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INTERNATIONAL
PLANT NUTRITION
INSTITUTE

4Rs are Needed to Feed a Hungry World

Fertilizer Industry Round Table
November 16-17, 2011

St. Petersburg, FL.

Terry Roberts, PhD
President, IPNI

Better Crops, Better Environment … through Science

The challenge of 9 billion by 2050…

- Reached 7 billion on October 31st
- Annual growth rate is 1.1% (200,000 people per day) … slowing down to < 1% in 2020

Source: http://ngm.nationalgeographic.com/2011/01/seven-billion/olson-photography

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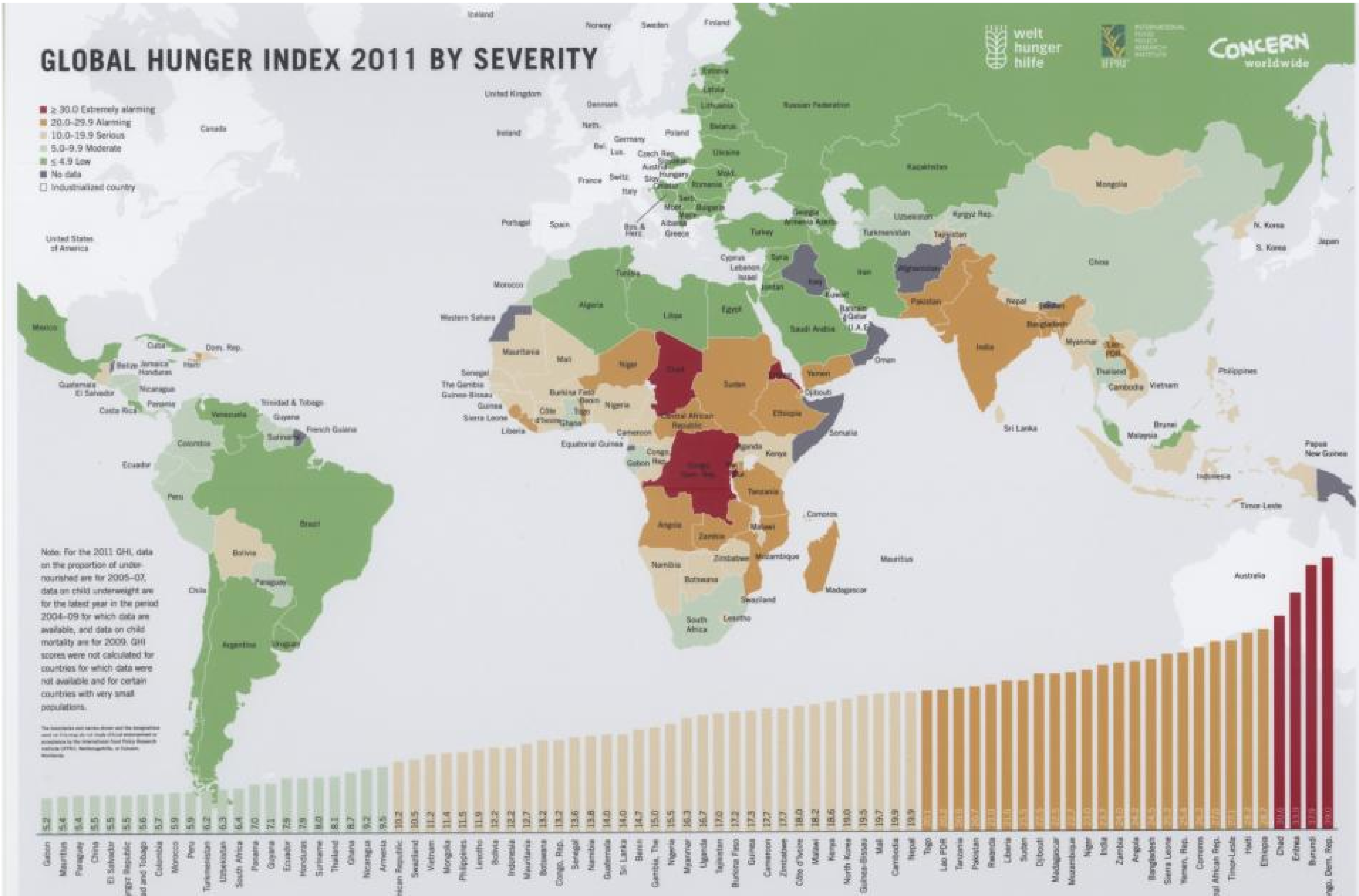
Where are the hungry?



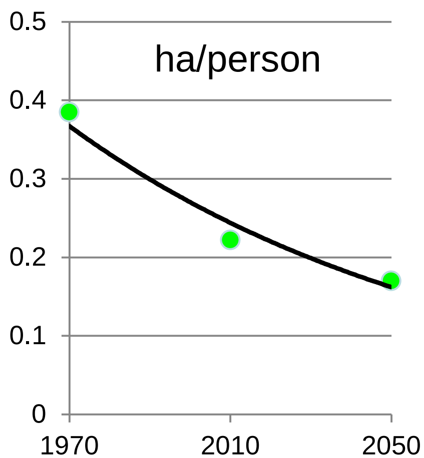
Source: International Food Policy Research Institute, Concern Worldwide and Welthungerhilfe

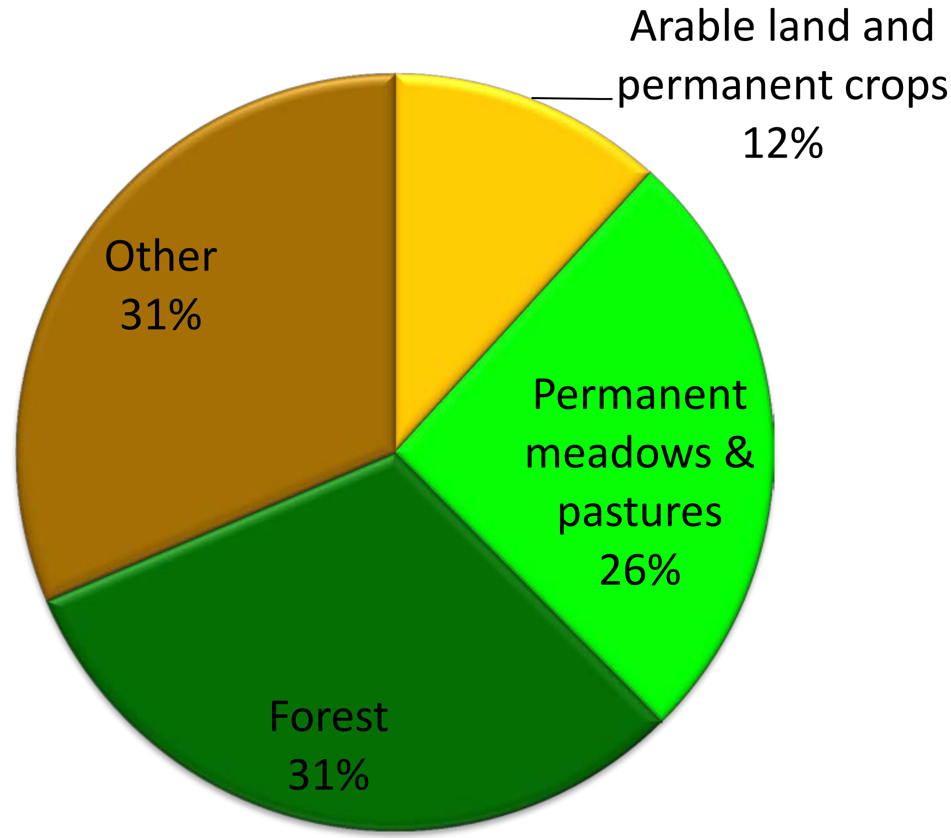
9 Billion Mouths to Feed?

- Food production will need to increase by some 70% by 2050 (from 2005/07 levels, FAO)
- Few options … more crop land and/or more production

The world has 13.0 billion ha land surface

- 1.5 billion ha for crop production
- Arable land per person is declining …





By 2050, arable land will increase about 70 million ha … 90% of growth in crop production globally will come from land already in production (Bruinsma 2009)

