# Farmer Network Design Manual

## A Guide for Practitioners, Advisors and Research Partners

MAY 2016

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*Environmental Defense Fund*
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# Executive summary

Farmer networks lead to better farm management, greater farm profits, and increased farm productivity and sustainability. The type of on-farm research conducted by farmer networks is designed to answer any number of agronomic questions and can provide a scientific rationale and basis for management adjustments. Farmers are often told that they should follow the 4Rs of nutrient stewardship: **R**ight source, **R**ight rate, **R**ight placement and **R**ight timing. But knowing *about* the 4Rs is one thing – implementing them, quite another. Farmer networks are the ideal platform for generating the **R**ight data (what we call the "5th R") that can bring the 4Rs into focus (see Figure 1). Without the right data, it is difficult to know which of the rate, timing, source and placement options are "right" for a particular operation.

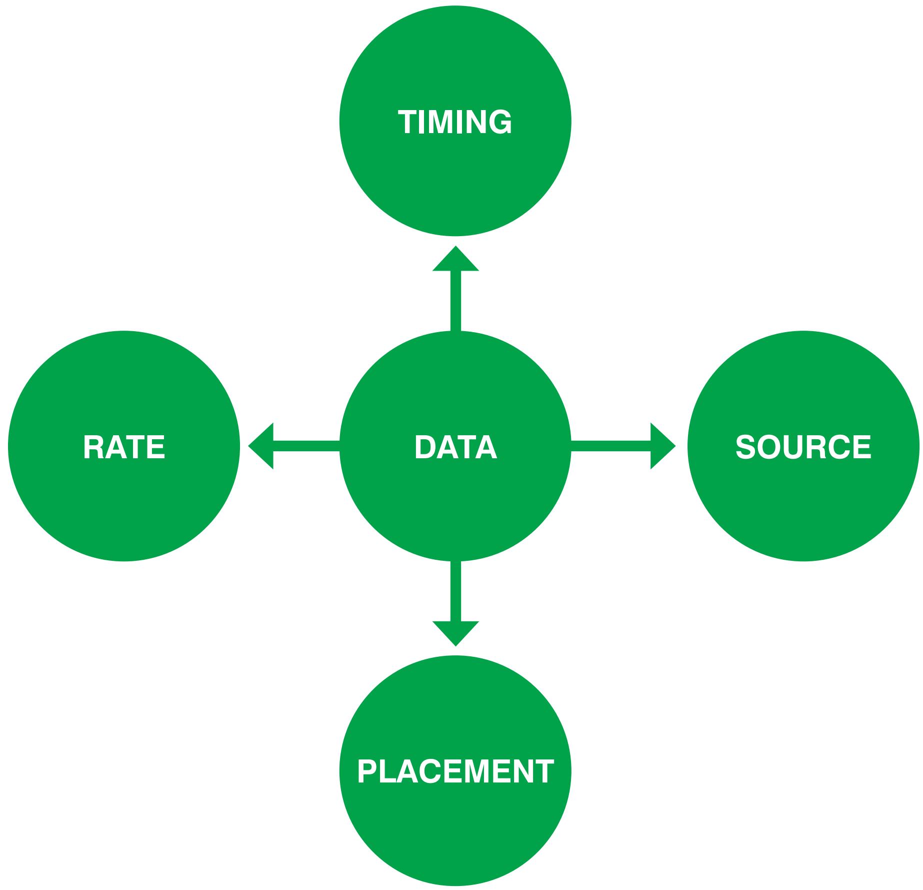
On-farm research involves farmers conducting replicated strip trials on working fields and sharing that information as a "network" through structured planning and activities. On-farm research through farmer networks provides a coordinated means of learning and evaluating data for improving almost any farm practice. Technical experts help to interpret the data generated from the trials in consultation with the farmer, thus increasing the value of the data. This information becomes more meaningful when it is combined with evaluations of similar on-farm research trials from multiple farms and brought into group discussions.

## Objectives and benefits of farmer networks

- Help optimize yields while minimizing nutrient losses and increasing nutrient use efficiency (NUE)—which often means increased profit for the farmer.
- Provide a process to fine-tune generalized recommendations for specific field conditions.
- Serve as an independent third party to rapidly assess risks and benefits from adoption of various agronomic and environmental practices.
- Collect data in a scientific manner to help other farmers make better management decisions and better manage production risks.
- Identify critical areas in crop and nutrient management and collect data to see the results in a timely manner.
- Provide venues for farmer education, outreach and communication of results.
- Provide a favorable environment for peer-to-peer learning and exchange of ideas among farmers, agronomists, scientists and environmentalists.
- Develop local leaders within agriculture (ag) communities to promote and communicate the role of farmer networks.
- Help state and federal agencies to quantify economic and environmental benefits of cost-share programs and assist in developing scientifically based, data-driven enhancements to those programs.
- Complement university and industry research efforts to develop and refine various recommendation and management systems.

FIGURE 1

## The "5th R" of the Right data is needed to inform the other 4Rs




- Help the overall agricultural community to more rapidly adopt promising new technologies and practices.
- Carry a positive image of agriculture into local communities and communicate agriculture's role for the general public.

Farmer network practitioners from across the United States were consulted in the writing of this manual. The collective learning and field experience represented in this document provide a valuable resource for any agriculture conservation professional or practitioner to begin a farmer network. Farmers are challenged to feed a growing population while simultaneously protecting precious soil and water resources. More and better tools, data, coordination and assistance can help farmers meet this challenge. Farmer networks are a pathway to higher profits, increased ability to manage risk, and long- term farm sustainability. We encourage you to read this manual, follow the step-by-step guide, and start your own farmer network! You and the farmers you work with will reap the rewards by gaining new insights, sharing information together and becoming better farm managers.

## CHAPTER 1

# Introduction

This manual is written by and for farmer network practitioners. Practitioners may be crop advisors, watershed coordinators, soil and water conservation districts, federal, state or county level agency representatives, agriculture associations, the conservation community, farmers themselves, and anyone else interested in learning about the design, rationale and benefits of farmer networks to conduct on-farm research. This manual provides a comprehensive look at designs, funding, structures and benefits of farmer networks that can help guide decisions about forming a farmer network.

