Optimization of Southeastern Forest Biomass Crop Production: Watershed Scale Evaluation of the Sustainability and Productivity of Dedicated Energy Crop and Woody Biomass Operations

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Goal Statement

Develop and disseminate science-based information for sustainable production of forest biofuel feedstock in the Southeast.
Quad Chart Overview

Timeline
• Start date – Sept. 30, 2010
• End date – Sept. 30, 2015
• Percent complete – 50%

Barriers
• Barriers addressed
  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

Budget
Funding FY11 - $417,426/$541,453
Funding FY12 - $400,947/$533,320
Funding FY13 - $442,073/$521,954
Project funded for 5 years
Avg. Annual Funds - $418,578
$542,982

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

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

Pine planted at a wide row spacing

Interplanted with perennial energy crop
**Project Overview**

**Needs**

- Science and tech transfer
- Economic guidance
- Operational practices – BMPs/Safety

**Outreach**

- Landscape scenarios
- Operational scale effects
- Plant processes

**Broad Models**

- Water quality
- Hydrology
- Nutrients
- Soil
- Biodiversity

**Sustainability Analysis**

- Watershed treatments
- Plot scale measurements
- Southern landscapes

**Field research**
High Level Objective

Knowledge Transfer

Outreach

Disseminate results through publications, presentations, and cooperation with scientists and operators

Develop and evaluate Best Management Practice (BMP) guidelines that ensure environmental sustainability
High Level Objective
Generalize Results

Landscape scale models
Water yield and quality effects of multiple biofuel scenarios

Watershed/operational scale models
The response to biofuel treatments of:
- Water yield/ET
- Water quality
- Nutrient cycling
- Soil productivity/erosion
High Level Objectives

Understand results

Hydrology
Water quality
Nutrient cycling
Evapotranspiration
Vegetation
Soil properties  Flora and fauna

Sustainability Analysis
High Level Objective
Perform field experiments and collect data

Field Research
1 - Approach

Treatments

- PINE-SWITCHGRASS
- PINE
- SWITCHGRASS
- REFERENCE STAND
Plot Scale Experiments

Plot size – 2 ha

3 Replicates

Measurements

- Continuous Climate and Precip
- Continuous Water Table Depth
- Soil Moisture
- Soil Physical Properties
- Groundwater Quality
- Soil N and C cycling
Watershed Experiments

Watershed size – 11 to 27 ha

Measurements (Hydrology)
- Continuous Climate and Precip
- Continuous Outflow
- Continuous Water Table Depth
- Continuous Soil Moisture
1 - Approach

Watershed Experiments

Measurements (Water Quality)
- Flow Proportional WQ Samples
  - NO$_3$, NH$_3$, TKN, TP, OP, DOC, TOC, TSS
- Continuous WQ samples at NC site
  - NO3, DOC, Turbidity
- Groundwater Quality
  - NO$_3$, NH$_3$, TKN, TP
1 - Approach

Watershed Experiments

Measurements (other)
- Soil Physical Properties
- Aquatic Macroinvertebrates
- Vegetation Characteristics
- N and C cycling
1 - Approach

Watershed Experiments

ET determination using Remote Sensing
- ET measurements (during satellite flyover)
  - LAI
  - Stomatal Conductance
  - Soil Moisture and Weather Parameters

Satellite image analysis
Correlation and ET modeling using
- Neural Networks
- Multivariate Analysis
Watershed Scale Modeling

Use process based models to simulate:

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

Using DRAINMOD-FOREST for watersheds in flat high water table soils and APEX for upland conditions.
Watershed Scale Modeling

Develop module to simulate competitive interaction between Pine and understory (can be natural, switchgrass, or other biofuel feedstock)

Models will be calibrated and validated using field collected data. Sensitivity and uncertainty analyses will be conducted on the models.
1 - Approach

Landscape Scale Modeling

Use SWAT model to simulate the impact of biofuel production on the hydrology and water quality at the landscape scale (such as Tombigbee Watershed (47,600 km$^2$))

Use watershed scale models to create realistic representations of biofuel production landuse

Calibrate & validate modified SWAT model using publically-available baseline data
Develop BMPs

Use measured data and models to develop BMPs for biofuel feedstock production.
Team of very bright researchers
Plot Scale Experiments

- Instrumentation of all sites completed
- High quality data collection completed
- N and C cycling experiments completed
- Water table monitoring continues
Plot Scale Experiments

Site preparation for interplanting caused some changes in soil physical properties

Example of observed changes in soil porosity ($\eta_o$)

Harvesting operations did not significantly affect soil physical properties
Plot Scale Experiments

No significant changes in water table depths between treatments. Water table significantly deeper in the 38 year old reference stand.
Watershed Experiments

- Instrumentation of all sites completed
- High quality pretreatment data collected
  - 1 yr at NC and 2 yr at MS/AL
- Treatment installation completed
- High quality treatment data collected
  - 2 yr at NC and 1 yr at MS/AL
Watershed Experiments

Installation of Treatments Completed (NC)

- Trees Harvested: 4/09
- Trees Planted: 1/10
- Data Begin: 5/10
- Grass Planted: 8/11
- Grass Replanted: 5/12
- ASAP

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- Grass Replanted: 5/12
- ASAP
Watershed Experiments
Installation of Treatments Completed (MS/AL)

- Trees Planted: Begin Data 1/10
- Trees thinned: 3/12
- Grass planted: 5/12
- Trees removed: 3/12
- Grass planted: 5/12
- Trees removed: 10/12
- Trees planted: 1/13
- Grass planted: ASAP

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Watershed Experiments
Sample of data sets collected
Transect of Leaf Area Index density running from South to North. Each chart line represents a particular wavelength of reflected light. Differences between these lines will be used to create an index value for stomatal conductance and canopy temperature.

