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# The '4R Nutrient Stewardship Framework' links indicators of sustainability performance to policies and practices

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## Executive Summary

The 4R Nutrient Stewardship Framework—recently developed by the fertilizer industry worldwide—aims to provide context for sustainability reporting. Its implication for policy analysis is to require balanced sets of performance indicators encompassing social and economic areas as well as those related to the environment. In order to have policy relevance, it is important that indicators on the national and regional scale be meaningful, and actionable, at the farm level as well. The OECD 2008 report on Environmental Performance of Agriculture states "*a key requirement of the indicators is that they adequately track developments that are of public concern, and are able to reflect changes in policies and farmer actions.*"

The 4R Framework describes on-farm nutrient management practices with irreducible simplicity: applying the right source at the right rate, time and place (Roberts, 2009; Thorup and Stewart, 1988). The definition of the normative "right" is provided by the principles of sustainable development: optimizing the sustainability performance of agriculture, using indicators selected by its stakeholders (GRI, 2006). Universal scientific principles of nutrient cycles, soil fertility, and plant nutrition manifest themselves in specific management practices that vary with climate, soils, access to technology, local economies, and culture. The highest probability of meeting the goals for agricultural systems occurs when science is applied to define a suite of practices from which farmers can select, using adaptive management.

Industry is working toward development of balanced sets of indicators of economic, social, and environmental performance. 4R Nutrient Stewardship emphasizes sustainability with a simple, but universal and complete, message: apply the right source at the right rate, at the right time, and in the right place. All those involved in the application of crop nutrients, from those making the applications to those making recommendations, need to consider the comprehensive impact of their practices on sustainability. The development and delivery of decision support for site-specific adaptive management practices needs support at the policy level.

## Introduction: 4R Nutrient Stewardship Framework – key elements and principles

The 4R Nutrient Stewardship Framework aims to provide context for sustainability reporting. The major manufacturers of NPK fertilizers are increasingly emphasizing sustainability. At least seven of the 16 member companies of the International Plant Nutrition Institute (IPNI) display sustainability reports prominently on their public websites. Most of these reports conform to the international guidelines of the Global Reporting Initiative (GRI). The 4R framework is based on long-understood principles (Thorup and Stewart, 1988). It was developed with input from the worldwide fertilizer industry, in both developed and developing countries, and applies to both. In addition to IPNI, organizations including the International Fertilizer Industry Association (IFA), The Fertilizer Institute (TFI) and the Canadian Fertilizer Institute (CFI) have contributed to the development of the 4R Nutrient Stewardship framework and continue to support its implementation (CFI, 2005; Fixen, 2007; Roberts, 2007; IFA, 2009; TFI, 2010).

Sustainable development is recognized to consist of three non-negotiable elements: economic, social, and environmental. Progress in each of those three areas is essential to sustainability. Progress assessment requires input from stakeholders, but how the progress will be achieved is a local decision best made by farmers. For fertilizer use to be sustainable, it must support cropping systems that provide economic, social, and environmental benefits to stakeholders.

The 4R Nutrient Stewardship Framework is based on universal scientific principles which serve as a guide to practices with the highest probability of supporting the economic, social, and environmental goals of sustainable development. The science-based principles of nutrient cycles, soil fertility, and plant nutrition manifest themselves in specific management practices that vary with climate, soils, access to technology, local economic conditions, and culture. These site-specific local practices comprise the right source, rate, timing and placement of plant nutrients.

The fertilizer industry's nutrient stewardship concept links management of plant nutrition to sustainability. The rights source, rate, time, and place of plant nutrient application are defined by the goals of sustainable development (Figure 1). The connection between practices and outcomes must be understood well, not only by crop producers and their advisers, but also by many other stakeholders: those who purchase the products of cropping systems and those who live in the environment impacted by those systems. For participation of these stakeholders to be meaningful, the essential components of plant nutrition must be communicated succinctly and completely – hence, the simple but complete 4Rs of source, rate, time, and place. Policies and programs involving payments to farmers for ecological goods and services—for example, carbon offsets related to greenhouse gas mitigation, loading reductions for water quality credit trading, etc.—depend on a clear public understanding of the linkage of fertilizer management practices to sustainability outcomes. The 4Rs provide a common language and basic vocabulary relating to fertilizer management, supporting an accurate understanding of its role in the whole agricultural system, even for those who may not understand all the details of managing crop nutrients.

