DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

Optimization of Southeastern Forest Biomass Crop Production:

Watershed Scale Evaluation of the Sustainability and Productivity of Dedicated Energy Crop and Woody Biomass Operations

March 23, 2015

Sustainability and Strategic Analysis

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FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

VirginiaTech College of Natural Resources

ncasi

Catchlight Energy
A Chevron | Weyerhaeuser joint Venture

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Goal Statement

Develop and disseminate science-based information for sustainable production of biofuel feedstock in a forestry setting in the Southeast

Relevance to goals of BETO

Evaluate the environmental and economical sustainability of a potentially viable biomass production technology that:

- Will not compromise availability of food, fiber, and water
- Can utilize over 15 million ha of pine plantation forests in the southeast

Quad Chart Overview

Timeline

- Start date - Sept. 30, 2010
- End date - Sept. 30, 2016
- Percent complete – 71%

Budget

	Total Costs FY 10 – FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding FY 15-End Date
DOE Funded	698 k	432 k	316 k	645 k
Cost Share				
NCSU	66 k	33 k	33 k	33 k
Weyer	431 k	211 k	350 k	727 k
Catchlight	390 k	195 k	195 k	
V-Tech	22 k	22 k	21 k	

Barriers

- **Ft-B.** Sustainable Production
- **St-C.** Sustainability Data across the Supply Chain
- **St-E.** Best Practices for Sustainable Bioenergy Production
- **St-G.** Representation of Land Use

Partners

- N. C. State University
- Weyerhaeuser Company
- Catchlight Energy LLC
- Virginia Tech
- US Forest Service
- National Council for Air and Stream Improvement (NCASI)

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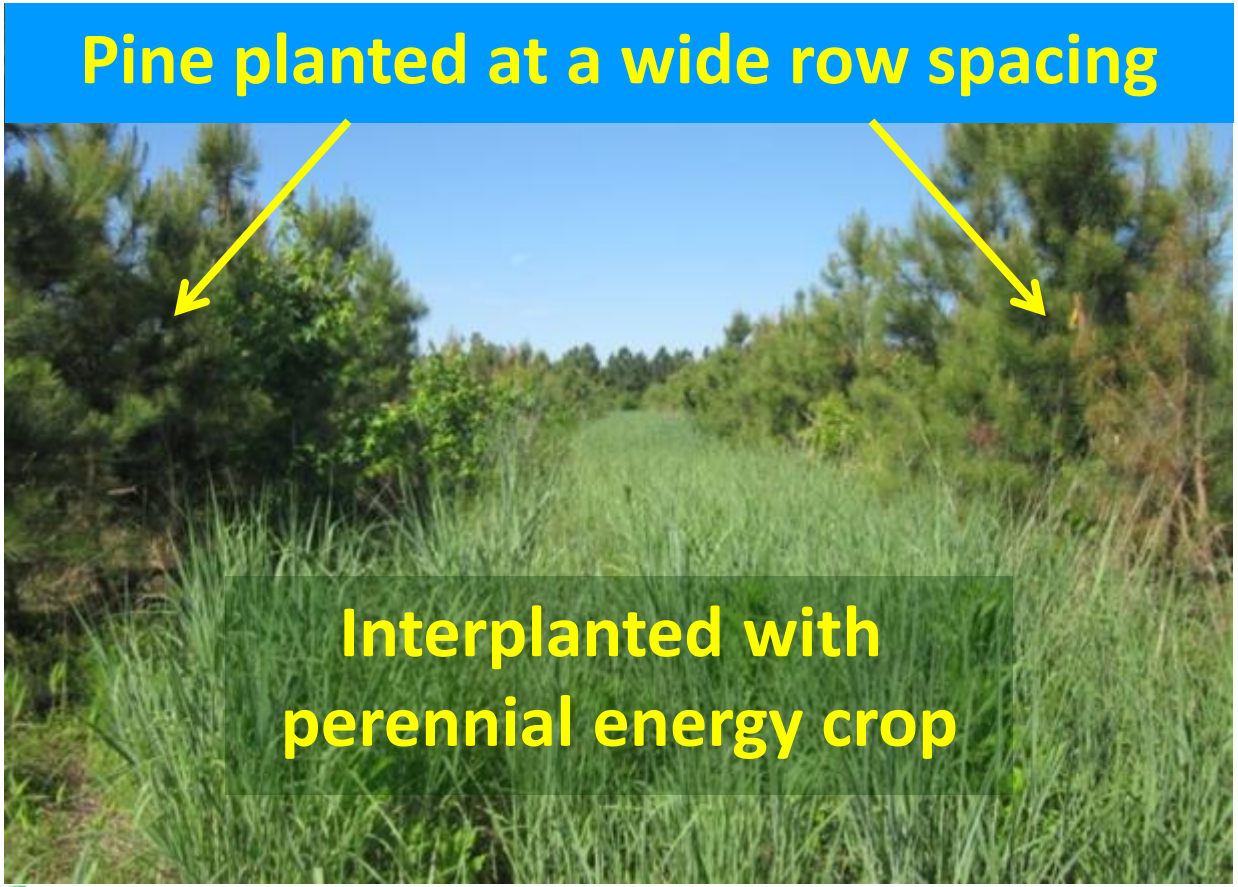
Project Overview