Source: FAO 2009

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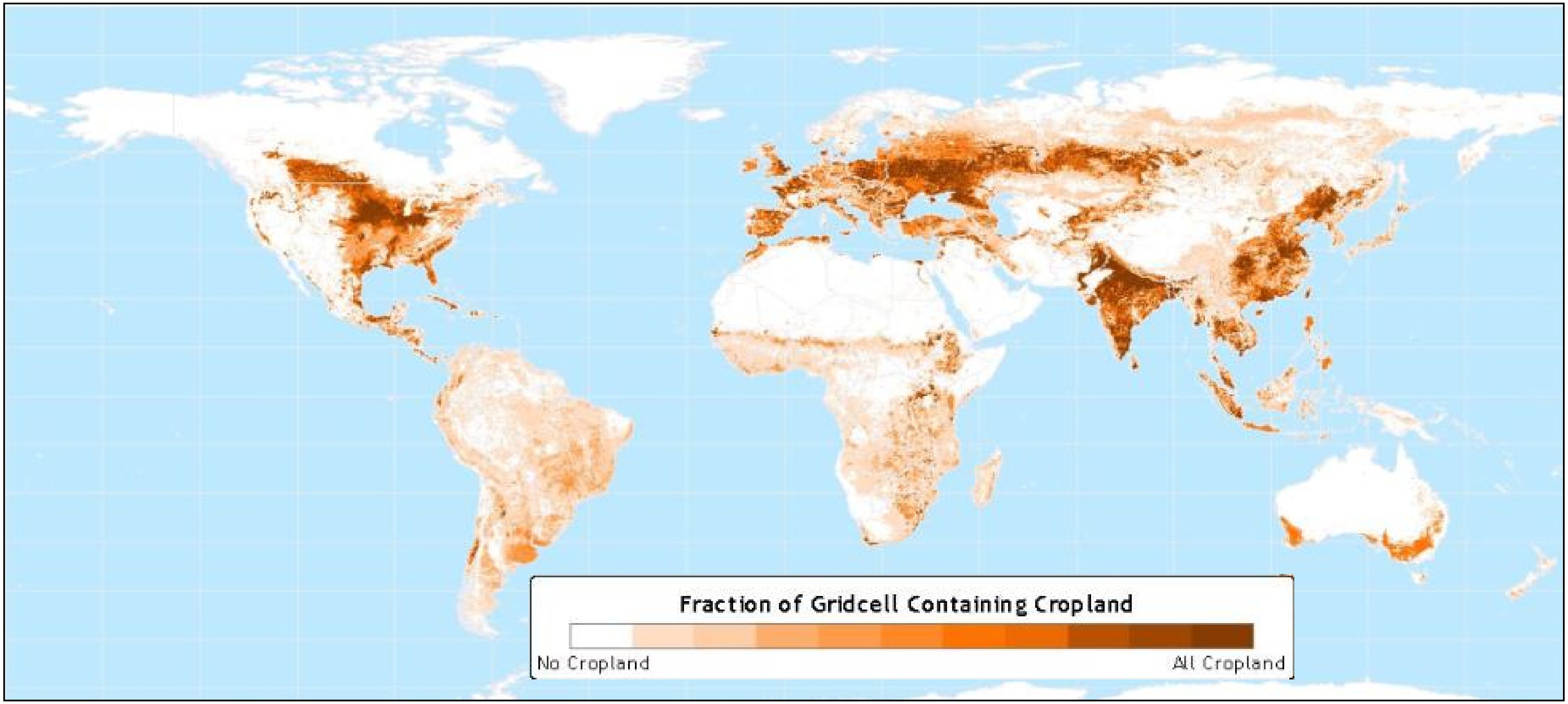
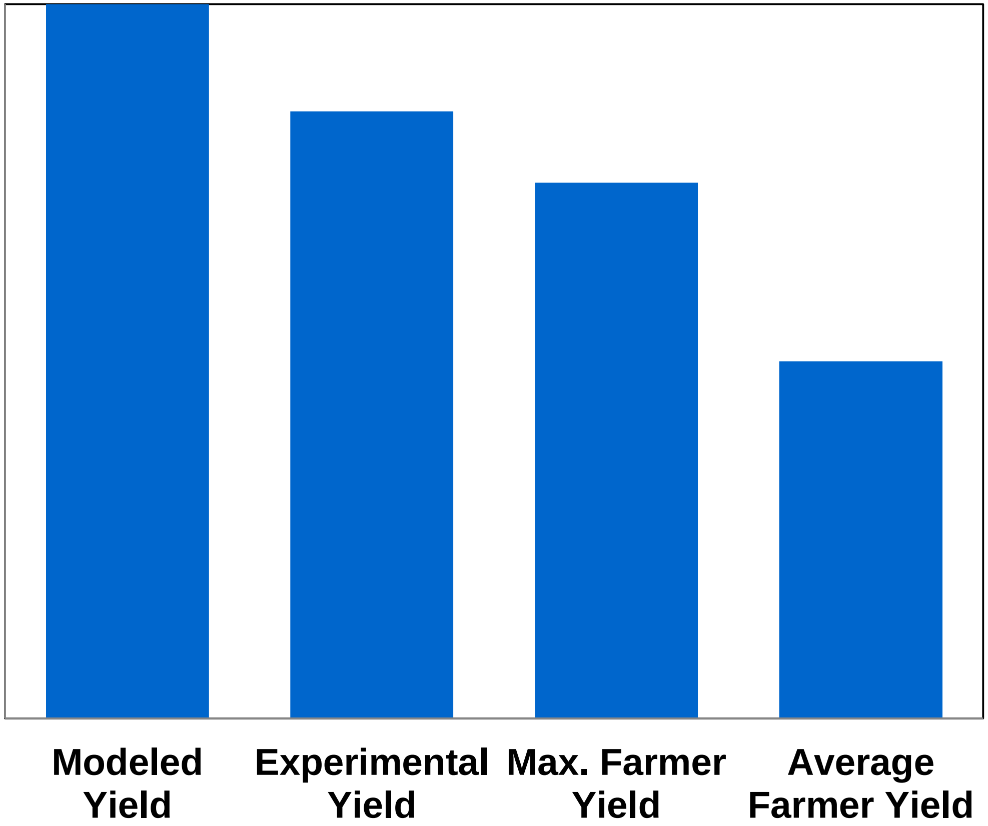
Croplands of the Earth



Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

Yield gaps* show room for improvement

- Yield gaps for major world cropping systems range from about 20-80% (Lobell, et al. 2009)



After Lobell et al., 2009

*Yield gap defined by some potential measure compared to average farmer yield

Projected source of growth in crop production to 2050*, percent

	Arable land expansion	Increases in cropping intensity	Yield increase
Developing countries	**21**	**8**	**71**
Sub-Saharan Africa	25	6	69
Near East/North Africa	-7	17	90
Latin America/Caribbean	30	18	52
South Asia	5	8	87
East Asia	2	12	86
World	**9**	**14**	**77**

**based on 2006 FAO baseline demand projections for 34 crops grown in 108 countries*

Source: Bruinsma (2009)

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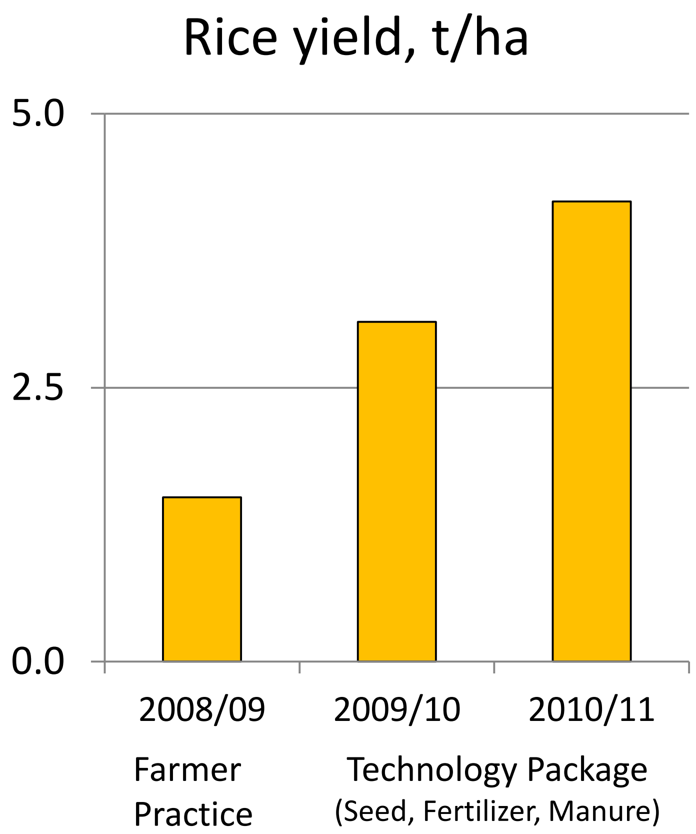
Madagascar village: irrigated rice yields 1 -1.5 t/ha

JICA Project for Rice Productivity Improvement in the Central Highlands of Madagascar



Japan International Cooperative Agency (JICA)

"Without the use of N fertilizers, we could not secure enough food for the prevailing diets of nearly 45% of the world's population, or roughly 3 billion people…"

Smil, V. 2011. Nitrogen cycle and world food production. *World Agriculture 2:9-13.*

How much crop yield is attributable to fertilization?

Agronomy Journal

Volume 97 January–February 2005 Number

FORUM

The Contribution of Commercial Fertilizer Nutrients to Food Production

W. M. Stewart,* D. W. Dibb, A. E. Johnston, and T. J. Smyth

ABSTRACT

Nutrient inputs in crop production systems have come under increased scrutiny in recent years because of the potential for environmental impact from inputs such as N and P. The benefits of nutrient inputs are often minimized in discussions of potential risk. The purpose of this article is to examine existing data and approximate the effects of nutrient inputs, specifically from commercial fertilizers, on crop yield. Several long-term studies in the USA, England, and the tropics, along with the results from an agricultural chemical use study and nutrient budget information, were evaluated. A total of 362 seasons of crop production were included in the long-term study evaluations. Crops utilized in these studies included corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), soybean [*Glycine max* (L.) Merr.], rice (*Oryza sativa* L.), and cowpea [*Vigna unguiculata* (L.) Walp.]. The average percentage of yield attributable to fertilizer generally ranged from about 40 to 60% in the USA and England and tended to be much higher in the tropics. Recently calculated budgets for N, P, and K indicate that commercial fertilizer makes up the majority of nutrient inputs necessary to sustain current crop yields in the USA. The results of this investigation indicate that the commonly cited generalization that at least 30 to 50% of crop yield is attributable to commercial fertilizer nutrient inputs is a reasonable, if not conservative estimate.