The challenges facing modern production agriculture today are matched by significant opportunities for progress and efficiency. Modern farming is not only about producing crops or raising animals but also about improving production efficiencies, protecting local soil and water resources and staying informed about new tools and technologies. Increased public pressure on farmers and scrutiny of farm practices due to growing water quality problems and other environmental concerns are leading to greater restrictions on how farmers operate. Food suppliers and retailers are also looking all along their supply chains for ways to meet demand for environmentally sound products, including the grain, oilseed, and other commodity crops that are the ingredients for many of the commercially produced food products consumed around the globe.

These realities, combined with the growing global need and desire for abundant but inexpensive food, fuel and fiber mean that stakeholders must all work together to ensure food production is sustainable and environmentally sound. These stakeholders—farmers, agronomists, conservationists, scientists and local, state and federal agencies—are searching for ways to increase crop production even as they look to optimize the use of fertilizer, while also assuring that what they apply is not lost to water bodies through surface runoff and subsurface drainage, or lost to the atmosphere through volatilization.

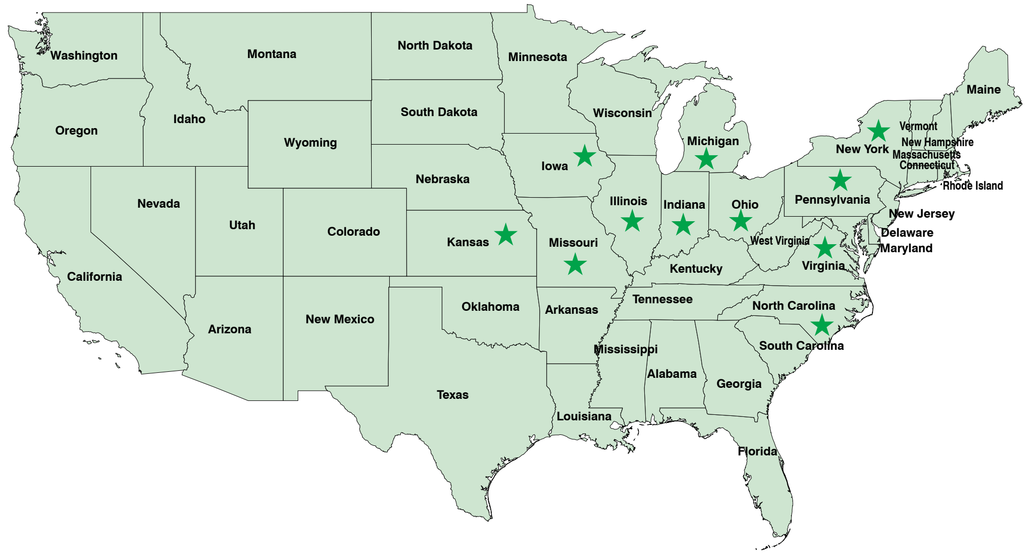
Farm management is complex. Many decisions require collection of data and related information about how different local factors and conditions including soil, weather and historic management decisions interact at different levels. Farmer networks are a platform for on-farm participatory research and learning that offer new ways to bring together science, technology and farmers' experiences to understand where farm management improvements are possible. Farmer Networks can help farmers manage their farms more effectively, and improve their efficiency, yields, sustainability and profitability.

More tools, products, technologies and programs are available to farmers now than ever before. Choices abound and farmers need to understand how the different available options might affect their operations. Farmer networks give farmers a scientifically credible way to generate information on their farms to guide them and their advisors to make better decisions about management of crop and soil inputs under commercial-scale farm conditions. Evaluations of farm practices over a number of years by farmer networks can refine the practices in ways that minimize risk and increase productivity and profitability.

Many farmer networks in existence are geared toward particular purposes, regions of the country, types of farmers (e.g. women farmers) and crops. A number of tool kits and resources are also available on how to launch farmer networks.

FIGURE 2

## Farmer network operations




This manual differs from others in that it has been written by farmer network practitioners with years of experience in conducting and analyzing on-farm research for nutrient use, crop production and product testing in commodity crop agriculture using robust, protocol-driven data collection and analysis based on precision farming. As such, it is intended to serve as a guide for those geared toward commodity crop agriculture, as well as those interested in on-farm research aimed at increasing farmer and partner learning through adaptive management.

The manual draws from the collective experience of farmer network practitioners in ten U.S. states (see Figure 2) to present the immense benefits and lessons learned from working collaboratively to implement farmer networks. Common to all networks is a foundation in solid science, use of valid data collection protocols and techniques, a forum for learning, and a goal of building farm profits, sustainability and resiliency over the long term.

However, while we're attempting to provide a step-by-step guide on implementing farmer networks from the ground up, we are not suggesting a cookie-cutter approach. Each region has unique social and environmental conditions with variations in cropping systems, farmers, practices, stakeholders and concerns. Farmer networks can be implemented in a variety of ways and should be flexible enough to address a variety of concerns and questions, including those unique to the region.

We invite comments and questions on this manual, and welcome any opportunities to share our experiences more in depth.

CHAPTER 2

# What is a farmer network?

A farmer network is a group of farmers working with one or more advisors dedicated to learning how to improve farm practices through collaborative, scientific evaluation of those practices, and sharing the evaluation results through meetings in groups or one on one. Farmer networks conduct on-farm research through replicated strip trials using production-scale equipment, and by testing a change in practice or management from the farmer's normal practice following a standard protocol (see Appendix D for sample protocol). Networks of farmers who learn from each other how to improve farm practices have probably existed for centuries, but the widespread availability of combine yield monitors has greatly increased farmers' ability to create scientifically valid data on a field scale from which to learn.

