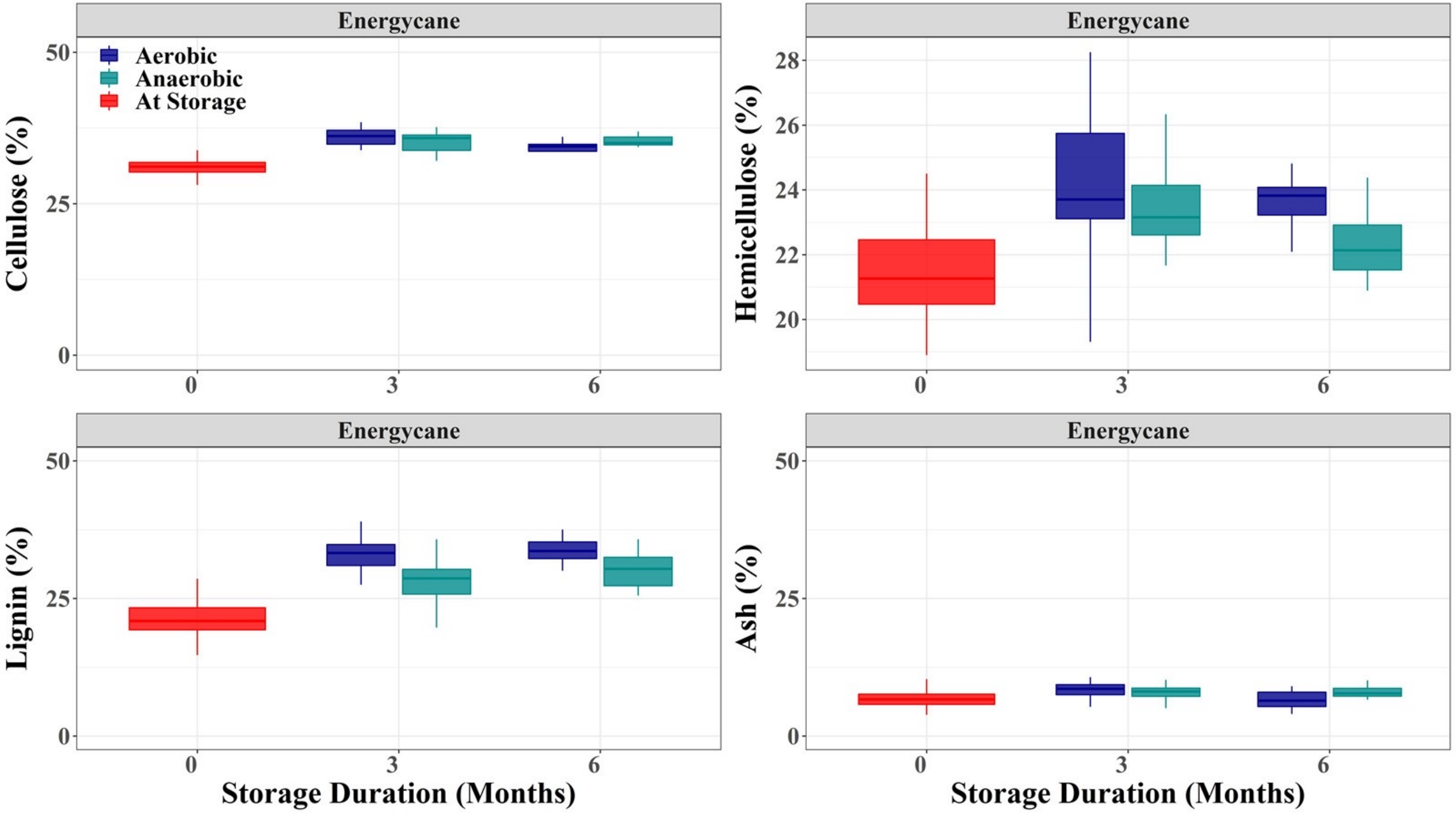
Biomass Moisture and Loss During Storage



- *Moisture decreased during aerobic storage, but changed little during anaerobic storage*
- *Almost linear biomass loss during storage, higher biomass loss for aerobic storage*

Progress and Outcomes: Agronomics Data (Biomass Storage)

