4R PRACTICE IMPLEMENTATION: ENVIRONMENTAL AND ECONOMIC IMPACTS

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The Fertilizer Institute

TFI is the voice of the fertilizer industry, representing the public policy, communication, stewardship and sustainability and market intelligence needs of fertilizer producers, wholesalers and retailers as well as the businesses that support them with goods and services.
GREENHOUSE GAS EMISSIONS

<table>
<thead>
<tr>
<th>Data reporting year</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse gas emissions reported to US EPA (in metric tons CO2 equivalents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHGs actually emitted</td>
<td>23,764,734</td>
<td>24,104,982</td>
<td>25,987,743</td>
<td>23,666,634</td>
<td>23,324,161</td>
</tr>
<tr>
<td>GHGs reported but not emitted (i.e., captured)</td>
<td>2,315,274</td>
<td>2,639,017</td>
<td>4,090,710</td>
<td>8,105,299</td>
<td>7,541,342</td>
</tr>
<tr>
<td>Percentage of GHG emissions that were captured (not emitted)</td>
<td>9%</td>
<td>10%</td>
<td>14%</td>
<td>26%</td>
<td>24%</td>
</tr>
<tr>
<td>GHGs emitted normalized (metric ton CO2 equivalent per metric ton produced)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1.2</td>
<td>1.24</td>
<td>2.27</td>
<td>1.8</td>
<td>2.11</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0.28</td>
<td>0.29</td>
<td>0.24</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>Combined (nitrogen and phosphate)</td>
<td>0.84</td>
<td>0.87</td>
<td>1.55</td>
<td>1.36</td>
<td>1.53</td>
</tr>
</tbody>
</table>

ENERGY

<table>
<thead>
<tr>
<th>Data reporting year</th>
<th>Participating companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Participation as a percent of the total U.S. fertilizer nutrient production capacity</td>
</tr>
<tr>
<td></td>
<td>Participation as a percent of the total U.S. phosphate production capacity</td>
</tr>
<tr>
<td>Total energy use (in gigajoules)</td>
<td>Direct (GJ)</td>
</tr>
<tr>
<td></td>
<td>Indirect (GJ)</td>
</tr>
<tr>
<td></td>
<td>Total (GJ)</td>
</tr>
<tr>
<td>Normalized</td>
<td>Direct (GJ per nutrient short ton produced)</td>
</tr>
<tr>
<td></td>
<td>Indirect (GJ per nutrient short ton produced)</td>
</tr>
<tr>
<td></td>
<td>Total (GJ per nutrient short ton produced)</td>
</tr>
<tr>
<td></td>
<td>Natural gas as a feedstock (not for energy production) (billion GJ)</td>
</tr>
<tr>
<td></td>
<td>Normalized (GJ per short nutrient ton of nitrogen produced)</td>
</tr>
<tr>
<td></td>
<td>Waste heat captured (GJ)</td>
</tr>
<tr>
<td></td>
<td>Ratio of waste heat captured to total energy use (waste heat captured / total energy use)</td>
</tr>
</tbody>
</table>

GREENHOUSE GASES (GHGs) CAPTURED & RE-USED

Minimizing GHG emissions is a priority for companies in the fertilizer industry.

#FertilizerReport
It’s A Priority

Better crop performance, improved soil health, and cleaner air and water.

**RIGHT SOURCE**
Matches fertilizer type to crop needs.

**RIGHT RATE**
Matches amount of fertilizer to crop needs.

**RIGHT TIME**
Makes nutrients available when crops need them.

**RIGHT PLACE**
Keeps nutrients where crops can use them.
What is 4R Nutrient Stewardship?

• Actively considering all management practices and site specific characteristics when making the right source, right rate, right time, and right place nutrient management decisions
It’s A Priority – Why?

Nutrient Use Efficiency
Sustainability
Climate Smart Ag
Soil Health
Water Quality
Air Quality
Nutrient Loss
Water Pollution
Regulation
Facebook/Twitter
<table>
<thead>
<tr>
<th>Company</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coca-Cola</td>
<td>Reduce GHG emissions across value chain by 25% by 2020</td>
</tr>
<tr>
<td>Unilever</td>
<td>Halve GHG impact of products across the lifecycle by 2020</td>
</tr>
<tr>
<td>Walmart</td>
<td>Fertilizer optimization on 14 M acres of U.S. farmland by 2020</td>
</tr>
<tr>
<td>Kellogg’s</td>
<td>Responsibly source top 10 ingredients &amp; materials by 2020</td>
</tr>
</tbody>
</table>
Industry Updates

