A Watershed Perspective on Bioenergy Sustainability
A Workshop held at Oak Ridge National Laboratory
Oak Ridge, Tennessee
3-4 February 2010

WORSKHOP OVERVIEW

An informal workshop focused on a watershed-scale perspective of cellulosic bioenergy feedstock sustainability was held at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee 3-4 February 2010. The workshop was sponsored by the National Council for Air and Stream Improvement, Inc. (NCASI), the U.S. Department of Energy's Office of Biomass Program, and the Center for BioEnergy Sustainability (CBES) at Oak Ridge National Laboratory (ORNL). The workshop included researchers from ORNL, Savannah River Site, NCASI, Weyerhaeuser, federal agencies, academic institutions, and other private industry groups. This overview and a list of the workshop attendees can be found at the CBES web site: http://www.ornl.gov/sci/besd/cbes/workshop.shtml.

The topics covered included water-related sustainability issues (particularly hydrology and water quality) associated with intensive cellulosic bioenergy feedstock production. Overall goals for the workshop included:

- Defining the type and level of intensive management inputs required to achieve various production levels for trees and switchgrass and the likely watershed hydrology and water quality consequences
- Exploring watershed standards in terms of hydrology and water quality regulatory compliance or targets in states in which intensive cellulosic production is possible
- Exchanging information about activities in this area and building collaborations and connections
- Identifying sustainability indicators relevant at a watershed scale
- Developing key attributes of watershed studies/experiments that address bioenergy sustainability
- Developing a network of experimental intensive cellulosic bioenergy watersheds where research is ongoing, planned, or potentially can occur in a collaborative fashion to characterize the variability in key sustainability attributes.

Workshop participants shared their current research and perspectives in a format that promoted communication among all participants. This workshop increased awareness of what research is occurring as well as research needed in this rapidly developing field.

Steering Committee:

ORNL: Virginia Dale, Pat Mulholland
US Forest Service/Savannah River Site (USFS/SRS): John Blake
NCASI: Al Lucier
Weyerhaeuser: Bob Bilby

BREAKOUT GROUP REPORTS

Topic 1: Critical Questions and Hypotheses with regard to hydrology and water-quality issues from intensive cellulosic bioenergy feedstock production at the watershed scale

Alan Lucier, NCASI, Moderator;
Steve Hamilton, Michigan State, Rapporteur
Mary Beth Adams, USFS/NRS
Yomas Demissie, ANL
Jennifer Knoepp, USDA/FS/SRS
Sheila Moynihan, DOE
Stephen Schoenholz, VPI
Peter Schweitzer, ORNL
Wayne Skaggs, NC State
Mark Walbridge, National Program Lead/Water
May Wu, ANL

Overview

- What we know already
  - Hydrology of traditional silvicultural and agricultural systems
  - Nutrient and sediment export from managed and unmanaged systems
- What is likely to change with biofuel production systems?
  - Novel cropping systems (incl. GMOs, algae)
  - Change in vegetation form (e.g. switchgrass in place of forest or grain crops or pasture) may alter water balance, soil properties
  - More/less frequent and complete harvest of biomass may affect soils, erosion, nutrient balances
- Net effects depend on what the biofuel production system is replacing or is compared with
  - Need to consider location, climate, etc.

Outstanding Issues

- Changes in terrestrial water balance
  - Change in plant water use (ET)
  - Groundwater recharge
  - Resultant changes in stream flow regimes, incl. magnitude, storm runoff, minimum flows, drought impacts
  - Ecological and socioeconomic effects of altered flow regimes
- Water quality
  - Will biofuel production improve or degrade it?
  - Surface and ground waters
- Nutrient loading to coastal zones subject to eutrophication
  - Mississippi River/Gulf hypoxia
  - Chesapeake Bay
- Thermal impacts (esp. forested catchments with coldwater fisheries habitat)

- Pesticides (esp. herbicides): Will overall use (and contamination) be increased or decreased?
- Climate change, changing water availability, and biofuel production
- Monocultures vs. polycultures: Consider ecosystem services as well as economics?
- Biorefinery water demands, nutrient recovery/recycling
- Bio-based products besides ethanol
- Scaling, sustainability, and reality
    - Land use change scenarios
    - Location/context are critical
    - Policymakers need spatially explicit projections
    - Incentives and subsidies to convince producers

Next Steps

- Develop opportunity for cross-site synthesis to understand geographic variability
    - Take advantage of long history of location-based research on forest and agroecosystem hydrology
    - Need further consideration of catchment-scale impacts of harvest of residues (esp. on sloping lands)
- Consider how can we partition nutrient, sediment & water loading among subcatchments of a flow network
    - Need to improve model validation at catchment scales (e.g. SWAT): More field experiments in diverse settings
    - Need to be able to route water, nutrients and sediments from sources to sensitive receptor environments (e.g. estuaries)
    - Need to understand changes in routing that may be attributed to changes in management systems/practices.
    - We can do this better in some environments than others.
- Need an integrated and interdisciplinary biophysical and socioeconomic approach
    - How can the necessary research effort be funded??