MODERN HIGH YIELD crop production and its associated inputs have come under intense scrutiny over the past several years. Concerns expressed often

technology and intensified production often involve a greater need for commercial fertilizer nutrients to avoi nutrient depletion and ensure soil quality and crop pro ductivity. The need for increased inputs correctly raise questions about associated risks. Potential risks are of ten widely publicized while the associated benefits o an abundant, affordable, and healthful food supply ca be overlooked or understated. To judge any such prac tice or system, the risks must be evaluated in compariso with the benefits. While misuses of agricultural fertiliz ers have undoubtedly occurred and concerns about how fertilizers affect the environment have sometimes bee overstated, the purpose of this article is not to addres these issues but to provide evidence of the impact com mercial fertilizers have had on agricultural production

Several attempts have previously been made to esti mate how much of the crop production in the USA i attributable to commercial nutrient inputs. These esti mates usually range from about 30 to 50% for majo grain crops (Nelson, 1990). Determining these estimate presents significant challenges, and assumptions are al ways required regardless of the approach taken. On difficulty that arises is that crops respond differently t application of a specific plant nutrient. For example corn response to N fertilizer is much greater than th

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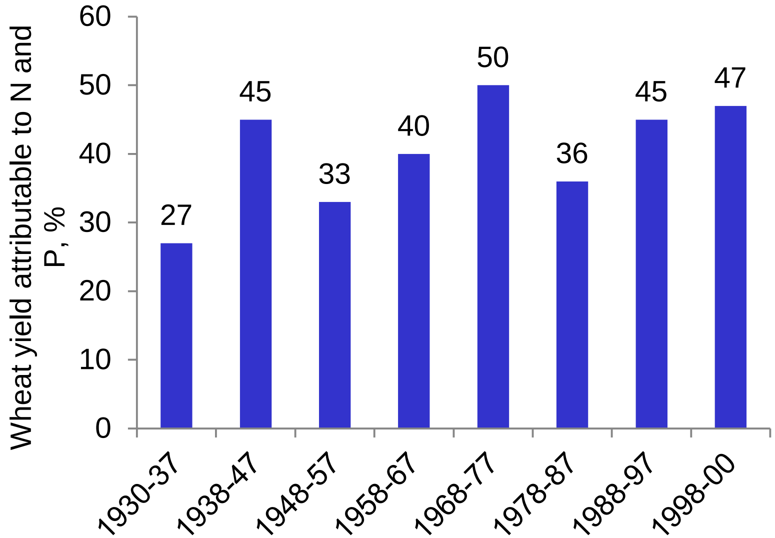
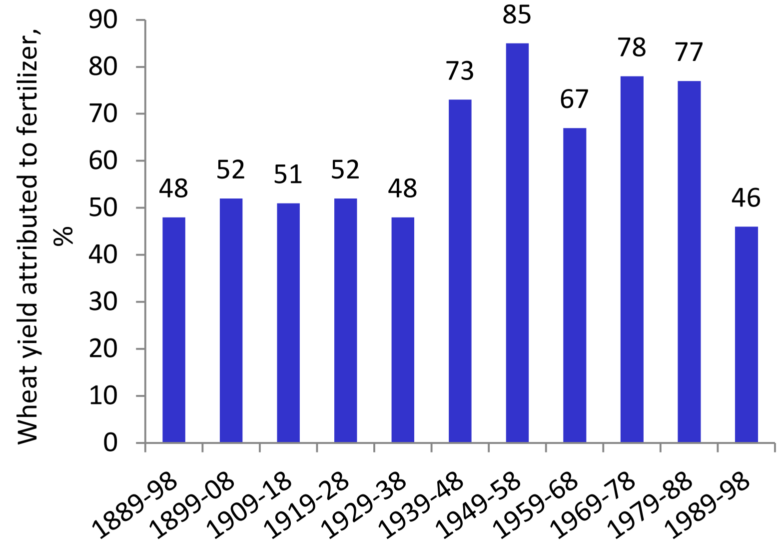
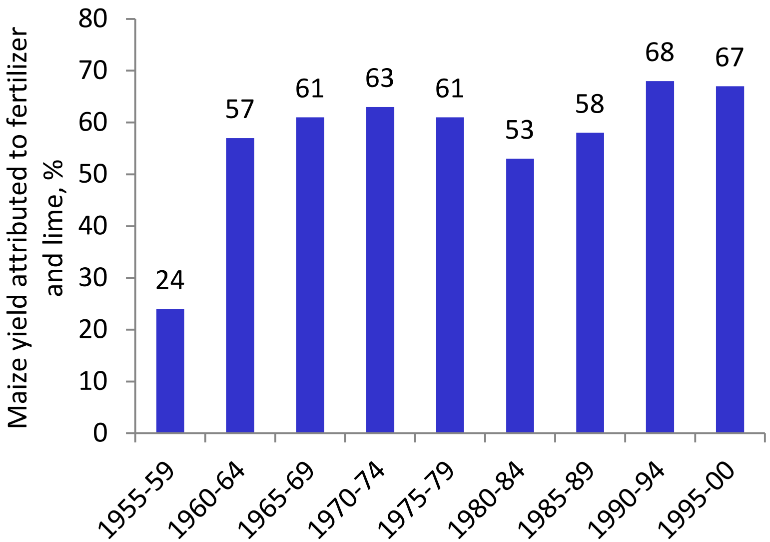
OSU Magruder Plots: Mean = 40%



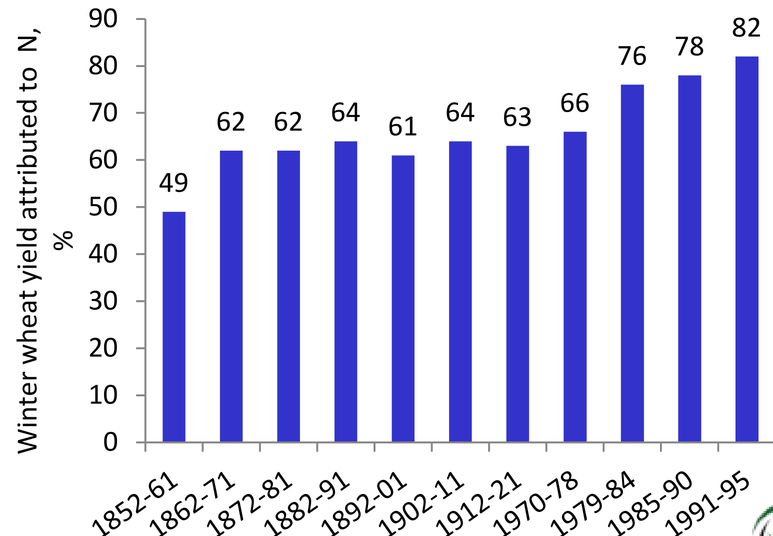
U of MO Sanborn Field Plots: Mean = 62%



U of IL Morrow Plots: Mean = 57%

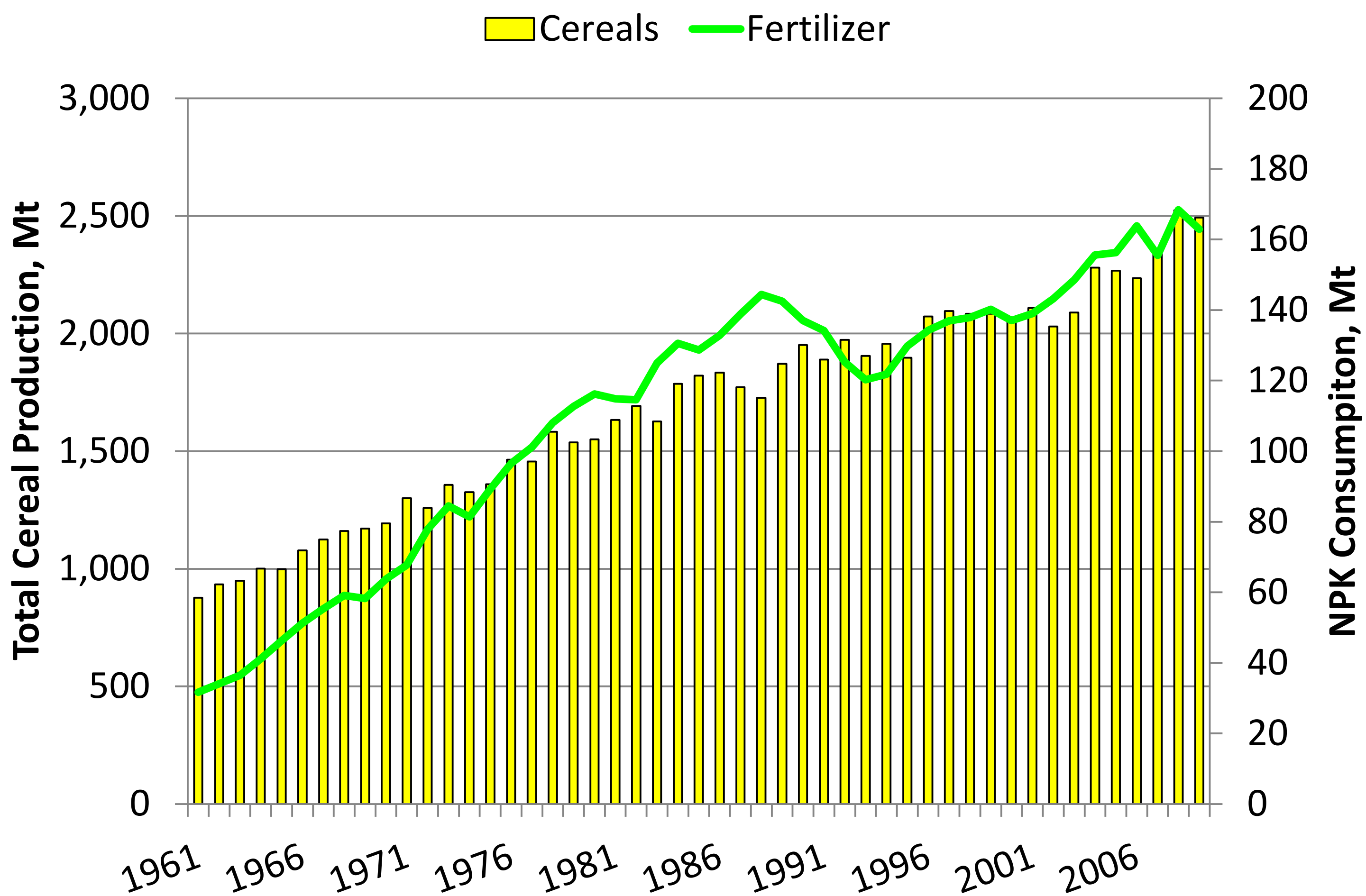


Broadbalk Experiment, Rothamsted: Mean = 64%



After Stewart et al. 2005

Role of fertilizers in food production is well recognized, but …



Source: FAO and IFA

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but, …
inundated with negative press

The New York Times

Environment

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Chemicals in Farm Runoff Rattle States on the Mississippi

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EPA Science Advisory Board Urges Action on Nitrogen Pollution

by Erik Stokstad on 19 August 2011, 6:25 PM | 4 Comments

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Editor's Note: The EPA report discusses reactive nitrogen compounds, not the inert nitrogen gas found in the atmosphere.