Evaluation of forest-based biofuel crop compatible with high-value timber production



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Project Overview

Field Research Objectives

Quantify the impacts of different energy crop production systems on:

- Hydrology (water movement, outflow, plant use)
- Nutrient dynamics (plant use, soil transformations, outflow)
- Soil structure, fertility, and organic matter content
- Flora and fauna populations and habitat quality

Using watershed and plot scale experiments

Project Overview

Modeling Objectives

Develop watershed and regional scale models to evaluate environmental sustainability of multiple biofuel scenarios

Watershed scale models to accurately simulate:

- Water yield/ET
- Nutrient cycling/water quality
- Soil productivity/erosion

Landscape scale models to predict:

- Water yield and water quality
- Energy crop productivity

Project Overview

Outreach Objectives

Develop and evaluate Best Management Practice (BMP) guidelines that ensure environmental sustainability

- Compare water quality, hydrology, and aquatic biology across treatments to determine practices that led to sustainability issues
- Use sediment survey data to pinpoint settings where BMPs were inadequate to protect water resources
- Collect and summarize applicable literature on forest bioenergy practices
- Develop operationally feasible BMP guidelines
- Publish guidelines and distribute through grower networks

Approach (Technical)

- Conduct watershed and plot scale experiments to provide data for watershed scale models
- Develop watershed scale models to simulate performance of energy crop production systems over a range of climatic and landscape conditions
- Use results of field and modeling studies to develop best management practices.

Critical success factors – Establish treatments, High quality field data, Appropriate and effective models

Challenges – Establishment of Treatments

Approach (Management)

Critical success factors – Appropriate and consistent data analysis and management, unrestricted flow of information and ideas between collaborators

Structure - Quarterly meetings:

Present results Review protocols Discuss logistics

Advisory board meetings with outside advisors:

Review results Evaluate progress Strategic planning

Share resources with outside colleagues:

Other Forest Service studies Other NCSU Departments

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Approach (Technical)

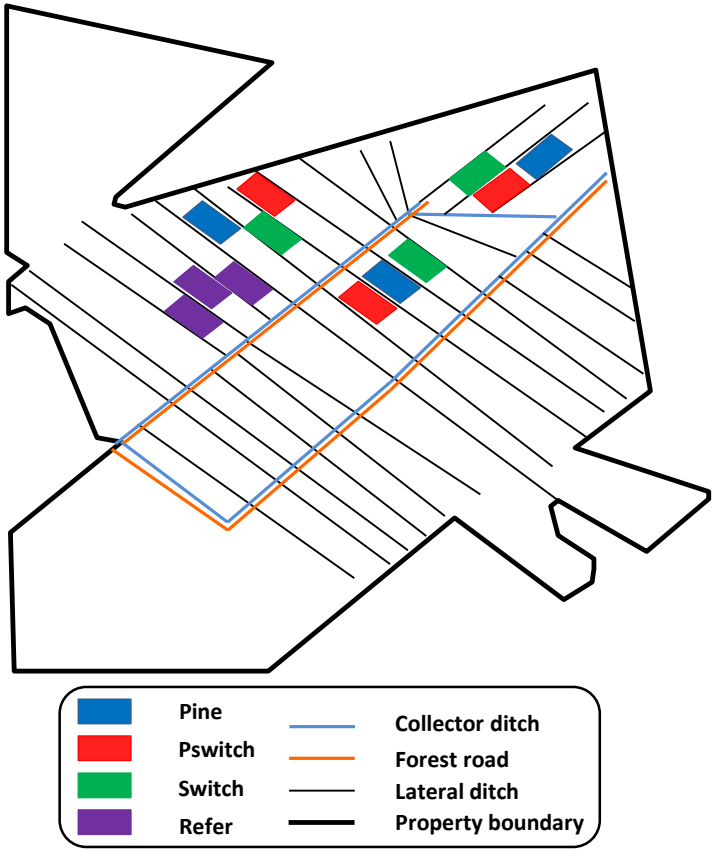
Plot Scale Experiments

Plot size – 0.8 ha

3 Replicates

Measurements:

- Continuous Climate and Precip
- Continuous Water Table Depth
- Soil Moisture
- Soil Physical Properties
- Groundwater Quality
- Soil N and C cycling
- Above ground biomass



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Approach (Technical)

