Applying 4R Nutrient Stewardship Principles in Precision Soil Management

By Brian Arnall and Steve Phillips

The goal of every land manager is to be as efficient and productive as possible. In other words, obtain maximum output with minimum input. As we explore the application of the 4R's in soil management, it becomes apparent that application of the 4R's can be closely linked with many existing precision agriculture (PA) technologies.

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By definition, precision means "being precise" or a "measure of exactness" regarding some practice. This definition perfectly describes what we are trying to accomplish at the core of 4R Stewardship in selecting the right source, rate, time, and place. In fact, multiple published sources define PA as "applying the right input at the right time and in the right place". Many people tend to think only of high-tech gadgets, satellites, and computers when defining PA; but in reality, PA is about using site-specific information to better equip advisors and growers to make knowledgeable management decisions and achieve more efficient and effective use of inputs. In some cases, technologies such as auto-guidance and variable-rate applicators makes this process easier, while in other cases low tech decision support tools, like leaf color charts and Nutrient Expert®, just as effectively increase knowledge and reduce the risk of mismanagement. Also important within 4R Stewardship is the dynamic feedback mechanism among stakeholders. The information management strategies common to PA greatly enhance this component of 4R. From immediate feedback to the operator to credibility in reporting to policy makers, PA makes it possible to go beyond "telling" someone that we are making the right decisions on the farm, but to "show" them.

Abbreviations and notes: N = nitrogen; P = phosphorus.

It's the connection between the science of the 4Rs and the tools and technology in PA that enhances the opportunity for producers and land managers to meet their sustainability goals and to achieve their management objectives.

For example, selecting the right nutrient source can have tremendous impact on the uptake efficiency by the plant, negating potential loss pathways, and timely delivery of essential nutrients. One group of nutrient source technologies that are widely used to meet these needs are those found in enhanced efficiency fertilizers. While marketed largely as a source solution, these products embody the interdependency of the 4Rs. By keeping the nutrients in plant-available forms and protecting them from various loss mechanisms in the field, the source can affect the ideal application rate (in some cases lowering it slightly due to higher uptake efficiency), application timing (lower risk of nutrient loss following preplant or early season applications), and nutrient placement (incorporation of the source is not as critical when volatilization and runoff are not a concern).

Choosing the right fertilizer rate of any nutrient is challenging due to temporal variability and spatial variability of nutrient availability and crop demand. The Stanford equation, which has been historically used to determine N fertilizer rate, states that N rate = [(N uptake by the plant – N contributions from the soil) / fertilizer use efficiency]. From the outside looking in this is a very simple calculation; however, each variable included in the equation is affected by variability in the field, creating challenges to be faced by the producer. First, N uptake is driven by yield. While the yield targeted by the producer tends to remain constant, the actual yield achieved can be vastly different from one year to the next, especially for rain-fed farming. In a long-term wheat fertility study conducted in Oklahoma, grain yields from the past ten years averaged 53 bu/A with a yield range of 31 to 88 bu/A (**Figure 1**). The economical optimum N rate for these five years ranged from 20 to 100 lb N/A, representing a nearly 2x swing in agronomic efficiency during the ten year period, due solely to temporal variability that could not have been predicted prior to the growing season. Today producers have access to a suite of in-season tools to help them select the right fertilizer rate. The use of large regional response databases tied to specific soils and environment, multiyear analysis of yield monitor data, crop and weather models, tissue testing, and sensors that measure plant status are all methods currently used to optimize fertilizer rate recommendations.

Establishing multiple management zones within a field based on some combination of factors is a well tested, commonly used way to address spatial variability. However, even when using the best science to identify where fields need to be treated differently, equipment limitations have prevented producers from treating spatial variability in soil nutrients at the resolution at which they existed. Oklahoma State University Extension Machinery Specialist, Dr. Randy Taylor points out that we (farmers) have been variable rate applying N for years, just not always at the grower's discretion. For example, anhydrous ammonia applicators commonly used over the past few years would often result in N delivery rates varying across the applicator and throughout the day as temperatures rise during the day and sink again in the evenings causing pressure changes within the tank. Today's advanced equipment not only allows for uniform rate across the applicator, but also allows for dynamic rate changes as the applicator travels through the field following either a prescription map or on-the-go technologies, such as crop sensors. Current variable rate technologies grant producers the ability to achieve the right fertilizer rate in all areas of the field.

