Assessing Regional Water Impacts of Biofuel Production Scenarios

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Water Quality and Quantity Impacts Must be Addressed for A Sustainable Biofuel Production

Competing water use from multiple sectors and projects
- Power
- Biofuel
- Agricultural
- Urban development

Large scale biofuel feedstock production
- Environmental loading to waterways
- Chemical and nutrient accumulation in surface and ground water

Compounding effect on water body
- Hypoxia zone expansion
- Aquatic ecosystem degradation
The region

- Covers
  - IL, IA, IN, Wis, MN, SD, MS
  - 131 sub-basins, 121 million acres
- Includes 27 Mln acres of corn in 2006, 68% of total corn acreages in UMRB states
- Produced 4,476 million bushels of corn in 2006 - 42% in U.S.

- Holds an ethanol production capacity of 5.3 billion gallons (in operation)
  - 48% of U.S. production in 2009
Agricultural Inputs and Land Use Changes

- Upholds modest to high fertilizer inputs
- Maintains high corn yield
  - 167 bu/acre compared to 149 bu/acre of U.S. average (2006)
- Productivity continues to increase in the past forty years.
  - More grain produced for each kg of nitrogen applied.
- Land use changes unstable

<table>
<thead>
<tr>
<th>State</th>
<th>N Applied (lb/acre)</th>
<th>P2O5 applied (lb/acre)</th>
<th>K2O applied (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>143</td>
<td>64</td>
<td>96</td>
</tr>
<tr>
<td>Indiana</td>
<td>147</td>
<td>72</td>
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<td>Iowa</td>
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<td>Minnesota</td>
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<td>Missouri</td>
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<td>South Dakota</td>
<td>107</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>100</td>
<td>31</td>
<td>50</td>
</tr>
</tbody>
</table>

Dynamic land use changes in recent years

Pasture land acreages
Live Stock Operation

- Major livestock: beef, dairy, swine.
- Estimated a total annual production of 129 million metric tons (wet) of manure in 2006.

Major WWTPs

- Water discharge: 10,191 BGY
- Nitrogen: 27,414 MT/yr

Total annual loading to UMRB from WWTP and major industries
- 29,000 metric ton nitrogen
- 48 metric ton phosphorus
Examine Options to Meet Sustainability Requirement for the Biofuel Production System

Factors considered:
- Types of biofuel feedstock
  - Grain
  - Ag residue
  - Perennial grass
- Yield increase due to improved N use efficiency
- Agricultural practices
- Land use changes
  - Pasture land

- Fertilizer run-off
- Soil erosion
- Municipal discharge
- Live stock operation

Watershed environmental loading

Surface water
Ground water
Soil water stock

Evapotranspiration

Precipitation

Groundwater stock

Irrigation uptake

Percolation

Surface water stock

Irrigation uptake

Runoff

Base flow

Upper stream inflow

Outflow to downstream

Water evaporation

Changes in Water Cycle Dynamics
Modeling Framework for UMRB

Ground surface topography

Water use

Sub basin

Others:
- Climate, Tile drainage
- Tillage, Point source
- Reservoirs

Model Calibration
- Water flow, nitrogen, and phosphorus (USGS)
- Corn yield (USDA)

Land use, crop rotation

Fertilizer

Soil type
Scenario I
Corn in 2015
• Large Increase in yield for corn and ethanol
• Moderate increase in fertilizer application rate
• No expansion in corn acreage

Scenario II
Corn
Stover harvest
• Various removal rate
• Additional fertilizer application
• Soil property changes

Scenario III
Corn
Switchgrass
• Pasture land conversion 10%
• Fertilizer application
• Average yield, high yield

Baseline year for crops: 2006
Baseline 2006
Corn 765 mln bu

Scenario I
Increased yield
Corn 1.5 bln bu

Scenario II
Stover
Corn 1.5 bln bu
Stover 25 mln d.t.

Scenario III
SWG
Corn 1.5 bln bu
SWG 8 mln d.t.

Bln Gallons

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Additional ethanol production</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>2.4</td>
</tr>
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</table>

- 24% of the corn stover is harvested for fuel production
- High yield scenario for SWG
N efficiency, fertilizer application practice, and nitrogen in agricultural residue all contribute to N loadings.

- Harvesting corn stover increases soil evaporation because of reduced ground cover.
- Growing perennial grass increases plant transpiration because of high water demand for fast growth.
- Perennial grass is able to reduce soil loss and capture some of the run-off phosphorus.
A landscaping design is recommended to incorporate water constraints and nutrient considerations into planning for a sustainable feedstock production.

Key factors affecting nutrient loadings:
- Crop nitrogen use efficiency
- Advanced fertilizer management (precision farming)

Cellulosic biomass feedstock may affect water cycle dynamics.

Data needs for large scale watershed modeling:
- Adequate crop and plant growth characterization that reflect advancement in plant biotechnology and genetics and new feedstock
- Groundwater nutrient monitoring data collection

Additional thoughts:
- Nitrate in groundwater requires a time delay before reaching the surface stream and current concentration in GW is a cumulative results of past 30-50 years of practices. Effect of newly implemented BMPs and other nitrate lowering strategies may not shown immediately until years later.
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