Topic 2: Sustainability Indicators (including most appropriate hydrologic and water quality measurements, other measurements), equipment and instrumentation needed

Pat Mulholland, ORNL, Moderator
Vince Neary, ORNL, Rapporteur
Ajay Bhardwaj, MSU
George Ice, NCASI
Jennifer Franklin, UTK
Chip Chesheir, NCSU
Eugene Yan, ANL

Outstanding Issues

- What are the key questions - Scale (spatial and temporal) of impacts and metrics
- Indicators of Sustainability
    - Hydrology

    - Sediments
    - Nutrients (N & P)
    - Herbicides
- Approaches for Impact Measurement
    - Reference watershed
    - Before-After
    - Upstream-downstream
    - How long pre-period???

Hydrology

- Water yield - budget
- Hydrograph properties (peak and base flows)
- Explanatory variables – Meteorological, soil, measurements, flow paths, etc.
- Historical data
- Need for hydraulic control to measure streamflow

Nutrients

- Issue primarily NO3, PO4 and TP (sometimes NH4)
- Need high frequency or flow weighted data
    - In-situ sensors (NO3 and PO4)
    - automated sampling
- Need to resolve on short (min-hours) to long (annual) temporal scales
- When and where to sample? Variations among flowpaths

Sediments

- Concerns are loads, concentrations (direct biological effects -exposure), morphology changes
- Need high frequency or flow weighted data
    - In-situ turbidity sensors with site calibration
    - Automated sampling
- Need to resolve on short (min-hours) to long (annual) temporal scales
- How much sediment is good? (reference condition hard to determine)
    - Need to measure change in sediment transport over time (including size distribution)
- When and where to sample?

Next Steps

- Need to Develop Guidelines
    - Key explanatory variables
    - Reference condition
    - Instruments used
    - When and where?
    - Sampling frequency?
    - local vs. regional questions
    - Cost-benefit of data collection and management

Topic 3: Field study design involving management treatments for planned experiments (site preparation, fertilizers, herbicides), considerations for observational studies (monitor, spatial considerations and nesting of catchment scales)

John Blake, USDA Forest, Moderator
Melanie Mayes, ORNL, Rapporteur
Gayathri Gopalakrishnan, ANL
Don Kaczmarek, USFS/SRS
Mike Kane, UGA
Jami Nettles, Weyerhaeuser
Matthew McBroom, SFASU

- Goals, objectives, and designs are operationally-defined, but we still need a framework
    - Negates the "co-op model" with prescribed treatments
    - No BMPs for SWG (or other biofuel) – compared to silviculture.
    - What is the control? Pasture? Row crops? Oil fields? Forest? Must be economically viable and logical.
- Sensitivity/Models
    - Studies need to be intensive enough to make observations, models needs to be sensitive enough to represent the processes (credibility gap on modeling)
    - But, the large scale processes might NOT be the sum of small scale processes; rather, might be "emergent processes"
- Realistic result might be "no or positive impact"
    - Compared to overall LUC or land use
- Need for BMPs
    - Knowledge transfer of practices at sites
    - How do we encourage simple expansion of field trials for productivity comparison and water quality indicators?
    - High value of small scale data and process-based data
- Heterogeneity of sites and dominant gw/sw/soil water processes
    - Note SWAT very poor at scaling up small plot data
    - Process-based model representation of field-scale processes
- How do we encourage communication and knowledge exchange?