Many issues associated with fertilizer use and fertilizer recommendations relate to sustainability. Some are positive, some negative, but in many the role fertilizer plays can go either way depending on management. On the one hand, nutrient applications increase yields of crops, nourishing the world while sparing land for other uses and increasing the return of organic carbon to the soil, thereby sequestering a greenhouse gas. On the other hand, unmanaged nutrient applications may increase nutrient losses, potentially degrading water and air quality in a number of ways and possibly increasing greenhouse gases. Fertilizer use also has longer-term and larger-scale impacts on soil productivity and the social and economic structure of rural areas. These issues are all part of sustainable development.

## Performance indicators – importance of economic and social as well as environmental impacts

A sustainability-focused approach includes input from all stakeholders in determining the indicators of performance of the management practices implemented. What's "right" is determined by the desired outcomes. "Right" is not primarily a scientific term. It's an ethical term. It depends on the values and beliefs of the stakeholders. When it comes to cropping systems, the range of stakeholders is broad – it extends to those who consume the products and to those who live in the environment impacted by the cropping system.

The four "rights" of plant nutrition stewardship have an ethical component. There is a value judgment to choosing the right nutrient source, metering out the right rate at the right time and in the right place. The value judgement is based on how this combination of actions meets sustainability goals. These goals are determined, not by science, but by people—informed by science—who apply their beliefs and values to choose targets for outcomes. For example, in a setting where a pre-plant application of nitrogen optimizes yield but results in excess groundwater nitrate, a stewardship approach would seek a management strategy (perhaps split-application, perhaps a controlled-release source, perhaps a technology yet to be developed) that both optimizes yield and limits nitrate loss to groundwater. If these benefits are understood by the stakeholders, public support for programs that provide incentives for changes in technology should be easier to obtain.

All stakeholders should have input to the outcome goals. However, the farmer—the manager of the land—needs to be the final decision-maker in selecting the practices suited to the local site-specific soil, weather, and crop production conditions that have the highest probability of meeting the goals. Because all these conditions can influence the decision on the practice selected, right up to and including the day of implementation, local decision-making performs better than a regulatory approach.

Setting sustainability goals involves science communication. Many scientists feel their work is not adequately understood or appreciated, and is not appropriately used in development of policy, regulation and practical recommendations. Science can help define the right management to achieve particular sustainability goals, but scientists must recognize the ethics, beliefs and values of their audience to meaningfully engage public dialogue on such goals.

Outcome-based indicators are generally preferred to those based on monitoring of practices. However, some outcomes, such as reduced delivery of nutrients to water, greenhouse gas emissions, or losses of ammonia, are very difficult to measure at the farm scale. In some cases, stakeholders may agree that a combination of outcome-based and practice-based indicators is most suitable for performance assessment. Practice-based indicators may give misleading impressions that simple regulations controlling practices will lead to positive environmental outcomes. An example is a ban on fall application of anhydrous ammonia. There are likely many farms that should be using an alternative practice, but there are also those in the western Corn Belt of the USA for whom fall application is a highly efficient and sustainable practice. Banning fall application may lead some producers to choices that are actually less beneficial in terms of economic and environmental performance.

Since fertilizer applications have multiple impacts, no single measure or indicator provides a complete reflection of performance. Neither can all possible impacts be measured. Stakeholders need to select the performance measures and indicators that relate to their greatest concerns.

## Measuring performance without restricting adaptive management

Many of the factors influencing plant growth, metabolism and nutrient needs are uncontrollable, resulting in considerable uncertainty in what the right source, rate, time, or place will be at a specific site in a specific growing season. The best the manager can do is to employ those available practices that have the highest probability of meeting objectives. Science allows us to define those practices.