• Walmart – Gigaton Challenge
  “The adoption of best-in-class agricultural practices, including precision agriculture and feed optimization, can help reduce farmer input costs, improve water quality and reduce greenhouse gas (GHG) emissions.”
  • Recommend 4R practices to reach goals

https://www.walmsustainabilityhub.com/project-gigaton/agriculture
4R N Management Goal

• Sustained and Increased:
  › Crop yields, Profitability, Soil fertility and Soil health
  › Reductions in losses of N
    • Ammonia volatilization
    • Nitrate-N (NO$_3$--N) to surface or groundwater
    • Gaseous emissions of nitrous oxide (N$_2$O) and dinitrogen (N$_2$) from wet or waterlogged/saturated soils
Initial projects: 5 meta-analyses
- Knowledge gaps related to 4Rs and environmental impact

Current research projects
- 4R practice impacts on N & P loss via water and air pathways and interaction with supporting conservation
A Meta-analysis of 4R Nutrient Management in U.S. Corn-Based Systems

- Rate, Source, Time, and Place – Crop yield, nitrate (NO$_3^-$) leaching, and nitrous oxide (N$_2$O) emissions response to N rates
- Learn how differences in climate and soil across North America affect these responses.
A Meta-analysis of 4R Nutrient Management in U.S. Corn-Based Systems


Rate – Strong positive relationship to yield, NO₃ leaching, and N₂O air loss.

2.9 to 11.9 % increase for each 10 kg N/ha increase

Source – N₂O losses are highest with Anhydrous Ammonia > Urea = Polymer Coated Urea = Urea Ammonium Nitrate (UAN) = UAN + Agrotain PLUS® > Super U

Time – Side dress fertilizer reduced N₂O emissions 30 to 39%

Place – Broadcast placement of N fertilized decreased N₂O losses by 25 to 33% compared to injecting or banding

Environmental – Nitrous oxide emissions dependent on temperature

1°C increase in average July temperate = increased emissions from additional application of 100 kg N/ha
4R and Conservation Practices

With conservation practices

Without conservation practices

59% reduction through combination of incorporation of P and conservation

Qian and Harmel. 2016. JAWRA.
Gaps in the Research

- Lack of complete data reporting
  - All forms of N and P
  - Yield
  - All site conditions
    - Soil type, slope, weather
  - Form of nutrient applied

- Lack of testing of rate changes with other 4R Practices

- Testing of conservation practices
  - Number of studies per practice
  - Interactions with other practices
In Field Studies
Minimizing P Loss with 4R Stewardship and Cover Crops

- Different combinations of time and place of P fertilizer with and without cover crops
- Working with soil physics, cropping systems, agronomy, economics, and extension staff to collect results that cross disciplines
- Cover Crop use in Kansas decreases sediment loss, changes type of P loss
Minimizing P Loss with 4R Stewardship and Cover Crops

Figure 4. Fertilizer management effect on dissolved P loss. Cumulative dissolved P loss was 0.1, 0.7, and 0.2 lb P₂O₅/ac for control, fall broadcast, and spring injected treatments respectively.
Evaluating the 4R Nutrient Stewardship Concept in the Western Lake Erie Basin

- Field level monitoring of implementation of 4R practices
- Analysis of the social and economic impacts
- USDA-ARS, Ohio State University, Heidelberg University, LimnoTech, IPNI, The Nature Conservancy, Private Farmers
- Placing P below the soil surface decrease P loss
Nitrogen Recovery Efficiency and Nitrous Oxide Emissions

- N2O emissions decreased with greater N recovery efficiency
- Relationship between N2O emissions and N recovery efficiency were observed under farmer practices, and zero or strip till
- Overall, for every 1% increase in N recovery efficiency, in season N2O losses decreased by 35 kg N/ha

- N recovery efficiency (NRE %)
- Total N Uptake with N Fertilizer
- Total N Uptake with no N Fertilizer
- $\Delta N_{\text{applied}} = \text{Difference in N applied}$
- NRE (%) = $\frac{\text{TNUN} - \text{TNU0}}{(\Delta N_{\text{applied}} \times 100)}$
Common Findings

- Timing of N application was has a large impact on yield and N loss
- Timing of N application when using an EEF can impact air and water losses
- Improved NUE can indicate decreased air losses of N
- The placement of P fertilizer influences P loss
- P application based on crop need and soil test has potential to reduce P losses
N Knowledge Gaps