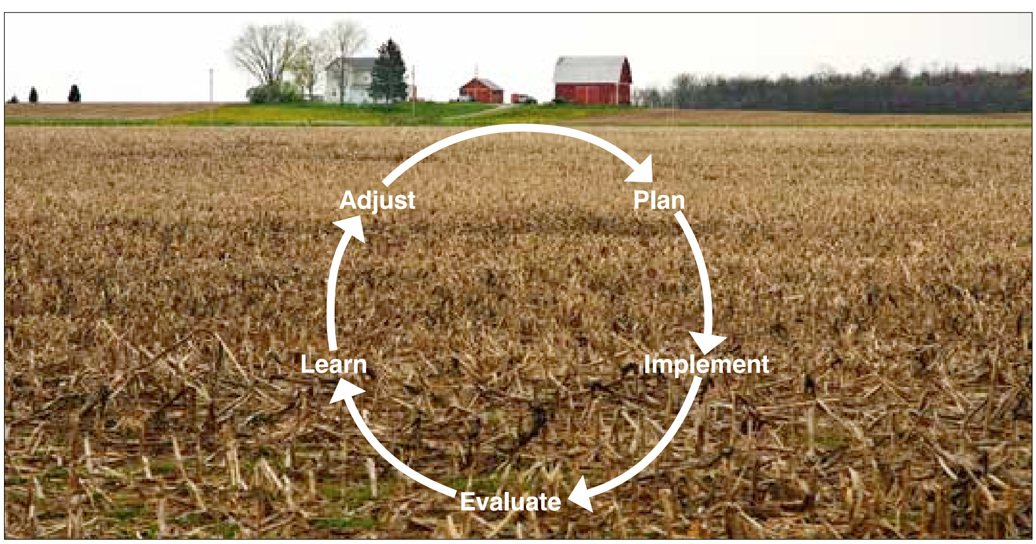
Farmer networks can follow several different types of models and typically involve agronomists, scientists and other stakeholders in addition to the farmers, who come together to identify and solve pressing issues or questions related to crop production and environmental conservation. The key elements of a farmer network are:

1. Participatory learning and adaptive management, using basic research principles
2. Use of the right data collection tools, technologies and protocols for the research conducted, assuring that results are scientifically valid and repeatable
3. Proven methods for sharing, discussing, and communicating results of on-farm studies

FIGURE 3

## The essential steps involved in participatory learning and adaptive management

The crux of the on-farm research process



Besides farmers and local agronomists, other major stakeholders that can benefit and learn from participating in or studying on-farm research include: scientists, agency personnel, conservationists, the agriculture industry and policy makers.

Focus areas for farmer network research can include:

- Nutrient management (both commercial fertilizers and animal manure)
- Crop protection, such as weed, insect and disease management
- Crop production, such as seeding rates, row spacing, and population studies
- Soil and water quality
- Energy efficiency and life cycle analyses
- Technology evaluation and adoption
- Product and practice testing

It is important to note that the process is iterative. In other words, implementing one trial, or testing a new tool for only one year, rarely provides sufficient information upon which to base management decisions. Rather, the first year establishes the starting point for subsequent trials and tests.

In practice, the typical on-farm research/farmer network project plays out along a time frame established by the cropping pattern and crops grown by the farmer. In the Midwest, for example, planning for the trials that will be conducted in the next season occurs in the late fall or winter. Implementation occurs when trials are laid out and tools and technologies are used, or nutrients are applied, in the spring and summer; and then again when tissue tests, plot and management data are collected in the fall.

Interpretation of the results occurs in discussions about the data during the winter meetings. This is when the learning phase occurs as well, either through group meetings or during sessions between individual farmers and their advisors. As this learning occurs, adjustments in management can be made during the next planning process and the cycle begins again for the next season. Each season is not only an opportunity to plant a crop, it is also an opportunity for rich experimentation, research and learning that can inform each subsequent season.

Common tools of on-farm research include: plant tissue testing, such as the cornstalk nitrate test (stalks collected from ¼ milk line to three weeks after black layer); aerial imagery to show visual characteristics of the field and choose locations from which to collect soil or plant tissue samples; yield monitor data; as-applied maps; and management information, including tillage, rate, timing, source and placement of nutrients applied, prior crop, type of hybrid, etc.

CHAPTER 3

# Evolution of farmer networks

For more than a decade, thousands of farmers have implemented on-farm research trials through farmer network programs in Iowa, Illinois, Indiana, Ohio, Michigan, Pennsylvania, Virginia, North Carolina, New York and Kansas. Additional on-farm research may be underway in other states; we discuss in this manual the networks that we are aware of through our various partnerships.

Initially, farmer networks formed to address pressing nitrogen (N) management concerns. On-farm research methods were designed to decrease the uncertainty around nitrogen application rates by using a unique combination of precision agriculture tools. When combined together and supplemented with the farmers' management data, these tools offered a more comprehensive picture of what occurred to the nitrogen that was applied. This information could be analyzed in the context of local weather patterns and then utilized in planning for the following season.

Networks have evolved to encompass much more than N rates. They continue, however, to revolve around farm-level research using replicated strip trials to generate information for farmers in the network. Topics for replicated strip trials can include any important agronomic question or concern that the network wants to address.

Many of the various networks established in the past decade were formed through partnerships between groups like the Iowa Soybean Association, Environmental Defense Fund (EDF) and the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). These groups established farmer networks to provide more accurate and site-specific nutrient management assistance to farmers and to promote the principles of adaptive nutrient management. The NRCS provided seed funding through Conservation Innovation Grants for some networks and also helped to lead an effort to embed the principles and tools of adaptive management into their programming. This made the information broadly accessible to farmers anywhere in the U.S. through Environmental Quality Incentives Program (EQIP) funding.

The interest in farmer networks and on-farm research continues to grow and evolve in new directions, and funding sources are becoming more diversified. To sustain existing networks and form many new networks, a variety of academic, grower, NGO and public entities must make a concerted commitment to promote the concept and collaborate on broad implementation goals. Service provider companies and agriculture technology companies may also emerge as more prominent partners and contributors to farmer networks and on-farm research, as field trial data on products and technologies is critical for calibration and validation purposes. The rapidly escalating interest by food supply chain companies in sustainable sourcing also offers an opportunity.