Performance is the outcome of implementing a practice. The impacts of fertilizer management are expressed in the performance of the cropping system. Performance includes the increase in yield, quality, and profit resulting from a fertilizer application and extends to long-term effects on soil fertility levels and on losses of nutrients to water and air. It also includes impacts on the regional economy and social conditions—for example, affordable food. Not all aspects of performance can be measured on each farm, but all should be assessed. Stakeholders need to agree on a set of performance indicators that reflects their aspirations.

In 4R Nutrient Stewardship, individuals working on the parts remain cognizant of the whole. Scientists working on optimum rates pay attention to source, timing and placement as well, and make sure the performance is assessed comprehensively. Stakeholders with specific interests in a certain outcome—for example, practices to improve water quality—are informed of the linkages of such practices to other aspects of performance. The integrated effect on the system performance as a whole needs to be the main guiding criterion.

The evaluation of outcomes takes place on several levels within 4R nutrient stewardship (Figure 2). At the farm level, producers and their advisers make decisions—based on local site factors—and implement them. Progressive producers always evaluate outcome. If they follow 4R nutrient stewardship, this evaluation of outcome is based on sustainability performance informed by stakeholders, and this evaluation influences the next cycle of decisions. At a more regional level, agronomic scientists work to provide decision support. Their output is a recommendation of the right source, rate, time and place – again in relation to local site factors. Progressive researchers also need to evaluate outcome, and if they follow 4R nutrient stewardship, this evaluation of outcome is based on sustainability performance informed by stakeholders – and influences the next revision of their recommendations. The same applies to the policy level, which supports research and extension and influences the context within which producers, advisers and research scientists work.

Adaptive management—defined as an ongoing process of developing improved management practices for efficient production and resource conservation by use of participatory learning through continuous systematic assessment—fits into the 4R Nutrient Stewardship concept, as illustrated in Figure 2. Adaptive management provides the site-specific practices needed to provide the highest probability of achieving the goals of sustainable development.

### Implications for policymakers at national and subnational levels – POLICY CONSIDERATIONS

A balanced set of performance indicators including economic and social areas needs to be considered. An example of a potential indicator set is shown in Table 1. The selected examples are intended to be “actionable” — that is, meaningful and measurable at scales that included the full range from farm to national. These do not reflect the consensus of any person or organization but are provided to show the forms of some of the indicators under consideration.

The 4R Nutrient Stewardship concept relates management practices—selection of nutrient source, rate, timing and placement—to sustainability goals at all levels. This includes the farm level. Asking farmers to define their sustainability goals encourages a higher level of commitment and participation and diminishes the negative reactions that tend to result from the imposition of sustainability accounting systems from other parties. The adoption of a 4R nutrient management plan would include identification of such sustainability goals.

Conciseness of indicators is important. Some indicators will reflect more than one sustainability goal. For example, yield per unit area of cropland is related to economic performance, but also to environmental to the extent that high yields enable the sparing of land for other uses, increasing biodiversity.

Indicators of one area (economic, social, environment) should recognize potential trade-offs and synergisms with the other areas. For example, on a per-hectare basis, nitrous oxide emission (an environmental impact) can be reduced by decreasing crop production (an economic impact), but if calculated on a per unit of crop production basis, the economic aspect of crop production would be recognized, and the focus would shift to a balanced management: producing the least nitrous oxide emission per unit of food production.

Indicators can be presented in many ways, influencing their perception by stakeholders. The time interval chosen for a trend is important. Short-term changes can be misleading. Since sustainability is a long-term issue, use of the longest feasible time interval should be encouraged. Context can be important. When a nutrient balance is presented showing only surplus, deficit, or ratio of output to input, the scope of the nutrient flows in and out of cropland is not apparent. Presentation of the full nutrient balance can lead to a different perception.