Watershed Experiments

Watershed size – 11 to 27 ha

Hydrology

- Continuous Weather, Outflow, WT Depth, Soil Moisture

Water Quality

- Flow Proportional and Continuous Stream Samples
- Monthly Groundwater Quality samples

Other

- Soil Physical Properties
- Aquatic Macroinvertebrates
- Vegetation Characteristics
- N and C cycling

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Approach (Technical)

Watershed Modeling

Watershed Scale

Use process based models to simulate:

- Hydrology
- Vegetation Growth
- N and C cycling
- Water Quality

DRAINMOD-FOREST for flat high water table soils

APEX for upland conditions

Landscape Scale

Use SWAT model to simulate the impacts of realistic representations of biofuel production on the hydrology and water quality of large watersheds

Technical Accomplishments

Successfully established switchgrass treatments

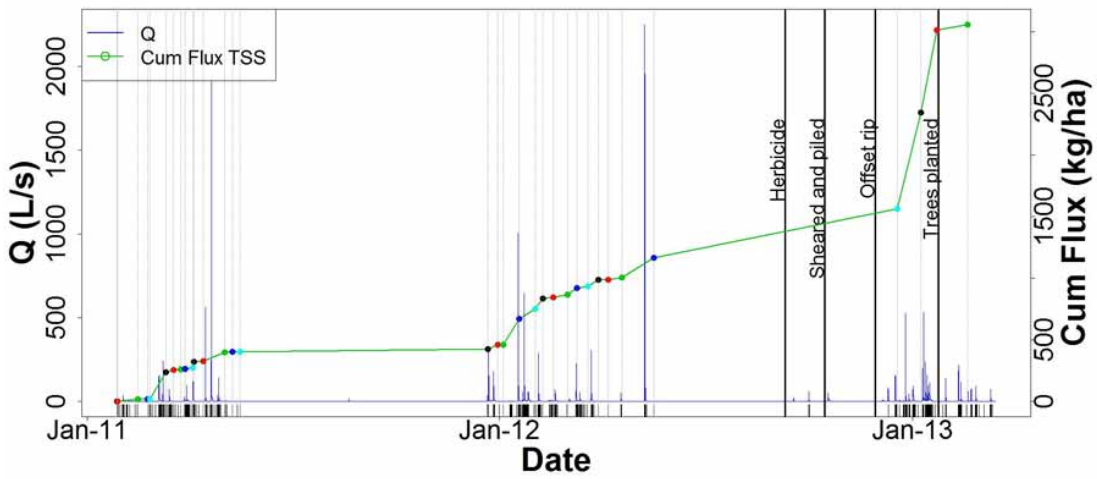
Technical Accomplishments

Documented impact of site preparation on sediment loads

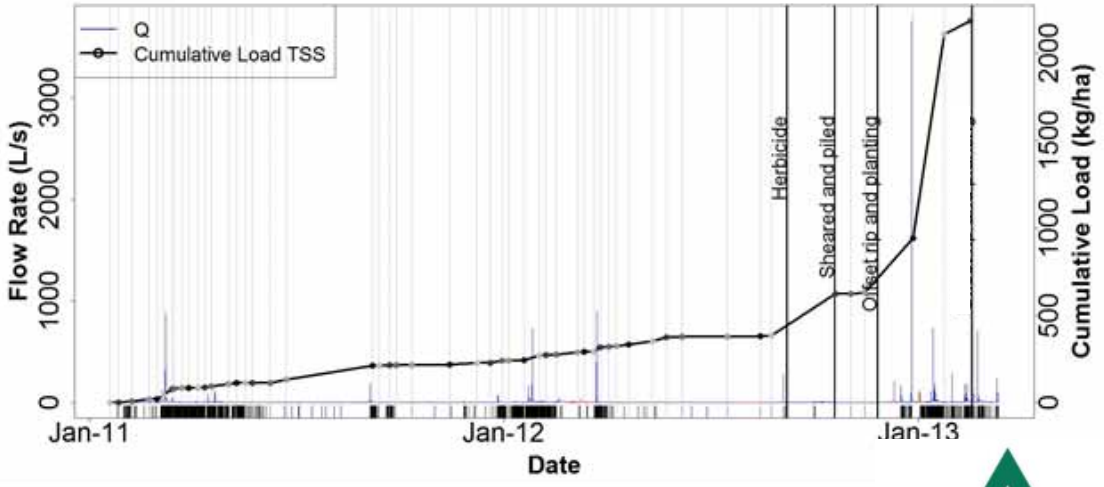
Sediment loads at MS/AL sites increased after site preparation.

Sediment loads at NC site were not affected after site preparation.
Annual load <40 kg/ha

Mississippi - SW Grass with age zero trees



Alabama - SW Grass with age zero trees



Bennett et al. in revision, Biomass and Bioenergy

Muwamba et al. in revision, Journal of Environmental Qual.