The Environmental Protection Agency and other agencies should take action to cut the amount of nitrogen pollution by 25% over the next 1 to 2 decades, according to EPA's external scientific advisers. EPA, for example, can more tightly regulate emissions from power plants. In a report released today, the EPA's Science Advisory Board (SAB) also urged the agency to revamp its regulatory and scientific approaches to dealing with nitrogen's

United States
Department of
Agriculture

USDA

Economic
Research
Service

Economic
Research
Report
Number 127

September 2011

Nitrogen in Agricultural Systems: Implications for Conservation Policy

Marc Ribaudo, Jorge Delgado, LeRoy Hansen, Michae
Roberto Mosheim, and James Williamson

Abstract

“... Fi

WATER POLLUTION: Most farmers improperly apply nitrogen fertilizers -- USDA

Amanda Peterka, E&E reporter
Published: Thursday, September 29, 2011

Two-thirds of U.S. farmers who treat their fields with nitrogen fertilizers apply it improperly, spurring runoff that damages waterways and contributes to global warming, according to a new report from federal scientists. The Agriculture Department's Economic Research Service found only 35 percent of crop acres treated with nitrogen met three criteria for proper application rates, timing and methods. And applications in other areas may have failed to meet at least one application criterion, the researchers said.

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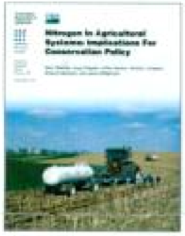
ERS *Report Summary*

Economic Research Service September 2011 U.S. Department of Agriculture



This is a summary of an ERS report.

Find the full report at *www.ers.usda.gov/publications/err127*

Nitrogen In Agricultural Systems: Implications For Conservation Policy

Marc Ribaudo, Jorge Delgado, LeRoy Hansen,
Michael Livingston, Roberto Mosheim, and James Williamson

What Is the Issue?

Nitrogen is an agricultural input that is critical for crop production. Human-induced production and release of reactive nitrogen has greatly affected the Earth's natural balance of nitrogen, contributing to changes in ecosystems, both beneficial and harmful, including increased agricultural productivity in nitrogen-limited areas, ozone-induced injury to crops and forests, over-enrichment of aquatic ecosystems, biodiversity losses, visibility-impairing haze, and global climate change. Incentives for encouraging farmers to adopt improved nitrogen management can take many forms, from purely voluntary to regulatory. Designing a cost-effective policy requires that factors influencing fertilizer use be fully understood. Also, an understanding of how farmers are likely to respond to different incentives may help policymakers assess potential environmental tradeoffs driven by nitrogen's ability to change forms and cycle through different environmental media.

What Did the Study Find?

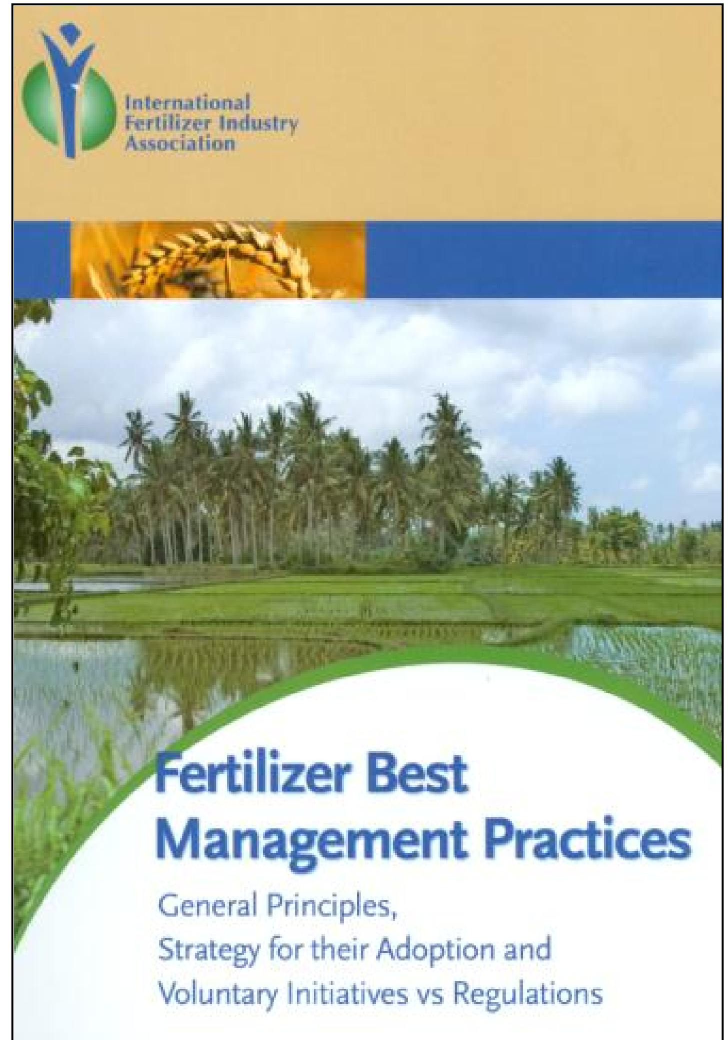
- Emission of reactive nitrogen to the environment can be reduced by matching nitrogen applications more closely with the needs of growing crops. This can be achieved by adopting three "best management practices" (BMPs):
  - *Rate*: Applying an amount of nitrogen at a rate that accounts for all other sources of nitrogen, carryover from previous crops, irrigation water, and atmospheric deposits.
  - *Timing:* Applying nitrogen as close to the time that the crop needs it as is practical (as opposed to the season before the crop is planted).
  - *Method:* Injecting or incorporating the nutrients into the soil to reduce runoff and losses to the atmosphere.
- Among all U.S. field crops planted in 2006 that received nitrogen fertilizers, 35 percent are estimated to have met all three of the nutrient BMPs. For the remaining cropland, improvements in management are needed to increase nitrogen use efficiency (i.e., reduce the amount of nitrogen available for loss to the environment).

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

International Fertilizer Industry Association (IFA) initiative on fertilizer BMPs

- International workshop in Brussels (2007) to define principles of FBMPs and a strategy for wider adoption

- Fixen … idea of a global framework from which FBMPs could be adopted



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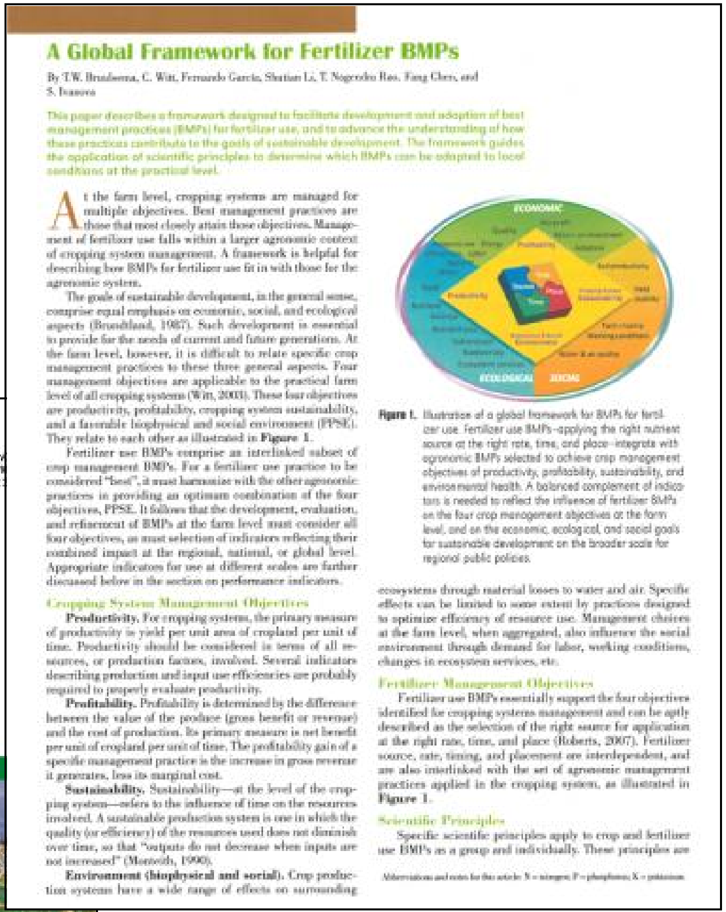
... concept developed into a global framework for nutrient stewardship



A Global Framework for Fertilizer BMPs

By T.W. Bruulsema, C. Witt, Fernando Garcia, Shutian Li, T. Nagendra Rao, Fang Chen, and S. Ivanova

This paper describes a framework designed to facilitate development and adoption of best management practices (BMPs) for fertilizer use, and to advance the understanding of how these practices contribute to the goals of sustainable development. The framework guides the application of scientific principles to determine which BMPs can be adapted to local conditions at the practical level.

At the farm level, cropping systems are managed for multiple objectives. Best management practices are those that most closely attain those objectives. Management of fertilizer use falls within a larger agronomic context of cropping system management. A framework is helpful for describing how BMPs for fertilizer use fit in with those for the agronomic system.

The goals of sustainable development, in the general sense, comprise equal emphasis on economic, social, and ecological aspects (Brundtland, 1987). Such development is essential to provide for the needs of current and future generations. At the farm level, however, it is difficult to relate specific crop management practices to these three general aspects. Four management objectives are applicable to the practical farm level of all cropping systems (Witt, 2003). These four objectives are productivity, profitability, cropping system sustainability, and a favorable biophysical and social environment (PPSE). They relate to each other as illustrated in **Figure 1**.