Commodity grain growers and buyers could form networks for the purpose of tracking metrics to fulfill company sustainability objectives and increase grower efficiency and profitability over the long term. Partners will continue to explore these various avenues for expanding and funding farmer networks, because we believe that farmers conducting research on their own farms and sharing that data with advisors and each other is the single most powerful learning tool available today. Even given the variety of tools and technologies available

TABLE 1

## Active networks currently operating

| State | Lead entity | Funders (past and present) | Partners | Nutrient of concern | Research and tools |
|---|---|---|---|---|---|
| Illinois<br><br>Mackinaw Farmer Network | The Nature Conservancy (TNC) | USDA NRCS Conservation Innovation Grants (CIG), Environmental Defense Fund (EDF), through Walton Family Foundation | TNC, EDF, McLean County Soil and Water Conservation District (SWCD), City of Bloomington, McLean County NRCS, Brucker Crop Services, University of Connecticut, Simplified Technology Services (STS) | Nitrogen (N); elevated nitrates in City of Bloomington drinking water reservoir | N rate and timing trials, guided stalk sampling, aerial imagery, N soil testing |
| Ohio, Indiana<br><br>Maumee Farmer Network, now the NutrientStar field testing network | EDF | Joyce Foundation, Walton Family Foundation, USDA NRCS CIG, Ohio Corn and Ohio Small Grains Marketing Boards, Mennel Milling Co. | EDF, STS, Brookside Labs, Ohio Corn & Ohio Small Grains Marketing Associations, Nester Ag Management, Haselman Ag Management, G&K Concepts, Mennel Milling Co., General Mills | Phosphorus (cyanobacteria blooms in Lake Erie), nitrogen | N rate trials, aerial imagery, guided stalk sampling, N Use Efficiency (NUE) tool and technology testing |
| North Carolina Agriculture Inputs Management Program (AIM) | North Carolina State University | EDF (through private donor) | Murphy Brown, EDF, NC State University | Nitrogen, phosphorus | N rate strip trials, GreenSeeker sensor technology trials, phosphorus and manure trials |
| Indiana<br><br>INfield Advantage | Indiana State Dept. of Agriculture | NRCS CIG, Indiana Soybean Alliance/ Indiana Corn Marketing Council (ISA/ ICMC), EDF (through Packard Foundation), Iowa Soybean Association (ISA) | ISA/ICMC, Indiana Conservation Partnership, NRCS, Indiana Association of Soil and Water Conservation Districts, Purdue Extension | Nitrogen, phosphorus | N rate trials, aerial imagery, guided stalk tests |
| Iowa<br><br>On-Farm Network® | Iowa Soybean Association (ISA) | ISA check-off dollars, state and federal government grants, private industry and foundation grants and contributions | Iowa Agriculture Water Alliance (IAWA), Iowa Department of Agriculture and Land Stewardship, INfield Advantage, Iowa State University, EDF, USDA NRCS, National Corn<br><br>Growers Association Soil Health Partnership, the Nature Conservancy, United Soybean Board and multiple agribusinesses. | Nutrients, products, practices (cover crops) | Replicated strip trials, aerial imagery, guided tissue and soil testing, crop canopy sensing |
| New York Spear Program | Cornell University Extension | New York Farm Viability Institute, USDA NRCS CIG program, Northern New York Agricultural Development Program, Northeast Sustainable Agriculture Research and Extension | Cornell, PRODAIRY | Manure, Nitrogen and Phosphorus | |
| Kansas<br><br>Kansas State University | Kansas State Research & Extension | K-State Research & Extension, Kansas Corn Commissionw | K State Research and Extension staff, Agricultural Extension agents and agronomists | N/A | Seeding rate, row spacing and hybrid trials |

More information on regional farmer network models already in operation is provided in Appendix A (Farmer network models from the field).

to farmers, the best way to test and understand the efficacy of these technologies for any individual farmer or farm operation is by conducting test trials on the farmers' own fields.

The power of the network is that the results of these tests and trials can be shared regionally with farmers in similar growing and environmental conditions so one research trial benefits many others in that area. With enough networks operating in a variety of geographical regions and agroecosystems, the benefits can be replicated, and shared with many more farmers throughout large watersheds and regions of particular interest for nutrient management.

## Field testing network

In the previous section we discussed the power of field trials for testing and assessing performance of tools and technologies under the farmer's own management scenarios and specific farm conditions. This concept has taken root in the NutrientStar program (nutrientstar.org)—a science-based, independent third party assessment program conceived and developed by EDF with guidance from key consultants and a Science Review Panel of leading nutrient use efficiency experts across the country. The Maumee Farmer Network was the foundation for the on-farm research component of NutrientStar, and has now become part of the NutrientStar field testing network, which expanded over the past year to include some 18 consultants and 80 field testing sites across eight Corn Belt states.

The NutrientStar mission is to identify nutrient management tools that can help reduce nutrient losses from agriculture to the environment, and provide valuable information to participants up and down the commodity crop supply chain—from farmers to food companies—while benefitting air and water quality across America. The four target audiences who will benefit from NutrientStar information are farmers, crop advisors, agribusinesses and food companies.

The three primary goals of NutrientStar include:

- Increase transparency about the performance of commercially available tools claiming nutrient use efficiency benefits and to what degree the tools achieve NUE and yield benefits as documented through replicated field-scale, on-farm research trials.
- Provide a common set of standards and protocols to improve the efficiency and effectiveness of both public and private sector research on tool performance and thus produce robust data sets of value to our target audiences.
- Spark further innovation, research and development of nutrient use efficiency tools.

The NutrientStar program is also developing and will produce first of its kind guidance on the use of an agroecological zone spatial framework to identify zones of similarity with regard to expected responses to crop and soil management. This framework allows: (i) better targeting of field trials to those zones with greatest crop area and thus largest impact, and (ii) identifying the spatial extent of the extrapolation domain for results from a field study conducted in that zone. The agroecological zone framework is based on a combination of climatic zones and water holding capacity within the rootable soil depth. This framework can aid companies in targeting field trials to those regions of greatest interest to them, focusing resources toward generating data around key geographies and farm management practices.

