4R Research: Science For Stewardship

Providing a common table in search of practical solutions.

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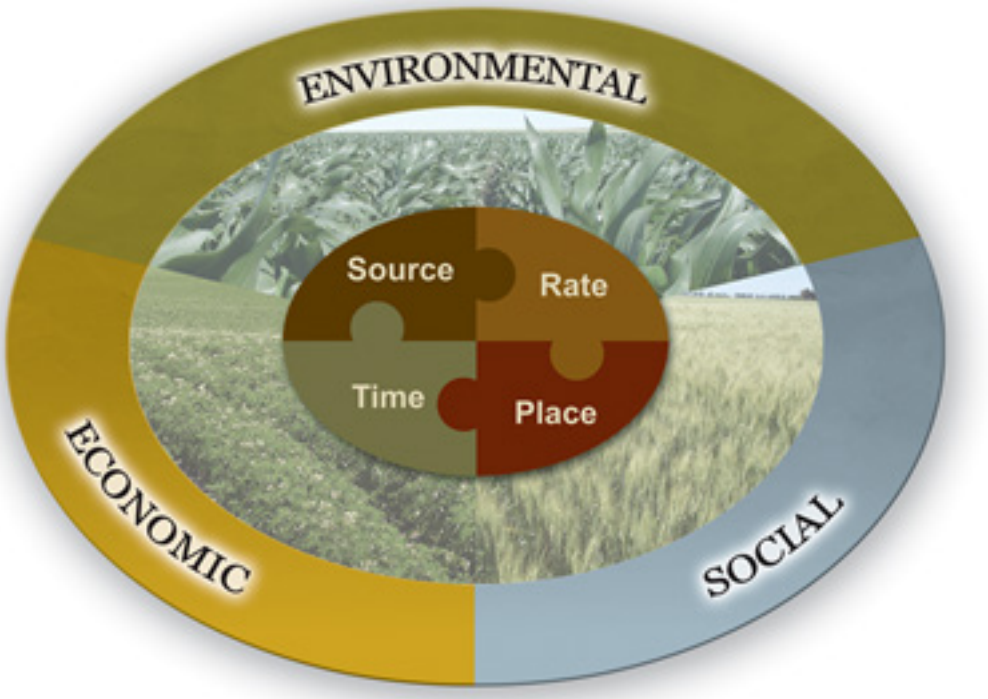
Summary: *Even though it is far too early to expect field-ready deliverables from these sophisticated projects initiated in 2014, the industry is already reaping benefits from the investment. A network of more than 40 leading scientists across North America is fully engaged in 4R Nutrient Stewardship and sees the commitment the industry has made to "science for stewardship."*



Today's world is data-rich. Big data are all around us—-from agriculture and natural resources (think of precision ag and climate applications), to clinical medicine, to consumer profiling, to government. In spite of that, we could be heading for a future that is defined by partial truths and misperceptions, or a future that is evidence-based and science-driven. Part of the challenge is in the dynamic nature of scientific truth where the discovery process over time alters what science says and in the process can erode public confidence in science. How well we transparently connect scientific data to the Big Data world will greatly influence which future is realized. The 4R Research Fund was established to help create that transparent connection between 4R Nutrient Stewardship practices and data showing impact on sustainability indicators and measures.

Looking back

The 4R Research Fund was established in 2013 by the North American fertilizer industry with initial pledges of $7 million over a five-year period. The first projects were initiated in 2014 as summarized in Figure 1. In addition to the 18 projects shown in Figure 1, five literature reviews with meta-analyses were funded and have now been completed.

Transparency has been a goal of the Fund from the very beginning. Since the primary funding source is the fertilizer industry, and stakeholders in nutrient stewardship are a diverse lot with wide-ranging priorities, we can anticipate that Fund protocols and results will be carefully scrutinized. To help provide the needed transparency, one of the requirements for funding was willingness to submit project data and articles to an open access data and information repository. That repository is being constructed at Purdue University and will provide a permanent home for project results and eventually for other 4R related research. It's a unique role for which the Fund is well suited and will provide a means of linking the Fund and state/province level projects.

