A system approach to N management

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Technology Transfer

Trial and Error

• Site and time specific
• Requires high human and financial resources

Analogy

Time (weather) specific

System approach with simulation modeling

• **Soil**: Soil texture, Organic matter
• **Weather**: Precipitation, Temperature Max and Min, Solar Radiation
• **Management**: Planting, Tillage, Fertilization, Irrigation
• **Genetics**: Duration, and kernels information
Model validation

Legend

- locations  number of papers
- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 10
- 19
- 26

Basso et al., 2016, Advances in Agronomy
SALUS Flow of Organic Matter into Soil Carbon Pools

Harvested Biomass

Standing Dead = Above Ground Biomass

Roots

Below Ground

Harvested Biomass

Incorporation Factor

Manures

Slow FOM

Humic FOM

Compost

Rapid FOM

Soluble Components

Fresh Organic Matter (FOM)

Intermediate FOM

Cellulose-Hemicellulose

Slow FOM

Lignin

5% Total Soil C
Active Pool

MRT < 1 yr

45% Total Soil C
Slow Pool

MRT 30 yr

50% Total Soil C
Resistant Pool

MRT 1000 yr

CO₂

CO₂

CO₂

CO₂

CO₂

CO₂

CO₂
Soil water content-based stress factors (0.0-1.0) reduce N processes.
ΣΑΛΥΣ Σιμουλατείδ πσ. Μεασυρεδ Ψελδς κγ/ημ

<table>
<thead>
<tr>
<th>Year</th>
<th>Measured δ</th>
<th>Simulated δ</th>
</tr>
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<tbody>
<tr>
<td>2006</td>
<td>8500</td>
<td>8500</td>
</tr>
<tr>
<td>2007</td>
<td>7500</td>
<td>7500</td>
</tr>
<tr>
<td>2008</td>
<td>9000</td>
<td>9000</td>
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<tr>
<td>2009</td>
<td>8000</td>
<td>8000</td>
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<tr>
<td>2010</td>
<td>10000</td>
<td>10000</td>
</tr>
<tr>
<td>2011</td>
<td>6500</td>
<td>6500</td>
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<tr>
<td>2012</td>
<td>7500</td>
<td>7500</td>
</tr>
<tr>
<td>2013</td>
<td>8000</td>
<td>8000</td>
</tr>
<tr>
<td>2014</td>
<td>11000</td>
<td>11000</td>
</tr>
<tr>
<td>2015</td>
<td>13000</td>
<td>13000</td>
</tr>
</tbody>
</table>
The **strategic** focuses on a **long-term objective**

\[ \downarrow \]

**Inter-year analysis**

Recorded climate = 0

The **tactical** addresses a **within season decision**

\[ \downarrow \]

**Intra-year analysis**

Recorded climate →

\[ D_{day} \]

\[ \leftarrow \]

Recorded climate →

\[ D_{day} \]

\[ \ldots \]
Developing a fertilization strategy

Cumulative Probability Function

Maize Grain Yield (t ha⁻¹)

Basso et al., 2007
2012 low yielding zone (higher elevation)
2013 till July 5, then wet year like 2011
2013 till July 5, then dry year like 2012
Wet yr with 10 days of 37°C and no rain for 1 mo
Dry year with deficit irrigation
Σιμουλατιγ ν πλαντ populatiοn ανδ Ν
Homogeneous zones

Tomography

Yield

High Yield Zone

Medium Yield Zone

Low Yield Zone
Strategic and tactical N management using spatially explicit crop modeling

Dual criteria optimization through tested model determines the N rate that minimizes nitrate leaching and increases net revenues for farmers (Basso et al., 2011; Eur J. Agron 35:215–222)
Welcome to the SALUS N Calculator. This calculator is designed to evaluate the nitrogen response to the soil, management practices, and weather of your location. In addition to the information you will enter, the model uses historical weather data based on the location you specify. The tool will be able to estimate your corn yield response, as well as nitrate leaching and nitrous oxide emission from your soil. SALUS can help you evaluate different farm practices and their impact on nitrogen loss and will provide useful information about nitrogen use and efficiency.