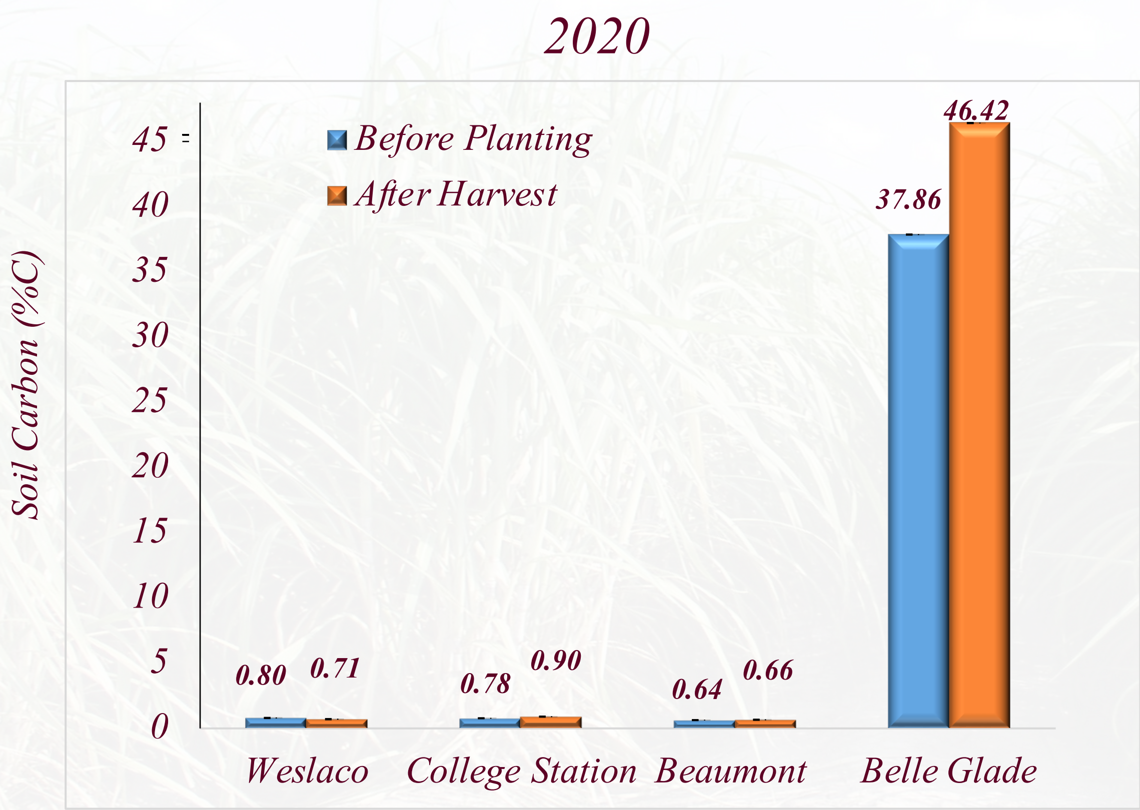
Biomass Composition Change During Storage