SPOT 5 Image of Carteret, NC
March 2013
Scintillometer installation on Switchgrass site
Carteret, NC – April 01, 2013

Measures intensity fluctuations of eddies between the laser light source and receiver
Watershed Scale Modeling

DRAINMOD-Forest was successfully calibrated and validated for its ability to simulate the hydrology and C and N cycling in managed forest conditions at the NC site. An uncertainty analysis was conducted using the generalized likelihood uncertainty estimation (GLUE) methodology.
Partitioning of solar radiation is a function of canopy fraction and leaf area;
Partitioning of soil water and nitrogen is a function of roots distribution;
Partition ET into two portions: up-story trees and understory bio-energy grasses.
Landscape Scale Modeling

Calibration and validation of SWAT for the Tombigbee Watershed
Our project is directly related to Environmental Sustainability and specifically to:

- Soil quality
- Water quality/quantity
- Biological diversity
- Land use
3 – Relevance

Contribution to Goals of Biomass Program MYPP

The sustainability activity addressed by our project: “Develop and evaluate best practices based on monitoring, field data, and modeling results.”
Success of this project will depend on:

• High quality data collection, and management

• Appropriate data analysis and interpretation

• Development and use of appropriate and effective models

• Presentation and publication of research results

• Development and dissemination of effective Best Management Practices
5 – Future Work

Tasks

• Complete data collection (watershed studies)
• Complete data analyses (watershed studies)
• 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
• Develop Life Cycle Analysis
• Co-host an External Conference
• Publish and disseminate results
Goal: Develop and disseminate science-based information for sustainable production of forest biofuel feedstock in the Southeast.

- Science and tech transfer
- Economic guidance
- Operational practices – BMPs/Safety

Outreach
- Landscape scenarios
- Operational scale effects
- Plant processes

Broad Models
- Water quality
- Hydrology
- Nutrients
- Soil
- Biodiversity

Sustainability Analysis
- Watershed treatments
- Plot scale measurements
- Southern landscapes

Field research
How is site variability being handled?

- We have a total of 14 sub-watersheds in 3 states, across a range of soils and climate conditions but with similar forest conditions and treatments. Within each set, we selected watersheds with similar soils, slopes, site characteristics, and locations adjacent or very close to each other. We are quantifying site and climatic variation that does occur in the field. The Before/After, Control/Impact setup should also allow us to quantify variability.

Have you thought enough about generalizing the results?

- Modeling is a major component of our effort, and is being used to extend our watershed-scale studies to larger landscapes. We have already published innovative methods that link multi-scale models, from plant growth through rainfall runoff. These process-based models will help us evaluate where generalizations are appropriate and what kind of errors may come out of generalizations. We put a lot of effort into balancing broad applicability with likely environmental and economic conditions necessary for feedstock growth.
Responses to Previous Comments

Do you have a plan to deliver BMPs and land management strategies to non-industrial forest landowners?

- We plan several methods of outreach. Scientific publications with research data and models will be very important for ongoing research, but we recognize the importance of more practical outreach and plan to use existing networks to transfer our results. Weyerhaeuser Company is part of several grower networks, and regularly provides outreach material to loggers and small private landowners. More popular publications will reach extension agents and consultants. Our outreach will include information on the biofuel treatments as well as BMP guidance and safety-related material.

Will a sensitivity analysis be performed on the data used in the modeling?

- Sensitivity and uncertainty analyses will be performed on the important model inputs. These analyses have been performed on the DRAINMOD-Forest model and methods and results of those analyses are presented in the publications listed on the next slides. After the plant growth and competition components are added to the models, these same analyses will be performed and presented. The main focus will be on the management and plant growth variables used to simulate the switchgrass, pine trees, and the interactions between them.
Publications:


Presentations:

Publications and Presentations

Presentations:


Presentations:


- Allen, Elizabeth, François Birgand, Vazken Andréassian, Charles Perrin and G.M. Chescheir. Quantifying the effect of biomass cropping system on hydrology by use of the GR conceptual model. Presented at the International American Society of Agricultural and Biological Engineers (ASABE) Conference 2012, July 29 – August 2, 2012, Dallas, TX. Paper # 1337210


Presentations:


- Nettles, J. and G. Chescheir. 2012. The water footprint of intensive forestry operations. NCASI Southern Regional Meeting, June 11 – 13, Greenville, SC.


Publications and Presentations

Presentations:


Publications and Presentations

Presentations:
