A Presentation of the 2012 Drainage Research Forum

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Cellulosic Biofuel Potential of a Winter Rye Double Crop across the U.S. Corn-Soybean Belt

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Thank you, Gary.
The question addressed in this presentation is . . . for a cellulosic double crop (winter rye in a corn-soybean rotation) . . . how much E can be harvested on C-Sb land in the U.S.?
How big is the bio E carrot?

- small
- BIG
Rationale

• Produce cellulosic biomass for energy w/o reducing food-feed harvest
  – Convert solar radiation before/after summer crop
    • Corn – Soybean Belt of U.S.
    • Winter Rye
Convert “Unused” Solar Radiation

NEE is Net Ecosystem Exchange of CO₂. Figure adapted from Baker and Griffis, 2009¹.

In spring, the rye continues to take up water and nitrogen, reducing drainage volume and nitrate-N concentration.
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High rye biomass tonnages are possible

Photo provided by Dr. Tyson Ochsner, Oklahoma State University
High rye biomass tonnages are possible
Challenge: establishing the cover crop early enough in fall

Rye can be seeded by helicopter into standing crops to provide soil cover after harvest. We are examining the factors that affect the success of aerial seeding.
Subsurface Drainage N Loss: Influence of Planting Date (Lamberton, MN)

\[ \Delta N = (W/\text{out Rye}) - (W/ \text{Rye}) \]

@ 50% Exceedance Probability
Subsurface Drainage N Loss: % Reduction w/ Rye

Mean values after 500 years of stochastic weather generation
Challenge: a winter cover crop can use water in the spring that is needed by the subsequent crop.
Materials & Methods

• Determine suitable C-Sb area
• Run plant-soil-atmosphere model at 30 locations for 14 y
• Develop a regression model based on $T_{\text{air}}$ and Precip
• Imbed regression model in GIS model
  – Identify subset of C-SB area suitable
  – Use PRISM weather inputs (30 y)
  – Estimate biomass by county
Selection of Cropping Area
Red: Counties where less than 2% of total county area is producing corn or soybeans
Red: Counties where greater than 5% of corn acreage is irrigated
Red: Counties where greater than 10% of total cropland is producing rice or cotton
96.6 million ac (≈ 28% of U.S. cropland)
RyeGro Model Locations
Simulation Model: RyeGro

- Uses solar radiation interception concept (Monteith, 1977)
- Infiltration concept of Holtan (1961)
- Point scale; daily time step
- Simple; robust
For each 1 mega Joule per of solar energy falling on each sq. meter of surface per day, 2.8 g of dry matter will be produced.

In RyeGro, the potential dry matter (or “biomass”) is modified by air temperature and soil moisture status.
Validation

• Compared BM prediction to mechanistic model of Baker-Griffis (2009)
  – Based on CO$_2$ assimilation (Collatz et al., 1991)
  – 8 locations in Midwest C-Sb Belt

• Same soil assumptions

• Assumed no nutrient limitations – “Best Case Scenario”
Validation (cont’d)

• Compared biomass to field studies in Iowa and Illinois
RyeGro Application

• Planting date assumptions
  – NASS dates on state basis
• Rye harvesting cases:
  – 14 days and 7 days prior to spring planting
Model Scenarios

- Rye planted 2 days after C or Sb harvest
- Rye harvested 14 days before planting:
  - Corn – Rye – Corn
  - Corn – Rye – Soybean
  - Soybean – Rye – Corn
- Rye harvested 7 days before planting, same 3 crop sequences
Results: Model Validation

RMSE = 0.83 Mg ha$^{-1}$
NSE = 0.85
PBIAS = 17%

RMSE = 1.17 Mg ha$^{-1}$
NSE = 0.78
PBIAS = 15%
## Comparison with Field Data

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Year</th>
<th>Rye BM Obs. (Mg/ha)</th>
<th>Rye BM Est. (Mg/ha)</th>
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<tbody>
<tr>
<td>Kaspar</td>
<td>Boone, IA</td>
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<td>Ruffo</td>
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<td></td>
<td>Brownsville, IL</td>
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### Modeling Statistics (“How good is the model”)