Indicators should be interpreted not only in terms of policies directly affecting producers, but also policies towards development of decision support, technology transfer, and last-mile delivery to producers, involving both public and private industries. For example, policies should consider:

- Investment in public research to harmonize production and environmental goals;
- Investment in public education in support of stakeholder participation at the local level;
- Recognition and support for independent certification efforts like that of the American Society of Agronomy's Certified Crop Adviser program.

### Conclusion

Industry is working toward development of balanced sets of indicators of economic, social, and environmental performance. 4R Nutrient Stewardship emphasizes sustainability with a simple, but universal and complete, message: apply the right source at the right rate, at the right time, and in the right place. All those involved in the application of crop nutrients, from those making the applications to those making recommendations, need to consider the comprehensive impact of their practices on sustainability. The development and delivery of decision support for site-specific adaptive management practices needs support at the policy level.

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**Table 1.** Example of an indicator set that may be considered for evaluation of sustainability outcomes arising from the implementation of 4R Nutrient Stewardship.

| Indicator | Units | Data sources | Comment |
|---|---|---|---|
| ***Environmental*** | | | |
| Producer adoption of 4R nutrient management plan | % of crop area | Surveys | Tracking a specific BMP does not measure environmental outcome, but can be a proxy if accepted by stakeholders |
| Partial factor productivity of fertilizer | kg of crop yield per kg of fertilizer applied | Government and industry statistics | Efficiency indicators for any single factor need to be interpreted in context of those for all other factors. |
| Crop nutrient balance | kg of nutrients applied and removed | Government statistics and census | Interpretation needs to consider soil fertility status – deficits or surpluses may be desirable in some cases. |
| Nitrous oxide emission | kg of $CO_2$-equivalents per tonne of crop produced | Nitrous oxide emission reduction protocol (NERP) in Alberta, Canada | Since emission is difficult to measure at any scale, the protocol requires a sound science-based relationship between practices and outcomes. |
| ***Social*** | | | |
| Injury rate | % of farm workers | Census of Agriculture | Isolated to injuries associated with fertilizer use |
| Farmers in possession of health and safety information | % farmers with fertilizer material safety data sheet (MSDS) | Survey | |
| Food quality | Difference in nutrient amounts between food grown using different plant nutrient management practices | Research laboratory testing | Depends on research relating practices to measured food quality parameters. |
| Food security | Tonnes yield increase resulting from fertilizer use | Research | |
| ***Economic*** | | | |
| Yield | Tonnes crop harvested per ha | Survey and government statistics | The economic indicators are not meant to include typical financial indicators. In the context of sustainable development, the economic dimension is not so much about straightforward revenues and profit, but more about the economic impact on various stakeholders. |
| Return on investment | $ crop sales/$ spent on fertilizer | Retail and government statistics | |
| Impact on suppliers | $ spent on fertilizer products and services | Industry statistics | |
| Impact on government | $ taxes/tonne fertilizer used | Government | |

Adapted from discussions with Mark Brownlie, consultant on GRI standards.

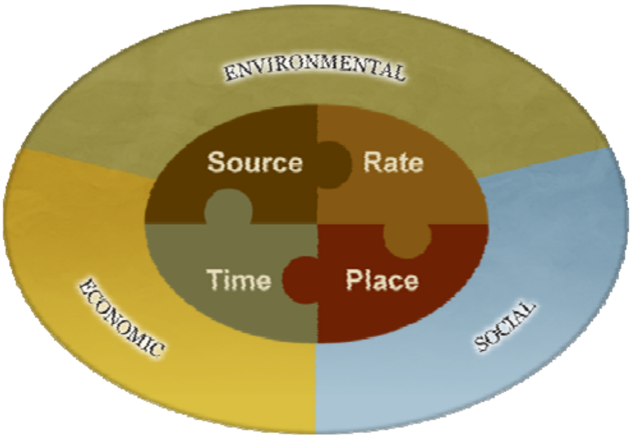


**Figure 1.** The 4R nutrient stewardship concept defines the right source, rate, time, and place for fertilizer application as those producing the economic, social, and environmental outcomes desired by all stakeholders to the agricultural system.

