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Adaptive Nutrient Management

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Cover photo:

Corn stalks are tested for nitrogen content as part of a year-long testing cycle to determine whether the optimum amounts of nitrogen are being applied to the land for growing corn, without over-applying to pollute water supplies. Photo by Lynn Betts, NRCS.

Adaptive Nutrient Management

Introduction

Climate, fertilizer costs, supply and demand, international market influences, and commodity prices are major factors that often compromise a grower's ability to maximize profit in any given year. This technical note offers an adaptive management approach that will enable growers to use a data-driven process to refine nutrient management to better adapt to conditions encountered on their farms. The adaptive management approach can promote better nutrient use efficiency on individual farms or throughout farming communities by means of multifarm participatory activities.

Managing nutrients is critical to producers because it affects productivity and profitability and can have natural resources consequences both on and off the farm. Nutrients, especially nitrogen and phosphorus, have multiple potential loss pathways in agricultural systems. The rate and magnitude of nutrient losses are influenced by a variety of factors that can interact with each other, including climate (weather conditions), management practices, and soil types. Consequently, there is no single nutrient management strategy that can be considered optimal for all cropping scenarios.

Traditionally, nutrient management strategies have been based on a "prediction only" strategy, without follow-up evaluations. Typical recommendation sources include university fertilizer recommendations (sometimes called Best Management Practices) or other guidelines that have been compiled to develop a prediction based upon past data collected and documented field experience. This strategy is simple and straight forward and requires little additional effort from the producer. However, it does not verify the performance of the recommendation on an individual field or farm and limits the ability of growers to further protect natural resources or refine their management to maximize production efficiency and profit. Under the prediction only strategy, future recommendations are not changed until the need becomes apparent to the technical expert developing and/or evaluating the recommendation. This can result in a repetitive cycle of unnecessary inputs and lower profits due to inefficient nutrient use.

The adaptive nutrient management approach can be used to:

- introduce new nutrient management technologies
- improve the nutrient use efficiency
- decrease the loss of nutrients to the environment
- use tools and/or techniques for nutrient management that are not currently in use
- evaluate post-season site-specific data that can be used to establish future optimal nutrient applications

Definition of adaptive nutrient management

Adaptive nutrient management is a process used to evaluate and adjust nutrient application and utilization strategies over time (multiple seasons). The process allows for continued adjustments of the NRCS-assisted Conservation Practice Standard (CPS) Code 590, Nutrient Management, to achieve better nutrient use efficiency. Adaptive nutrient management promotes the coordination of amount (rate), source, timing, and placement (method of application) of plant nutrients to minimize nutrient losses.

Nutrient Management Practice (CPS Code 590) and the adaptive nutrient management process

State-approved adaptive nutrient management activities are considered in compliance with the operation and maintenance requirements of the CPS Code 590, Nutrient Management, and step 9 of Title 180, National Planning Procedures Handbook (NPPH), Part 600, Subpart A, Section 600.11, The Planning Process. Nutrient management plans, including adaptive nutrient management tactics, will require periodic reviews involving the grower and a nutrient planning specialist.

The purpose of the review is to evaluate what has been learned and make adjustments to the plan, as needed, to further improve nutrient use efficiency and reduced nutrient losses.

How the adaptive nutrient management process works

Adaptive nutrient management is a process for evaluating and adjusting nutrient management based on data collected at the field level following a set of protocols. Adaptive management (fig. 1) can help producers make better nutrient management decisions leading to reduced nutrient inputs, higher yields, increased profits, and improved environmental benefits such as water quality. Four basic steps are involved:

Step 1 Develop the plan for the evaluation.

