Nutrient best management practices: Western perspectives on global nutrient stewardship

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Abstract
A global framework designed to aid the development and adoption of fertilizer best management practices (FBMPs) is described within the context of sustainable development. The framework is based on the premise that four principles of nutrient management-right source, right rate, right time, and right place-provide the basis and flexibility needed for nutrient management in global agriculture and be adaptable from small to large farmers.

Key Words
4Rs, nutrient best management practices, BMPs.

Introduction
Agriculturalists have been implementing and refining nutrient management since farmers first recognized crop growth could be enriched by the use of animal manures, composts, ashes, fish meal, bones, and other soil additives. However, the idea of nutrient best management practices (BMPs) is a relatively recent concept. Defined by fertilizer industry scientists as research proven practices that have been tested through farmer implementation to optimize production potential, input efficiency, and environmental protection (Griffith and Murphy 1991), BMPs related to nutrients encompass a host of terms. Fertilizer best management practices, integrated plant nutrient management, code of best agricultural practices, site-specific nutrient management, and other similar expressions are all descriptive components of plant nutrient management. All have an underlying goal to help ensure plant nutrients are used efficiently and effectively in ways that are beneficial to society without adversely impacting our environment. The concepts involved can best be described through global guidelines for nutrient stewardship. Three years ago the International Fertilizer Industry Association (IFA) launched an initiative on FBMPs with an international workshop in Brussels to define general principles of FBMPs and to develop a strategy for their wider adoption. During that workshop, Fixen (2007) introduced the idea of a global framework within which FBMPs could be adapted to local conditions. Since then, the concept of a global framework for FBMPs has been further developed by IPNI scientists (Bruulsema *et al.* 2008) and an IFA Task Force on FBMPs culminating with the publication of *The Global "4R" Nutrient Stewardship Framework* (IFA Task Force 2009). The framework is intended to aid the development and adoption of nutrient BMPs that meet sustainable development goals (i.e. economic, social, and environment) through simultaneously increasing crop productivity and profitability, while protecting the environment.

Sustainability
The global framework recognizes there are many stakeholders interested in nutrient management-farmers, crop advisers, scientists, policymakers, consumers, and the general public. Each stakeholder has different expectations of nutrient management which revolve around the pillars of sustainability. Farmers need to be profitable and, as stewards of the land, desire to protect their natural resource; the public wants safe, nutritious food, a clean environment, and land for forests, wildlife, and recreation, and policymakers want to ensure we produce enough food while providing for the needs of current and future generations. These are all components of sustainability supported by economic, social, and environmental goals. Ideally, these three pillars of sustainability would be equally balanced, but in reality that does not occur. The balance between economic, social, and environmental goals for nutrient management depends on the issue, its context, and the stakeholders (IFA Task Force 2009). In some sensitive ecosystems, more emphasis might be placed on environmental goals, where in other situations social goals may be of greatest concern or economics (i.e. farmer profitability) may dominate. Regardless of the balance, it is constantly changing with improvements in knowledge and technology and changes in stakeholder expectations.

4R nutrient stewardship

The global 4R nutrient stewardship framework attempts to integrate the economic, social, and environmental expectations of the different stakeholders within cropping system management objectives of productivity, profitability, cropping system durability, and a healthy environment (Figure 1). Central to the framework are the 4Rs-right nutrient source (or product), applied at the right rate, time, and place.

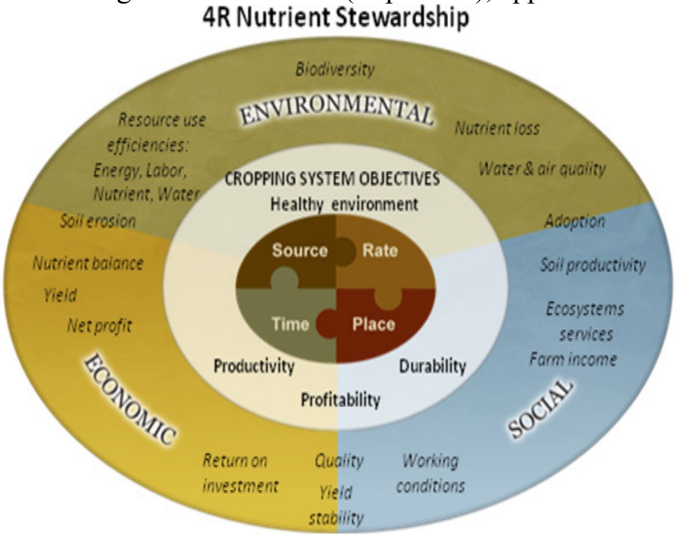

Figure 1. The 4R nutrient stewardship concept defines the right source, rate, time, and place for plant nutrient application as those producing the economic, social, and environmental outcomes desired by all stakeholders to the soil-plant ecosystem.

The 4Rs are the foundation and guiding principles of nutrient BMPs (Roberts 2007). The approach is simple and universally applicable … apply the correct nutrient in the amount needed, timed and placed to meet crop demand. Examples of the 4 rights of nutrient stewardship include:

Right Source – match the nutrient source or fertilizer product with soil properties and crop needs. Apply nutrients in plant-available forms. Balance applications of nitrogen, phosphorus, potassium, and other nutrients according to crop needs and available soil nutrients. Beware of nutrient interactions, blend compatibility, and non-nutritive elements.