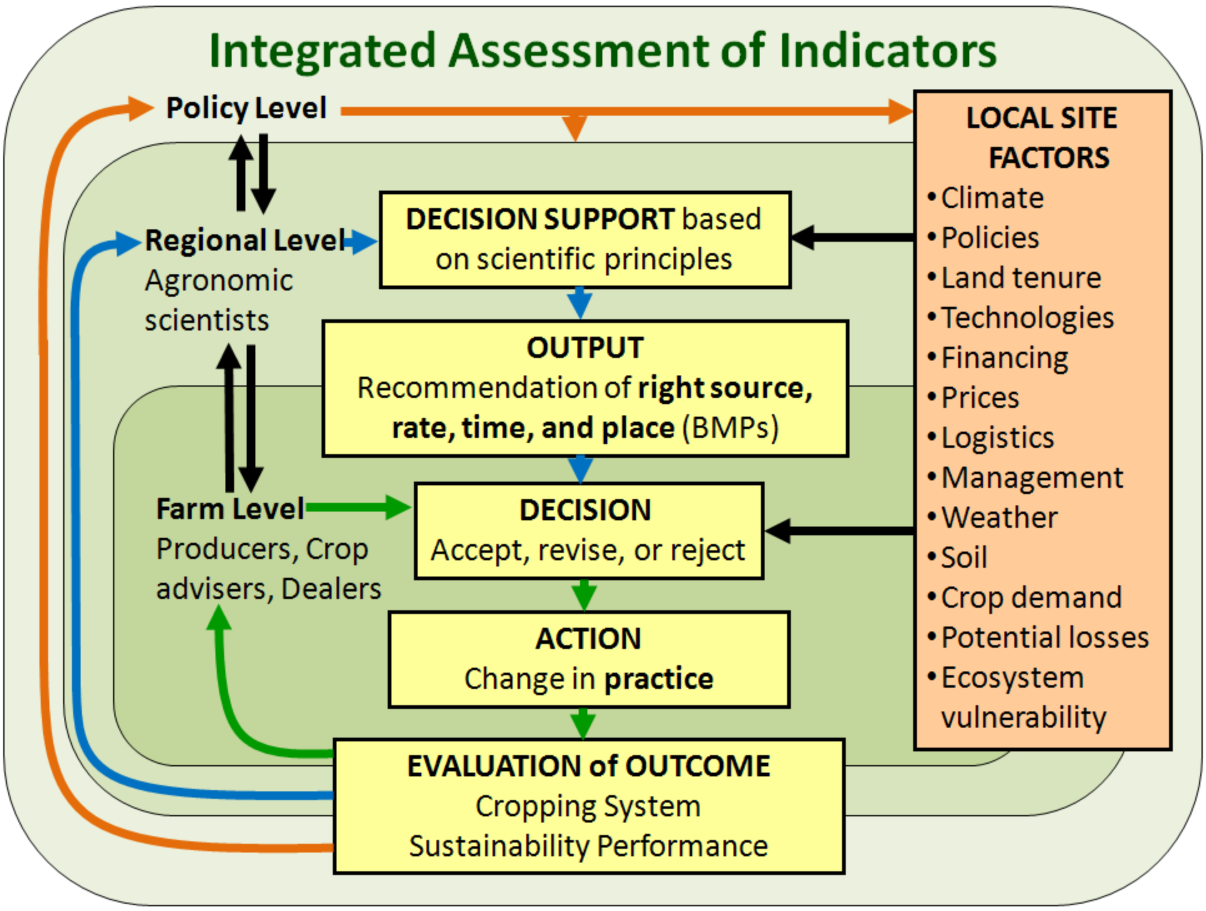


**Figure 2.** The 4R Nutrient Stewardship concept requires evaluation of sustainability performance, whether applied on-farm by producers and advisers, in recommendation development by agronomic scientists, or in consideration at the policy level. Policy influences both the information developed for decision support, and the decisions made by producers.