- Average Observed: 3.83 Mg/ha    Average Estimated: 4.07 Mg/ha
- Percent Bias: 6.2% overprediction “Very Good”
- Modeling efficiency (NSE): 0.60 “Satisfactory”
- Root mean square error: 1.26 Mg/ha
- Ratio of RMSE and Obs. Std Dev.: 0.63 “Satisfactory”
Regression Modeling

- PRISM $T_{\text{air}}$ and Precip inputs
- Run at 800-m resolution
- Regression model yields compared to RyeGro yields: 30 locations
  - $R^2$, RMSE, PBIAS=0
- Results summed to county level
- Following 3 maps are for 14-d scenario
Corn – Rye – Corn: 14d

Rye Biomass Yield
Corn - Rye - Corn Rotation
14-day Scenario

Mg/ha
- < 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- > 6.0
Corn – Rye – Soybean: 14d
Soybean – Rye – Corn: 14d
Production Density

• Rye BM yields multiplied by available corn-soy and corn-corn area
• Total BM divided by total county area = “Production Density”
Production Density: 14d
Corn – Rye – Corn: 7d

Rye Biomass Yield
Corn – Rye – Corn Rotation
7-day Scenario

Mg/ha

< 2.0
2.0 - 3.0
3.0 - 4.0
4.0 - 5.0
5.0 - 6.0
> 6.0

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Corn – Rye – Soybean: 7d
Soybean – Rye – Corn: 7d
Production Density: 7d

Rye Production Density
7-day Scenario

Total Rye Production: 151 Tg

Mg Rye / ha of Total County Area

0.00
0.01 - 0.50
0.51 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.72
## Total Rye BM Production

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Rye BM (U.S. ton)</th>
<th>Quads ($10^{15}$ BTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14d</td>
<td>120,000,000</td>
<td>1.9</td>
</tr>
<tr>
<td>7d</td>
<td>170,000,000</td>
<td>2.5</td>
</tr>
</tbody>
</table>
How big is the bio E carrot?

- small
- BIG
Billion-Ton Update: 2022 est.

- Forest & Wood Resources
- Agric. Residues & Wastes
- Energy Crops
- Rye Double Crop

Baseline assumptions and biomass price of <$60 ton⁻¹.

How much E?

• “It depends . . .”
  – Local climate, available water, cropping and management practices
  – Acceptable risk to subsequent summer crop

• What will it take? What will it cost?
## Energy Matrix

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Size of Contribution</th>
<th>Pro’s</th>
<th>Con’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
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<td></td>
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<tr>
<td>Nuclear</td>
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<tr>
<td>Natural Gas</td>
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<tr>
<td>Biofuels</td>
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<tr>
<td>Solar</td>
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<td>Wind</td>
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<tr>
<td>Hydrogen</td>
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<tr>
<td>Conservation</td>
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</table>
How will this particular biofuel production impact water supply / quality?

• Good questions. Further research on the topic has begun.
• One thing is for sure: biofuel supplies will be more variable than traditional sources of energy.
How will various biofuel production strategies impact food supply?
Currently: 2B people are undernourished.
Situation: Only maintain current food supply
Desired Situation: Reduced no. of undernourished people

- **2010**: 7 billion
- **2050**: 9.3 billion
- **2060**: 10.1 billion

Population (billions)

- **1950**: 6 billion
- **1960**: 7 billion
- **1970**: 8 billion
- **1980**: 9 billion
- **1990**: 10 billion
- **2000**: 10.1 billion
- **2010**: 7 billion
- **2020**: 9.3 billion
- **2040**: 10.1 billion

Multi-state Drainage Forum

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Summary

• Capture of solar energy during season after-harvest and before-planting (primarily south of I-80)
• Biomass roughly equivalent to current corn stover available
• Concerns over subsequent crop yields need to be addressed
• Water impacts being researched
Thank you!