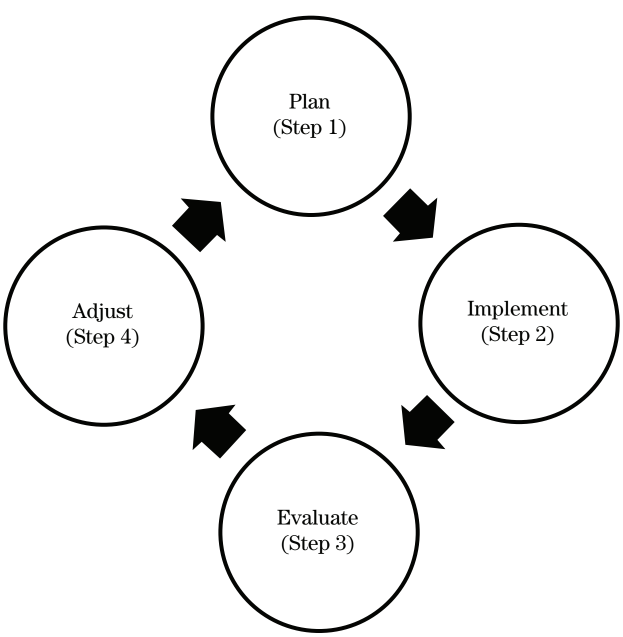
Step 2 Implement the nutrient management plan.

Step 3 Evaluate the plan based on lessons learned.

Step 4 Adjust the nutrient management.

Adaptive nutrient management is a repetitive evaluation and learning process, as compared with the more common prescriptive process used to develop nutrient management plans. Specifically, adaptive nutrient management tailors nutrient management for the grower's unique farming operation. The iterative evaluation also helps growers to better tailor conservation practices that are best suited to their unique farming operations to address identified natural resource concerns.

Figure 1 Adaptive nutrient management process



Planning and implementation

Planning is a requirement for any nutrient management strategy. The goal is to coordinate the amount, source, placement, and timing of nutrient applications to protect the environment, lower production costs, and maximize the realized profit from each field or subfield.

When planning a nutrient management strategy, it is important to recognize that there are several approaches from which to choose. All involve initial planning or predicting. However, most nutrient management planning strategies involve only implementation of the plan and do not include an evaluation component. If an evaluation component is added to the planning process, the evaluations can be used to guide management in current and future years.

Adaptive nutrient management protocol

To make meaningful adaptive nutrient management decisions, a grower needs reliable data. The following is a how-to guide for farmers and professionals relating how to implement the adaptive nutrient management process. This protocol provides:

- a process and the guidelines for making objective evaluations and informed decisions
- guidance relating how the adaptive nutrient management process can be used to evaluate new nutrient strategies

Growers can use on-farm field trial procedures to evaluate various nutrient rates, timing, sources, and methods of application. By following the on-farm field trial procedures in this document, growers can objectively conduct a field trial on their land, interpret the results, and make adaptive management changes to their nutrient management strategy. These same on-farm field trial techniques can also be used to evaluate other management changes such as seeding rates, hybrid selection, tillage systems, cover crops, weed and pest control, etc.

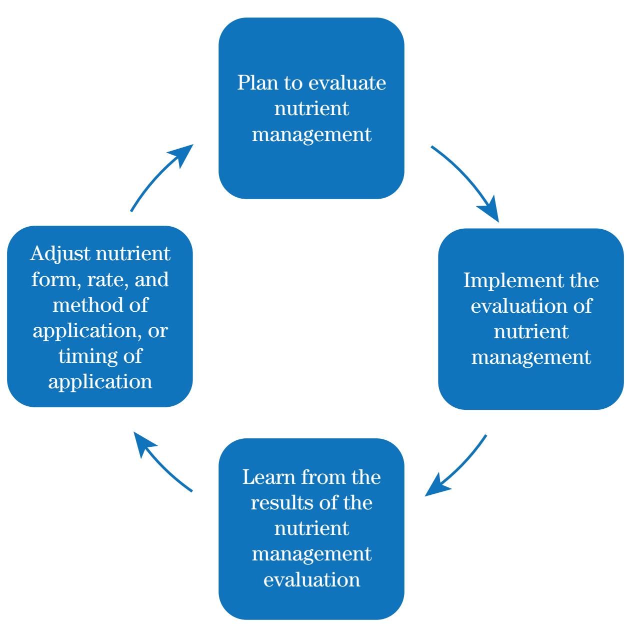
On-farm field trial comparisons need to be carefully planned to produce credible results. A simple side-by-side comparison of two different management systems will not provide the credible data needed to make informed decisions regarding changes in future management. Reliable data is also important to document changes across years in support of longer term nutrient planning.