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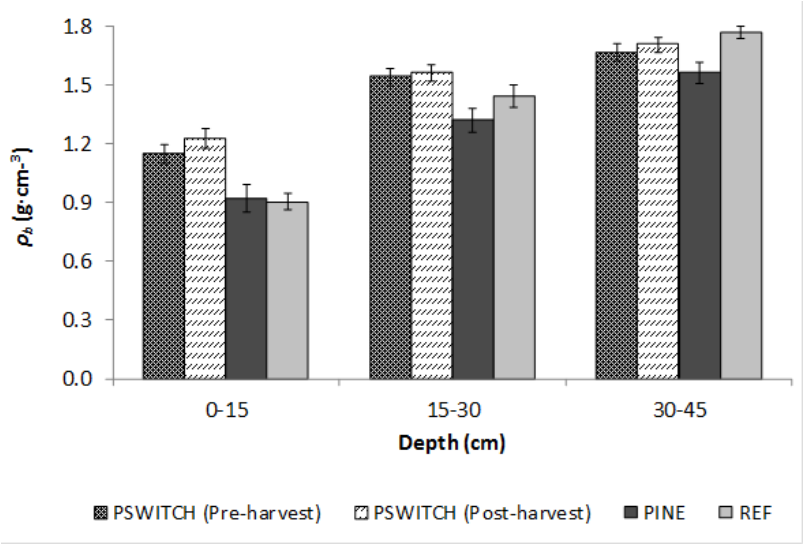
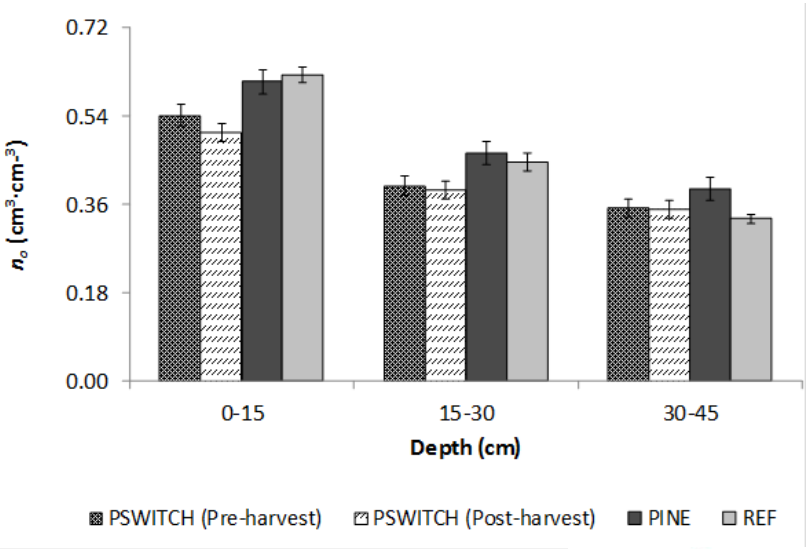
Technical Accomplishments

Documented impacts of site preparation on soil properties

Soil bulk density was higher and soil porosity was lower at 0-15 cm and 15-30 cm depths at interplanted site.

Soil properties were not affected by third switchgrass harvest.





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Cacho et al. submitted, TRANSACTIONS of ASABE

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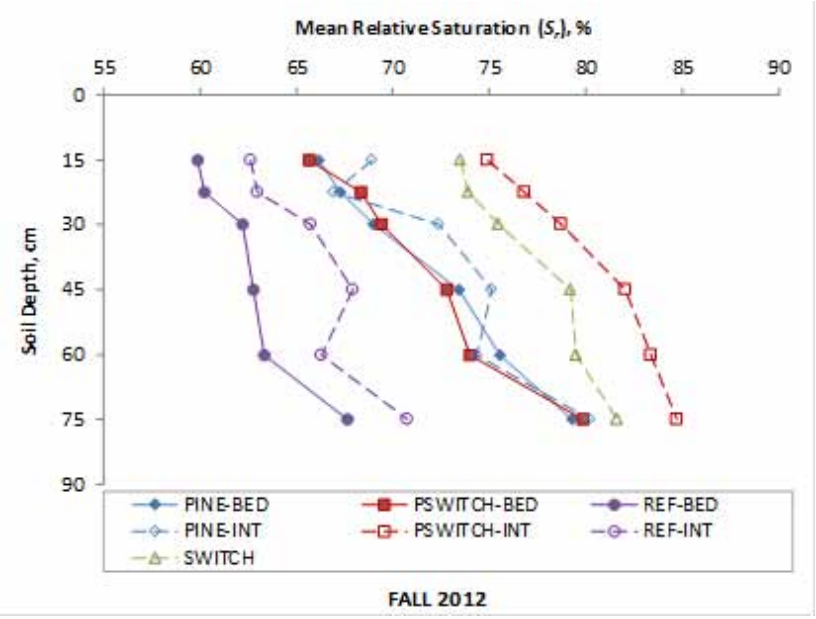
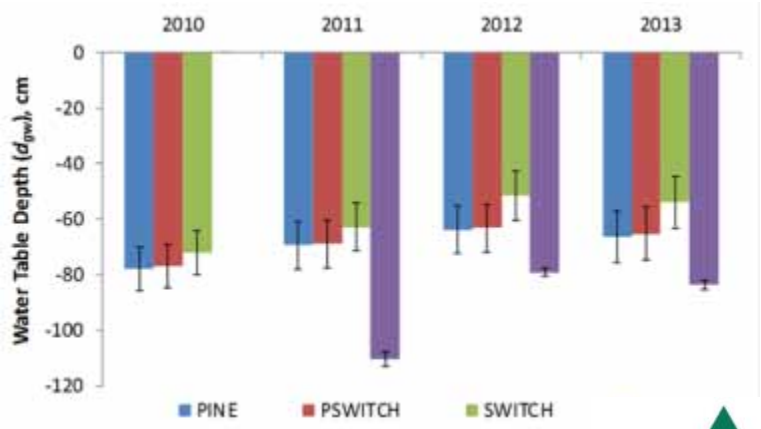
Technical Accomplishments