Before you begin please enter the ID number located on the front of your mail survey here: [ID Number]. This allows us to match your use of the calculator with your survey responses; it does not provide any other identifying information.
Select your approximate location so we know which weather stations to use.
Results below are based on: Soil: deep silty clay loam; Grown for: grain, Tillage: no till; Planted: April 15; Irrigate: no; Cover Crop: no; Fertilizer: 180 lbs N/acre; Manure/compost: none

<table>
<thead>
<tr>
<th>Results over 10 years</th>
<th>Worst year</th>
<th>Average year</th>
<th>Best year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/acre)</td>
<td>83</td>
<td>157.9</td>
<td>276</td>
</tr>
<tr>
<td>Fertilizer Use Efficiency (bu/lbs N)</td>
<td>0.19</td>
<td>0.36</td>
<td>0.63</td>
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<tr>
<td>Days over 90 F</td>
<td>57</td>
<td>23.7</td>
<td>0</td>
</tr>
<tr>
<td>N leaching (lbs/acre)</td>
<td>272</td>
<td>72.2</td>
<td>0</td>
</tr>
</tbody>
</table>

10 Year Total N$_2$O Emissions: 18 lbs/acre

10 Year Total N Leaching: 722 lbs/acre

The above tables show the corn yield (bu/acre) and the nitrogen (N) loss estimates over ten years for the selected location. The worst and best categories in the table refer to the worst and best years out of ten, while the average is across all ten years. Below the table is the ten year total of N loss estimates in water (as nitrate leaching) and air (as nitrous oxide gas emission). The Salus N Calculator model uses a small number of variables that influence yield and N loss. Your actual corn yield or N loss may vary depending on seed type and soil properties not considered here. The type of fertilizer, application timing and method will also have an impact on N loss. The model is intended to illustrate differences related to the input values you specify. It is not intended to provide recommendations or advice.
Select your approximate location so we know which weather stations to use.
What is your soil texture?  Silty Loam

How deep is your top soil?  Deep (more than 40"

Do you grow corn for silage or grain?  Silage  Grain

How do you till the soil?  No Tillage

When do you plant your corn?  Month: April  Day: 15

Do you irrigate?  Yes  No

Do you grow a cover crop over the winter?  Yes  No

Enter inorganic fertilizer weight by?  N  Product

How much inorganic N fertilizer do you apply?  180 (lbs/acre)

This simulation assumes 63 lbs N/acre at planting and a 117 lbs N/acre side dressing.

Do you apply manure or compost?  None
Results below are based on: Soil: deep silty loam; Grown for: grain, Tillage: no till; Planted: April 15; Irrigate: no; Cover Crop: yes; Fertilizer: 180 lbs N/acre; Manure/compost: none

<table>
<thead>
<tr>
<th>Results over 10 years</th>
<th>Worst year</th>
<th>Average year</th>
<th>Best year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/acre)</td>
<td>70</td>
<td>156.1</td>
<td>276</td>
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<tr>
<td>Fertilizer Use Efficiency (bu/lbs N)</td>
<td>0.16</td>
<td>0.35</td>
<td>0.63</td>
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<tr>
<td>Days over 90 F</td>
<td>57</td>
<td>23.7</td>
<td>0</td>
</tr>
<tr>
<td>N leaching (lbs/acre)</td>
<td>273</td>
<td>721</td>
<td>0</td>
</tr>
</tbody>
</table>

10 Year Total N$_2$O Emissions: 18 lbs/acre

10 Year Total N Leaching: 721 lbs/acre

The above tables show the corn yield (bu/acre) and the nitrogen (N) loss estimates over ten years for the selected location. The worst and best categories in the table refer to the worst and best years out of ten, while the average is across all ten years. Below the table is the ten year total of N loss estimates in water (as nitrate leaching) and air (as nitrous oxide gas emission). The Salus N Calculator model uses a small number of variables that influence yield and N loss. Your actual corn yield or N loss may vary depending on seed type and soil properties not considered here. The type of fertilizer, application timing and method will also have an impact on N loss. The model is intended to illustrate differences related to the input values you specify. It is not intended to provide recommendations or advice.
Results below are based on: Soil: deep clay loam; Grown for: grain, Tillage: no till; Planted: April 15; Irrigate: yes; Cover Crop: yes; Fertilizer: 180 lbs N/acre; Manure/compost: none