Funded projects

The following is a list of the funded projects shown in Figure 1. Project proposals and program reports are available on-line at http://research.ipni.net/toc/category/4rresearchfund.

1. **Improving Nitrogen Management Tools for Reduced Environmental Losses from Corn Production.** Dr. Claudia Wagner-Riddle, Guelph, Ontario, CAN-4RC01. Documenting potential improvements of N efficiency is achieved by adopting 4R management techniques for corn production with field experimentation and synthesis of existing data. A survey of on-farm data from local farmers participating in on-going 4R programs allows analysis of the effectiveness of

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current 4R practices. New field data are used to refine a simulation model to predict the fate of N in agricultural fields.

2. **Improved Nitrogen Application Methods and Nitrogen Sources for Corn in Southwestern Ontario.** Dr. Craig Drury, Woodslee, Ontario, CAN-4RC02. Understanding how 4R stewardship can compensate for the need to quickly apply N fertilizers prior to spring planting while improving efficiency. The urgency to rapidly plant and fertilize crops in the spring when weather conditions become ideal has complicated farmer decisions. Using 4R principles for N fertilizer management can improve corn yield, while reducing greenhouse gas and ammonia emissions.
3. **Optimization of 4R Nitrogen Fertilization Practices in Response to Production System Uncertainties Quantifying the Influence of Soil and Weather on Crop Yield and Potential N Fertilizer Loss.** Dr. Nicolas Tremblay, St. Jean, Quebec, CAN-4RC03. In this scientific review, datasets are being collected and combined to determine how factors such as precipitation, temperature, and season of year can be included in implementation of 4R practices.
4. **Can Foliar Urea Reduce Nitrogen Losses from Potato Production in Atlantic Canada?** Dr. David Burton, Truro, Nova Scotia, CAN-4RC04. Spraying potato leaves with a urea- containing solution might allow farmers to reduce the amount of N fertilizer applied to the soil. Potato yields, N leaching, and greenhouse gas emissions are being measured in potato fields receiving combinations of foliar and soil-applied N.
5. **Nitrogen Stabilizers to Enhance Nitrogen Use Efficiency (NUE) and Reduce Greenhouse Gas Emissions.** Dr. Linda Hall, Lethbridge, Edmonton and Devon, Alberta, CAN-4RC05. Determining how urea fertilizer stabilizer additives applied to spring wheat increase yield and quality, while reducing gaseous and leaching losses of N.
6. **Coordinated Nitrogen and Sulfur Management in Sulfur-deficient Soils.** Dr. Miles Dyck, Breton, Alberta, CAN-4RC06. Fertilizing with both N and S has been linked

to increased crop yields and reduced emissions of greenhouse gas. The long-term Breton Classical Plots (established in 1930) are being used to measure the impact of fertilization practices on nitrous oxide emissions from soil.