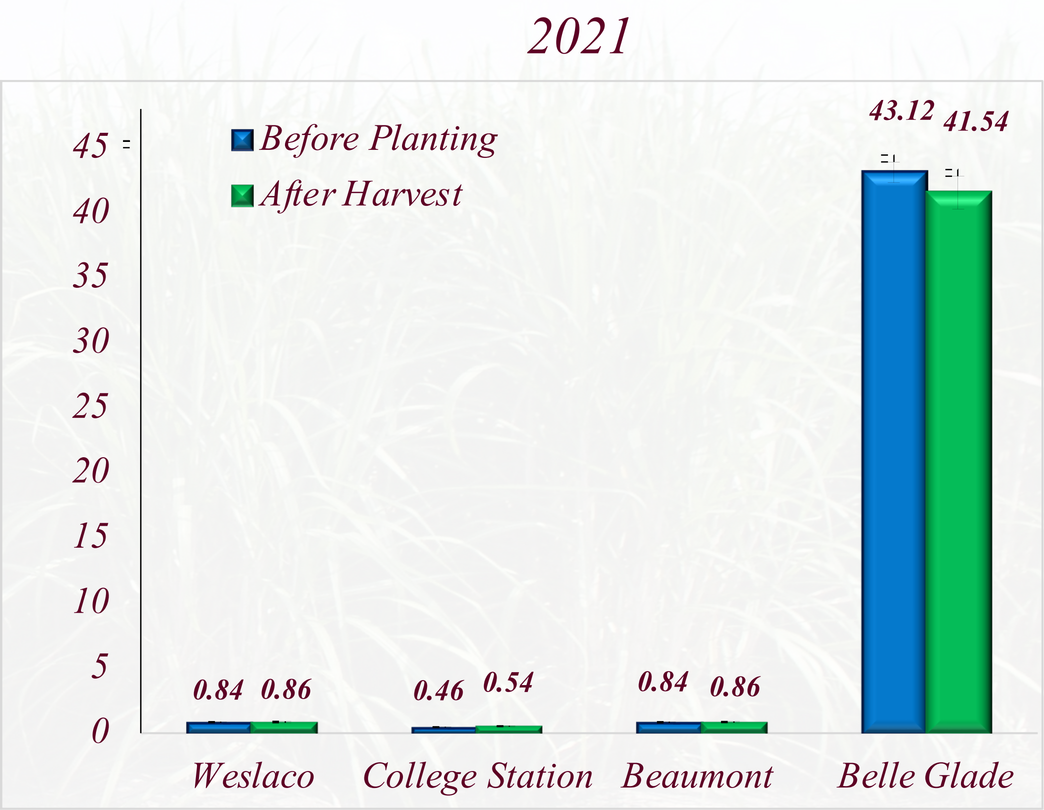


- *Cellulose, hemicellulose, lignin, and ash all increased during the first 3 months of storages*

Progress and Outcomes: Sustainability Data (Soil Carbon)

Change in Soil Carbon under Biomass Sorghum



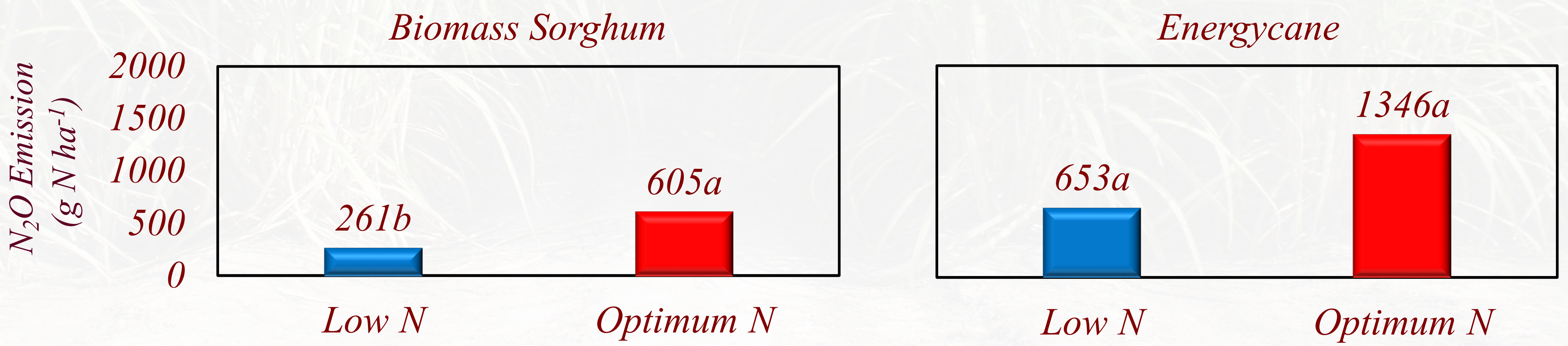


- Soil carbon trended to be higher post-harvest than pre-planting
- Belle Glade had much higher soil carbon compared to other sites, due to its organic soil

Progress and Outcomes: Sustainability Data (Greenhouse Gas)