Fertilizer use BMPs comprise an interlinked subset of crop management BMPs. For a fertilizer use practice to be considered "best", it must harmonize with the other agronomic practices in providing an optimum combination of the four objectives, PPSE. It follows that the development, evaluation, and refinement of BMPs at the farm level must consider all four objectives, as must selection of indicators reflecting their combined impact at the regional, national, or global level. Appropriate indicators for use at different scales are further discussed below in the section on performance indicators.

Cropping System Management Objectives

Productivity. For cropping systems, the primary measure of productivity is yield per unit area of cropland per unit of time. Productivity should be considered in terms of all resources, or production factors, involved. Several indicators describing production and input use efficiencies are probably required to properly evaluate productivity.

Profitability. Profitability is determined by the difference between the value of the produce (gross benefit or revenue) and the cost of production. Its primary measure is net benefit per unit of cropland per unit of time. The profitability gain of a specific management practice is the increase in gross revenue it generates, less its marginal cost.

Sustainability. Sustainability—at the level of the cropping system—refers to the influence of time on the resources involved. A sustainable production system is one in which the quality (or efficiency) of the resources used does not diminish over time, so that "outputs do not decrease when inputs are not increased" (Monteith, 1990).

Environment (biophysical and social). Crop production systems have a wide range of effects on surrounding ecosystems through material losses to water and air. Specific effects can be limited to some extent by practices designed to optimize efficiency of resource use. Management choices at the farm level, when aggregated, also influence the social environment through demand for labor, working conditions, changes in ecosystem services, etc.

Figure 1. Illustration of a global framework for BMPs for fertilizer use. Fertilizer use BMPs–applying the right nutrient source at the right rate, time, and place–integrate with agronomic BMPs selected to achieve crop management objectives of productivity, profitability, sustainability, and environmental health. A balanced complement of indicators is needed to reflect the influence of fertilizer BMPs on the four crop management objectives at the farm level, and on the economic, ecological, and social goals for sustainable development on the broader scale for regional public policies.

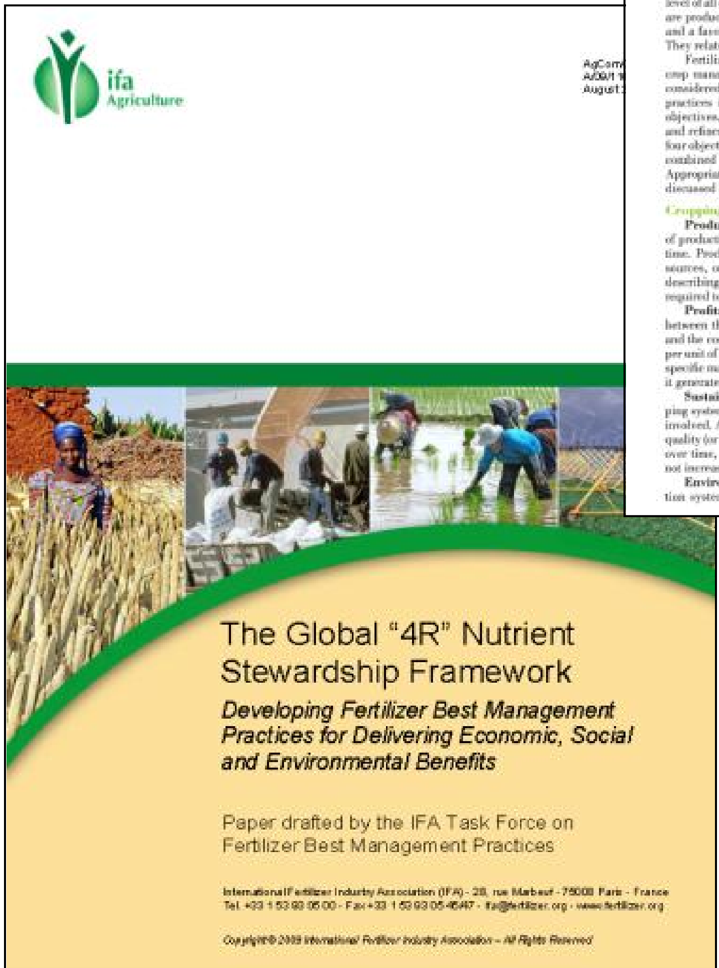
Fertilizer Management Objectives

Fertilizer use BMPs essentially support the four objectives identified for cropping systems management and can be aptly described as the selection of the right source for application at the right rate, time, and place (Roberts, 2007). Fertilizer source, rate, timing, and placement are interdependent, and are also interlinked with the set of agronomic management practices applied in the cropping system, as illustrated in **Figure 1**.

Scientific Principles

Specific scientific principles apply to crop and fertilizer use BMPs as a group and individually. These principles are

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium.



ifa Agriculture

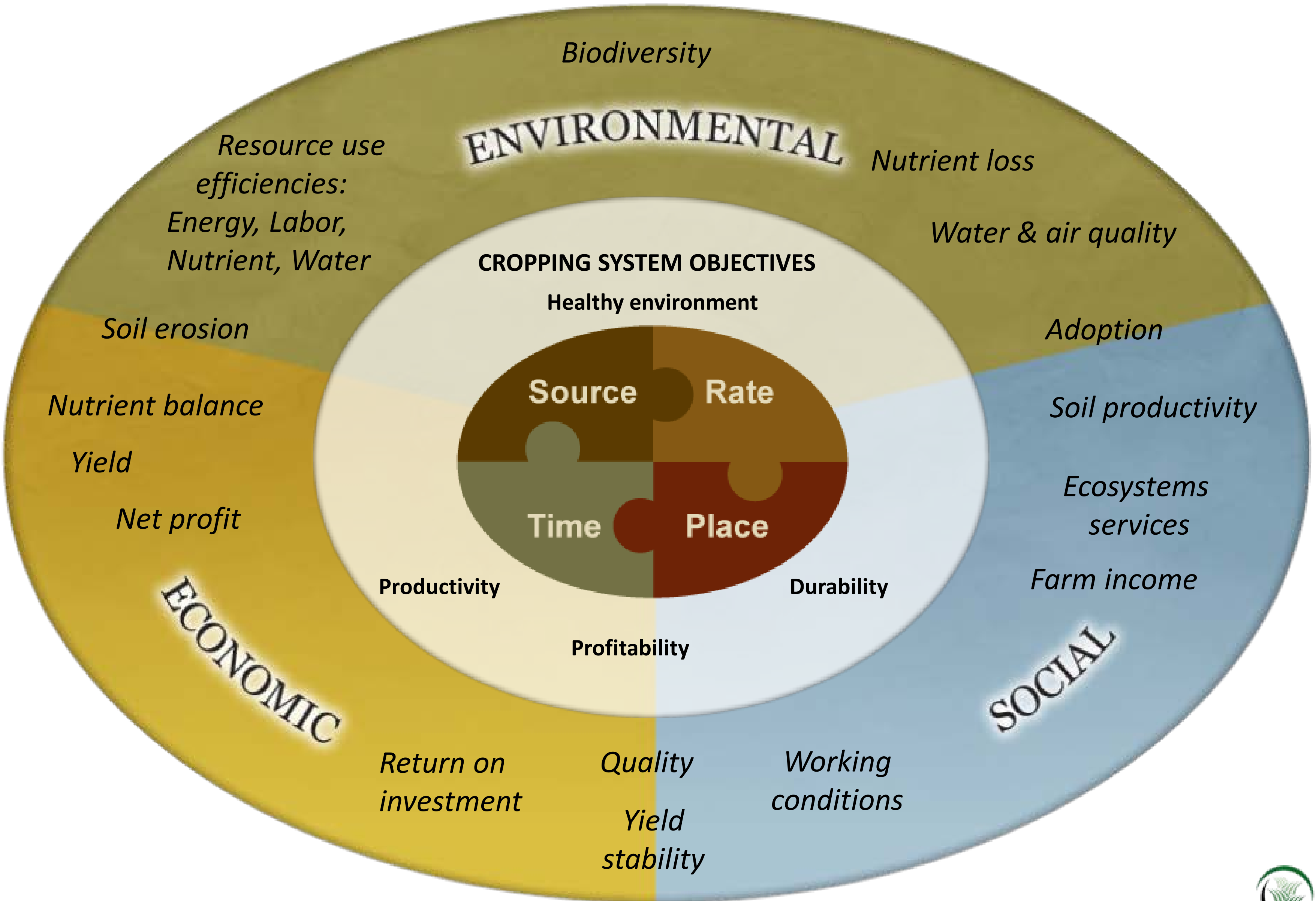
The Global "4R" Nutrient Stewardship Framework

Developing Fertilizer Best Management Practices for Delivering Economic, Social and Environmental Benefits

