1.0 Background of 4R Nutrient Stewardship

Key Messages:

- 4R nutrient stewardship aims to use the right nutrient source, rate, time and placement to optimize agronomic crop yield and quality, economics of production, environmental sustainability and social good on a site-specific basis.
- While multiple stakeholders with differing concerns may be affected by nutrient management, the farmer plays the key role in how nutrients are managed
- 4R nutrient management is a science-based, flexible and adaptive approach that will continue to evolve over time as new products, practices and information become available.

Summary

The 4R nutrient stewardship framework means applying the right nutrient source or product at the right rate, right time and right place to optimize agronomic crop yield and quality, economics of production, environmental sustainability and social good on a site-specific basis (Figure 1). Within the 4R framework, fertilizer beneficial management practices (BMPs) should be developed for each location considering all three of these areas of sustainable development.

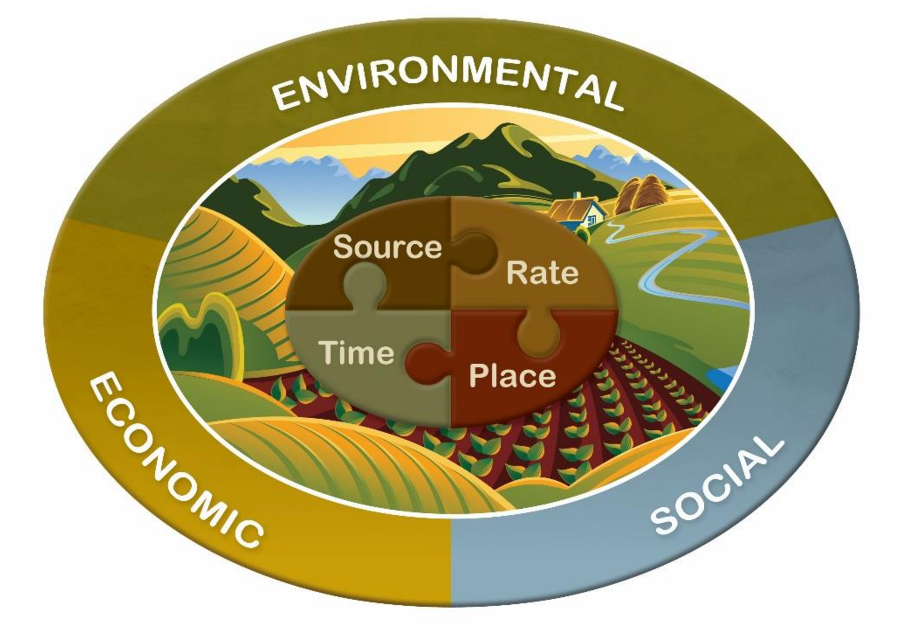

Figure 1 . The 4R nutrient stewardship concept defines the right source, rate, time, and place for plant nutrient application as those producing the economic, social, and environmental outcomes desired by all stakeholders to the soil-plant ecosystem (Roberts 2010) figure credit: http://www.ipni.net/ipniweb/portal/4r.nsf/article/communicationsguide

The framework recognizes that there are multiple stakeholders affected by nutrient management practices and that they will frequently have differing concerns. Farmers may focus on the agronomic and economic aspects of production, as well as stewardship of their land. The public may be more concerned with safe, nutritious and affordable food, clean air and water, and habitat preservation. Policy makers may focus on food security and addressing the evolving needs of both current and future generations. Balancing the varying concerns of the different stakeholders is a major challenge and the “right” choices will depend on the environmental, economic and societal conditions of each situation. The desires of the various stakeholders are considered within the management goals of crop productivity, economic profitability, cropping system durability, and environmental health. However, ultimately, the farmer as the manager of the land has direct control on how nutrients are managed to meet these goals.