Effect of Genotype and Nitrogen on Nitrous Oxide Emission

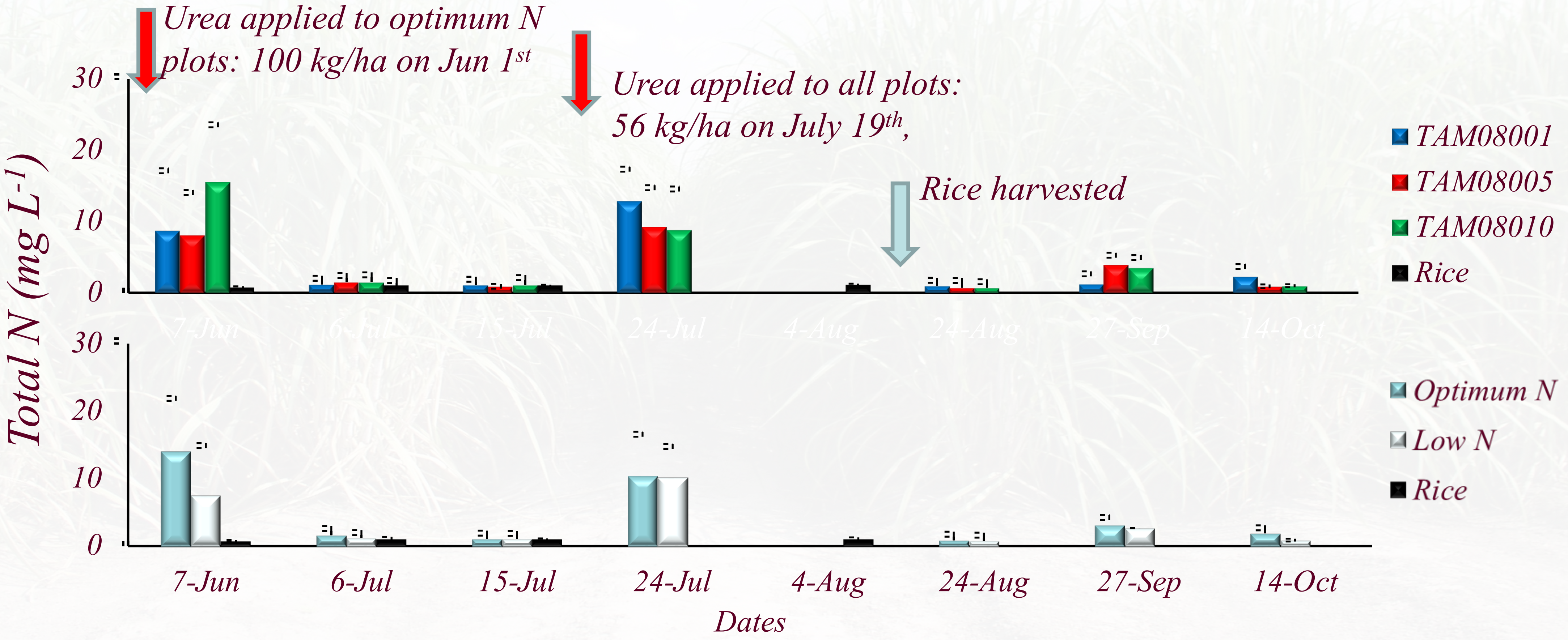
Source	DF	Biomass Sorghum Significance	Energycane Significance
Model	5	**	N.S.
Genotype (G)	2	N.S.	N.S.
N Rate (N)	1	***	N.S.
G x N	2	N.S.	N.S.
Error	6		
C. Total	11		



- *Optimum N rate had greater N_2O emission than low N rate for biomass sorghum but not for energycane*

Progress and Outcomes: Sustainability Data (Water Quality)