• Lack of studies:
  › Measuring N loss from multiple pathways
  › Comparing suites of 4R practices
  › Measuring N losses outside the growing season
  › Conservation practices

• Need for more studies beyond Midwest cropping systems
P Knowledge Gaps

- **Lack of studies:**
  - Investigating P sources, timing, and placement
  - Addressing P form (particulate vs. dissolved)
  - Conservation Practices

- **Need to incorporate P forms into water quality models**

- **Need for more studies beyond Midwest cropping systems**
Efficiency, Environment, and 4R

- Strong, positive linear relationship between N$_2$O and net N balance
- N$_2$O response to N management systems related to net N balance

(Vyn, Halvorson, & Omonode – http://research.ipni.net/project/IPNI-2015-USA-4RN27)

- Intermediate: Reduce N Balance by 33% resulting in additional 7% reduction in N$_2$O emission
- Advanced/Emerging: Reduce N Balance by 66% resulting in 14% reduction to N$_2$O emission
## Non-irrigated Corn-Soybean – Eastern US

<table>
<thead>
<tr>
<th>Practice Level</th>
<th>Right Source</th>
<th>Right Rate</th>
<th>Right Time</th>
<th>Right Place</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic -</strong> adopted by approximately 50% of growers</td>
<td>• Guaranteed or book value for all sources applied</td>
<td>• Rate based on evidence recognized by regional soil fertility extension</td>
<td>• Spring; not on frozen soil</td>
<td>• Broadcast and incorporated, injected or subsurface band</td>
</tr>
<tr>
<td></td>
<td>• Urea, UAN, Anhydrous Ammonia, Manure</td>
<td>• Properly accounting for legume &amp; Manure N</td>
<td>• Apply manure according to a manure management plan</td>
<td>• If broadcasted Urea accompanied by an inhibitor</td>
</tr>
<tr>
<td></td>
<td>• Guaranteed or known analysis for all sources applied</td>
<td>• Rate based on evidence recognized by regional soil fertility extension, including results of local adaptive management research.</td>
<td>• Some or all applied nitrogen in season or if pre-plant used with NI or polymer coated Urea</td>
<td>• UAN w/herbicide no more than 40 Lbs</td>
</tr>
<tr>
<td></td>
<td>• with nitrification inhibitor or controlled release if preplant; with urease inhibitor for urea/UAN surface applied sidedress</td>
<td>• Manure analysis required to determine rate</td>
<td>• Broadcast and incorporated, injected or subsurface band, surface application only for sidedress urea with UI or dribbled UAN</td>
<td></td>
</tr>
<tr>
<td><strong>Intermediate</strong> adopted by approximately 20% of growers</td>
<td>• Guaranteed or known analysis for all sources applied; with nitrification inhibitor or controlled release if preplant; with urease inhibitor for urea/UAN surface applied sidedress</td>
<td>• Rate based on evidence recognized by regional soil fertility extension, including results of local adaptive management research.</td>
<td>• Some or all N applied in-season</td>
<td></td>
</tr>
<tr>
<td><strong>Advanced</strong> adopted by approximately 5% of growers</td>
<td>• Guaranteed or known analysis; with nitrification inhibitor or controlled release if preplant; with urease inhibitor for urea/UAN sidedress</td>
<td>• Rate based on evidence recognized by regional soil fertility extension, or results of local adaptive management research, AND, in addition, addressing within-field and weather-specific variability using tools such as crop sensors, PSNT, models that allow adjustment of in-season N rates</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Soil Health as Driver of Change

Getting the 4Rs right means:

67% Improving soil health, and that means improving crop performance

50% Minimizing impact on environment & retaining nutrients in the field

39% Reducing risks associated with good & bad weather, improving yield

45% Action now may reduce the need for regulation later

37% Doing more to improve our crop yields and profit
Farmer Information Sources

76%
Frequently speak to other farmers about fertilizer practices

76%
Agronomist & retailers top fertilizer information source
2019 4R Advocates

• Brian Herbeck, Deweese, NE – Corn, Wheat, Soybean, Alfalfa
  Bill Nejezchleb, Fairfield Non Stock Coop, Fairfield, NE

• Danny Basham, Madisonville, KY - Corn
  Phillip Osborn, Nutrien Ag Solutions, KY

• Dustin Grooms, Plant City, FL - Strawberries
  Jerrod Parker, Chemical Dynamics, INC, FL

• Jonathan Quinn, Warwick, MD – Corn, Soybeans, Wheat, Barley, and Spinach
  Kenny Glenn, Southern States Cooperative, INC, DE

• Michael Ganschow, IL – Corn and soybean
  Malcolm Stambaugh, Growmark FS, IL
Cox Land and Cattle Co.