<u>Next Steps</u>

- Share distribution list of this conference, plus other interested parties
- Develop list of community sites for research, e.g., Jami Nettles offer of Weyerhaeuser sites
- Consider treatments that are of measureable differences
- Prepare list of simple water quality measurements (e.g., yield, fertilizer, soil, water quality indicators

Topic 4: Linking Empirical Studies (Experiments, Observations) and Modeling

Bob Bilby, Weyerhaeuser, Moderator
Marilyn Buford, USFS/Washington, Rapporteur
Rhett Jackson, UGA
Yetta Jager, ORNL
Latha Baskaran, ORNL
Devendra Amatya, USFS
Sheila Christopher, VPI

Overview

- Models will be important tools in the evaluation of impacts of biomass production on water
- Current hydrology and water quality models are relatively complete but will require better quantification of some parameters for application to biomass production
- Linking hydrology models with predictive tools for biological response and land use decisions will enhance the value of these tools

Outstanding Issues

- Data specific to biomass production will be required to parameterize existing hydrologic models; data needs include:
  - ET for biomass crops or tree/crop combinations
  - Albedo
  - Nutrient application rates
  - LAI curve for biomass crops
  - Development of appropriate curve numbers
  - Rooting depth
  - Initial nutrient loads in the soil
  - Land use history
- Models need to balance complexity with ability to model processes of interest
  - Highly complex models often require data that is available for very few sites; requires large number of assumptions and injects an unknown amount of uncertainty into model output
  - Simple models are easier to parameterize but may not provide the flexibility required to generate projections about some key aspects of biomass production
  - Should select models that strike a balance between data requirements and flexibility
- Additional information required to enhance ability to scale-up from field/stand-scale models to larger spatial scales
  - Understanding and quantifying spatial and temporal variation in in-stream processes
  - Model parameterization and validation hampered by the fact that long-term databases at large scale containing flow, chemistry and sediment data are rare but there are some opportunities to synthesize existing disparate data sets

  - Manipulative experiments are not amenable to examining hydrological process at large scales; can small watershed studies be designed in a manner that will provide some information about cumulative effects?
  - Need to account for point-source inputs when expanding to larger scales
- Certain aspects of aquatic system response to biomass production are not understood well enough to develop quantitative models
  - These topics might be explored through the development of detailed conceptual models
  - Can provide an indication of key knowledge gaps
  - Linkages between water quantity/quality conditions and the status of aquatic and riparian flora and fauna not as well established
  - An improved ability to simulate landowner decision processes relative to land use would make projections more realistic

Next Steps

- Establish an online repository for common model parameters for different regions and biomass production systems
  - Compile currently available information and incorporate new data from biomass/watershed studies as it becomes available
  - Ultimately expand site to include results from the biomass/watershed studies including FS and ARS experimental watersheds
- Incorporate mechanisms into models that better quantify and simulate spatial and temporal variability
- Begin to develop conceptual models for linking hydrologic and water quality conditions with system ecology/biology
  - Could be initiated by a subgroup of workshop participants
  - Might be able to incorporate some of the findings from this exercise into the watersheds studies currently being established

Topic 5: Concerns other than water quality that are a part of the watershed perspective of bioenergy sustainability (the catch-all group for other environmental concerns)

Virginia Dale, Moderator
Esther Parish, ORNL, Rapporteur
Charles Kwit, UT
Roxanne Dempsey, DOE
Rebecca Efroymson, ORNL
Keith Kline, ORNL
Chuck Garten, ORNL

Overview

- What is stability and resilience of bioenergy systems?
  - Complex interactions of issues requires a holistic approach over time (integrative and comparative analysis)

    - Are monocultures more or less "stable" than diverse systems (effects on biodiversity)
- Compared to what? (what baseline to use?)
    - Land use – history and what may otherwise happen
        - Can the past be used to predict future?
        - Land ownership patterns (and what influences those)
        - How is land valued? – price, diversity, water quality, etc.
        - Roads and other infrastructure changes
        - Movement to large farms
        - Rural/urban interface and flights to cities
            - Conversely, using bioenergy to live off the grid)
    - Other energy decisions
        - E.g. mountain top removal
    - Disturbances - esp. unforeseen ones
        - Double whammy effects (synergistic effects can lead to new equilibrium)
        - Fire and role of prescribed burns (how will burning change under short rotation crops)
    - Other ongoing changes (consider land use changes and adaptations in context of these changes)
        - Climate change
        - Economic change
        - Disease outbreaks
        - Technology changes
- Crop characteristics
    - Weediness
    - Algae and other options
    - Nonnative issues and invasiveness
    - Important to focus on crops with multiple uses
    - Genetically engineered organisms
        - Biocontainment issue
        - Crossing with native species and/or invasiveness – loss of adaptability
        - Contributing to sustainability by reducing costs (N and water use efficiency increased) and allowing quotas to be met
- What is really most important in particular regions
    - Need to have a vision at watershed scale that is developed internal to those within watersheds
    - Opportunities for education
        - Surf your watershed
        - Watershed signs
        - Stream buffers was a good example for farmers (importance of ag extension agents)
    - Social welfare
    - Using energy (as an excuse) to make proactive choices for the future
        - E.g., bioenergy has drawn attention to long-term problems of land use and social issues