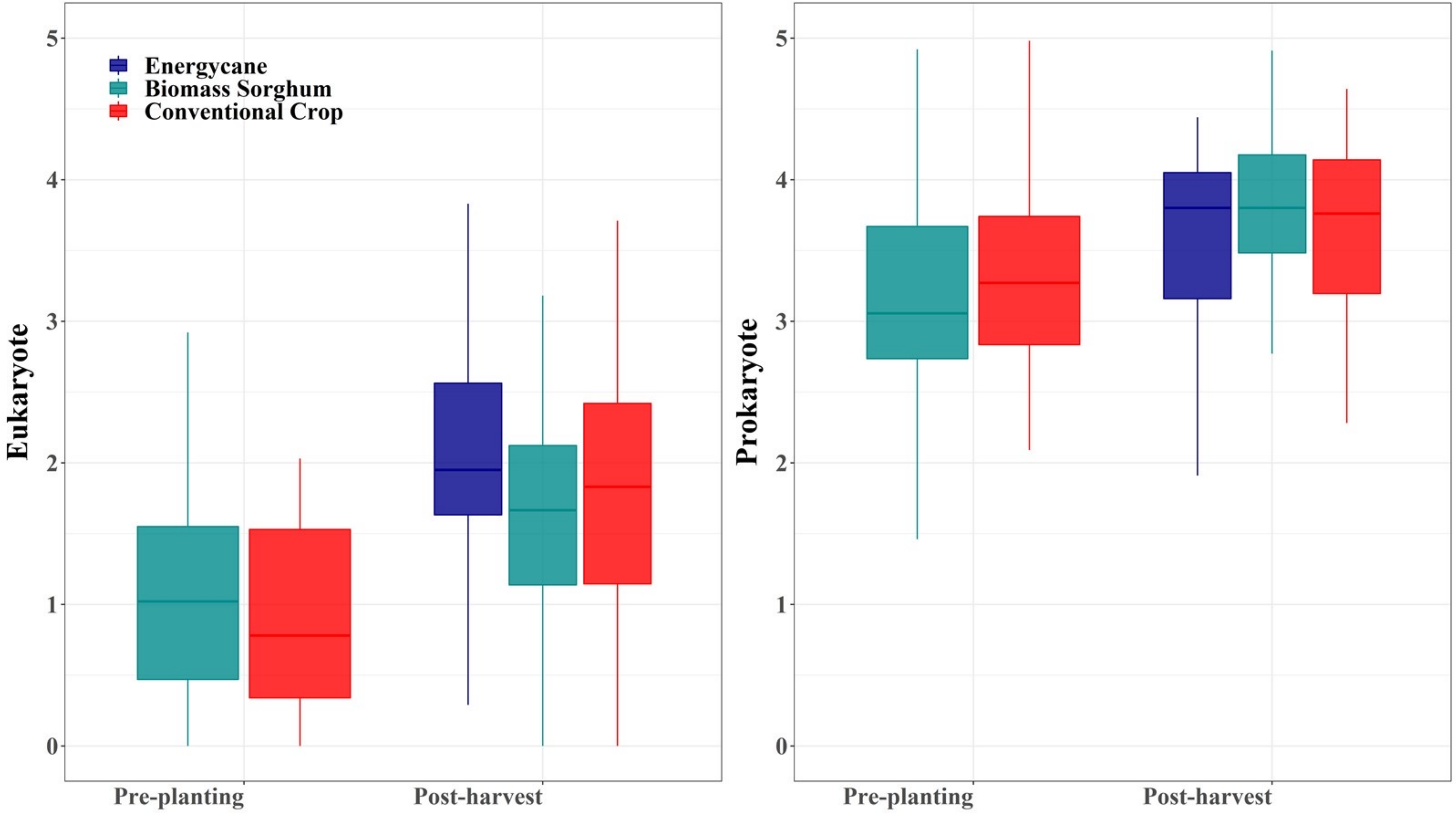
Total Nitrogen Concentration in Surface Runoff Water (Biomass Sorghum)



- *Total N spiked after N application and decreased thereafter for all genotypes and N rates*

Progress and Outcomes: Sustainability Data (Microbial Diversity)

