THE NUTRIENT STEWARDSHIP

4R POCKET GUIDE

nutrient stewardship

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Foreward

4R Nutrient Stewardship is a new innovative approach for fertilizer best management practices adopted by the world's fertilizer industry. This approach considers economic, social and environmental dimensions of nutrient management and is essential to sustainability of agricultural systems. The concept is simple—apply the right source of nutrient, at the right rate, at the right time and in the right place—but the implementation is knowledge-intensive and site-specific.

While this pocket guide is a much condensed version of the International Plant Nutrition Institute's 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition, it highlights the key points associated with 4R Nutrient Stewardship.

Details on obtaining a complete copy of the manual from IPNI , as well as other resources supporting 4R Nutrient Stewardship, can be obtained at www.ipni.net/4R.

Goal of Sustainable Agriculture

The challenge to increase food production in an economically viable way while retaining the ecological integrity of food systems is the underlying aim of sustainable agriculture.

The 4R Nutrient Stewardship approach is an essential tool in the development of sustainable agricultural systems because its application can have multiple positive impacts in the assets mentioned above.

There is an immediate connection between applying the right nutrient source, at the right rate, right timing, and right placements, and beneficial impacts on components of the natural capital evidenced through better crop performance, improved soil health, decreased environmental pollution, and the protection of wildlife.

Similarly, positive effects are expected on financial capital, as farmer profits improve, bringing about improvement in their quality of life and increased economic activity in their communities.

The 4R Nutrient Stewardship Concept

Fertilizer management, to be considered "right," must support stakeholder-centric goals for performance. However, the farmer, the manager of the land, is the final decision-maker in selecting the practices—suited to local site-specific soil, weather, and crop production conditions, and local regulations—that have the highest probability of meeting the goals.

Because these local conditions can influence the decision on the practice selected, right up to and including the day of implementation, local decision-making with the right decision support information would perform better than a centralized regulatory approach. Specific scientific principles guide the development of practices determining right source, rate, time and place. Farmers and crop advisers make sure the practices they select and apply locally are in accord with these principles.

THE 4R NUTRIENT STEWARDSHIP CONCEPT

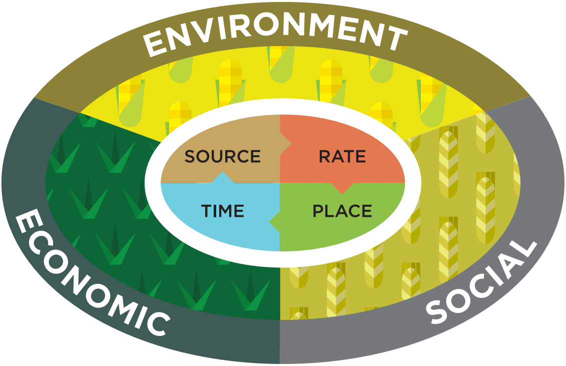
The principles are the same globally, but how they are put into practice locally varies depending on specific characteristics:

Soil	Weather
Crop	Economic
Climate	Social Conditions

The four "rights" provide a simple checklist to assess whether a given crop has been fertilized properly. To help farmers and advisers identify opportunities for improvement in fertilizing each specific crop in each specific field, they can ask:

"Was the crop given the right source of nutrients at the right rate, time and place?"

The sciences of physics, chemistry and biology provide fundamental principles for the mineral nutrition of plants growing in soils. The application of these sciences to practical management of plant nutrition has led to the development of the scientific disciplines of soil fertility and plant nutrition.



A balance of effort among the four "rights" is appropriate. It helps avoid too much emphasis on one at the expense of overlooking the others. Rate may sometimes be overemphasized, owing to its simplicity and direct relation to cost.

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 plant ecosystem.

THE 4R NUTRIENT STEWARDSHIP CONCEPT

Source, time and place are more frequently overlooked and may hold more opportunity for improving performance. Plant nutrition practices interact with the surrounding plant-soil-climate system (Figure 2). For fertilizer use to be sustainable, it must enhance the performance of the plant system.

The performance of the system is influenced not only by the 4Rs, but also by how they interact with other management practices such as tillage, drainage, cultivar selection, plant protection, weed control, etc.