There is virtually no limit to what can be assessed through field trials, and NutrientStar is committed to providing robust scientific guidance for practitioners wanting to test the ever-increasing number of tools and products being marketed to farmers. As crop prices fluctuate, farmers need confidence that the money they spend on tools to improve fertilizer management will, when used appropriately, deliver results and improvements in any one or more of the 4Rs: timing, placement, rate and source of fertilizer.

For more information about field trials, product and decision support tool testing and other details of the program please visit the NutrientStar website (nutrientstar.org).

## Key attributes of farmer networks = "FARMNET"

- Farmer-driven—farmers own the data and in many cases decide what to test
- Adaptive—flexible enough to work in a variety of crops and regions
- Research trials—using established on-farm research protocol leads to high value data
- Management oriented– information collected is used to inform management decisions in future seasons
- Network—farmers learn from each other informally and in group settings
- Participatory learning—farmers and farm advisors learn together to interpret field data that varies across years and fields to make better decisions
- Team approach—farmers, advisors and partners all work together and play a role

## Why are farmer networks needed?

Increasingly, farmers need decision support tools and platforms that provide the foundation for objective and defensible farm management. They need information that helps them understand the impact of management decisions on both economic and environmental outcomes, and to adjust management to achieve ever better outcomes.

Farmers need to have confidence that they are achieving a high level of stewardship and preserving the land for future generations. The best person to make decisions about the land being farmed is the farmer and/or the landowner—but often they receive conflicting information, confusing messages and high level marketing materials that do nothing to advance their understanding of what is happening on their farms, in their fields. On-farm networks deliver a model and a platform for decision-making solidly relevant to their operations - whether it is nutrient management, soil health, product evaluation or hybrid testing.

The concept of on-farm research is not new. Universities have conducted on-farm research trials and trials on university demonstration farms for many years. However, the model of on-farm research conducted on the farmer's field, with farmer involvement, to produce data and information that goes directly back to farmers, is relatively unique. Farmer networks combine precision agriculture tools, advisor technical assistance, and peer-to-peer learning in a model that maximizes the potential for incorporating new information into management adjustments over time.

The data generated by farmer networks provides a gold mine of information that can deliver new insight as new data is added and analyzed. We can illustrate this using the example of adaptive nutrient management—in this case, for nitrogen management. There is great uncertainty in the amount of fertilizer needed to obtain the economic optimum N rate (EONR) for any particular field. Research trials conducted by universities as well as trials conducted through farmer networks clearly show that any generalized recommendation of the rate of fertilizer needed will be off by a large margin, a large percent of the time. In fact, data analyzed from these trials (and examined in Appendix E—Results of farmer networks) shows that the chance of hitting the EONR for an individual field is only about 20%, and the chance that the recommended rate might be greater than needed is about 60%. The data clearly show that there is much potential for improving NUE in corn throughout the Corn Belt.

Farmer network experience shows that database-driven adaptive management practices can reduce the uncertainty in nutrient availability by better predicting response to nutrients—in this case, nitrogen – for field-specific combinations of management practices and soil and weather conditions. Information from farmer network adaptive management programs reduces uncertainty by allowing farmers to better predict the optimal N rate, form, timing and placement optimum for their fields.

Adaptive management can also be useful for managing phosphorus, a critical nutrient for crop production that has been implicated in many water quality problems over the past decade, particularly in Lake Erie.

The science on nutrient use efficiency, tools to improve efficiency, and ways to track improvements in efficiency are all constantly evolving, and platforms like farmer networks provide an ideal way for farmers to evaluate these evolving tools, science and approaches on their fields.

Farmer networks provide more than just an arena for farmer learning. Non-traditional partners that are engaged in farmer networks through their roles as funders, collaborators, advisors or even environmental organizations can learn from their involvement and gain a much greater appreciation and understanding of what occurs on the farm and how complex farm management can be. Farmer networks offer great untapped potential for exchange of ideas, clearing up of misconceptions, and forming collaborations around mutually beneficial solutions to pressing issues like water quality.

CHAPTER 4

# Impacts of farmer networks

## ASSESSING AND COMMUNICATING RESULTS

A fundamental question that arises when working with a farmer network is: **How do we know farmers are using data from the network to support management decisions in the field?**

Farmer network data typically belongs to the farmer and is used to support decision making in the advisor-farmer relationship. Since farmers may want to keep their personal data private, network administrators may wish to perform additional activities to discover if and how farmers may be putting the information gained from the on-farm research to work. Many times network funders will want to know this as well. Thus far, within the existing farmer networks, data collection and analysis has focused almost exclusively on the trial results and interpretation of the trial results back to farmers.

There has been only spotty time and effort dedicated to measuring how farmers are using the data they receive from being in a network. We have learned that establishing some benchmarking statistics against which to measure progress is an important first step in the process. At the very least, consider documenting the following basic information:

1. Number of farmer participants
2. Number of acres farmed by participants
3. Number of field trials, by category (e.g. 10 strip trials, 44 guided stalk fields)
4. Number of acres in trials
5. Incremental and additional changes in these numbers—e.g. for year two of a network, number of returning and new participants/how many acres farmed in addition to those documented already
6. Any changes in practices or nutrient application rate, timing, form or placement that can be captured through data collection

Building a spreadsheet with the appropriate categories that you can fill in annually as these numbers grow will help expedite the process and ensure the information is current and at your fingertips.

