Optimizing Agriculture Management Practices to Improve the Environmental Footprint of biofuel Feedstock Production

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PhD Candidate

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Background

- In 2007, US used 93 million acres farmlands to produce 13 billion bushels of corn, about 14 percent of which were consumed to produce 4.6 billion gallon of ethanol.

- EPA recognizes agricultural systems as a leading source of water quality degradation to surveyed rivers and lakes. Row crop production of US Corn Belt is considered as one of growing hypoxic zone in Gulf of Mexico.

- Greater quantity of ethanol used as motor fuel is expected according to Energy policy act (EPACT2005).
Background

2007, US
93 billion acres farmlands
13 billion bushels corn

Corn usages
- Ethanol feedstock
- Other usages

4.6 billion gallon ethanol
A Quick Look at Some Bioproducts

Miller et al., *Environ Sci Technol* 2007
Research question:
How can agricultural Best Management Practices (BMPs) minimize environmental impacts?

NOAA & EPA suggest:
• Change flood control practices
• Use fertilizers more efficiently
• Control discharges of nitrogen
• Create and restore wetlands
• Reduce nutrient loading

USDA: Agricultural BMPs are practical, cost-effective actions that agricultural producers can take to reduce the amount of pesticides, fertilizers, animal waste, and other pollutants entering our water resources.
• Conservation tillage
• Crop nutrient management
• Conservation buffers
<table>
<thead>
<tr>
<th>Management Practice:</th>
<th>Advantages</th>
<th>Disadvantages</th>
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</thead>
<tbody>
<tr>
<td><strong>Choice of Fertilizer type</strong></td>
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<tr>
<td>organic manures</td>
<td>• Less energy use</td>
<td>• inhomogeneous nutrient contents</td>
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<tr>
<td></td>
<td>• enrich P for soil</td>
<td>• hard to handle</td>
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<tr>
<td>synthetic inorganic fertilizers</td>
<td>• appropriate N,P,K ratios</td>
<td>• soil compaction after long term use</td>
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<td></td>
<td>• easy to apply</td>
<td>• energy requirements</td>
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<td></td>
<td></td>
<td>• demand to produce fertilizers</td>
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<tr>
<td><strong>Tillage</strong></td>
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<td></td>
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<tr>
<td>conventional tillage</td>
<td>• easy incorporation of fertilizers and sediment</td>
<td>• destroy natural aggregation and enhances organic matte loss</td>
</tr>
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<td></td>
<td>• temporarily reduces compaction</td>
<td>• surface crusting and accelerate erosion common</td>
</tr>
<tr>
<td>no tillage</td>
<td>• little soil disturbance</td>
<td>• hard to incorporate fertilizers and amendments</td>
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<td></td>
<td>• low energy use</td>
<td>• can not alleviate compaction by using no tillage</td>
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<td></td>
<td>• most surface residue cover and erosion protection</td>
<td></td>
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<td><strong>Buffer strips</strong></td>
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<tr>
<td>Grassy, woody</td>
<td>• filtration of sediment</td>
<td>• maintenance of grassy buffers requires active management</td>
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<td></td>
<td>• bank stabilization</td>
<td>• limited capability of nutrient sequestration</td>
</tr>
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<td></td>
<td>• flood control</td>
<td>• economic restriction</td>
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<td></td>
<td>• removing nutrient to some extent</td>
<td></td>
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<tr>
<td></td>
<td>• adsorb other toxic matters</td>
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<td><strong>Crop rotation</strong></td>
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<td></td>
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<tr>
<td>corn/soybean, use of cover crops,</td>
<td>• nutrient shares between rotation crops</td>
<td>• less quantity of corn/soybean produced</td>
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<tr>
<td>winter crops</td>
<td>• less fertilizer demand</td>
<td></td>
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<td></td>
<td>• maintain soil fertility</td>
<td></td>
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<td><strong>Fertilizers application methods</strong></td>
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<td></td>
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<tr>
<td>Broadcasting, knifing, application timing</td>
<td>• maintain soil fertility</td>
<td>• on-field GHG emissions</td>
</tr>
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<td></td>
<td>• Precision application</td>
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</tbody>
</table>
*Note: GREET modified with much additional data:
- handling manures as fertilizers
- agricultural machines usage
- maintaining buffer strips
Emission Factor Equations:

\[ L^{in} = R \times Y^{-1} \]
\[ L^{runoff}_N = L^{in} \times f_{em} \times (1-f_{TN,NO}^{-3} \times f_{de}) \]
\[ L^{runoff}_P = L^{in} \times f_{em} \]

- \( L^{in} \) = nutrient input load
- \( R \) = rate of fertilizers application
- \( Y \) = crop yield,
- \( L^{runoff}_N \) = N load in runoff,
- \( L^{runoff}_P \) = P load in runoff,
- \( f_{em} \) = N/P runoff coefficients,
- \( f_{TN,NO}^{-3} \) = ratio of nitrate to total nitrogen,
- \( f_{de} \) = denitrification factor.
Environmental tradeoffs of fertilizers practices

- CH₄ emission, CO₂ equivalent
- N₂O emission, CO₂ equivalent
- CO₂ emission, CO₂ equivalent
- Energy consumption
- N nutrient leaching, N equivalent
- P nutrient leaching, N equivalent

Graph showing GWP and energy consumption for different fertilizer types: synthetic fertilizer, manure as co-product, manure as waste.
Environmental tradeoffs of tillage practices

- GWP (Global Warming Potential)
- Nutrient leaching
- Energy demand

Comparison between conventional tillage and no tillage.
Environmental impacts of buffer strips

- Nitrogen runoff concentration g/kg corn
- Phosphorus runoff concentration g/kg corn
- CO$_2$ flux g/kg corn
- Nitrogen flux, N equivalent
- Phosphorus flux, N equivalent

Comparing without and with buffer strips.
## Conclusions

<table>
<thead>
<tr>
<th>Tillage Practices</th>
<th>Saving more energy</th>
<th>Generating less GHGs</th>
<th>Producing less nutrient runoff</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional tillage</td>
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<td></td>
<td></td>
<td>Although median value of total N-equivalent leaching is smaller for no tillage, probability distribution range for no tillage is quite similar to conventional tillage.</td>
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<tr>
<td>No tillage</td>
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<td>Synthetic fertilizers</td>
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<td>Manure practices tend to discharge wider range of nutrients than synthetic fertilizers.</td>
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<td>Organic manures</td>
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<td>With/without buffer strips</td>
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<td>Installing buffer strips requires low energy input. Buffer strips sequester soil organic carbon and reduce nutrient runoff.</td>
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<tr>
<td>With buffer strips</td>
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<td>Without buffer strips</td>
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Future work

- Evaluate the impact of farming practices within biofuels’ life cycle

- Inventory current farming practices to create a more accurate estimate of environmental impacts.

- Use of LCA/LCI to evaluate potential for minimizing environmental impacts.

- Combine geological models (SWAT, SPARROW, etc) with LCA information to model eutrophication potential of corn/soybean farming systems.

- Cost and benefits analysis of farming management practices.

- Couple with GIS tools to suggest best placement and use of buffer strips at risk watershed.
Acknowledgment

- Alcoa Corporation
- PennDOT
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Thank you: Questions?

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