Conducting on-farm field trials requires:

- Developing a hypothesis—“If I make this change, I expect these results.”
- Planning of replicated comparison plots—paired comparison plots for evaluation of two different management or a randomized complete block design layout if three or more managements are going to be evaluated.
- Determining the resources needed to carry out the plot comparisons.
- Measuring or “laying out” the replicated plots in the field.
- Collecting data important to evaluation of your hypothesis.
- Analyzing of the data collected (may involve pre-season, in-season and post-season data).
- Summarizing of the data and conclusions.

Step 1 Develop the hypothesis:
Example hypothesis: The nitrogen use efficiency will increase if changed from fall application of nitrogen to spring applied nitrogen. Figure 2 describes the adaptive management process for nutrient management.

Figure 2 Adaptive nutrient management process



Step 2 Plan the replicated comparison plots:
The plots and replications must be randomized to minimize the bias contributed by differing soils, topography, pest infestations, etc., that may be present on one plot and not another. Based on the hypothesis, this is a simple evaluation of two different management approaches that can be done with paired comparison plots.

Paired comparison plots should have six to seven replications. The actual minimum is five to analyze with confidence. However, using six or seven replicated plots allows for the loss of one or two plots due to weather damage, pest problems, etc. In this case, two harvest weights are measured from each paired treatment area. The harvest weights for each treatment and replication are then averaged, and the treatments are compared. The typical layout for a comparison for two treatments would look like the example in table 1.

Because of variations in year-to-year weather, pest problems, etc., the replicated plots should be conducted for at least 3 years to properly account for variations in weather, pests, etc. The reliability of the data can also be increased by increasing the number of replications. One way to do this is to partner with neighbors who would evaluate the same variables on their farms (minimum 5 replications on each farm) that have similar management systems and soils. This also increases the learning that occurs through the sharing of results, evaluations, and discussion of adjustments they may consider.

If three or more variables will be evaluated, then a randomized complete block design layout is needed to properly evaluate the variables and the results. For the randomized complete block design layout, a minimum of four randomized replicated plots are required for reliability and confidence. It is best to establish at least five randomized replicated plots to allow for any weather or pest damage that may occur on one of the plots. The typical randomized complete block design layout for three variables would look like those found in table 2.

Individual plots should be planned so they accommodate the width of the planter, fertilizer applicator, and harvesting equipment that will be used. In most cases, the paired comparison plots or randomized complete block plots will require a width of 280 feet to perhaps more than 600 feet, depending on the width of the treatments and the number of replications.

Table 1 Paired comparison layout of two different treatments

Pair 1		Pair 2		Pair 3		Pair 4		Pair 5		Pair 6		Pair 7	
A Treatment	B Treatment	B Treatment	A Treatment	B Treatment	A Treatment	A Treatment	B Treatment	B Treatment	A Treatment	A Treatment	B Treatment	B Treatment	A Treatment

Table 2 Randomized complete block layout used for three or more treatments

Block 1			Block 2			Block 3			Block 4			Block 5			Block 6			Block 7		
A Treatment	B Treatment	C Treatment	B Treatment	C Treatment	A Treatment	C Treatment	A Treatment	B Treatment	A Treatment	B Treatment	C Treatment	C Treatment	A Treatment	B Treatment	B Treatment	C Treatment	A Treatment	A Treatment	B Treatment	C Treatment

Step 3 Determine the resources needed to carry out the plot comparisons.

Consider the following:

- The equipment must be capable of delivery of planned amount, source, placement, or timing of the planned treatments for each plot.
- The materials to be used to identify the boundaries of each plot. Markers should be easily found and identifiable throughout the season. A plot map should clearly indicate the boundaries and treatments applied.
- Consider GPS requirements, if used.
- Calibrate the application equipment, harvesting equipment, weigh wagons, etc.
- Plan for the proper equipment to accurately measure yield, moisture, etc.
- Determine the need for supplies associated with record keeping, recording, or evaluating data.
- Plan for the required analysis of plot results, including an evaluation of least significant difference (LSD). You may need consultant or university expert assistance to properly analyze the data collected.

Step 4 Lay out the replicated plots.

(a) The replicated plots must be laid out in widths (typically, the most limiting piece of equipment) that will facilitate the planting, harvesting, nutrient application, and other equipment used on the plots.