<table>
<thead>
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<th>Average year</th>
<th>Best year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/acre)</td>
<td>127</td>
<td>178</td>
<td>305</td>
</tr>
<tr>
<td>Fertilizer Use Efficiency (bu/lbs N)</td>
<td>0.29</td>
<td>0.4</td>
<td>0.69</td>
</tr>
<tr>
<td>Days over 90 F</td>
<td>57</td>
<td>23.7</td>
<td>0</td>
</tr>
<tr>
<td>N leaching (lbs/acre)</td>
<td>286</td>
<td>101.1</td>
<td>1</td>
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</table>

10 Year Total N$_2$O Emissions: 18 lbs/acre

10 Year Total N Leaching: 1011 lbs/acre

The above tables show the corn yield (bu/acre) and the nitrogen (N) loss estimates over ten years for the selected location. The worst and best categories in the table refer to the worst and best years out of ten, while the average is across all ten years. Below the table is the ten year total of N loss estimates in water (as nitrate leaching) and air (as nitrous oxide gas emission). The Salus N Calculator model uses a small number of variables that influence yield and N loss. Your actual corn yield or N loss may vary depending on seed type and soil properties not considered here. The type of fertilizer, application timing and method will also have an impact on N loss. The model is intended to illustrate differences related to the input values you specify. It is not intended to provide recommendations or advice.
What is your soil texture? Clay Loam

How deep is your top soil? Shallow (less than 20"

Do you grow corn for silage or grain? Silage, Grain

How do you till the soil? No Tillage

When do you plant your corn? Month: April, Day: 1

Do you irrigate? Yes, No

Do you grow a cover crop over the winter? Yes, No

Enter inorganic fertilizer weight by? N, Product

How much inorganic N fertilizer do you apply? 160 lbs/acre

This simulation assumes 0 lbs N/acre at planting and a 0 lbs N/acre side dressing.

Do you apply manure or compost? None
Results below are based on: Soil: shallow clay loam; Grown for: grain, Tillage: no till; Planted: April 1; Irrigate: no; Cover Crop: no; Fertilizer: 160 lbs N/acre; Manure/compost: none

<table>
<thead>
<tr>
<th>Results over 10 years</th>
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<th>Average year</th>
<th>Best year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/acre)</td>
<td>78</td>
<td>153.2</td>
<td>245</td>
</tr>
<tr>
<td>Fertilizer Use Efficiency (bu/lbs N)</td>
<td>0.24</td>
<td>0.46</td>
<td>0.74</td>
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<tr>
<td>Days over 90 F</td>
<td>43</td>
<td>14.2</td>
<td>0</td>
</tr>
<tr>
<td>N leaching (lbs/acre)</td>
<td>432</td>
<td>54.7</td>
<td>0</td>
</tr>
</tbody>
</table>

10 Year Total N\textsubscript{2}O Emissions: 16 lbs/acre

10 Year Total N Leaching: 547 lbs/acre
### Results over 10 years

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<thead>
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<td>54.7</td>
<td>0</td>
</tr>
</tbody>
</table>

10 Year Total N\(_2\)O Emissions: 16 lbs/acre

10 Year Total N Leaching: 547 lbs/acre

Results below are based on: Soil: shallow clay loam; Grown for: grain, Tillage: no till; Planted: April 1; Irrigate: no; Cover Crop: no; Fertilizer: 110 lbs N/acre; Manure/compost: none

### Results over 10 years

<table>
<thead>
<tr>
<th></th>
<th>Worst year</th>
<th>Average year</th>
<th>Best year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/acre)</td>
<td>57</td>
<td>149.5</td>
<td>245</td>
</tr>
<tr>
<td>Fertilizer Use Efficiency (bu/lbs N)</td>
<td>0.26</td>
<td>0.68</td>
<td>1.11</td>
</tr>
<tr>
<td>Days over 90 F</td>
<td>43</td>
<td>14.2</td>
<td>0</td>
</tr>
<tr>
<td>N leaching (lbs/acre)</td>
<td>432</td>
<td>54.6</td>
<td>0</td>
</tr>
</tbody>
</table>