- 3,000 ac
  - Corn grain
  - Soybeans
  - Corn silage
  - Hay and cover crops
  - 750 cattle – cow/calf
  - No-till since 1988
  - Strip-till in corn

Maria Cox, Farmer
Kyle Lake Crop Consultant
Soybeans

• **Cereal Rye Cover crop**
  - Plant soybeans into green standing rye

• **4R Practices**
  - 2.5 ac grid sampling
  - Variable rate nutrient prescriptions using grid samples and yield maps
  - All P and K spring applied
  - Test manure for crediting

• **Performance**
  - 2016 – 71 bu/ac
  - Plus cereal rye hay production
Corn

- Strip-Till planting into cereal rye terminated at 10”
- No-till 25%
- Strip-till 50%
- Tillage on 25% that has hog manure
- 4R Practices
  - Variable rate N, P, K
  - Use N-serve (nitrification inhibitor) on all anhydrous ammonia
  - Split application
- Performance
  - 2016 – 190 bu/ac
Other Conservation

- Dry Dams
- Conservation Reserve Programs
  - Pollinator Program
  - 80 acres CRP long-term
- Buffer strips around feed lots
- Grassed waterways
- Buffer Strips
Maria says:

• “We use cover crops as a way to build organic matter, prevent erosion, lessen weed pressure, and potentially lower fertilizer application rates long-term.”

• “4Rs can be implemented in all tillage situations, but we feel a no-till system on fields keeps the fertilizer from eroding and washing away.”
MN 4R Advocate

- 800 acres
- Corn
- Soybeans

Dave Legvold, Farmer
Ken Thomas, Crop Consultant
4R Practices and Soil Health

- Strip-tills with a 12-row Soil Warrior on 30-inch spacings
  - MAP and DAP
  - Spring Urea
  - Zn and S

- No Fall N
- Sidedress N in season
- Improve drainage
- Cover Crops
On-Farm Research

• **N Rates for Strip-Till Corn**
  
  › 40, 77, 90, and 120 lbs N sidedress
  
  › 77 lbs N dribbled
  
  › 28% Liquid N
# On-Farm Research

<table>
<thead>
<tr>
<th>N Rate (lbs N/ac)</th>
<th>Yield (bu/ac)</th>
<th>Net Return to N ($/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>77</td>
<td>160.6</td>
<td>$ 998.02</td>
</tr>
<tr>
<td>90</td>
<td>166.0</td>
<td>$ 1032.89</td>
</tr>
<tr>
<td>120</td>
<td>158.8</td>
<td>$ 984.31</td>
</tr>
</tbody>
</table>
David on the 4Rs:

• “I don’t want to leave dollars in the field. If I use excess fertilizer, I’m leaving dollars in the field.”
Economics of 4R Stewardship

- **Basic**: spring pre-plant anhydrous ammonia with inhibitor, liquid starter fertilizer with seed, early post-plant N with herbicide, liquid N side-dress with Y-drop placement

- **Intermediate**: Liquid starter with seed, early post-plant N with herbicide, side-dress anhydrous ammonia with inhibitor

- **Advanced**: Liquid starter with seed, early post-plant N with herbicide, side-dress anhydrous ammonia with inhibitor, liquid side-dress with Y-drop (V10)
## On Farm Data – IL Corn

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4R Practice Level</strong></td>
<td>Basic</td>
<td>Basic</td>
<td>Intermediate</td>
<td>Advanced</td>
</tr>
<tr>
<td><strong>Corn Grain Yield (tonnes/ha)</strong></td>
<td>14.4</td>
<td>13.8</td>
<td>15.4</td>
<td>16.1</td>
</tr>
<tr>
<td><strong>N Application Rate (kg/ha)</strong></td>
<td>284</td>
<td>234</td>
<td>284</td>
<td>229</td>
</tr>
<tr>
<td><strong>Nitrogen Use Efficiency (tonnes/kg N)</strong></td>
<td>1.11</td>
<td>0.95</td>
<td>1.03</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>N Balance (kg N applied – kg N harvested)</strong></td>
<td>77.2</td>
<td>35.2</td>
<td>62.7</td>
<td>-2.35</td>
</tr>
</tbody>
</table>
On Farm Data – IL Corn