Other good reasons to document and share results:

- To communicate learning from the data more broadly – some farmers may never participate in a network but the information from a network can be shared in aggregate across an entire watershed/state/region
- To gain support and interest from key partners, grower associations, state agencies, academia and others for the concept of data-driven, peer-to-peer networking and learning
- To share data gained from farmer networks with environmental groups, urban populations, and the public about farming practices that are largely invisible to them, helping to bring science and data into what can often be polarizing discussions
- To demonstrate to funders the impacts that farmer networks are generating
- To share data with other groups and even other farmer networks so it is more broadly used

Documenting management changes or decisions that were supported by participation in a farmer network can prove challenging. Take, for example, the difficulty of tracking increased nutrient use efficiency (NUE) due to participation in a network. Increased NUE means farmers may reduce nitrogen use on some acres but increase nitrogen use on other acres according to the different soil type responses that they see in the field trials. Not only is it difficult to understand the specific NUE achieved as a result of varying nitrogen rates in this manner, it is also difficult to know for certain how farmers may have changed management on the remainder of their acres outside of the trial footprint – information that is important to determine a clearly quantifiable whole-farm NUE impact. We have found that simply asking the farmers what they did through farmer surveys can generate some idea of network impact. There is evidence in recent and historic farmer surveys conducted by some of the networks that, where NUE is a goal, participating farmers increase their nutrient use efficiency by 15 to 20%. The longer they participate in a network, the more comfortable they become with making adjustments in N applications.

For example, Maumee Farmer Network collaborators conducted an informal anonymous survey of 37 farmers in Ohio and Indiana during the March 2013 grower meetings. The survey showed that on 5,735 acres, farmers reduced their average N applications from fertilizer by 32.5 lbs. per acre. On 1,600 acres, the farmers increased their N applications by 21.0 lbs. per acre, for a net reduction of nearly 153,000 pounds of N. The increase in N was from starter N fertilizer applied to fields that had shown early season deficiencies in previous years. We can conclude from this survey that farmer network participants learned not only that they could reduce N rates for greater profits on certain acres, but also that there were areas of the field where soil fertility and nutrient uptake could be greater, thus also leading to higher profits on those acres.

Anonymous surveys of 48 Maumee Farmer Network participants were again conducted during the 2015 winter meetings, showing similar results: farmers reported reducing N rates by 32 pounds on 7,340 acres, for a reduction in N applied of nearly 235,000 pounds. When farmers were asked the question, “How much has your participation in the farmer network influenced your selection of your nitrogen fertilizer rate?” nearly 90% of respondents replied that the network had “somewhat” or “substantially” influenced their selection.

Some notable quotes from that survey are included below:

**“Using our stalk nitrate tests on our GSS fields, we concluded we could lower our N rate and still maintain yield. We have also learned that rain is a factor. We had the best yields we ever had this year with reduced N.”**

**“We need to remember that we are stewards of our soils. We need to maintain our soils to feed the world for many generations to come.”**

**“Adapt [network] has saved or made me more money than anything else in 2013 and 2014.”**

Appendix B provides an example farmer feedback survey that might be helpful to use as a guide if you wish to design your own survey. The survey was built by a small team of social scientists and farmer network practitioners associated with EDF. There are certainly other means of gathering information on farmers' use of the data generated from farmer networks. The farmers themselves may have ideas about how to report management changes that result.

CHAPTER 5

# Before you begin

## TAKING STOCK

Even if you are familiar with issues and farmer attitudes in a given region, it is a good idea to take a deliberative approach and note key challenges and attributes you may confront in your watershed, region or county, and incorporate these into the planning process to avoid surprises down the road.

- **Regulatory structure and issues of concern.** First, what is the current regulatory structure or set of policies governing agriculture in the area? Increasingly, states are implementing water quantity and quality measures that could impact agriculture. These measures include nutrient reduction strategies, required certification or training programs, restrictions on nutrient applications in regions where drinking water concerns are present, limits on irrigation water extraction and use, and others. Are there permitted livestock facilities in the watershed, or a number of non-permitted smaller operations? Is manure being applied in the watershed, or being brought into the watershed? Have regulating agencies identified nutrient or resource concerns and if so, what are those concerns?

- **Farmer attitudes.** What do farmers think about the concerns identified above, and what kinds of proactive steps have they taken to identify issues and resolve them? What types of nutrient use efficiency or soil health practices have they adopted or might they be willing to adopt? Have any farmer surveys been conducted in the area, or any university social science studies that might inform your effort? Do farmers have access to funding sources for conservation practices? If you do not work regularly with farmers, interview an extension agent, county surveyor, certified crop advisor, soil and water district technician or all of the above to gauge farmer attitudes in the area. You might consider convening a focus group of farmers, or farmers and advisors, which can provide valuable insight to help shape the program.

- **Management practices.** What are the prevailing nutrient use practices in the area (e.g. fall-applied vs. spring, or split application)? What types of tillage practices are common? Do farmers regularly plant cover crops, and what are common soil health practices? Do farmers in the area typically use precision ag tools and yield monitors? If so, is such equipment calibrated on a regular basis? What are the common crop rotations and what factors influence planting decisions each season? When do farmers typically make these decisions? Understanding these practices and decision points can help farmer network advisors suggest on-farm research trials that can reinforce the efficacy of existing practices or show where greater efficiencies can be made. Knowing when farmers make decisions is important when considering timing of information sharing and structuring of all the other network activities.

- **Environmental conditions.** What are the prevailing soil types in the region, if any? Are there geological considerations affecting drainage (sandy soils, karst, etc.) to take into account? Do heavy clay soils predominate? How much surface and subsurface drainage exist? Is there a trend toward more drainage (which can impact nutrient leaching potential) and what are the factors influencing drainage in a region? What are climatic conditions in a “typical” season, what have weather patterns looked like, and where are they trending?

- **Socioeconomic considerations.** Assess the typical farm sizes and types of operations and trends in ownership—are there many full-time farmers, absentee landowners, family-owned operations or integrated operations? Who do farmers go to for information, from whom do they buy product, where does the bulk of the local grain harvest go, and what kinds of economic realities do farmers face that might influence their decision making? Are there ethanol plants in the region? Having an understanding of the basic landscape of demand and supply in an area will also provide useful information about what farmers are thinking about and the factors that may influence their economic decisions.

CHAPTER 6

# Starting a farmer network

## CHECKLIST AND STEPS INVOLVED

Designing a farmer network program is best done with input from the farmers themselves. This can be done by working through a trusted advisor, convening farmers for a focus group, or if funds permit, conducting a more comprehensive university-designed survey. Asking farmers what they think can ensure participation in the network, as they will feel more ownership around a program that identifies issues important to them.