The plant-soil-climate system interacts with the management of plant nutrition and includes factors such as:

Genetic yield potential	Drainage
Weeds	Compaction
Insects	Salinity
Diseases	Temperature
Mycorrhizae	Precipitation
Soil texture and structure	Solar radiation

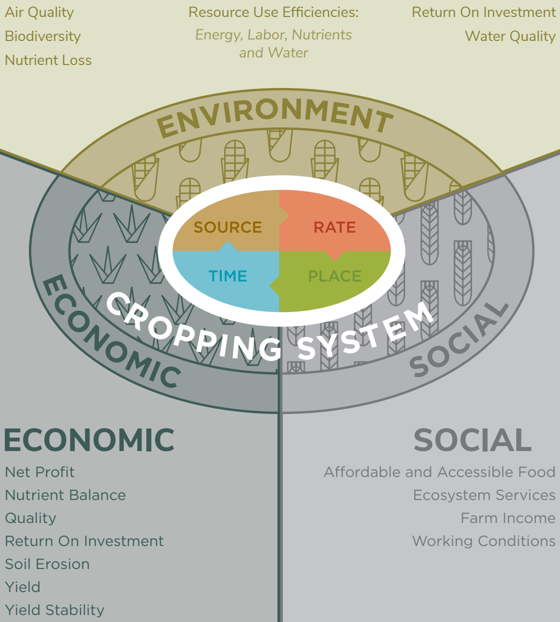


FIGURE 2 Performance indicators reflect the social, economic and environmental aspects of the performance of the plant-soil-climate system. Their selection and priority depends

CONCEPT

THE 4R NUTRIENT STEWARDSHIP CONCEPT

At the farm or local production system level, producers and their advisers make decisions— based on local site factors—and implement them. They then evaluate the outcome of their decisions to determine what decision to make the next time in the cycle.

Ideally the assessment of practice performance would be done on the basis of all indicators considered important to stakeholders. Essentially, this is the practice of adaptive management—an ongoing process of developing improved practices for efficient production and resource conservation by use of participatory learning through continuous systematic assessment.

For sound guidance in this process, it is important that crop advisers have some level of professional certification and training.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Source

The core scientific principles that define right source for a specific set of conditions are the following:

Consider rate, time and place of application.

Supply nutrients in plant-available forms. The nutrient applied is plant-available, or is in a form that converts timely into a plant-available form in the soil.

Suit soil physical and chemical properties. Examples include avoiding nitrate application to flooded soils, surface applications of urea on high pH soils, etc.

Recognize synergisms among nutrient elements and sources. Examples include the P-zinc interaction, N increasing P availability, fertilizer complementing manure, etc.

Recognize blend compatibility. Certain combinations of sources attract moisture when mixed, limiting uniformity of application of the blended material; granule size should be similar to avoid product segregation, etc.

Recognize benefits and sensitivities to associated elements.
Most nutrients have an accompanying ion that may be beneficial, neutral or detrimental to the crop. For example, the chloride (Cl-) accompanying K in muriate of potash is beneficial to corn, but can be detrimental to the quality of tobacco and some fruits. Some sources of P fertilizer may contain plant-available Ca and S, and small amounts of Mg and micronutrients.

Control effects of non-nutritive elements.
For example, natural deposits of some phosphate rock contain non-nutritive trace elements. The level of addition of these elements should be kept within acceptable thresholds.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Rate

The core scientific principles that define right rate for a specific set of conditions are the following:

Consider source, time and place of application.

Assess plant nutrient demand.
Yield is directly related to the quantity of nutrients taken up by the crop until maturity. The selection of a meaningful yield target attainable with optimal crop and nutrient management and its variability within fields and season to season thus provides important guidance on the estimation of total crop nutrient demand.

Use adequate methods to assess soil nutrient supply.
Practices used may include soil and plant analysis, response experiments, omission plots, etc.

Assess all available nutrient sources.
For most farms, this assessment includes quantity and plant availability of nutrients in manure, composts, biosolids, crop residues, atmospheric deposition and irrigation water, as well as commercial fertilizers.

Predict fertilizer use efficiency.
Some loss is unavoidable, so to meet plant demand, the amount must be considered.

Consider soil resource impacts.
If the output of nutrients from a cropping system exceeds inputs, soil fertility declines in the long term.

Consider rate-specific economics.
For nutrients unlikely to be retained in the soil, the most economic rate of application is where the last unit of nutrient applied is equal in value to the increase in crop yield it generates (law of diminishing returns). For nutrients retained in the soil, their value to future crops should be considered. Assess probabilities of predicting economically optimum rates and the effect on net returns arising from error in prediction.

Right Rate

TABLE A

CROP***	UNIT	N	P2O5
Alfalfa (DM)	ton	51	12
Barley grain	bu	0.99	0.4
Beans (dry)	bu	3	0.79
Bromegrass (DM)	ton	32	10
Canola grain	bu	1.9	1.2
Corn grain	bu	0.67	0.35
Cotton (lint)	bale	32	14
Flax grain	bu	2.5	0.7
Millet grain	bu	1.4	0.4
Oat grain	bu	0.77	0.28
Peanut nuts	ton	70	11
Potato tuber	cwt	0.32	0.12
Red clover (DM)	ton	45	12
Rice grain	bu	0.57	0.3
Rye grain	bu	1.4	0.46
Sorghum grain	bu	0.66	0.39
Soybean grain	bu	3.25	0.73
Sugarbeet root	ton	3.7	2.2
Sugarcane	ton	2	1.25
Tomatoes	ton	2.5	0.92
Wheat straw	bu	0.7	0.16
Wheat (spring) grain	bu	1.49	0.57
Wheat (winter) grain	bu	1.16	0.48