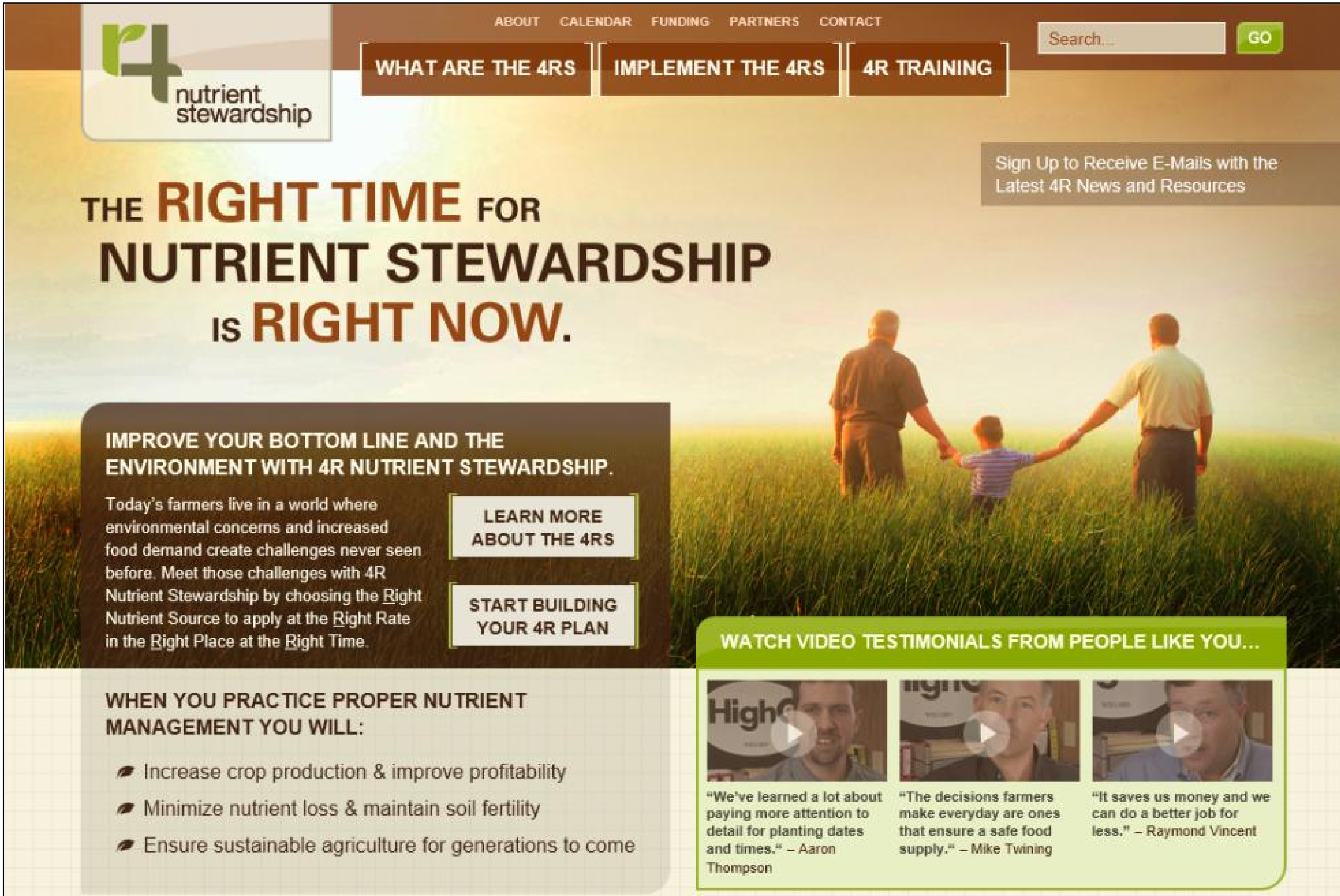
Paper drafted by the IFA Task Force on Fertilizer Best Management Practices

International Fertilizer Industry Association (IFA) - 28, rue Marbeuf - 75008 Paris - France
Tel. +33 1 53 93 05 00 - Fax +33 1 53 93 05 45/47 - ifa@fertilizer.org - www.fertilizer.org

4R Nutrient Stewardship



http://www.nutrientstewardship.com



4Rs provide a voluntary option to address nutrient related regulatory issues

- Endorsed by: NRCS, AAPFCO, CTIC, and AFBF
- Implemented within Alberta's N_2O reduction protocol (NERP) and are under consideration in other provinces
  - a proposed system to reward producers for adoption of sustainable practices reducing N_2O emissions per unit of production

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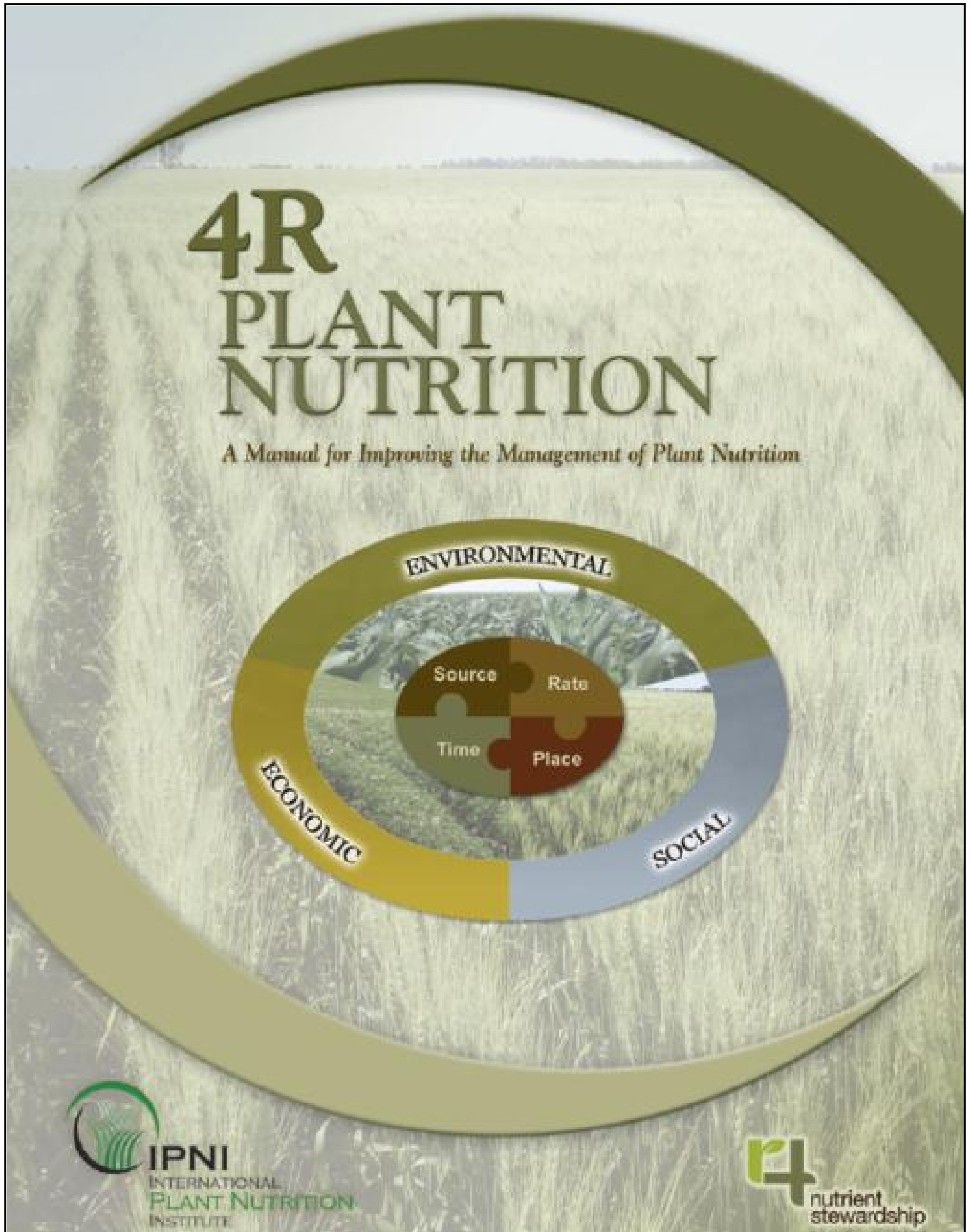
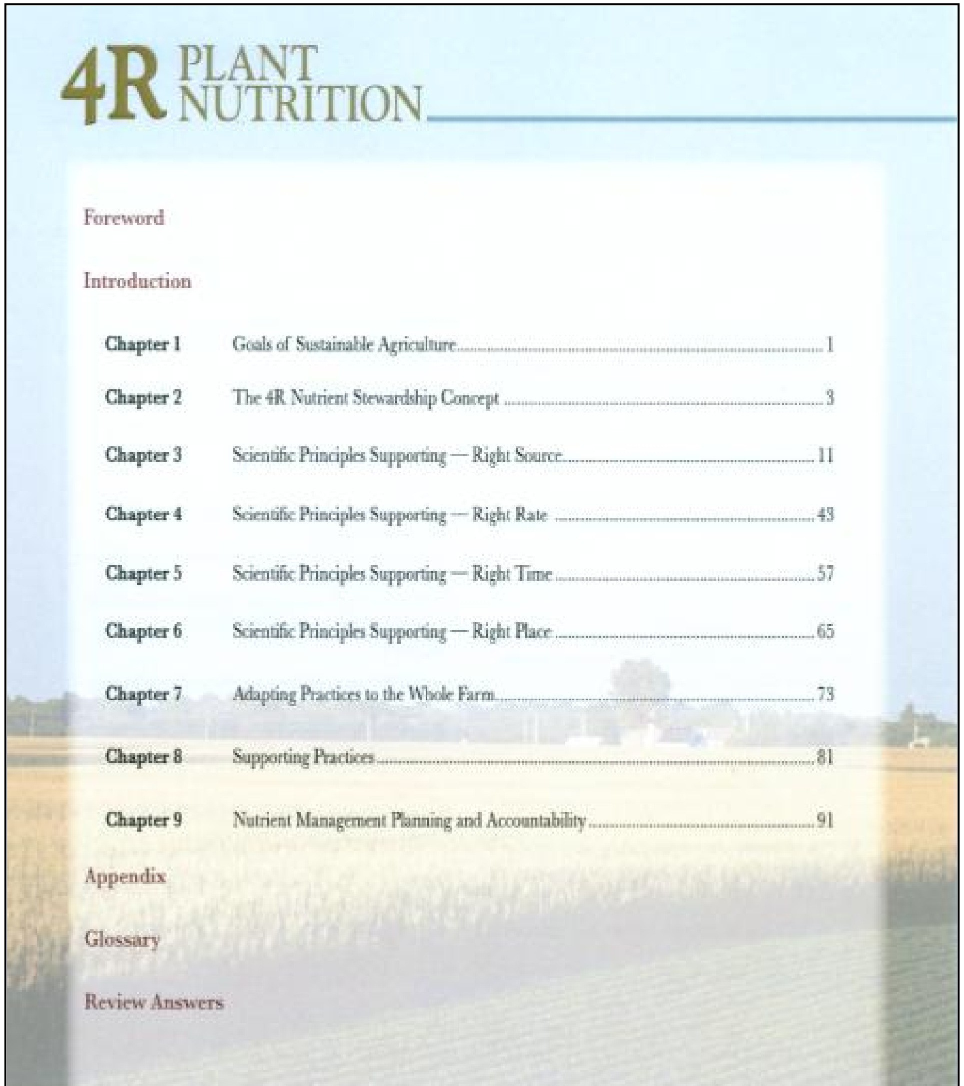


… to explain the concept of 4R Nutrient Stewardship and to outline the scientific principles that define the four "rights".