        - Google Earth effect – now that people see these effect they are concerned about them
    - Can groups share risks and benefits (e.g., cooperatives)
- Incentives (include environmental concerns as part of economic and non-monetary incentives)
    - Affect choices of crops, land management, etc.
    - Accounting for co-products benefits and costs
    - Considering in relation to life decisions (health care, education, stage of life)
    - Social incentive (peer influence)
- Soil quality and productivity over the long run
    - Essential to long-term support of civilization
    - N balance, carbon, and long-term soil productivity and stability are connected
    - Less of an issue with woody biomass than herbaceous cropping systems in which products and wastes are removed annually
    - Variation of space
    - Standards for comparative analysis
- Dealing with complexity of system and the tradeoffs and their implications

<u>Outstanding Issues</u>

- Ways to measure long-term attributes (indicators)
    - What?
        - GHG emissions
        - Soil productivity and quality
        - Water quality
        - Habitat and biodiversity
    - How?
        - Need accepted ways to make these measures
        - A commitment to long-term measures and appropriate places to take these measures
        - How to get this info out to land owners and managers (funding for incentives and education)
        - Linking to existing systems
            - USGS
            - USDA Environmental Benefits Index (EBI)
            - How does NEON relate?
    - Methods to assess integrated and complex systems over time
- Education on causes and effects of different decisions (e.g., effects on water quality, recreation, etc.)
    - Risk mitigation - how can farmers know when they are approaching thresholds
    - Ways to convey information on effects of choices
        - Compatible land uses (e.g. wind turbines and bioenergy crops)
        - How to deal with water constraints
        - Connection between education and incentives (educating policy makers)
        - Benefits of tax on petroleum (to make price be steady and high)

- Value of multiple markets

Next Steps

- Research
  - Integrated projects that examine diverse attributes (both environmental and social issues)
  - Can current watershed research be linked and compared to other uses on the land?
  - Can a procedure for common measures be developed so that comparison can be made?
  - Can watershed information be made jointly available (e.g., using KDF)?
  - Can there be a publication that compares some of these studies (e.g., a special issue of a journal with several studies)?
  - Comparison of using land for different energy uses – based on incentives (and disincentives) and effects of these different uses.
  - Effects of bioenergy on biodiversity and habitat (relates to choice of selection of crops, management practices, location, past land use, etc. and effects on other ecosystem services)
- Demonstration projects
  - What are ideal attributes of a farm to grow bioenergy crops within a watershed context?
  - Regional efforts to develop common goals for bioenergy (e.g., nine counties/one vision; river keeper groups)
  - Projects that consider multiple goals and way to management for diverse goals over long time (how to consider tradeoffs, risk sharing)
- Education
  - Efforts to work with NGOs
  - Efforts address paucity of science journalism in US

WORKSHOP OUTCOME

Proposed Next Steps

- Plan to hold symposium in two years and to prepare a special issue of a journal
- Hold a workshop with extension agents, modelers, and those who collect and process data that focuses on Best Management Practices (BMPs). The workshop needs to consider how biomass issues will relate to current best management practices and focus on how much material to leave on the ground (work with manufacturers)
- Need to develop guidelines
    - Key explanatory variables
    - Reference conditions
    - How to conduct field experiments (sampling designs, water quality metric selection)
- Work with NRCS to identify landowners and other interested in outreach and potentially hosting studies
- Explore educational option (e.g., NEON)
- Prepare a PowerPoint presentation from this workshop that is customized to various audiences
- Reach out to machine groups (e.g., John Deere, Caterpillar)
- Relate ideas from this workshop to SunGrant intiatives
- Develop an on-line repository of experimental outcomes for models and other uses
    - On-line discussion site of various topics
    - Model parameters and data for theme

WORKSHOP AGENDA

February 3rd, Day 1:

8:30 Welcome and Introduction

Oak Ridge National Laboratory – Martin Keller

DOE: Office of the Biomass Program – Alison Goss Eng

National Council for Air and Stream Improvement (NCASI) – Al Lucier

Center for BioEnergy Sustainability (CBES)– Virginia Dale

Invited Presentations

9:00 Tom Fox, Virginia Polytechnic Institute (VPI), and Mike Kane, University of Georgia (UGA): Inputs needed to achieve high biomass production for SE trees

9:25 George Ice (NCASI): Groundwater and stream water quality compliance standards and expectations

9:50 Break

10:05 Jami Nettles (Weyerhaeuser): Weyerhaeuser Catchlight study

10:30 Wayne Skaggs, North Carolina State University (NCSU): Eastern NC study

10:55 Matthew McBroom (Stephen F. Austin State University): Texas study of water quality impacts of intensive forestry

11:20 Melanie Mayes (ORNL): Soil water quality under fertilized switchgrass plots in Alfisol soils, Milan, TN.