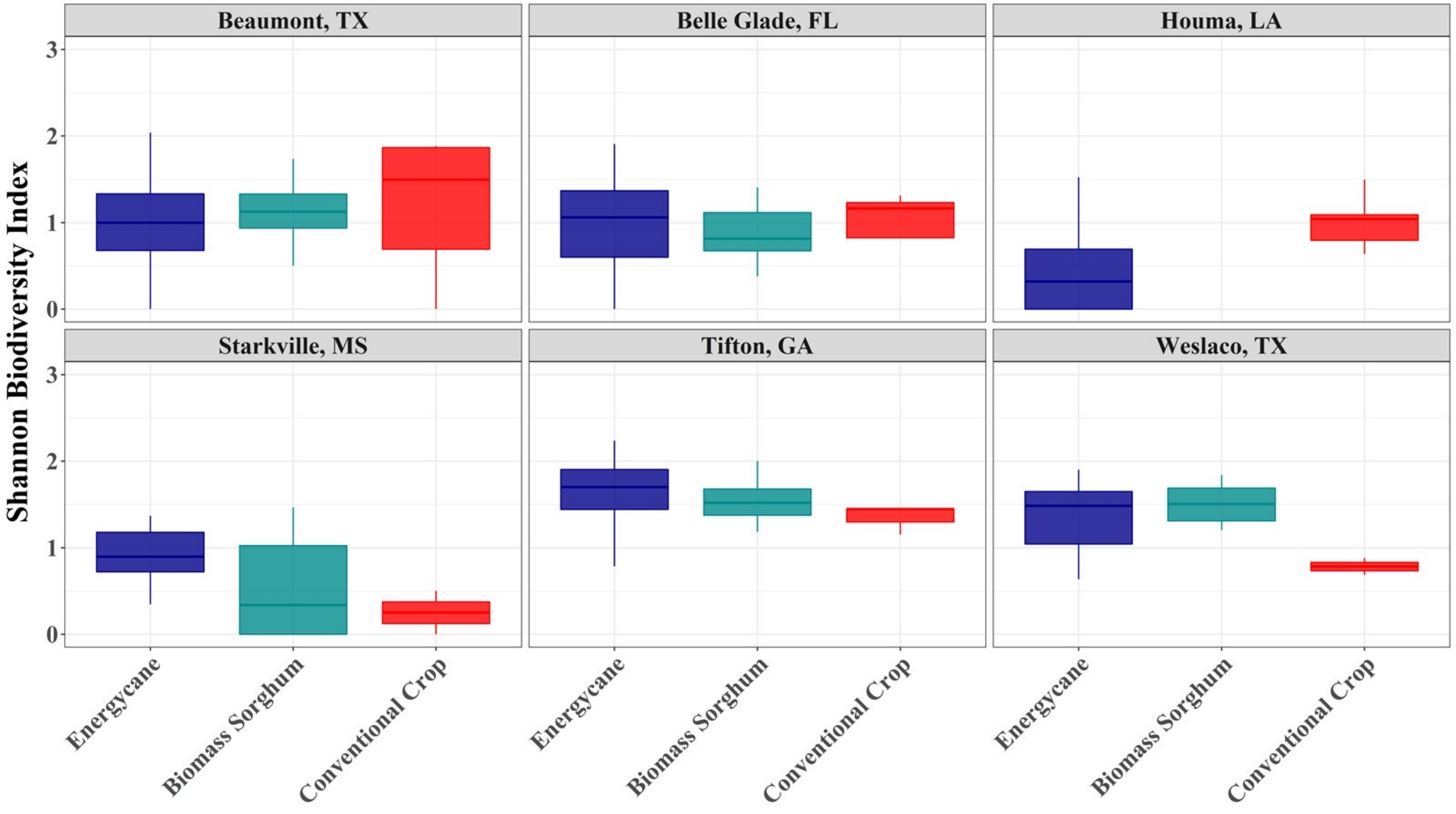
Seasonal Change in Shannon Diversity Index



- *There were no significant differences in microbial diversity between pre-plant and post-harvest*
- *There were no significant differences in microbial diversity between energy and conventional crops*

Progress and Outcomes: Sustainability Data (Ground-Active Invertebrates)