Documented effects of switchgrass treatments on soil moisture and water table depth

Soil moisture is greater under switchgrass treatments.

Water table is more shallow under switchgrass only treatment.





Cacho et al. in internal review

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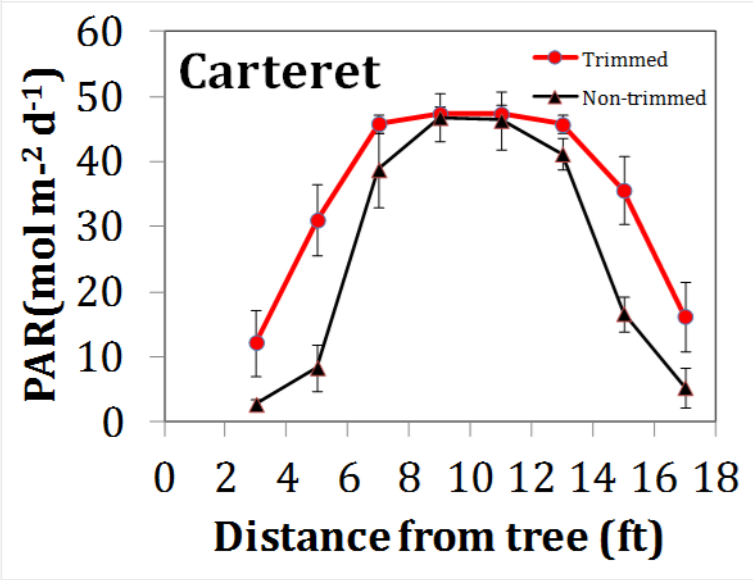
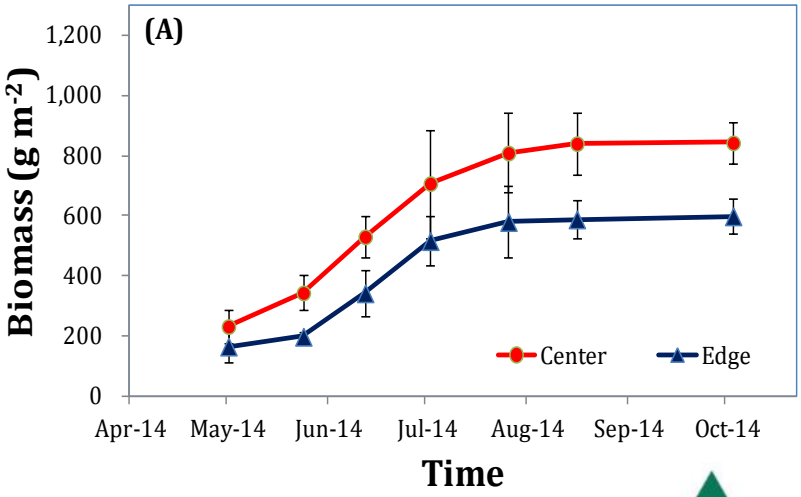
Technical Accomplishments

Documented effects of tree shading on switchgrass growth

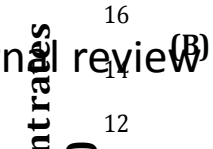
Biomass accumulation is lower at edge of row near trees.

Biomass accumulation is greater in switchgrass only treatments.