11:45 Rhett Jackson (UGA): Sites for watershed studies

12:10 Lunch

1:10 Yetta Jager and Latha Baskaran (ORNL): Modeling direct and indirect landscape influences on water quality and fish biodiversity over large spatial extents

1:35 Stephen Schoenholtz/Sheila Christopher (VPI): Scaling up results from small watershed studies to larger spatial scales

2:10 Break

2:25 *"3 in 5" Presentations*

Stephen Hamilton and Ajay Bhardwaj (MSU): Terrestrial water balance and water footprints of grain-based and cellulosic biofuel crops: Research at the DOE Great Lakes Bioenergy Research Center

Jim Pease (VT): Biomass Feedstocks with the Chesapeake Bay watershed

Donna Perla (EPA): Biomass production in the Chesapeake Bay Watershed: Framing Critical Environmental Questions

Devendra Amatya (USDA/FS): Effect of Switchgrass as a Biofuel Intercropping on the Water Quality and Quantity from a Drained Pine Plantation - A New Study

Gayathri Gopalakrishnan (Aragonne): Resource recovery designs for sustainable lignocellulosic biomass

Mark Walbridge (USDA/ARS): Watershed Scale Analysis of Bioenergy Production – A Key Component of Agricultural Sustainability

Rebecca Efroymson (ORNL): Analytical frameworks for watershed analysis

May Wu (ANL): Addressing Water Resource and Water Quality Issues for Biofuel Production - Quantifying Regional Impact

Jennifer Knoepp and James Vose (USDA/FS/SRS): Long-term research at Coweeta Hydrologic Laboratory: Forest management impacts on ecosystem sustainability

Pat Mulholland (ORNL): Hydrology and water quality impacts of short-rotation wood biomass for bioenergy: a watershed-scale experiment at DOE's Savannah River Site

Mary Beth Adams (USDA/FS): Biomass, Biofuels and Sustainability in the Central Appalachians

Jeff Warren (ORNL): Sweetgum plantation water use under elevated CO2

Marilyn Buford (USDA/FS): Integrating Bioenergy and Sustainable Productivity

4:30 Adjourn

Dinner at Museum of Appalachia

February 4th, Day 2:

8:30 *"3 in 5" Presentations*

Al Lucier (NCASI): NCASI Priorities Regarding Sustainable Production & Use of Forest Biomass

Jennifer Franklin (UT): Root distribution and the soil moisture profile

Keith Kline (ORNL): Watershed Land-Use Planning - Ingredients for success from international development experiences

Virginia Dale (ORNL): A landscape design for bioenergy feedstock

Mike Hilliard (ORNL): A spatial optimization approach to modeling water quality implications of perennial crops planting for bioenergy feedstocks

Esther Parish (ORNL): Selecting sites for bioenergy crop plantings within a watershed experimental design

Mark Downing (ORNL): Economic modeling and environmental modeling approaches to figuring out why farmers are doing what they are doing

9:30 Breakout Groups Assignments and Topics [moderator]

- Discussion topic 1 – What are the critical questions/hypotheses with regard to hydrology and water quality issues from intensive cellulosic bioenergy feedstock production at the watershed scale [Al Lucier]
- Discussion topic 2 - Sustainability indicators (including most appropriate hydrologic and water quality measurements, other measurements), equipment and instrumentation needed [Pat Mulholland]
- Discussion topic 3 - Field study design involving management treatments for planned experiments (site preparation, fertilizers, herbicides), considerations for observational studies (monitor, spatial considerations and nesting of catchment scales) [John Blake]
- Discussion topic 4 – Linking empirical studies (experiments, observations) and modeling [Bob Bilby]
- Discussion topic 5 – Other environmental indicators (e.g. greenhouse gas emissions, long-term soil productivity, HG issues, biodiversity [Virginia Dale]

9:30 Break

9:50 Convene Breakout Groups

12:00 Lunch

1:00 Breakout reports and discussions

2:45 Break

3:00 Discussion of next step and summary of workshop results [Moderator: Virginia Dale]

4:00 Workshop Adjourned