Detailed Information

1.1 History

The idea of effectively managing nutrients for crop production is not a new one. Marcus Porcius Cato, the Elder in ancient Rome (234 to 149 B.C.E.) laid out principles for using manure and legume crops effectively to optimize crop yield and sustain soil fertility (Cato the Elder 2016). However, development and application of Beneficial Management Practices (BMPs) for fertilizer applications have evolved with increasing understanding of the impact of nutrient management on agronomic productivity and the environment. In 2007, the International Fertilizer Industry Association (IFA) initiated a program to define the principles of fertilizer BMPs and develop a strategy to encourage their international adoption. At an IFA workshop held in Brussels in 2007 to define and encourage the adoption of fertilizer BMPs, Paul Fixen described the idea of a global BMP framework that would be science-based, tested through farmer implementations, adaptable to local conditions and able to change and evolve as understanding of the system increased (Fixen 2007). The framework was based on economic, agronomic, environmental and social stewardship goals that could be addressed by fertilizer management objectives using the right rate, source, placement and timing of nutrient application, based on fundamental scientific principles on a site- and grower-specific basis. The concept of a global framework for sustainable nutrient management that could be applied on a local level was further developed by IFA and the International Plant Nutrition Institute and became the Global “4R” Nutrient Stewardship Framework (Bruulsema 2017; Bruulsema et al. 2009; Bruulsema et al. 2008; IFA 2009).

1.2 Background and principles

The 4R nutrient stewardship framework is a conceptual approach to optimize agronomic crop yield and quality, economics of production, environmental and social good on a site-specific basis (Bruulsema 2017; Bruulsema et al. 2009; Flis 2018; IPNI 2012). The initiative focusses on applying the right nutrient source or product at the right rate, right time and right place to achieve sustainability goals. The framework also recognizes that there are multiple stakeholders affected by nutrient management practices and that they will frequently have differing concerns. Farmers may focus on the agronomic and economic aspects of production as well as stewardship of their land. The public may be more concerned with safe, nutritious and affordable food, clean air and water, and habitat preservation. Policy makers may focus on food security and addressing the evolving needs of both current and future generations. Balancing the varying concerns of the different stakeholders is a major challenge and the "right" choices will depend on the environmental, economic and societal conditions of each situation.

The economic, environmental and social desires of the various stakeholders are considered within the cropping system management goals of crop productivity, economic profitability, cropping system durability, and environmental health. However, ultimately, the farmer as the manager of the land has direct control on how nutrients are managed to meet these goals.

The 4Rs are the tools that are used by the producer in the management system to address the sustainability goals. The basic principle is to apply the right source (or product) at the right rate, right time and right place. These four "rights" (4R) encompass the nutrient management options available to achieve the economic, social and environmental goals. The 4R framework is adaptable and allows a producer to make nutrient management decisions based on site-specific conditions such as soil characteristics, climate, cropping history, as well as the local sustainability imperatives (Bruulsema 2017; Bruulsema et al. 2009; Bruulsema et al. 2008; Flis 2018; IPNI 2012; Johnston and Bruulsema 2014). Therefore, within the 4R framework, these fertilizer BMPs should be developed for each location considering all three goals for sustainable development.

Right Rate - Choosing the right rate means matching the fertilizer applied to the crop demand. The rate required will be affected by crop type, yield potential, residual soil nutrient levels, crop sequence, and other management factors. Accurate assessment of nutrient supply is a first step to selection of the right rate. Optimum rate will reflect the balance between crop demand and soil supply. Rate is also affected by source, timing and placement methods and by short- and long-term sustainability goals.

Right Source - Using the right source means using a form that is suitable to the crop being grown, the management practices used and the environmental conditions occurring in the field. The source selected should provide plant-available nutrients to meet crop demand. Sources of P fertilizer include fluid fertilizers such as ammonium polyphosphates, dry granular products such as monoammonium or diammonium phosphate, triple superphosphate, rock phosphate, or compound fertilizer. Composts, manures and reclaimed materials such as struvite are also sources of P. Various additives, coatings and amendments may also be used to improve the effectiveness of applied fertilizer sources. Source selection will be affected by balance and interaction with other nutrients and the presence of other nutrients or contaminants in the fertilizer material. Selection of source must also consider factors such as soil characteristics, timing of application, method of placement, availability of P over time, compatibility issues, and cost per unit of "actual" nutrient.