(b) The plots should be laid out where soils, fertility, slope, and drainage are as uniform as possible.

(c) Clearly stake out and mark all treatments. Do not rely on memory. GPS can be used in addition to markers to document treatments.

Step 5 Collect the data.

(a) Record the date of planting, amount, source, placement and time of nutrient applications, pesticide applications, pest activity, and weather. Also record other observations that may impact plot performance, e.g., lodging, plot damage due to animals, etc. This will help in the final analyses of the data.

(b) Ensure harvest yield measurement equipment is properly calibrated (includes combine yield monitors, weigh wagons, moisture testers, etc.)

(c) Make plans before harvest on how the data will be recorded. It is best to develop a form that can be used to record all the data completely and uniformly.

(d) Record the data in the planned format at the time of measurement.

Step 6 Analyze the data.

Quick observations of yield data without statistical analyses of the data can lead to false conclusions. The data collected from the replicated plots must be analyzed to determine where differences in treatments received were meaningful (significant). The least significant difference (LSD) tool is often used to evaluate significant differences when plot yield results are compared.

Tables 3 and 4, and the following procedure are adapted from the "On-Farm Research Handbook" (Anderson 1993) and illustrate how to record data and calculate the LSD.

To record and calculate the LSD:

Step 1 Calculate the variance.

$$\text{variance} = \frac{D^2_{total}}{r-1}$$

where:

r = number of repetitions

$$D^2_{total} = 54.84$$

$$(r-1) = (6-1) = 5$$

$$\frac{54.84}{5} = 10.97$$

Step 2 Calculate the variance of the means = variance ÷ r.

$$\frac{10.97}{6} = 1.83$$

Step 3 Calculate the standard error – standard error = square root of the variance of the means.

$$\sqrt{1.83} = 1.35$$

Step 4 Calculate the least significant difference (LSD).

(a) Multiply the standard error in number 3 above by the appropriate t-value

(b) Appropriate t-value (confidence level) found in table 4

(c) Use t-value = 2.57 (use an alpha of 0.05)

$$1.35 \times 2.57 = 3.47 = \text{LSD}$$

(d) Compare LSD to C average = -6.8. Ignore the negative value. Since the C average of 6.8 is more than the LSD, then the observed difference is significant at the alpha level of 0.05 for the B treatment (spring N applied).

Step 5 Application—Nitrogen use efficiency and profitability is improved by spring application compared to fall application.

Table 3 Example worksheet (sum of squares calculation) (Anderson 1993)

	Treatments		Difference (C)	Deviation (D)	Deviation squared (D^2)
Blocks (r)	A N* fall applied	B N* spring applied	C = A – B	D = C – C average	$D^2 = D \times D$
I	141	150	-9	-2.2	4.84
II	147	156	-9	-2.2	4.84
III	149	155	-6	0.8	0.64
IV	151	157	-6	0.8	0.64
V	149	150	-1	5.8	33.64
VI	142	152	-10	-3.2	10.24
Totals	879	920	-41		D^2 total = 54.84
Averages	A = 146.5	B = 153.3	C = –6.8		

* N=Nitrogen

Table 4 Appropriate T-values

	T-Values		
Number of reps (r)	Alpha 0.05	Alpha 0.10	Alpha 0.30
2	12.71	6.31	1.96
3	4.30	2.92	1.39
4	3.18	2.35	1.25
5	2.78	2.13	1.19
6	2.57	2.02	1.16
7	2.45	1.94	1.13
8	2.37	1.90	1.12
9	2.31	1.86	1.11
10	2.26	1.83	1.10

Summary

Adaptive nutrient management using the on-farm field trials protocol enables growers to make well-informed and documented decisions on how to adjust their management to be more profitable and sustainable. The protocol helps the grower establish and test a hypothesis in consideration of the biological processes taking place in their fields. The process provides an analytical method for determining if a significant difference occurred between the existing and proposed treatments.

Adaptive nutrient management is dependent upon following well-accepted protocols for planning and then evaluating accurate results. By following a well-designed planning and evaluation procedure, true differences among tested treatments can be determined, and superior management options can be selected and applied.

References

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