S R T P

K2O	S
49	5.4
0.32	0.09
0.92	0.52
46	5
2	0.34
0.25	——
19	——
0.6	0.19
0.4	0.08
0.19	0.07
17	——
0.55	0.03
42	3
0.16	——
0.31	0.1
0.27	0.06
1.18	——
7.3	0.45
3.5	——
5.7	——
1.2	0.14
0.33	——
0.29	——

***Reported** nutrient removal coefficients may vary regionally depending on growing conditions. Use locally available data whenever possible.

****DM = dry matter basis;** otherwise moisture content is standard marketing convention or at the stated moisture content.

Example: Using Table A, an example of nutrient balancing would be a 200 bu/A corn crop removes 70 lb P2O5 from the soil (200 x 0.35=70). So, the maintenance P2O5 application will be 70 lb/A.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Time

The core scientific principles that define right time for a specific set of conditions are the following:

Consider source, rate and place of application.

Assess timing of plant uptake.
Nutrients should be applied to match the seasonal crop nutrient demand, which depends on planting date, plant growth characteristics, sensitivity to deficiencies at particular growth stages, etc.

Assess dynamics of soil nutrient supply.
Mineralization of soil organic matter supplies a large quantity of some nutrients, but if the crop's uptake need precedes its release, deficiencies may limit productivity.

Recognize dynamics of soil nutrient loss.
For example, in temperate regions, leaching losses tend to be more frequent in the spring and fall.

Evaluate logistics of field operations.
For example, multiple applications of nutrients may or may not combine with those of crop protection products. Nutrient applications should not delay time-sensitive operations such as planting.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Place

Right place means positioning needed nutrient supplies strategically so that a plant has access to them. Proper placement allows a plant to develop properly and realize its potential yield, given the environmental conditions in which it grows.

Right place is, in practice, continually evolving. A host of factors can affect proper fertilizer placement, including but not limited to, the following:

Plant genetics	Plant spacing
Placement technologies	Crop rotation or intercropping
Tillage practices	Weather variability

Consequently, there is much yet to learn about what constitutes the "right" in right place and how well it can be predicted when management decisions need to be made.

The core scientific principles that define right place for a specific nutrient application are the following:

Consider source, rate and time of application.

Consider where plant roots are growing.
Nutrients need to be placed where they can be taken up by growing roots when needed.

Consider soil chemical reactions.
Concentrating soil-retained nutrients like P in bands or smaller soil volumes can improve availability.

Suit the goals of the tillage system.
Subsurface placement techniques that maintain crop residue cover on the soil can help conserve nutrients and water.

Manage spatial variability.
Assess soil differences within and among fields in crop productivity, soil nutrient supply capacity, and vulnerability to nutrient loss.

The Whole Farm

As illustrated in Figure 3, nutrient management practices are always nested in cropping systems within other management and site factors such as tillage, drainage, cultivar selection, etc., which can greatly influence the effectiveness of a specific practice.

Many factors interact with plant nutrition and nutrient management practice effectiveness:

Genetic yield potential	pH
Weeds	Drainage
Insects	Compaction
Diseases	Salinity
Mycorrhizae	Temperature
Soil texture and structure	Precipitation and solar radiation

Best practices are dynamic and evolve as science and technology expands our understanding and opportunities, and practical experience teaches the astute observer what does or does not work under specific local conditions.

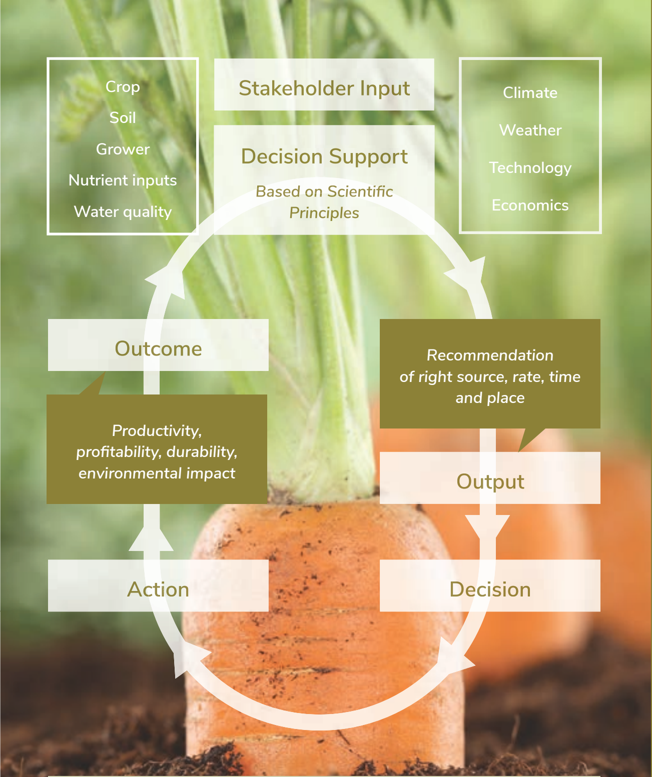


FIGURE 3 The role of adaptive management in practice refinement for 4R Nutrient Stewardship.