The manual incorporates the scientific principles behind each of the Rs with supporting practices.



4R PLANT NUTRITION

Includes:

- ✓ adoption of practices on the farm
- ✓ approaches for nutrient management planning
- ✓ measuring sustainability performance.
- ✓ case studies illustrating various applications of 4Rs

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For example …

Chapter 5

SCIENTIFIC PRINCIPLES SUPPORTING - RIGHT TIME

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

- **Assess timing of plant uptake.** Fertilizer 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.

5.1 Assessing timing of plant uptake

Assessing crop uptake dynamics and patterns can be an important component in determining appropriate timing of nutrient application. The uptake of major nutrients and dry matter accumulation patterns are similar for most crops and usually follow a sigmoid or "S" shaped curve (**Figure 5.1**). This is characterized by rather slow early uptake, increase to a maximum during the rapid growth phase, and decline as the crop matures. Rate of plant nutrient uptake is thus not

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Review questions …

consistent throughout the season. Applications timed and targeted at specific growth stages may be beneficial to crop yield and/or quality in some production systems for some nutrients, most notably N. Timed and targeted applications may also be beneficial to reduce environmental impacts of nutrient loss from soil.

Many examples of timing fertilizer applications based on stage of crop growth can be given, but only a few will be offered here.

- **N and K application to cotton.** The majority of both N and K in cotton production are taken up after the appearance of first flower, or the onset of the reproductive phase. It is important to make sure that adequate amounts of these nutrients are available when demand is highest. In some circumstances foliar application of N and even K starting at first flower can improve cotton yield and/or quality.

- **N application to small grains such as wheat.** Most wheat recommendations call for some N applied at planting, with the majority topdress applied by (before) jointing. By the time wheat begins heading later in the season the majority of N has been taken up, and if good N management practices were not previously used, then yield will suffer. Although yield has been determined by the heading stage, late season application of N during this stage in some wheat production systems can increase grain protein. This may be beneficial where a premium is paid for protein. Care should be taken in these late-season applications to avoid damage that might impact grain fill (e.g. flag leaf burn).

- **Fruit trees.** Fruit trees are perennial plants whose characteristics of nutrient uptake and distribution are different from most field crops. A good example is grape plants that have three distinct stages for nutrient uptake: the period between sprouting/early foliage growth and new shoot/fruit development, the period between early fruit development and fruit expansion, and the period after fruit expansion up to fruit maturity.

- **Semi-perennial tropical crops.** For crops such as oil palm or banana that have continuous harvest, the right timing will depend mostly on weather patterns and opportunity for application. It is important nonetheless, to take into account anticipated peaks of productivity, for instance when rains start after a dry period.

Another consideration for timing is crop sensitivity to specific nutrient deficiencies, often related to soil conditions. Some crops are more prone to certain deficiencies than others, therefore susceptible crops may require specific fertilizer application timing.

- **Ca for peanut.** Peanuts are especially sensitive to Ca deficiency. High levels of available Ca are needed in the soil zone where peanuts are developing, and thus pre-bloom applications of soluble Ca materials (i.e. calcium sulfate or calcium nitrate) are sometimes made to peanuts.

- **Mn for soybean.** Early season foliar applications of manganese (Mn) are often made to soybean in areas when deficiency symptoms appear on the plant tissue.

Questions ?

1. The 4Rs of fertilizer management are
   a. independent.
   b. interdependent.
   c. inverse.
   d. irrelevant.

2. Which of the following is important when considering right time of nutrient application?
   a. Environmental consequences.
   b. Product color.
   c. Herbicide program.
   d. Fertilizer density.

3. Where N is fall-applied, an important consideration is soil temperature. Soil temperature should consistently be below __ °F (°C) before applying N in the fall.
   a. 50 (10.0).
   b. 60 (15.6).
   c. 70 (21.1).
   d. 80 (26.7).

4. Which of the following forms of N should be avoided for fall (over winter) applications?
   a. Ammonium.
   b. Nitrate.
   c. Urea.
   d. Ammonia.

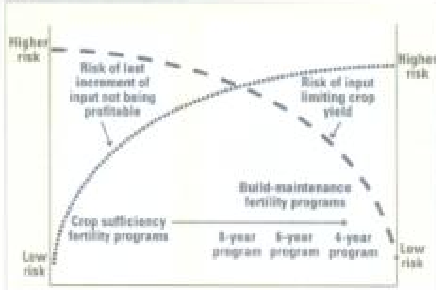
5. Nutrient demand is not consistent throughout the season, and accumulation follows a __ shaped curve.
   a. sigmoid.
   b. rhomboid.
   c. spheroid.
   d. linear.

6. Which of the following is a pathway of N loss from the soil-plant system?
   a. Nitrification.
   b. Mineralization.
   c. Denitrification.
   d. Immobilization.

Learning modules with supporting data …

M

Module 5.2-1 High soil test levels allow flexibility in timing of P and K application. The Kansas State University (KSU) soil testing laboratory makes fertilizer recommendations based on the sufficiency approach or the build-maintenance approach to nutrient management. The customer chooses which of these approaches best fits their operation. The goal of the sufficiency approach is to apply just enough P and/or K to maximize profitability in the year of application, but minimize nutrient applications and fertilizer costs. The objective of build-maintenance fertility programs is to manage P and/or K soil test levels as controllable variables. At low soil test values, recommendations are intended to apply enough P and/or K to both meet the nutrient needs of the immediate crop and to build soil test levels to a non-limiting value, above the critical level. KSU faculty generated some classic information and figures on relationships among soil test level, crop yield, and fertilizer recommendations. The generalized relationship in the following graph shows how as soil test level increases flexibility in timing also increases, and the risk of input (fertilizer) limiting crop yield is reduced. **Source:** Leikam, D.F., et al. 2003. *Better Crops with Plant Food.* Vol. 87, No. 3, p. 6-10.



Module 5.3-1 Spring applied N increases N recovery and profit for corn in southern Minnesota. A long-term U.S. Corn Belt study conducted in Waseca, MN compared fall application of ammonia with and without a nitrification inhibitor (N-Serve, or nitrapyrin) to spring preplant application without the nitrification inhibitor. The table below shows the result of this 15-year study. In short, the data show that applications of N (as ammonia) in the late fall with the nitrification inhibitor and spring preplant were best management practices. However, it should be noted that when spring conditions were wet the spring application resulted in substantially greater yield and profit than fall+N-Serve. Overall, the least risky timing option was spring preplant, followed by fall+N-Serve, with fall (no inhibitor) being the most risky and least efficient. Thus, N application for maize should be avoided in areas with warm/open winters, and where it is appropriate it should be delayed until soil temperature is below 10°C (50°F) and expected to continue cooling so as to slow nitrification in the fall and avoid increased nitrate leaching and/or denitrification. Use of a nitrification inhibitor can help further delay nitrification, but even with an inhibitor, fall application, where appropriate, should be delayed until soil temperature cools. **Source:** Randall, G. 2008. *In* Proc. 20th Annual Integrated Crop Manag. Conf., Dec. 10-11, Iowa State Univ., Ames. p. 225-235.

Years were 1987-2001 Parameter	Time of N Application		
	Fall	Fall + N-Serve	Spring
15-Yr Avg. Yield (bu/A)	144	153	156
15-Yr Avg. Economic return over fall N ($/A/yr)[1]	--	$28	$48
15-Yr Avg. FW NO_3-N Conc. (mg/L)	14.1	12.2	12
7-Yr Avg. Yiel (bu/A)[2]	131	146	158
7-Yr Avg. Economic return over fall N ($/A/yr)[1]	--	$52	$108
Nitrogen recovery in grain (%)[3]	38	46	47

[1] Based on N @ $0.70/lb N; N-Serve = $8.00/A; Corn = $4.00/bu

[2] Only those seven years when a statistically significant yield difference occurred among treatments.

[3] Nitrogen recovery in the corn grain as a percent of the amount of fertilizer N applied.

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Applying 4Rs …

Chapter 7

ADAPTING PRACTICES TO THE WHOLE FARM

THE UNIVERSAL 4R PRINCIPLES previously discussed are used to select practices with the highest probability of meeting management objectives for the cropping systems of specific sites and more broadly, the economic, social, and environmental goals of sustainable development. Each of the resulting best practices should be consistent with the principles of all four "rights". Local conditions can influence the decision on practice selection, right up to and including the day of implementation.

7.1 Nutrient Management Practices within Cropping Systems

Nutrient management practices are always nested in cropping systems within which other management and site factors such as tillage, drainage, cultivar selection, etc. can greatly influence the effectiveness of a specific practice. Factors such as genetic yield potential, weeds, insects, diseases, mycorrhizae, soil texture and structure, drainage, compaction, salinity, temperature, precipitation and solar radiation can all interact with plant nutrition and nutrient management practice effectiveness.

7.2 Role of Adaptive Management

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. Thorup and Stewart wrote in 1988:

"Research performed on university farms and by professional researchers on farmer's fields are extremely valuable. However, they do not necessarily relate directly to every farmer's fields. Soils have tremendous variability from one farm to another. Cultural practices vary markedly from one farmer to another. Even climatic factors can vary significantly over very short distances. All of these factors affect possible responses from fertilizer programs. All of this means that the farm operator who survives in the 1990s and beyond is going to have to experiment a little on his own, keep accurate records, be flexible to government programs, world market price fluctuations and soil and water conservation needs."

Though the term did not yet exist, these agronomists were describing adaptive nutrient management.