The assessment phase described in chapter five could be undertaken prior to or in the course of identifying partners and defining goals. The impetus for starting a farmer network can come from a variety of directions: desire to provide a meaningful structure in which to gather data and assess prevailing nutrient recommendations; desire to improve or protect water quality in a local watershed; interest in testing different products or technologies through field research. The reasons for starting a farmer network will vary and will inform thinking on what groups should be involved and who should lead the formation of the network.

You may want to start out with a small network and a tightly focused plot layout, with a field trial protocol limited to a few replications and a simple with/without scenario. You may want to consider input from numerous potential partners and build objectives with buy-in from a large set of stakeholders from inception. Or, perhaps you already have a good idea what your goals and objectives are and you want advice from a limited set of experts as you establish the network.

This initial scoping of partner organizations and information collection may also reveal other existing programs in the area with elements that could be incorporated into the network, avoiding duplication of effort and ensuring the most efficient and effective use of partner time. For example, your state land grant university may be working on revisions for fertilizer recommendations in a region and already recruiting farmers to conduct on-farm trials on nitrogen and phosphorus to collect relevant data. This presents an ideal opportunity for partnership and collaboration, and establishes the infrastructure for on-going research objectives to be met – provided the research objectives are reflected by local farmer priorities and the data is shared with participating farmers.

In the following section we offer a suggested series of steps in order of priority that you may want to consider as you start your network. Some of these steps may unfold concurrently.

## Starting an on-farm program, step by step checklist

### Step 1: Identify shared goals and partners

✔ Develop initial set of goals
✔ List objectives and questions to answer
✔ List partners to help implement and promote the network
✔ Decide on a process for convening partners

### Step 2: Build budget

✔ Maintain realistic network based on funding potential
✔ Understand costs and prioritize activities accordingly
✔ Decide whether to charge a participation fee
✔ Set funding expectations and timeline

### Step 3: Identify roles and responsibilities

✔ Name a lead coordinator
✔ Define and prioritize roles
✔ Assign responsibilities
✔ Establish farmer advisory council if desired

### Step 4: Conduct outreach and promotion

✔ Decide how you will recruit farmer participants
✔ Establish outreach methods (meetings, word-of-mouth)
✔ Formulate a plan for sharing data
✔ Define audiences for the results

### Step 5: Build data management and analytical capacity

✔ Recruit academic assistance or experts
✔ Obtain training for data analysis if needed
✔ Establish database location and manager
✔ Establish clear data handling protocol
✔ Establish timelines for data collection

### Step 6: Develop tools and protocols

✔ Identify partners to help develop protocol (university, extension, etc.)
✔ Ensure field trial protocol can be implemented
✔ Define tools to be used (precision ag tools & technologies)

### Step 7: Assemble training materials and plan

✔ Define training methods/identify trainers
✔ Establish plan for ongoing training

### Step 8: Develop data sharing and protection policy

✔ Consult with database manager
✔ Decide who can see the data and what level (individual or aggregated)
✔ Define protection standards and methods
✔ Record policy to share with farmers

### Step 9: Implement plan, evaluate

✔ Benchmark and track progress from the beginning
✔ Develop farmer survey
✔ Evaluate, adjust, incorporate
✔ Look back, look forward

## STEP 1
### Identify shared goals and partners

✔ Develop initial set of goals
✔ List objectives and questions to answer
✔ List partners to help implement and promote the network
✔ Decide on a process for convening partners

The goals of the project will drive how the project is constructed. If the goal is to achieve better water quality, for example, understanding what water quality concerns exist in the watershed provides a starting point for constructing outreach, knowing what practices to target and deciding how trials will be conducted.

The agricultural sector is increasingly being called upon to step up efforts to reduce nutrient runoff from farms. In 2015, a lawsuit in Iowa, toxic algae blooms in Lake Erie, the Gulf of Mexico hypoxic zone and Chesapeake Bay nutrient issues were all impacting public opinion, and policymakers were considering more stringent controls on what has always been an unregulated industry. Farmer networks offer a way to answer the question, "Am I contributing to the problem, or am I doing everything I can to be as efficient as possible?" Farmer networks can collect and supply the scientific data that can objectively answer that question for each farmer in the network. The farmer network can also answer that question collectively, through the sharing of aggregate data.

If you are just forming a farmer network, the goal may be to simply implement a handful of on-farm research trials with local grower cooperation and then build from there. In our experience, the first year or two of on-farm research trials provide a valuable learning experience that will inform adaptive management of the project going forward.

You will need to identify the key partner organizations that will contribute in some way to the formation and continuation of the network – these could include funders, technical advisors, agency personnel, academia and others whose continued support and advice is important to the functioning of the network and/or with whom you want to share the data, outcomes and experiences of the network.

Set realistic goals and objectives that reflect existing human resource capabilities, technical expertise and farmers' willingness to participate. Depending on the responses, feedback and interest you obtain during the assessment process, you will need to prioritize objectives based on funding status and current capacity for execution of those objectives. Partner input can be helpful in prioritizing objectives.

Generally speaking, a network will begin with a handful of farmer participants, one to two advisors, a source of funding depending upon the scope of the objectives and expense of implementation, and one specific question or objective for the first season that might center around one of the 4Rs: what is the right rate, right source, right timing or right placement of a product? The most common "R" tested in farmer networks thus far is rate, because it is the most elusive variable to manage and the variable most controlled by externalities, yet rate trials are the easiest to implement. Timing trials can be conducted as well; such as testing fall-applied vs. later season applications or split applications of nutrients. Product trials to test the efficacy of a fungicide, stabilizer or new technology can be an objective.

Regardless, consider the size of the network (the number of farmers, and the number of advisors able to work with those farmers), the elements you will need to fund (aerial imagery, soil tests, tissue tests, management data collection and consultant time), the database management capacity, and the data analysis help you will require. Consider how you will attract the core group of first farmer network participants. This stage may be as much about discussing the potential benefits of participating in a network (see discussion of the benefits of farmer networks list, in Conclusion) as it is about getting feedback and recruiting participants. Farmers may be unsure how a farmer network might benefit them, so drawing on some of the case studies and experience provided in this manual may be useful in this regard. Some networks have established farmer advisory councils to guide the research objectives of the network, help recruit additional farmers, and provide leadership and decision-making support. The important thing is to find farmer network participants who believe in the concept, can share a common goal, are willing to commit to multiyear test strips, and see the long-term advantages for the agricultural industry as a whole.