Example 1

Practices listed here are being utilized and evaluated by a grower with the assistance of an agronomic service provider.

This is not a template for nutrient management in a cropping system, rather it serves as an example of what a suite of utilized practices could entail.

Cropping System Objectives:
Utilize emerging tools and technologies to maintain responsible and sustainable agriculture.

Additional Practices:

- Utilize technology-driven data management and decision-making tool for precision agriculture decision making to enhance producer profitability and environmental stewardship
- Plant 800 acres of cover crops to help naturally control weeds and to hold moisture and nutrients in the soil
- Utilize irrigation management to avoid over or under watering

RIGHT SOURCE

Utilize nitrogen stabilizers for liquid and dry fertilizers

Use phosphate efficiency enhancement additives to increase first season benefit of the fertilizer

RIGHT RATE

Grid soil sample all acres for variable rate application of nutrients to help determine the right rate and right placement of nutrients

Account for nutrient credits from the previous year to help determine the right rate

Test irrigation water on some fields for nitrogen content and adjust application rates of fertilizer as needed

RIGHT TIME

Utilizes split application of nitrogen; pre-season urea applications followed by liquid UAN as either a pre-plant or side-dress to assure the right rate is available at critical growth stages for the crop and to minimize N loss to volatilization and leaching

Use plant tissue testing to evaluate effectiveness of the fertilizer program and as a diagnostic tool when needed

RIGHT PLACE

Use GPS technology to avoid skips and prevent over-application

Deploys variable rate seeding to maximize yield while controlling input costs

Auto steer and GPS guidance is used on all field operations and spraying applications

Use satellite imaging to help with yield potential and fertilizer plans

ADDITIONAL PRACTICES:

Utilize technology-driven data management and decision-making tool for precision agriculture decision making to enhance producer profitability and environmental stewardship

Plant 800 acres of cover crops to help naturally control weeds and to hold moisture and nutrients in the soil

Utilize irrigation management to avoid over or under watering

Example 2

Cropping System Objectives:
Make cropping decisions that result in higher nutrient use efficiency and increase farm profitability.

The process relating source, rate, time and place of nutrient applications to sustainability outcomes can be daunting.

Sustainability impacts are highly complex, site-specific and varying over time. They involve uncertainty and require further research in support of continuous science-based improvement.

Nevertheless, practical common-sense thinking—guided by an appropriately global framework—can change practices and improve outcomes within both short-term and long-term time frames. Guiding practices towards plant nutrition for optimum productivity can help to resolve many of the current issues associated with plant nutrient use.

RIGHT SOURCE

Use custom blend of ammoniacal nitrogen, liquid phosphorus and potash that are mixed with proven nitrogen inhibitors and stabilizers

Apply minor elements based on soil and tissue test results

RIGHT RATE

Utilize soils sampling and soil maps to determine macro and minor element application needs

Tissue sample throughout the season to assess and add plant nutrition for each stage of plant development for N, P and K as well as minor elements

Evaluate annual yield and nutrient use to determine efficiency of utilized practices

RIGHT TIME

Utilizes split application of nitrogen; pre-season urea applications followed by liquid UAN as either a pre-plant or side-dress to assure the right rate is available at critical growth stages for the crop and to minimize N loss to volatilization and leaching

Use plant tissue testing to evaluate effectiveness of the fertilizer program and as a diagnostic tool when needed

RIGHT PLACE

Use RT K guidance to enable better implementation of precision practices

Implement strip tillage and banding of fertilizer to ensure the right placement of critical nutrients and minimize the risk of erosion and runoff

Inject liquid N, P and K six to eight inches underground to prevent runoff and volatilization

Implement fertigation on irrigated acres to apply nutrients to the most productive field areas

ADDITIONAL PRACTICES:

Utilize agronomic decision support tool to make better overall cropping decisions that result in higher nutrient use efficiency and profitability

Use Daikon forage oilseed radishes as cover crops to reduce soil compaction and retain residual N, P and K through winter; in addition these cover crops minimize tillage and erosion

For more information on the 4Rs,
visit **nutrientstewardship.org**

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The Fertilizer Institute
Nourish, Replenish, Grow