Right Place – Applying fertilizer in the right place means that the nutrient must be in a position where the crop can access it when needed and where it will not be lost from the system. Phosphorus is not very mobile in the soil and should be placed in a position where the crop roots can access it early in the growing season. Seed-placement or side-banding P ensure that the crop roots reach the fertilizer early in the season to correct P deficiencies. Root geometry is an important factor in selecting proper placement. Surface applications of P, especially if not incorporated, are at risk for transport off-site to surface waters, so should not be used in environmentally sensitive areas.

Right Time - Applying fertilizer at the right time means making nutrients available to the crop when they are needed. Nutrient use efficiency can be increased significantly when availability is synchronized with crop demand. Early-season P supply is critical for optimum crop growth, so it is important that P be accessible by the crop early in the season. Placement and source will interact with timing, to ensure that a readily available form of P can be safely placed near the seedling for the plant to use early in the season. Timing of application may also influence risk of off-site movement of P, through snow-melt or rainfall events.

Although the “4R” title for this nutrient management framework is relatively new, most of the science-based fertilizer management principles within the framework have been developed and tested over many years. Nevertheless, these principles and practices are dynamic and will continue to change as knowledge and technology evolve. They are interdependent and must be developed as a package, rather than as individual practices; hence, the portrayal of them as interlocking pieces of a puzzle in Figure 1. They are also dependent on the other crop management practices being used in a cropping system. Tillage, cultivar selection, weather, pest management practices, land tenure, equipment and labour availability and a range of other factors will impact 4R choices. Therefore, the 4R framework is flexible and adaptable and allows a producer to make nutrient management decisions to address short- and long-term sustainability issues on a site-specific basis. Sound science provides the basis for current recommendations and for 4R practices to evolve and adapt to changing conditions and changing technology.

While application of 4R stewardship occurs at the farm level, development and evaluation of 4R stewardship will also occur at regional and policy levels (Figure 2). At a regional level, scientists work to provide locally tested, science-based tools for farmers, with recommendations for the right source, rate, time and place for local conditions. At a policy level, resources are allocated to support research and extension, regulations are made that will influence the practices that will be allowed on the farm, and subsidies or incentives may be provided to encourage adoption of BMPs. At each level, the success of 4R stewardship practices should be assessed based on the performance of the cropping system in addressing the sustainability goals and decisions made to continue, revise or discard the practices, based on their measured performance. Performance indicators on-farm will include crop yield and quality, nutrient use efficiency, change in soil nutrient reserves, improved operational efficiency and economic profitability. Other indicators such as long-term resource sustainability, environmental impact, or societal effect may be more difficult to measure directly in an individual field, but may be calculated based on estimate of aggregate risk. Successful 4R nutrient stewardship will address multiple and site-specific sustainability goals.