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Case studies …

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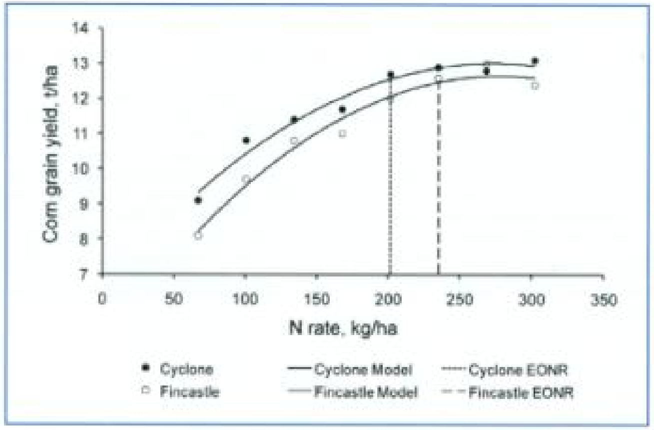
Case study 7.2-1 Selecting N Rates for Corn Based on a Local Study. An example of adaptive N management comes from the U.S. Midwest. In this example (Murrell, 2004), an agronomist sought to make improvements upon the N rates recommended by the university in his state. The agronomist had already established a site-specific management program in which soil types were used as the basis for creating management zones within fields. Phosphorus, K, and lime were varied across these zones as their individual needs dictated. However, N was still being applied at one uniform rate across the field, and the university did not provide guidance for site-specific applications.

To determine what differences, if any, should be made to the recommended N rates for the two predominant soil types in his area, the agronomist conducted a 5-yr. study that examined maize response to various N rates for the two soil types: a Fincastle silt loam and a Cyclone silt loam. Nitrogen rates were selected to encompass local farmer management practices as well as university recommendations. The study was designed so that maize always followed soybean, reflecting local cropping practices.

The Figure shows the 4-yr. average results (a drought year excluded), indicated that the Cyclone silt loam, which was higher in organic matter, had an economically optimum N rate (EONR) 35 kg/ha lower than that recommended by the university. The Fincastle silt loam, which was lower in organic matter, still needed the fully recommended rate (235 kg N/ha). These results were counter to the opinion held by the farmers in the area that the Cyclone soil, because it was more productive, should receive more, not less, N. Results from this experiment were used to create new recommendations for the Cyclone soil and created the scientific basis for the agronomist to begin a new site-specific N program that varied N rate according to soil types within the field.
Source: Murrell, T.S. 2004. p. 155-165. *In* A.R. Mosier et al. (eds.) Agriculture and the nitrogen cycle: Assessing the impacts of fertilizer use on feed production and the environment. Scope 65. Island Press, Washington, DC. p.155-165.



4Rs for nutrient management plans …

Chapter 9

NUTRIENT MANAGEMENT PLANNING AND ACCOUNTABILITY

Managing plant nutrition according to principles of 4R Nutrient Stewardship includes accountability for full impacts on sustainability: economic, environmental and social. This chapter discusses and compares approaches used for nutrient management planning and measuring sustainability performance.

9.1 Nutrient Management Plans

In many regions where the intensity of livestock and poultry production has resulted in nutrient surpluses (where more nutrients are excreted in manure than are taken up by crops in the fields), formal nutrient management plans detailing all aspects of nutrient applications have been made mandatory. While some regions have achieved good compliance, limitations to this approach include an onerous amount of work to assemble the detailed information required, lack of flexibility in making changes to respond to weather, markets and other dynamic site-specific factors, and lack of connection to the farm business plan and the goals it entails.

An appropriate nutrient management plan should serve two purposes. First, it should track and record all crop management practices applied relevant to plant nutrition as part of the adaptive management cycle. This information is primarily for the benefit of the manager and advisers, for use in making decisions on practices to adopt or revise for the next production cycle, as discussed in Chapters 2 and 7. Second, nutrient management plans need to track performance, the outcome of implementing a set of practices.

People are increasingly asking for information on performance and its improvement over time is increasingly sought by stakeholders. Purchasers of a crop product want to know its environmental footprint based on whole-system performance. For example, large food industry corporations are preparing to launch global initiatives to promote sustainable agriculture, to help businesses put an economic value on the environmental and social impacts of their supply chains. One such initiative focuses on

> …"*resource management, such as water, energy and emissions, as well as farm productivity, preservation of soil fertility, and biodiversity. It will also cover social impacts, such as the effects on farming communities, human rights, and compliance with local laws, standards and regulations.*" (Businessgreen.com)

9.2 4R Nutrient Stewardship Plans

The process of setting sustainability goals should include selecting specific performance targets. Performance is assessed through measures and indicators related to economic, environmental and social outcomes. It relates to all outcomes considered important to stakeholders (i.e. farmers, agribusiness, consumers, and the general public).

Example worksheets …

9.7 Example 4R Plan Worksheet

Attached below is an example is of a worksheet that could be used by a crop consultant or crop advisor to help a farmer develop a nutrient stewardship plan for a field.

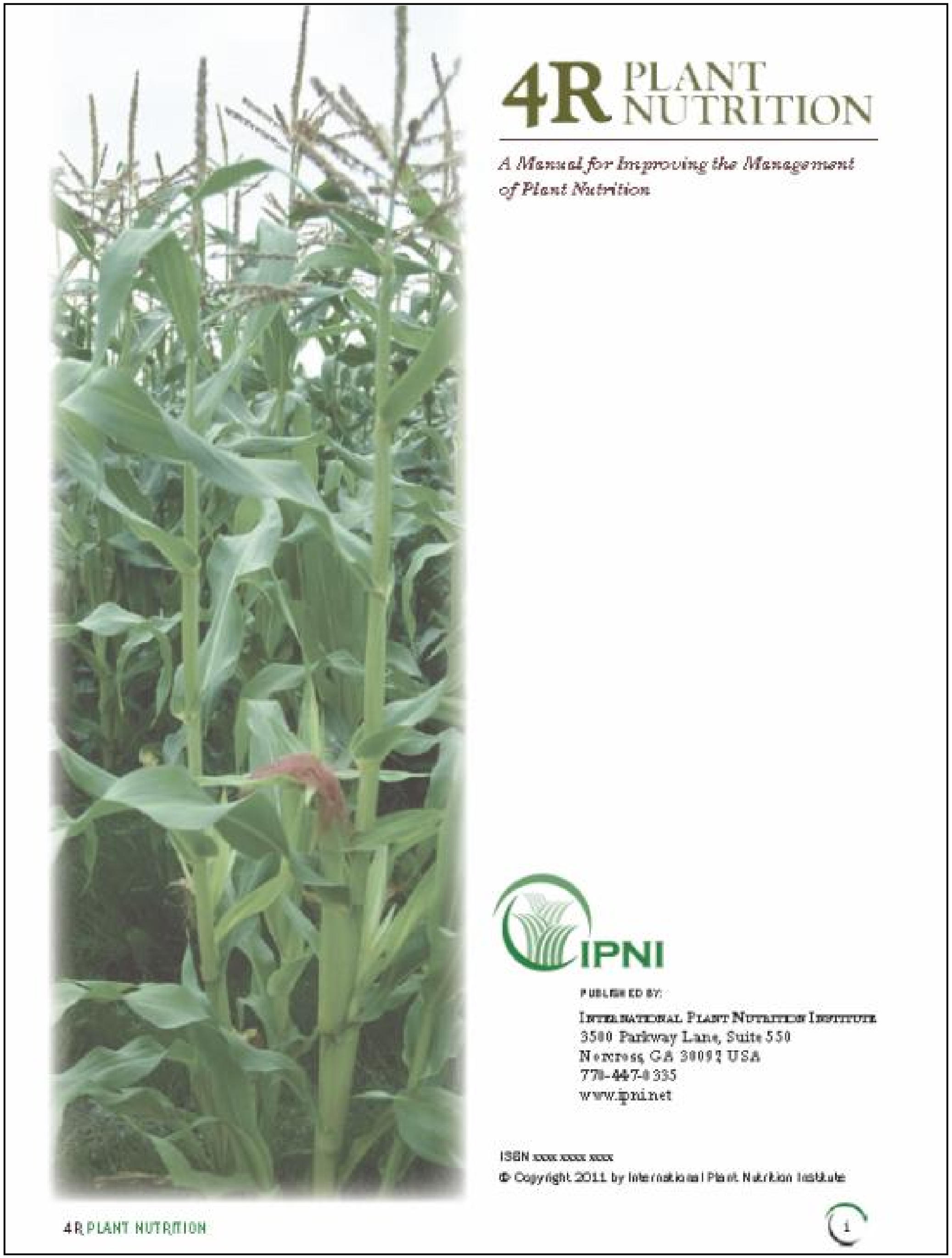
Enterprise Name	*Title*
Contact Information	*Farmer*
Contact Information	*Certified Crop Advisor, or Consulting Agronomist*

Enterprise Description	*Total number of fields or management zones, total crop area, crops grown, livestock and poultry, on-farm nutrient sources (i.e. manures, composts, and other organic materials).*

Sustainability Goals—and indicators related to nutrients		
	Goals	**Performance Indicator(s)** related to nutrient management for each goal
Economic		
Environmental		
Social		

Field Information *(for each field)*					
Field or Management Zone Name or Number					
Legal Location, GPS Coordinates, Description, or Map					
Area (size)					
Landscape Topography and Soil Drainage Characteristics					
Soil Characteristics		**Extractable Nutrients**			
Organic Matter		**P**		**Zn**	
Texture		**K**		**Mn**	
pH		**Mg**		**Other**	
CEC		**Ca**		**Other**	
Previous Crop					
Specific Crop/s *(for this planning event)*					
Realistic Target Yield *(projection of past five year trend)*					

Estimate of Nutrient Uptake							
N	P	K	S	Other	Other	Other	Other



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- Developing world — 4Rs will increase crops
- Developed world — 4Rs good for the environment

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