7. **Effect of Broadcast versus Banded Phosphorus Application on Fate of Applied Phosphorus in Soils and Snowmelt Water Flow.** Dr. Jeff Schoenau, central Butte, Saskatchewan, CAN-4RC07. Placing P fertilizer close to soybean seeds may boost crop yield and reduce losses in water runoff. Fertilizer placement and the time of its application for soybean production are under investigation. Loss of soluble P in snowmelt water from frozen soil and during spring thaw is also being measured.
8. **Enhanced Efficiency Fertilizer Technologies to Reduce Nitrous Oxide Emissions from Cropped Soils in Prairie, Canada.** Dr. Mario Tenuta, Winnipeg, Ontario, CAN-4RC08. Applying anhydrous ammonia is popular due to its low cost, but complications arise from field operations. New application equipment allows a variety of fertilizer additives to be used with anhydrous ammonia, which may improve efficiency. Precision fertilizer placement techniques, rates of N conversion by soil microbes, and agronomic efficiency from fall-applied ammonia are being measured.
9. **Canadian Project Management-Integration of the 4R Nutrient Stewardship Research Network Project Activities.** Clyde Graham, Ottawa, Ontario, CAN-4RC09. A nationwide network of researchers is currently cooperating to quantify yield and environmental benefits from adopting the 4R framework
10. **How does 4R Nutrient Stewardship Affect Environmental, Social, and Economic Outcomes?** Dr. Alison Eagle, Ottawa, Ontario, CAN-4RC10. Evaluating the environmental and economic impacts of N and P fertilization practices in various Canadian cropping systems and potential improvements by implementing 4R Nutrient Stewardship. This activity synthesizes results of all Canadian network projects.
11. **Impact of Degree of Fertilizer and Manure Incorporation and Timing of First Runoff Event on Phosphorus Losses in Surface Runoff.** Dr. Ivan O'Hallaran, Guelph, Ontario, CAN-4RC11. Reducing runoff loss of fertilizer and manure P can be accomplished by improved placement and timing of application. These controlled runoff studies provide practical 4R guidelines for minimizing off-site transport of valuable crop nutrients.
12. **Fund Research Repository.** Dr. Sylvie Brouder, W. Lafayette, Indiana, USA-4RN45. Developing an information repository is used to preserve the data from all 4R Fund projects in a standardized way for future reuse. The research repository and framework will ensure that research data are standardized across projects, widely accessible, and archived for long-term preservation and reuse. The database is housed within the Purdue University Research Repository.
13. **Evaluating the 4R Nutrient Stewardship Concept and Certification Program in Western Lake Erie Basin.** Dr. Kevin King, Columbus, Ohio, USA-4RN09. Project is monitoring the impacts of 4R Nutrient Stewardship on crop productivity, profitability, nutrient loss, and water quality. The impacts of 4R adoption of the Western Lake Erie watershed are being measured and modeled. Follow-up surveys of farmers and crop advisors will guide future educational efforts for promoting widespread 4R adoption.
14. **Impacts of 4R Nitrogen Management on Crop Production and Nitrate-Nitrogen Loss in Tile Drainage.** Dr. Matt Helmers, Sutherland, Iowa, USA-4RN16. Reducing nitrate leaching losses to tile drainage can be achieved by implementing 4R-based practices for corn production. The field site has an instrumented tile drainage system that allows analysis of water flows and nutrient composition under 4R- managed fields. This provides a direct link between 4R practices and water quality measurements from fields hydrologically linked to the Mississippi River.
15. **Supplemental Late-vegetative Nitrogen Applications for High-yield Corn: Agronomic, Economic, and environmental implications with Modern Versus Older Hybrids.** Dr. Tony Vyn, W. Lafayette Indiana, USA-4RN25. Developing 4R fertilizer recommendations for modern corn hybrids requires understanding if they are more responsive to very late vegetative N applications than older varieties. Various fertilizer rate and timing combinations are being studied to measure crop performance and nutrient efficiency.
16. **Minimizing Phosphorus Loss with 4R Stewardship and Cover Crops.** Dr. Nathan Nelson, Manhattan, Kansas, USA-4RN26. Planting winter cover crops has the potential to increase corn and soybean yields, while minimizing P loss. Eighteen instrumented watersheds allow collection of runoff water from plots receiving various P fertilizer management practices with winter cover crop treatments.
17. **17 & 18. Relationships of Nitrous Oxide Emissions to Fertilizer Nitrogen Recovery Efficiencies in Rain-fed Corn Systems.** Dr. Tony Vyn, W. Lafayette, Indiana, USA- 4RN27, USA-4RN28. Emitting nitrous oxide (N2O) during corn production is a concern because this crop responds well to N fertilization and agriculture is the largest source of N_2O emissions. Most studies rely on measures of N use efficiency (grain N harvested), but total plant N uptake is a better indicator of making productivity estimates. N_2O emissions are measured from corn fields fertilized with different N sources and tillage systems. Scientific literature will be synthesized to understand the relationship between the N accumulation by corn and N_2O emissions as influenced by 4R management practices.