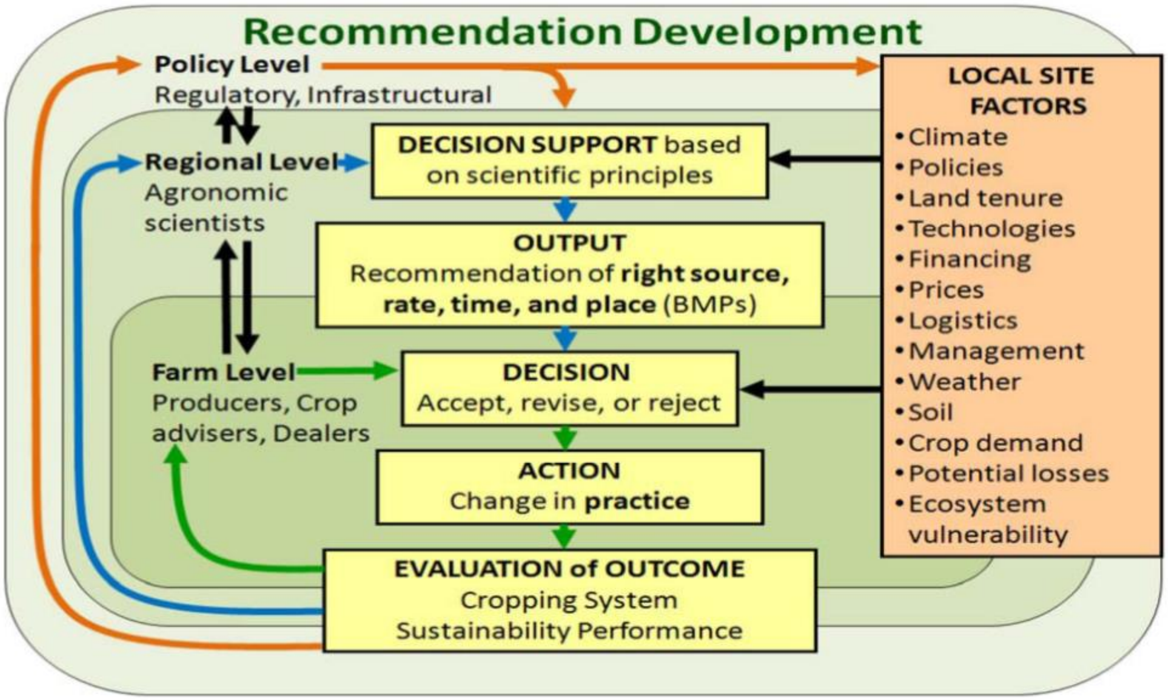

Figure 2. The 4R nutrient stewardship concept requires evaluation of sustainability performance, whether applied on-farm by producers and advisers, in recommendation development by agronomic scientists, or in consideration at the policy level. Practical decisions depend on close attention being paid to the full range of local site factors (Johnston and Bruulsema 2014).

The 4R Nutrient Stewardship Framework provides a flexible and adaptive method of selecting nutrient management practices to address short- and long-term economic, social and environmental sustainability issues on a site-specific basis. Sound science provides the basis for current recommendations and for 4R practices to evolve and adapt to changing conditions and changing technology. The following chapters will provide an outline of the 4R nutrient stewardship tools and the science behind their development in the Northern Great Plains.

Gaps in Knowledge

More information is needed on:

- comprehensive evaluation of 4R nutrient stewardship practices as packages, rather than individual practices. A greater emphasis on integration of 4R nutrient stewardship practices would be valuable, as well as more effort to integrate the environmental and production aspects of P management.
- how P management influences nutritional quality of food, especially as related to trace element concentration and bioavailabilty for human nutrition and health.

References

Bruulsema, T. 2017. 4R Phosphorus management practices for major commodity crops of North America. Pages 12. International Plant Nutrition Institute, Norcross, GA.

Bruulsema, T., Lemunyon, J. and Herz, B. 2009. Know your fertilizer rights. Crops and Soils 42(2):13-18.

Bruulsema, T., Witt, C., García, F., Li, S., Rao, T. N., Chen, F. and Ivanova, S. 2008. A global framework for fertilizer BMPs. Better Crops with Plant Food 92:13-15.

Cato the Elder, M. P. 2016. Delphi complete works of Cato the Elder (Illustrated). Pages 352. Delphi Publishing Ltd., Hastings, UK.

Fixen, P. 2007. Can we define a global framework within which fertilizer best management practices can be adapted to local conditions? Pages 77-86 IFA International Workshop on Fertilizer Best Management Practices International Fertilizer Industry Association, Brussels, Belgium.

Flis, S. 2018. 4R history and recent phosphorus research. Crops and Soils 51(2):36-47.

IFA. 2009. The Global ‘‘4R’’nutrient stewardship framework: Developing fertilizer best management practices for delivering economic, social and environmental benefits. International Fertilizer Industry Association (IFA), Paris, France, 10 pp. International Fertilizer Industry Association.

IPNI. 2012. 4R Plant Nutrition Manual: A manual for improving the management of plant nutrition. *in* T. Bruulsema, P. Fixen, G. Sulewski, eds. International Plant Nutrition Institute, Peachtree CornersGA.

Johnston, A. and Bruulsema, T. 2014. 4R nutrient stewardship for improved nutrient use efficiency. Procedia Engineering 83:365-370.

Roberts, T. L. 2010. Nutrient best management practices: Western perspectives on global nutrient stewardship. Proc. 19th World Congress of Soil Science, Soil Solutions for a Changing World, p172-75, Brisbane, Australia.