<table>
<thead>
<tr>
<th></th>
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<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>4R Practice Level</td>
<td>Basic</td>
<td>Basic</td>
<td>Intermediate</td>
<td>Advanced</td>
</tr>
<tr>
<td>Corn Grain Yield (tonnes/ha)</td>
<td>24% Reduction on CO$_2$e emissions with 4R practice suites that include N stabilizer products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1.11</td>
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<td>-2.35</td>
</tr>
</tbody>
</table>
NUE (kg N harvested/kg N applied)

Risk of inefficient N use

Desirable range for NUE

Risk of mining soil N
4R and Tomatoes

- **Reason for practice changes:**
  - Challenges with inputs
  - Environmental nutrient loss concerns
  - Labor

- **Practices Changed from Basic to Intermediate:**
  - Starter fertilizer mixed with soil in bed versus surface placement
  - Addition of new nutrient sources to fertilizer blend
  - N fertilizer in starter treated with inhibitor
  - Soil testing and nutrient recommendations before each crop
  - In-season tissue testing

![Graph showing Tomatoes: 1,432 to 1,729 boxes/ha]
No-Till Corn

- *Practices Changed from Basic to Advanced:*
  - Removed ammonia sulfate from fall strip-till application
  - Variable rate seeding and starter fertilizer application
  - Sidedress N with inhibitors applied at a variable rate and knifed-in
  - Phosphorus and potassium applications with strip-till and variable rate

NW Ohio Corn-Soybean No-till Rotation (10.7 to 12.1 tonnes/ha)
<table>
<thead>
<tr>
<th>Year</th>
<th>Yield (tonnes/ha)</th>
<th>N Rate (kg/ha)</th>
<th>N rate difference for 14% reduction</th>
<th>Field Print New CO2e/bu</th>
<th>Practice Level</th>
<th>CO2e Reduction with 4R Practice Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>11.2</td>
<td>229</td>
<td>10.3</td>
<td>B</td>
<td>B</td>
<td>-</td>
</tr>
<tr>
<td>2015</td>
<td>12.1</td>
<td>251</td>
<td>10.15</td>
<td>B</td>
<td>B</td>
<td>-</td>
</tr>
<tr>
<td>2016</td>
<td>10.7</td>
<td>219</td>
<td>10.4</td>
<td>I</td>
<td>I</td>
<td>9.67</td>
</tr>
<tr>
<td>2017</td>
<td>11.0</td>
<td>206</td>
<td>9.70</td>
<td>A</td>
<td>A</td>
<td>8.34</td>
</tr>
<tr>
<td>2017 R</td>
<td>11.0</td>
<td>163</td>
<td>29</td>
<td>8.23</td>
<td>A</td>
<td>-</td>
</tr>
</tbody>
</table>

19% Reduction on CO₂e emissions with 4R practice suites that include N stabilizer products

*R = N rate reduction for 14% decrease in FieldPrint New Calculations emissions
4R NUTRIENT STEWARDSHIP CERTIFICATION PROGRAM

Voluntary program in Western Lake Erie Basin (WLEB) and entire state of Ohio for agricultural retailers & nutrient service providers implementing the 4Rs

- 48 CERTIFIED BRANCH FACILITIES
- 38 FACILITIES IN WLEB
- 6,300 CLIENTS SERVICED
- 2.9M TOTAL ACRES
- 1.85M ACRES IN WLEB
- 4
- 1 43

GOALS
- Alternatives to nutrient inputs and management strategies
- Positively impact local water bodies
- Provide up-to-date information on nutrient management
- Help the agriculture sector adapt to new research and technology

RIGHT SOURCE - RIGHT RATE - RIGHT TIME - RIGHT PLACE

REQUIREMENTS
- Initial training and ongoing education
- Monitoring of 4R implementation
- Nutrient recommendation and application

THIRD-PARTY VERIFIED
- Audits every training and education; recommendation to growers; and application reports
- Third-party, state-verified occurs each year

For more information, visit: 4Certified.org
2018 Farm Bill

• Research Title
  › Fertilizer Nutrient Research
    – High Priority

• Conservation Title
  › TSP and CCA
  › More EQIP $ for nutrient management
  › CEAP Reports
Resources

nutrientstewardship.org

@4Rnutrients

4R Nutrient Stewardship

https://www.youtube.com/user/1fertilizer/video
Questions?