Hydrology and Water Quality Impacts of Biomass Intercropping in Managed Pine Plantations of the Southeastern United States

Elizabeth Allen[1], François Birgand[1], George Chescheir[1], Erin Bennett[1], Vazken Andréassian[2], Charles Perrin[2],& Timothy Appelboom[1]

1. Biological and Agricultural Engineering, North Carolina State University 2.IRSTEA, Antony, France

Research funded by: U.S. DEPARTMENT OF ENERGY Energy Efficiency & Renewable Energy

1.Introduction

- Governmental policy requires production of 36 billion gallons of biofuels from domestically produced feedstocks per year by 2022 (Energy Independence and Security Act of 2007)
  - 21 billion gallons per year of advanced biofuels from cellulosic feedstocks
  - Many will come from forests and energy crops
- Assessment of the environmental sustainability of novel types of feedstock production and removal from the land is needed, especially at the watershed scale
- **Intercropping** thinned pine plantations with an energy crop is an innovative, dual land use, management approach to creating additional biomass resources without removing agricultural land dedicated to food production

2.Research Question & Project Design

Present forestry management practices are considered sustainable. Will the addition of intercropped switchgrass as a biomass feedstock and associated management practices (i.e. implementation, maintenance, and harvest) impact hydrology and water quality in pine plantations of the southeastern region of the U.S.?

- **3** matched, managed pine plantation research sites
- **4-5** upland watersheds each
- Paired watershed design

3.Study Site: Calhoun County, MS

- 5 watersheds similar in size, location, topography, climate, and pre-treatment vegetation cover selected for the paired watershed experimental design in Calhoun County, Mississippi
- Biomass production scenarios involving Loblolly pine and Alamo switchgrass

Watershed outlet/monitoring station

Watershed	Area (ha)	Treatment	Tree Birth Year	Switchgrass Planted
BF1	14.1	Young Pine	2007	
BF2	12.8	Young Pine-Switchgrass Intercrop	2007	2012
BF3	10.9	Switchgrass	2006	2012
BF4	15.2	Age Zero Pine/Switchgrass Intercrop	2006/2013 replanting	
BFREF	12.6	Mid-rotation Pine	1995	

BFREF

Searcy, J.K. 1959. Flow-duration curves. *Geological Survey Water-Supply Paper*. United State Government Printing Office: Washington.
Ritchter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. *Society of Conservation Biology*. 10(4): 1163-1174.
Moatar, F. and M. Meybeck. 2007. Riverine fluxes of pollutants: towards predictions of uncertainties by flux duration indicators. *Comptes Rendus Geoscience*. 339: 367-382.
Baker, D.B., R.P. Richards, T. T. Loftus, and J. W. Kramer. 2004. A new flashiness index: characteristics and applications to Midwestern rivers and streams. *Journal of The American Water Resources Association*. 40(2): 503-522.3
Perrin, C., C. Michel and V. Andréassian. 2003. Improvement of a parsimonious model for streamflow simulation. *Journal of Hydrology* 279(1–4): 275-289.
Andréassian, V., J. Lerat, N. Le Moine and C. Perrin. 2012. Neighbors: Nature's own hydrological models. *Journal of Hydrology* 414–415(0): 49-58.

4.Objectives

Determine differences in *hydrology* and *water quality* in a paired watershed experimental design by :

- establishing natural differences between watersheds in a **pre-treatment** phase where all watersheds consist of 5-6 year pine stands (2010-2012)
- comparing differences among control and treated watersheds in a **post-treatment** period (2012-present)
- determining deviation between **pre- and post-treatment** conditions within each watershed

5.Methods

Data Collection

Monitoring Discharge

- **Data:** Height and velocity of water leaving the outlets to calculate discharge (Discharge=Velocity*Wetted Cross Section)
- **Measurement Interval:** 2 min
- **Equipment:** Trapezoidal flume, doppler velocity meter, pressure transducer water level recorder

Monitoring Weather

- **Data:** Rainfall, temperature, wind speed, gust speed, solar radiation, atmospheric pressure, relative humidity
- **Measurement Interval:** 15 min
- **Equipment:** Weather station, tipping bucket rain gauge

Monitoring Water Quality

- **Data:** Composite samples of water at the watershed outlets
  - Concentrations: NO_3^--N,NH_4^+-N, TKN, TSS, TP, DOC, DIC
- **Measurement Interval:** Flow dependent
- **Equipment:** Automated water sampler, automated acidifying system

Data Analysis

Hydrology

Objective: Evaluate differences in the amount of water leaving the outlets

Method: Calculate and compare cumulative discharge volumes (Fig. 1)

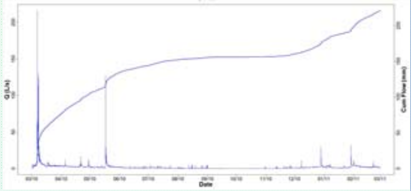


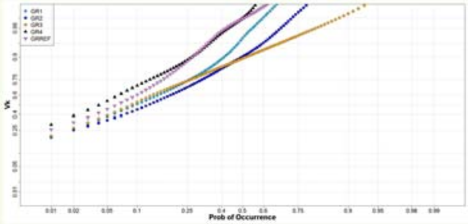
Fig. 1. Example of hydrograph plotted with cumulative discharge

Data Analysis Continued

Objective: Evaluate differences in the flashiness (how quickly and frequently streamflow responds to precipitation) of the watersheds

Methods:

- Vk% Curves (Moatar and Meybeck, 2007) (Fig. 2)
- Indicators of Hydrologic Alteration (Richter et al., 1996)
- Richards-Baker Index (Baker et al., 2004)
- Flow duration curves (Searcy, 1959)



Vk% is the percentage of the total discharge that occurs in a percentage of total monitoring time. Lower percentages of time correspond with higher flow rates, thus the steeper the slope, the relatively flashier the system.

Fig. 2. Example of Vk% curves plotted for 5 watersheds in Alabama

Water Quality

Objective: Evaluate differences in the amount of nutrients and sediment being exported from the watersheds

Method: Calculate and compare cumulative loads

Objective: Detect differences in loading and provide explanations

Method: Determine trends in nutrient/sediment concentrations exported by plotting cumulative load versus cumulative flow (Fig. 3)

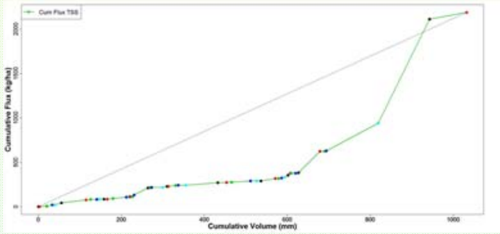


Fig. 3. Example of cumulative TSS flux versus cumulative discharge plot in an Alabama watershed

Modeling Component

Two conceptually based hydrological models developed in France will be applied to the dataset as an additional method to complete hydrology objectives.

Two types of modeling to detect impacts of a land cover change will be applied:

- **Rainfall-runoff modeling**
  - Model: GR4J (Perrin et al., 2003)
  - Inputs: Daily rainfall and PET
  - Output: Discharge
  - 4 free parameters
- **Paired watershed design modeling**
  - Model: Neighbor Catchment Model (Andréassian et al., 2012)
  - Inputs: Discharge of neighboring catchment
  - Output: Discharge
  - 3 free parameters