Funded reviews

Funded literature reviews with meta-analyses (when possible) are available at the same url indicated for the previous projects. They are:

1. **A "MANAGE"ed approach for 4R Nutrient Stewardship on Drained Land.** Laura Christianson. The Conservation Fund/USDA-ARS, USA-4RM04.
2. **Meta-Analysis of Enhanced Efficiency Fertilizers in Corn Systems in the Midwest.** Rachel Cook. Southern IL Univ, USA-4RM06.
3. **Assessing the Effects of Conservation Practices and Fertilizer Application Methods on N and P Loss from Farm Fields – A Meta-Analysis.** Song Qian. University of Toledo, USA-4RM07.
4. **Meta-analysis of Phosphorus Fertilizer Placement and Tillage Interaction for Corn and Soybeans in the U.S.** Dorivar Ruiz Diaz. Kansas State Univ., USA-4RM09.
5. **Nitrogen Losses: A Meta-Analysis of 4R Nutrient Management in U.S. Corn-based Systems.** Alison Eagle. Duke Univ., USA-4RM10.

These five independent literature reviews proved to be valuable in two ways:

- They provided summaries of the published literature on impacts of 4R practices
- They clearly showed knowledge gaps due either to the absence of research or incomplete reporting of information (meta-data) needed for research results to be synthesized with other results in a meta-analysis.

Communication among the five review teams indicated that many of the same limitations were being encountered by all teams. Therefore, the teams have now joined forces and are working on a summary journal article that will identify the most critical data gaps and provide recommendations to field researchers on actions they can take to enable the most effective use of their data following publication.

The journal article will be an appeal to the general scientific community to address the unique research needs of 4R Nutrient Stewardship. Dr. Alison Eagle of Duke University is leading that effort.

Phase two

We are now entering phase two of project funding where another set of projects will be established in response to the critical knowledge gaps identified in phase one.

"40 leading scientists are engaged in 4R Research across North America."

Two of the major gaps were:

- Impact of 4R practices on N mass balance (crop N uptake, nitrate leaching, N_2O emissions, etc.) allowing simultaneous evaluation of environmental and economic impacts.
- Impacts of 4R P practices, other system and site factors, and their interaction on P losses to water and on crop yield.

The Fund will also attempt to complement on-going studies funded at state or provincial levels, capitalize on existing research resources whenever possible, and leverage the Fund's unique North American-wide scale. The next step in phase two is to conduct two workshops in March of 2016 that will assemble researchers with oversight responsibilities for existing research sites with the potential to become 4R Fund locations.

One workshop will focus on the use of established long-term research sites to evaluate impacts of 4R Nutrient Stewardship. It will 1) attempt to identify treatments and measurements in long-term research sites that can contribute to our understanding of the long-term impacts of fertilizer source, rate, time, or placement on productivity, crop quality, soil health or the potential for nutrient loss to the environment, 2) identify additional measurements that could be made in support of objective one if funding was available; and 3) evaluate the potential for standardization of some treatments and/or measurements across sites to address common objectives

The second workshop will focus on the use of established research sites having the capacity to measure drainage losses of N and P. It will 1) attempt to identify treatments in these research sites that could be enhanced to deliver a complete mass balance evaluation of N and P inputs and losses as well as determine the impacts of fertilizer source, rate, time, or placement on that mass balance; 2) evaluate the potential for modification of current treatments to make critical 4R stewardship comparisons within and among research sites; and 3) consider the establishment of a "hub and spoke" network in North America with the drainage locations as hubs and supporting spoke sites within each hub domain.

Summing up

Even though it is far too early to expect field-ready deliverables from these sophisticated projects initiated in 2014, the industry is already reaping benefits from the investment. A network of more than 40 leading scientists across North America is fully engaged in 4R Nutrient Stewardship and see the commitment the industry has made to "science for stewardship." In this age where science finds itself under attack from many quarters, the industry is demonstrating how full transparency and upfront commitment can bring skeptical stake holders with diverse priorities to a common table in search of practical solutions to shared problems. The world is taking note as the 4R concept grows in formal acceptance, in certification programs, in the scientific literature, and in the general lexicon of agronomy and sustainability. A network of more than 40 leading scientists across North America is fully engaged in 4R Nutrient stewardship and sees the commitment the industry has made to "science for stewardship."

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