Hydrologic and Water-Quality Impacts of Agricultural Land Use Changes Incurred from Bioenergy Policies

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EISA (2007) and land use changes

Independence and Security Act (EISA) signed in December 2007
- Mandates use of 15 BGY corn-based ethanol in transportation fuels by 2015 and 36 BGY of renewable fuels by 2022
- 137 BG gasoline consumed in US in 2014 (EIA)

Wright & Wimberly (2013)
- GRCS – Grassland to Corn or Soybeans from 2006 to 2011
- Relative GRCS – absolute GRCS divided by 2006 grassland

Red River Basin (RRB)
Other issues in RRB: (1) Spring flood

- Wet weather cycle since 1993
- 7 out of 15 major floods occurred in the last 20 years (Fargo)
- 2009 (1st), 2010 (7th), 2011 (4th)
Other issues in RRB: (2) Nutrients to Lake Winnipeg

- RRB’s portions among all Lake Winnipeg tributaries
- Monthly average flow: 16%
- TP load: 55% (US 32%)
- TN load: 34% (US 22%)

— Source: Manitoba Water Stewardship (2011)
Objectives

- To estimate agricultural land use changes that occurred in the Red River Basin after the enactment of EISA of 2007

- To assess the impacts of the bioenergy-related land use changes on spring flood and water quality in the Red River Basin through economic-hydrological modeling
Overall land use changes – CropScape

Pre-EISA Land Use = \( \frac{LU_{2006} + LU_{2007}}{2} \)

Current Land Use = \( \frac{LU_{2012} + LU_{2013}}{2} \)
Crop yields at different locations and under different management

Econ Model

Plant/hydrology Models

Land-use distribution probabilities

Hydrology and water quality impacts

Bioenergy policies and market demand

Economic-physical modeling

Hydrology and water quality impacts
Plant growth and hydrology model – SWAT

- Development and calibration
  - 178 subbasins/2136 HRUs
  - 45 counties (SSURGO)
  - 30 weather stations
  - 12 land-use classes
  - 5-m DEM (LiDAR)
  - 5 large lakes and reservoirs
- Calibration
  - County-level crop yields
  - 16 streamflow stations
  - 2 water quality stations
- Simulation (2000-2012)
  - 4 dry years + 4 wet years
- Lin et al. (2015)
Results and Discussion
Bioenergy-induced land use changes

- **Corn**
  - Pre-EISA (NASS 2006)
  - Current (NASS 2013)
  - Corn demand + 60%

- **Soybean**
  - Pre-EISA (NASS 2006)
  - Current (NASS 2013)
  - Corn demand + 60%

- **Wheat**
  - Pre-EISA (NASS 2006)
  - Current (NASS 2013)
  - Corn demand + 60%

- **Sugarbeet**
  - Pre-EISA (NASS 2006)
  - Current (NASS 2013)

- **Forest**
  - Pre-EISA (NASS 2006)
  - Current (NASS 2013)

- **Pasture**
  - Pre-EISA (NASS 2006)
  - Current (NASS 2013)
  - Corn demand + 60%
Land use change impact on WQ (1)

**Sediment**

- Pre-EISA: 4000 tonnes/yr
- Bioenergy: 3900 tonnes/yr
- Overall: 3900 tonnes/yr

**Total Phosphorus (TP)**

- Pre-EISA: 1500 tonnes/yr
- Bioenergy: 1400 tonnes/yr
- Overall: 1400 tonnes/yr
Land use change impact on WQ (2)

Nitrate (NO$_3$)

Total Nitrogen (TN)

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<th>Pre-EISA</th>
<th>Bioenergy</th>
<th>Overall</th>
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<td>7.5%</td>
<td>9.1%</td>
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Impacts on spring flood

Normalized Hydrographs
(2000-2012 Single Peak Snowmelt Events)
Conclusions

* Land-use changes in the RRB from 2006 to 2013:
  * Increased: Corn (62%), Soybean (18%), sugarbeet, canola, dry beans, alfalfa;
  * Decreased: Spring wheat (30%), forest (18%), pasture (50%), barley, oats;
  * Factors: bioenergy policies, soil salinity, etc.

* Impacts on water quality
  * Overall land use change – sediment by 2.6%, TP by 14.1%, nitrate by 5.9%, TN by 9.1%.
  * Bioenergy policy contributions – sediment by 1.8%, TP by 2.2%, nitrate by 8.0%, TN by 7.5%

* Impacts on spring flood
  * No change on flood magnitude
  * Greater prediction uncertainty under post-EISA condition
Acknowledgements

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