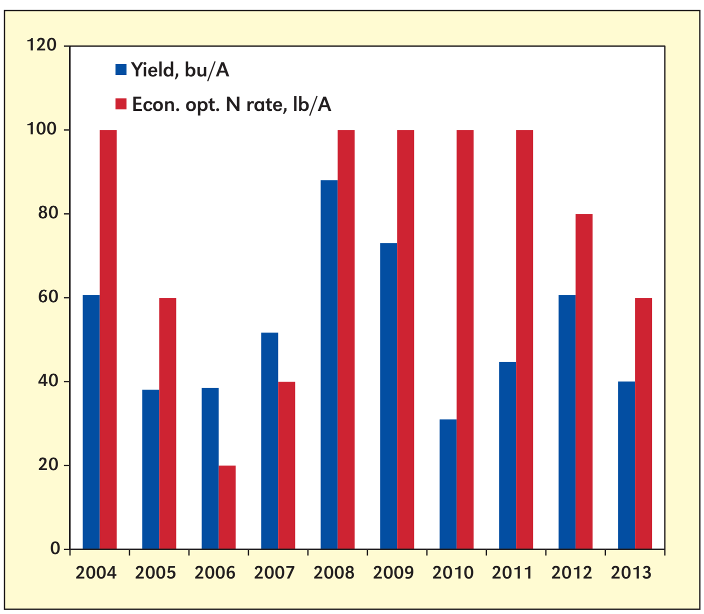
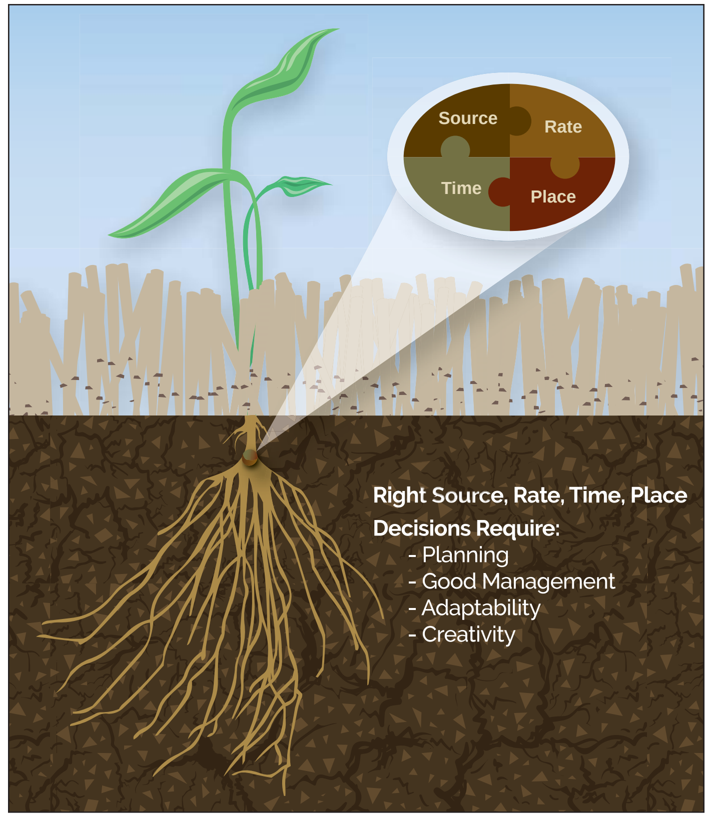


Figure 1. Wheat grain yield (bu/A) at the economical optimum N fertilization rate (US$/A) derived from the long-term winter wheat fertility study located near Lahoma, Oklahoma. Economical optimum calculated as (Yield x 6.00) – (N-rate x 0.60). Nitrogen rates evaluated ranged from 0 to 100 in increments of 20. Only plots received balanced P and K rates were evaluated (from unpublished data).



The science of 4R Nutrient Stewardship supports the implementation of precision agriculture through an integration of our knowledge of factors controlling nutrient supply.

Ideally, the right time to apply nutrients will correspond with plant uptake and occur over the entire growing cycle of the crop to ensure that the applied nutrients are neither lost to the environment nor bound organically or chemically in plant unavailable forms. Much like the case for accurate rate delivery, improvements in machinery have allowed producers to be more flexible with nutrient timing by affording them the ability to cover ground more quickly and over taller crops. Applicators have been engineered with tool bars to coulter inject while having six foot of clearance, while high clearance sprayers equipped with drop nozzles can pass through a corn field at tasseling. Variable rate irrigation is a technology that has enhanced the science of fertilizer timing by giving producers the ability to spoon feed nutrients to the crop throughout the growing season. Many producers have found that by using fertigation they are able to fine-tune their fertilizer rate, timing, and placement to improve nutrient use efficiency.

The right place can also have implications on the efficiency of nutrients applied. For immobile nutrients such as P and many of the secondary nutrients, the placement of the fertilizer in bands greatly increases the fertilizer use efficiency by improving root interception and slowing the rate in which the nutrient becomes plant unavailable through chemical reactions. The placement of the fertilizer below the surface reduces losses from runoff, volatilization, and immobilization in crop residue. In the past, no-till producers were challenged by fertilizer application as the majority of the equipment available to incorporate fertilizer caused significant soil disturbance. However, the introduction of low disturbance applicators have allowed no-till producers to incorporate fertilizer with little loss of surface residue. These same applicators can also be used to incorporate top-dress N in wheat without damaging the crop, thus giving growers yet another option for merging the right time and the right place.

By implementing 4R Nutrient Stewardship practices, producers are able to maximize yields, optimize fertilizer efficiency and minimize environmental impacts. The implementation of 4R Nutrient Stewardship requires significant planning, good management, ability to adopt new ideas, and a bit of creativeness. Many of the PA technologies available today aid in our goal to be the best stewards of the land. A successful PA program must be based on sound agronomic science, such as the fundamental principles that guide 4R Nutrient Stewardship.

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