Tian et al. in internal review

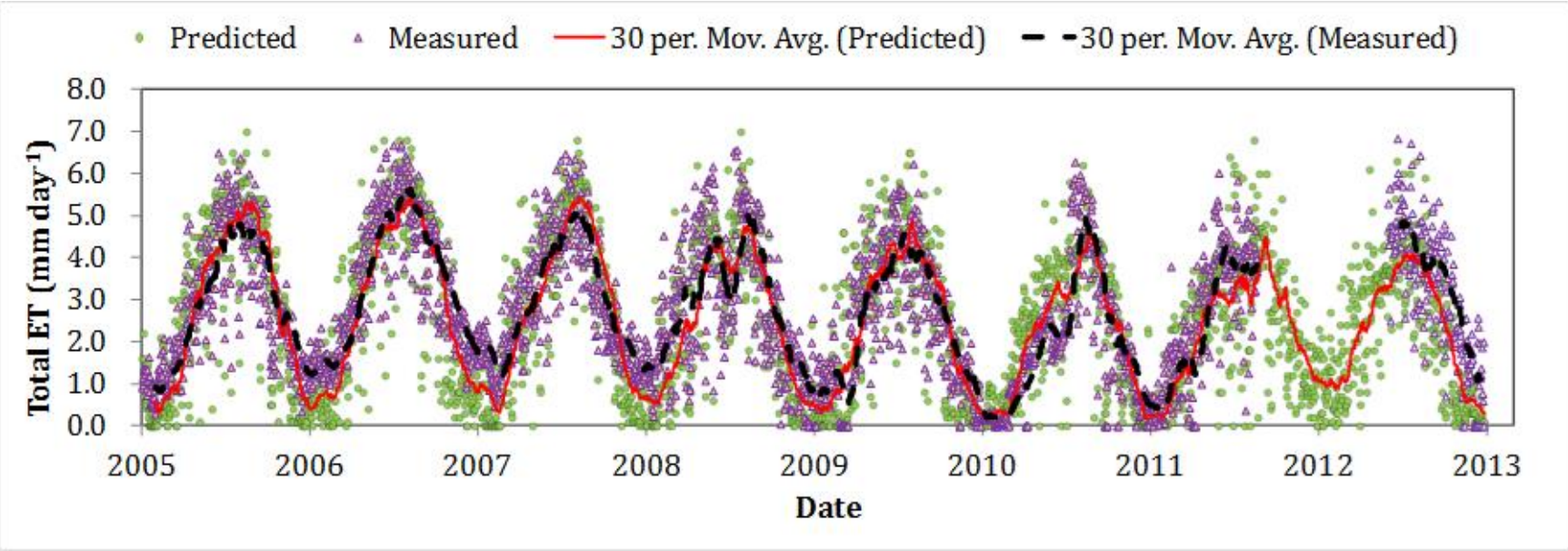


Technical Accomplishments

Evapotranspiration dynamics predictions by DRAINMOD-FOREST compared well to eddy flux