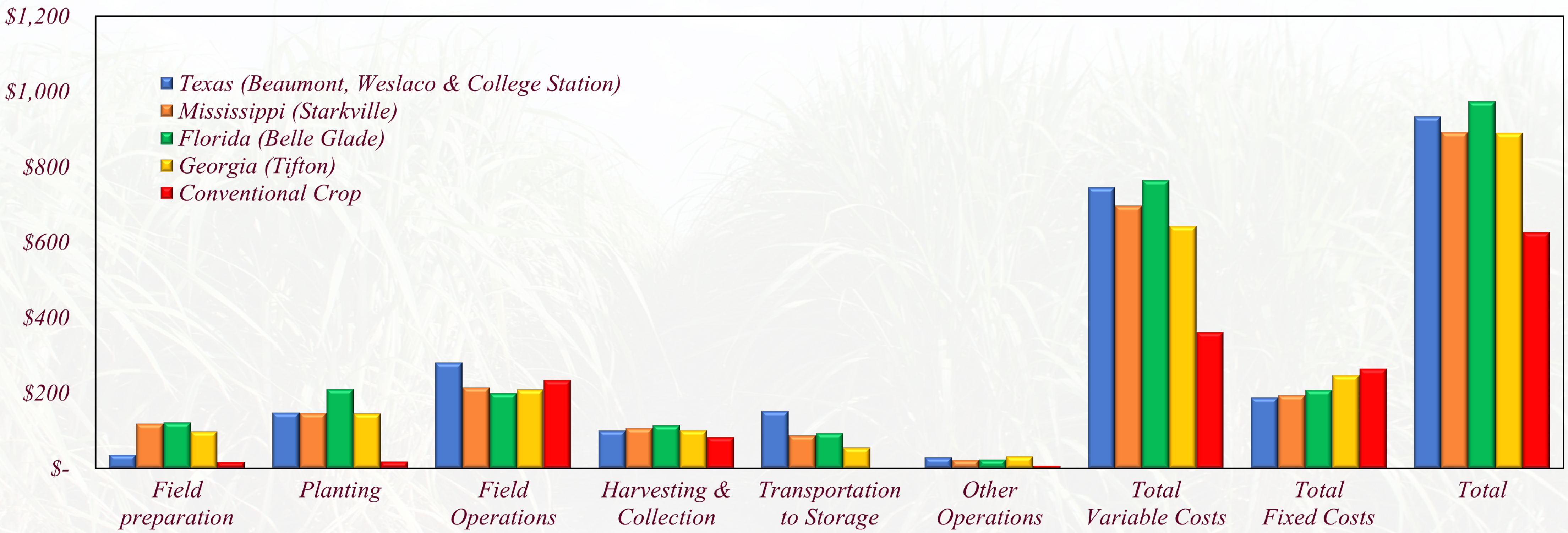
Shannon Diversity Index



- *Ground-active invertebrate diversity was significantly affected by site and crop*

Progress and Outcomes: Data Integration & Analysis (Economics)

Enterprise Budgets (Biomass Sorghum)



- *Field operations account for the largest cost component*
- *Higher total cost for biomass sorghum compared to conventional crop*

Impact

- *Project complements existing studies on energy crops and assesses the economic viability and sustainability of cellulosic energy crop production in the southeast US*
- *Provides seasonal biomass growth dynamics, off-season storage loss and composition change, and addresses year-round biomass supply constraints*
- *Sustainability and biodiversity data provide comprehensive assessment of environment impacts and ecosystem services of energy crop production*
- *The integrated analysis will identify best sites for biorefinery development in the southeast US and provide critical decision data for biorefinery developers*
- *Site-specific best management practices will serve as an indispensable guide in feedstock production and promote early adoption by feedstock producers*
- *Accelerating the adoption of cellulosic bioenergy development will support DOE BETO's strategic goal to reduce the price of biofuels to < $3/gasoline gallon equivalent and reduce the cost of feedstock to less than $84/dry ton*

Summary

Agronomics

- *Stem and root biomass increase through the season while leaf biomass peaks toward the middle of the season*
- *Energycane yielded more than biomass sorghum and southern sites produced higher yield*
- *Almost linear biomass loss with time during storage, with higher loss for aerobic storage*
- *Cellulose, hemicellulose, lignin, and ash increased during the first 3 months of storage*

Sustainability

- *SOC was on average higher post-harvest than pre-planting*
- *Higher N rates had significantly greater N_2O emission*
- *Surface runoff water: Total N spiked after N application and decreased thereafter*
- *Deep percolation water: Nitrogen application did not affect total N concentration*
- *Higher soil microbial diversity post-harvest than pre-planting*
- *Considerable variability in ground-active invertebrate diversity across sites and crops*

Integration and Analysis

- *Field operations account for the largest cost component in enterprise budgets*
- *Higher total cost for biomass sorghum compared to grain sorghum*

Deliverables that will be achieved in 2023 through to the end of the project

- *Comprehensive integrated analysis (field-fuel economic viability and sustainability, site-specific BMPs, and operational plans) will contribute to accelerating cellulosic bioenergy development in the southeast US*
- *Support DOE BETO's strategic goal of reducing the feedstock cost and biofuel price*

Quad Chart Overview

Timeline

- Project start date: 10/01/2018
- Project end date: 03/31/2024

	FY22 Costed	Total Award
DOE Funding	*$2,448,804*	**$4,999,539**
Project Cost Share	$836,796	$1,252,066

Project Partners

Mississippi State University, University of Florida, Tennessee State University, USDA-ARS Sugarcane Research, Houma, LA, USDA-ARS Crop Genetics & Breeding, Tifton, GA, Verde Company, Houston, TA

Project Goal

Develop a comprehensive assessment of the economic viability and environment sustainability of producing advanced energycane and biomass sorghum for optimizing biomass production in the southeast United States

End of Project Milestone

Economic Viability Costs and benefits of energy crop production, harvest and storage

Environment Sustainability Carbon footprint from biomass production, harvest, storage and delivery

Ecosystem Services Effects on water quality, soil erosion, nutrient retention, soil quality and biodiversity

Site-specific Best Management Practices and Operational Plans on biomass production, harvesting, storage, and land allocation, derived from economic and environment impact analysis

Funding Mechanism

Affordable and Sustainable Energy Crops (ASEC) DE-FOA-0001917