Right Rate – Match application rates with crop requirements. Set realistic yield goals and use adequate methods to assess soil nutrient supply (e.g. soil testing, omission plots) and crop need (e.g. tissue analysis, crop nutrient budgets, crop scouting). Predict fertilizer use efficiency, consider economics and soil resource impact.

Right Time – Assess timing of crop uptake and synchronize nutrient availability with crop demand. Assess soil nutrient supply. Utilize pre-plant, split applications, controlled release fertilizers, and urease and nitrification inhibitors to manipulate the timing of nutrient availability and consider logistics of field operations.

Right Place – Recognize root-soil dynamics. Place and keep nutrients where the crop needs them and where nutrient use efficiency will be maximized. Crop, cropping systems, and soil properties will dictate the most appropriate method of placement, but incorporation is usually preferred to keep nutrients in place and increase their use efficiency. Beware of and manage spatial variability.

Right source, rate, time, and place are science-based principles of fertilizer management. Each of the 4Rs is guided by scientific principles and supported by years of research. They are not static, but are changing and improving with new gains in knowledge and technology development. They are interdependent and interlinked with agronomic management practices applied in cropping systems (Bruulsema *et al.* 2009). The 4Rs provide flexibility to nutrient management recognizing that FBMPs are site and crop specific depending on soils, climatic conditions, crop and cropping history, and management expertise, and can be applied in large-scale, extensive agriculture or small family farms. In-depth discussions of nutrient source, rate, time, and place have recently been published by the American Society of Agronomy as a five-part series titled "Know Your Fertilizer Rights" (Mikkelsen *et al.* 2009; Phillips *et al.* 2009; Stewart *et al.* 2009; Murrell *et al.* 2009).

The framework shows the interaction between BMPs and allows assessment of FBMPs on the cropping system performance within the goals of sustainability. Performance is the outcome of implementing a FBMP. Figure 1 shows various cropping performance indicators, i.e. yield, quality, soil productivity, nutrient loss, etc. and how they are interconnected. A "best" management practice should positively address at least two and preferably three goals of sustainability within the cropping systems. For example, nutrient use efficiency is often considered the foremost performance indicator relative to fertilizer use. Nutrient use efficiency can be increased simply by reducing application rates (Roberts 2007). If the objective of nutrient management was to maximize nutrient use efficiency, then the farmer would merely target lower parts of the yield response curve where the first increments of applied fertilizer gives the greatest yield response. Singling out rate reductions could reduce nutrient loss (beneficial for the environment), but it may also negatively impact yields and profitability, reducing the economic sustainability of the farmer. Performance measures or indicators must be considered within a cropping system and in relation to the goals of sustainability. They are set by the farmer, his or her advisers, and other stakeholders in society concerned with how nutrients are managed. The need for and usefulness of performance indicators in improving FBMPs is outlined at greater length by Bruulsema *et al.* (2009) and by the IFA Task Force (2009).

Concluding comments

Right source, right rate, right time, and right place is a simple slogan that integrates a century of science and experience into nutrient stewardship. Who decides what is right? Who decides the best application, best method of placement, or best nutrient source? There is no right answer … right must be site-specific, dictated not only by soil and environmental conditions, but by social and environmental concerns and objectives. Research backstops the principles of 4Rs with science, but the stakeholders decide what is right. The farmer, the fertilizer industry, natural resource managers, extension workers, crop advisers, environmental NGOs, and others with a vested interest help in deciding what is the right or best nutrient management practice. The people impacted by nutrient management decisions, i.e. the consumer, are also involved and policymakers help make those decisions for them.

Nutrient use regulatory and policy developments are becoming common place in North America and the European Union. 4R nutrient stewardship provides a voluntary option to address nutrient related regulatory issues, whether they are related to water quality or greenhouse gases (GHG). In North America, IPNI has been working with The Fertilizer Institute (TFI) and the Canadian Fertilizer Institute (CFI) to promote the adoption of the 4R system within legislative and regulatory frameworks. Currently in the U.S., 4R nutrient stewardship has been endorsed by the United States Department of Agriculture (USDA), through both the Natural Resources Conservation Service (NRCS) draft 590 standard and through consideration of a Memorandum of Understanding of the USDA Climate office. The 4R system has also been sanctioned by state fertilizer associations, the Association of American Plant Food Control Officials (AAPFCO), the Conservation Technology Information Center (CITC), and the American Farm Bureau Federation (AFBF) as well as other agricultural organizations. In Canada, the Province of Alberta has recognized 4Rs are part of its nitrous oxide emissions reduction protocol (NERP) and other provinces are looking to 4Rs as a voluntary means to assist farmers in reducing GHG emissions. Carbon credit and offset trading programs are considering 4R nutrient stewardship as an acceptable method of recognizing farmers' contributions to earning credits.

Farmers can achieve better management through implementation of 4R nutrient stewardship. Validated by research, the 4R nutrient stewardship framework allows farmers to improve their performance and sustainability. Economic, social, and environmental performance is reflected through performance indicators chosen by the stakeholders of the cropping system. 4R nutrient stewardship is gaining global acceptance, but continued education and multi-stakeholder dialog between farmers, the fertilizer industry, policymakers, and other relevant groups are still needed to keep moving forward.

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