Annual ET predictions were within 4.5% of measured

The model tended to under predict ET in the winter



Tian et al. in press, Forest Ecology and Management

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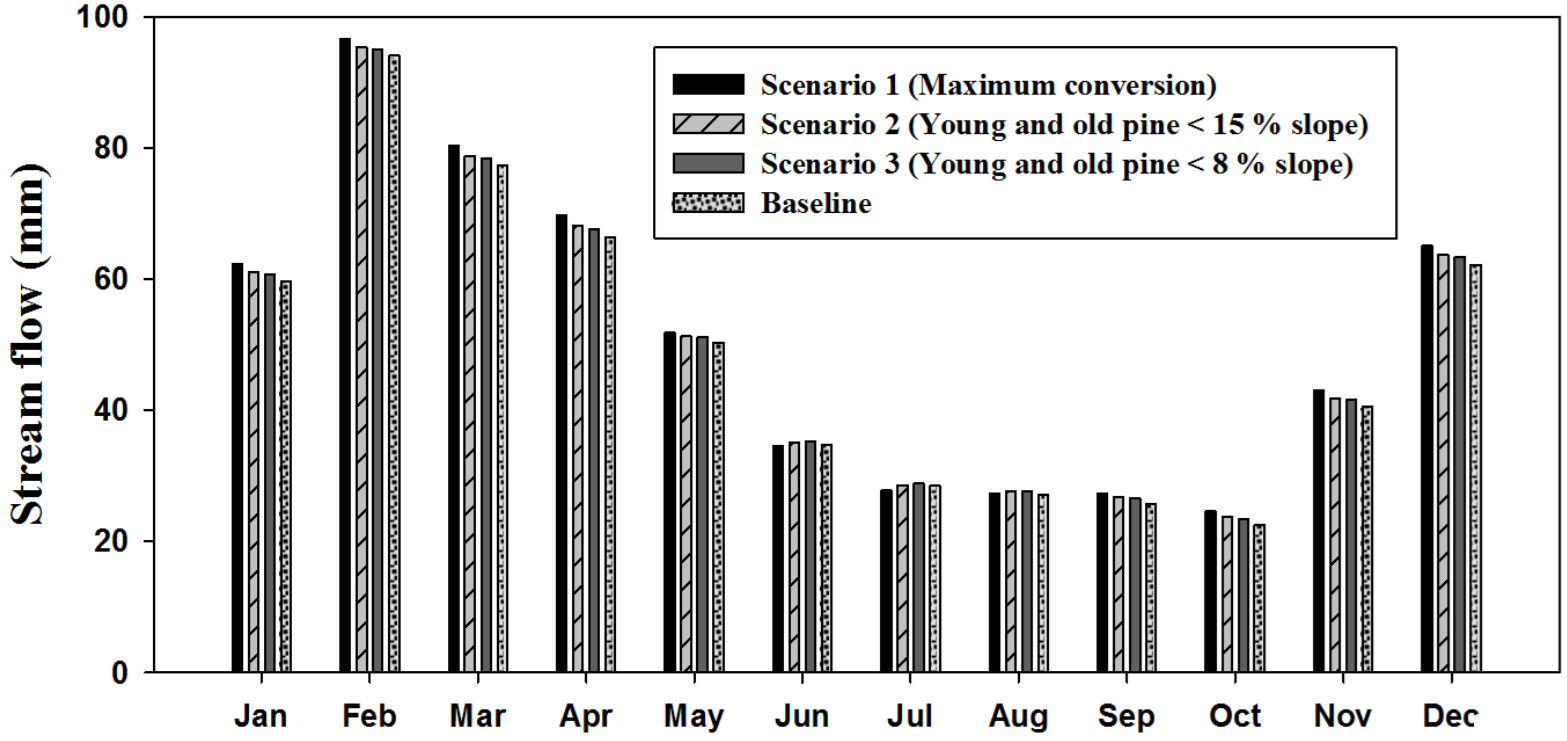
Technical Accomplishments

SWAT simulations of Tombigbee Watershed predicted impacts of intercropping on streamflow

Predicted streamflow increases of 2 to 7%

Higher increases predicted in winter



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Christopher et al. submitted, Biomass and Bioenergy

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Technical Accomplishments

Educational and Training Opportunities

University Student Opportunities

5 - Post-Doc Fellows 2 Completed

5 - PhD students 1 Completed

5 - Masters students 3 Completed

12 - Undergraduate assistants

45 - Undergraduate students have participated in a prepared biofuel lecture and field exercise.

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Relevance

Contribution to Goals of BETO Multi-Year Program Plan

Our project is directly related to Environmental Sustainability and specifically to:

- Soil quality
- Water quality/quantity
- Biological diversity
- Land use

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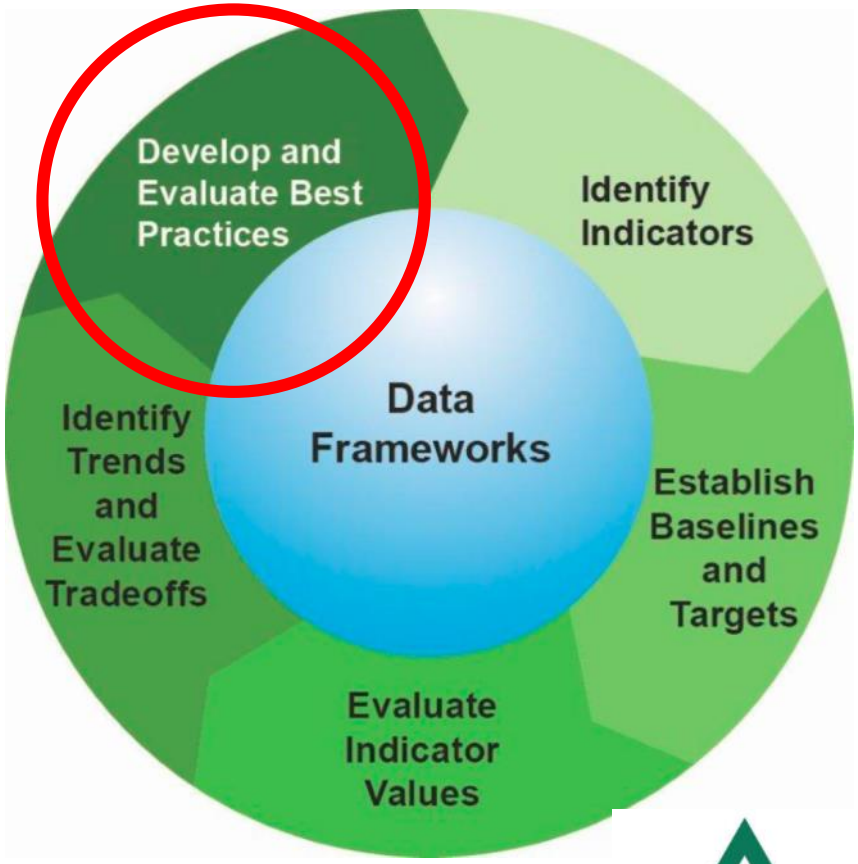
Relevance