10 Year Total N\(_2\)O Emissions: 11 lbs/acre

10 Year Total N Leaching: 546 lbs/acre
### Results over 10 years

<table>
<thead>
<tr>
<th></th>
<th>Worst year</th>
<th>Average year</th>
<th>Best year</th>
</tr>
</thead>
<tbody>
<tr>
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<td>149.5</td>
<td>245</td>
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<tr>
<td>Fertilizer Use Efficiency (bu/lbs N)</td>
<td>0.26</td>
<td>0.68</td>
<td>1.11</td>
</tr>
<tr>
<td>Days over 90 F</td>
<td>43</td>
<td>14.2</td>
<td>0</td>
</tr>
<tr>
<td>N leaching (lbs/acre)</td>
<td>432</td>
<td>54.6</td>
<td>0</td>
</tr>
</tbody>
</table>

10 Year Total N\textsubscript{2}O Emissions: 11 lbs/acre

10 Year Total N Leaching: 546 lbs/acre

Results below are based on: Soil: shallow clay loam; Grown for: grain, Tillage: no till; Planted: April 1; Irrigate: yes; Cover Crop: no; Fertilizer: 180 lbs N/acre; Manure/compost: none

### Results over 10 years

<table>
<thead>
<tr>
<th></th>
<th>Worst year</th>
<th>Average year</th>
<th>Best year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/acre)</td>
<td>115</td>
<td>162.6</td>
<td>265</td>
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<tr>
<td>Fertilizer Use Efficiency (bu/lbs N)</td>
<td>0.26</td>
<td>0.37</td>
<td>0.6</td>
</tr>
<tr>
<td>Days over 90 F</td>
<td>43</td>
<td>14.2</td>
<td>0</td>
</tr>
<tr>
<td>N leaching (lbs/acre)</td>
<td>467</td>
<td>54.2</td>
<td>0</td>
</tr>
</tbody>
</table>

10 Year Total N\textsubscript{2}O Emissions: 18 lbs/acre

10 Year Total N Leaching: 542 lbs/acre
Set Management

What is your soil texture? Silty Clay

How deep is your top soil? Shallow (less than 20"

Do you grow corn for silage or grain? Silage Grain

How do you till the soil? No Tillage

What is your plant population (Seeds/acre)? 38000

What is your maturity hybrid? 100 Day Corn

When do you plant your corn? Month: May Day: 1

Do you irrigate? Yes No

Do you grow a cover crop over the winter? Yes No

Enter inorganic fertilizer weight by?
- N 150 (lbs/acre)
- Product Ammonium Nitrate: 34% N 450 (lbs/acre)

Do you apply manure or compost? None 10 (tons/acre)

Run SALUS
Measured profit 2011

Green: Profit  Red: Lower Profit  Avg: $740/acre

Net Profit (dollars/acre)
- High: $1176
- Low: $310
Measured profit 2012

Green: Profit  Red: Loss  Avg: $194/acre
SALUS Profit Zones: 2012

Green: Profit  Red: Loss  Avg: $428/ acres

2012, Only 30 # N/ac

Net Profit (dollars/hectare)

- $400 to -$300  $0 to $200  $800 to $1,000
- $300 to -$200  $200 to $400  $1,000 to $1,200
- $200 to -$100  $400 to $600  $1,200 to $1,400
- $100 to $0  $600 to $800  > $1,400