Contribution to Goals of BETO Multi-Year Program Plan

The sustainability activity addressed by our project:

"Develop and evaluate best practices based on monitoring, field data, and modeling results"



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Future Work

Tasks

- Complete data collection (Established treatments)
- Complete data analyses (Established treatments)
- Calibrate and validate watershed scale models
  - Go/No Go decision point on model validation
- Simulate multiple biofuel scenarios (watershed scale)
- Develop land use representations for SWAT
- Simulate multiple biofuel scenarios (landscape scale)
- Develop Best Management Practices (BMPs)
- Develop Life Cycle Analysis (LCA)
- Publish and disseminate results (including BMPs and LCA) to scientists and industry operators
- Co-host an External Conference

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Summary

The critical success factors have been to 1) establish treatments, 2) collect high quality field data, 3) develop and apply appropriate and effective models.

At the 2013 Project review, we had not yet established good switchgrass treatments.

We established good treatments at the end of 2013 and the quality of those treatments improved in 2014.

We have continued to collect high quality data from the treatments and have developed effective models.

We will collect data through the coming growing season and will complete our project in the following year.

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Summary

The models we develop will be evaluated using the 5 years of data we have collected from our watershed and plot scale studies.

With the validated models and our field data we will:

- Develop and evaluate Best Management Practice guidelines that ensure environmental sustainability
- Quantify the production systems in terms of bioenergy crop yield versus the energy and economic costs of production

This will give us valuable science-based information to disseminate through publications, presentations, and cooperation with scientists and industry operators.

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Response to Previous Reviewers' Comments

Given the difficulties in switchgrass stand establishment, it seems unlikely that good, robust data on all treatments will be adequate for any sort of bona fide treatment effect analysis within the timeline of the project.

Some watersheds had low establishment rates in 2013. Our research team and external advisors thoughtfully assessed our operational and scientific options and we decided to move forward with a plan for analysis and modeling that optimized our field data set under current constraints. We replanted or overplanted the switchgrass sites as necessary to ensure successful establishment. By the end of 2013 we established good treatments and the quality of those treatments improved in 2014. Data collection will continue through the 2015 growing season. The project has collected high quality data and is making excellent progress toward documenting the sustainability of established treatments. This complements our previous documentation of the effects of site preparation.

Manuscripts submitted to journals

Ssegane, H., D.M. Amatya, A. Muwamba, G.M. Chescheir, T.Appelboom, E.W.Tollner, J.E.Nettles, M.A. Youssef, F.Birgand, and R.W. Skaggs. Hydrologic Calibration of Paired Watersheds on Pine and Switchgrass using a MOSUM Approach. Posted for open discussion at Hydrology and Earth System Sciences. http://www.hydrol-earth-syst-sci-discuss.net/12/245/2015/hessd-12-245-2015.pdf

Muwamba A., D.M. Amatya, H.Ssegane, T.Appelboom, E.W.Tollner, G.M. Chescheir, J.E.Nettles, M.A. Youssef, F.Birgand, R.W. Skaggs, and S.Tian. Effects of Site Preparation for Switchgrass-Pine Forest Intercropping on Drainage Water Quality. In revision for Journal of Environmental Quality.

Bennett, E.M., Birgand, F., Chescheir, G.M., Allen, E, Appelboom, T., Robert Lagacé, R., and Nettles, J.E. Hydrology and water quality impacts of site preparation for Loblolly Pine (Pinus taeda) and Switchgrass (Panicum virgatum) intercropping in upland forested watersheds in Alabama. In revision for Biomass and Bioenergy

Manuscripts submitted to journals

Cacho, J.F., Youssef, M.A.,, Chescheir, G.M., Skaggs, R.W., Leggett, Z.H., Sucre, E.B., Nettles, J.E. Impacts of switchgrass-loblolly pine intercropping on soil physical properties of a drained forest. Declined by Forest Ecology and Management. Submitted to TRANSACTIONS of ASABE

Tian, S., Youssef, M.A, Sun, G., Chescheir, G.M., Noormets, A, Amatya, D.A., Skaggs, R.W., King, J.S., McNulty, S., Gavazzi, M., Miao, G., Domec, J.C. Testing DRAINMOD-FOREST for predicting evapotranspiration dynamics of a mid-rotation pine plantation. In press Forest Ecology and Management.

Christopher, S.F., S.H. Schoenholtz, J.E. Nettles. Water quantity implications of regional-scale switchgrass production in the southeastern U.S. Submitted to Biomass and Bioenergy