0 0.1 Miles
Plant extractable soil water

- <80 mm
- 80-160 mm
- 160-240 mm
- 240-320 mm
- >320 mm

Modeling Midwest Cropping Systems
Modeling Midwest Cropping Systems

Plant extractable soil water:
- Gray: Corn fields
- Red: <80 mm
- Orange: 80-160 mm
- Green: 160-240 mm
- Blue: 240-320 mm
- Sky blue: >320 mm
<table>
<thead>
<tr>
<th>Scenario description</th>
<th>Rotation</th>
<th>Manure</th>
<th>N fertilization</th>
<th>Tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC1</td>
<td>Continuous Corn</td>
<td>Fall manure</td>
<td>Inorg. N: 200kgN/ha (@ planting)</td>
<td>Conv. Till.</td>
</tr>
<tr>
<td>SC2</td>
<td>Continuous Corn</td>
<td>No manure</td>
<td>Inorg. N: 200kgN/ha (@ planting)</td>
<td>Conv. Till.</td>
</tr>
<tr>
<td>SC3</td>
<td>Continuous Corn</td>
<td>No manure</td>
<td>Inorg. N: 50-150kgN/ha (Plt-V6)</td>
<td>Conv. Till.</td>
</tr>
<tr>
<td>SC4</td>
<td>Continuous Corn</td>
<td>No manure</td>
<td>Inorg. N: 50-150kgN/ha (Plt-V6)</td>
<td>No Till.</td>
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<tr>
<td>SC5</td>
<td>Continuous Corn + CC</td>
<td>No manure</td>
<td>Inorg. N: 50-150kgN/ha (Plt-V6)</td>
<td>No Till.</td>
</tr>
<tr>
<td>SC6</td>
<td>Corn/SB + CC</td>
<td>Fall manure</td>
<td>Inorg. N: 50-150kgN/ha (Plt-V6)</td>
<td>No Till.</td>
</tr>
<tr>
<td>SC7</td>
<td>Corn/SB/WW + CC</td>
<td>Fall manure</td>
<td>Inorg. N: 50-150kgN/ha (Plt-V6)</td>
<td>No Till.</td>
</tr>
</tbody>
</table>
Corn Yield under Climate Change

Current

550 ppm CO2 (RCP6)

Basso and Dumont, 2016
Continuous Corn

Corn-Soybean-Wheat Rotation

Basso and Dumont, 2016
Nitrogen in the soil profile

Continuous Corn  Corn-Soybean-Wheat Rotation

Basso and Dumont, 2016
Results

Model outputs intercomparison: Corn yield in Iowa

Focus of the research:

- Yield trend over CC
Model outputs intercomparison:

<table>
<thead>
<tr>
<th>Variable</th>
<th>SC1 vs.</th>
<th>BL</th>
<th>RCP2.6</th>
<th>RCP6</th>
<th>BL</th>
<th>RCP2.6</th>
<th>RCP6</th>
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<tbody>
<tr>
<td>Yield [%]</td>
<td>SC1</td>
<td>-</td>
<td>-25.84</td>
<td>-41.60</td>
<td>-2.23</td>
<td>-31.68</td>
<td>-33.50</td>
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<tr>
<td>SC4</td>
<td>NO₃⁻ [%]</td>
<td>-</td>
<td>40.07</td>
<td>35.06</td>
<td>-90.77</td>
<td>-43.43</td>
<td>-21.62</td>
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<tr>
<td>SOC [%]</td>
<td>-</td>
<td>30.30</td>
<td>48.23</td>
<td>-104.89</td>
<td>-74.49</td>
<td>-56.96</td>
<td></td>
</tr>
<tr>
<td>Yield [%]</td>
<td>SC6</td>
<td>-</td>
<td>-30.48</td>
<td>-44.71</td>
<td>-5.64</td>
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<td>-47.40</td>
</tr>
<tr>
<td>NO₃⁻ [%]</td>
<td>-</td>
<td>40.07</td>
<td>35.06</td>
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<td>-66.06</td>
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<tr>
<td>SOC [%]</td>
<td>-</td>
<td>30.30</td>
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<td>Yield [%]</td>
<td>SC7</td>
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<tr>
<td>NO₃⁻ [%]</td>
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<td>40.07</td>
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<td>-97.70</td>
<td>-95.44</td>
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<td>SOC [%]</td>
<td>-</td>
<td>31.98</td>
<td>50.91</td>
<td>12.04</td>
<td>9.74</td>
<td>25.37</td>
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</tbody>
</table>
Net surface flow (Runon-Runoff)

Gallant and Basso 2016 in preparation