Even if a farmer network starts small and with a handful of farmers, usually some outside expertise is needed to provide some technical support and to make sure the information gathered will be useful and unbiased, using sound methods for data collection.

Finally, you might consider writing a statement of the core principles for the network to share with partners and farmers. This might take the form of a paper defining the principles, goals and objectives—essentially an “operating agreement” to underscore understanding of each partners’ responsibilities.

# STEP 2
## Build budget

✔ Maintain realistic network based on funding potential
✔ Understand costs and prioritize activities accordingly
✔ Decide whether to charge participation fee or not
✔ Set funding expectations

Farmer networks require funding. The process of designing protocol for on-farm research, coordinating the collection of the data, analyzing the data and coordinating meetings obviously requires time and some skilled technical assistance. However, funding often evolves and grows as the network generates quality results and begins to share knowledge and lessons learned. What might start as a small amount of funding and a few farmers can grow into a larger, more complex and robust network, especially when the network organizers and participants share findings and take time to publicize results.

Funding for the network can come from a variety of sources (see discussion of funding models in Chapter 10). A network is typically funded externally by several partners who provide either in-kind or cash support. Implementation costs can be minimal or significant according to the data sought and the complexity of the network. Depending on whether you begin with a source of funds in hand, or if you are forming a strategy to approach a funder, you will need to think through the reasons why you want to start a network and approach the funder with a sound strategy including goals, objectives, roles and responsibilities, and how you will measure progress.

Whatever funding model is used at the outset will set up expectations for the future. If you start by asking farmers to contribute a small amount toward network functioning through membership fees, for example, it will be easier to adjust those fees as expenses either go up or down according to economy of scale, as well as to continue charging a fee, even if that fee is a small amount.

If a network is fully funded by other sources from the start, it will be much more difficult to begin charging farmers in the future for benefits they have received for free. In fact, this is a fundamental question that might be posed to your nascent group of farmers and partners: "should we charge farmers to participate?" Even if the answer is "no," simply by having the conversation, you have established a collective awareness around operating costs, and around the fact that other sources of funding will be needed. Sometimes it is difficult to fully convey the benefits to farmers that a network might bring, particularly if they have not seen or experienced it themselves. That is where some of the examples in this manual of successful networks in operation may come in handy.

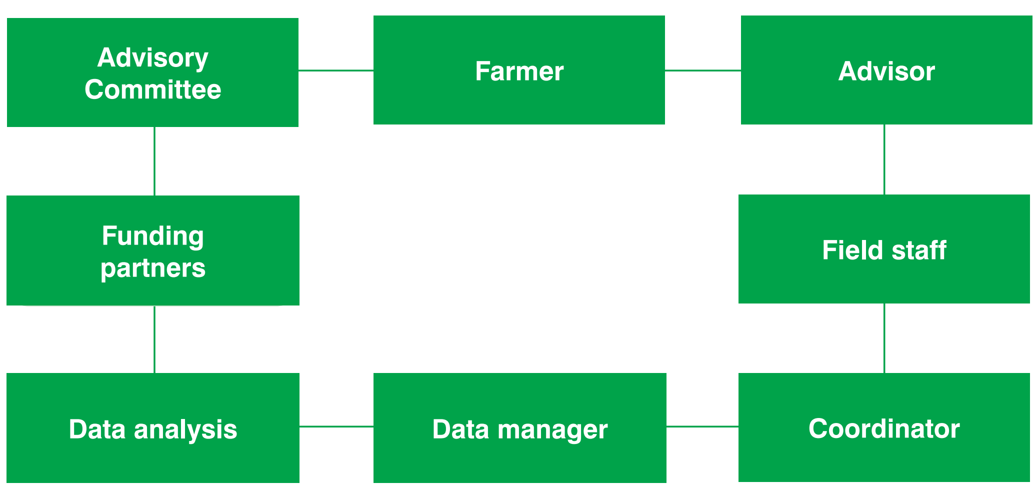
# STEP 3
## Identify roles and responsibilities

✔ Name a lead coordinator
✔ Define and prioritize roles
✔ Assign responsibilities
✔ Decide if a farmer advisory council is needed

A coordinator and point-of-contact (POC) is essential. This person will organize meetings, emails, teleconferences and administration and keep things moving forward. If you are reading this manual, that person might be you! The coordinator could be a volunteer farmer, crop advisor, community leader, conservation district technician, university extension agent, representative from a state agriculture or natural resource agency, or a conservation organization representative. This person does not need to be an agronomist, but should be a good communicator and taskmaster. The coordinator could also handle dual roles, but from the outset it should be made very clear who will take on the coordinator duties. The coordinator, working with any technical advisors on the project, will set timelines for various field plot activities and ensure they are met, including identifying locations of plots (GPS boundaries), sample acquisitions, report filings and data submission.

Figure 4 represents some of the roles and responsibilities that might be filled in the implementation of a farmer network research project. Who fills these roles is decided by the partners based on capacity, and there are several models in place that demonstrate the different entities likely to fill each role. For example, the role of coordinator can sometimes also be combined with a network leader who may work for another organization, or who might be a farmer or an advisor. In some cases the data manager acts as coordinator. Some networks operate with a farmer advisory board, which might provide overall direction. Other likely candidates to fill different roles in a farmer network include university extension advisor, retail cooperative agronomist or advisor, state ag organization, university researcher (to provide analytical support), technical advisor for GPS capability, conservation district technician, USDA agency field staff, and many others. The key is to ensure the skill set is in place for the task required, and/or to ensure proper training where it may be needed. Dedication and commitment to the objectives of the network are also critical.

FIGURE 4
### Roles and responsibiltiies



## STEP 4
### Conduct outreach and promotion

✔ Decide how you will recruit farmer participants
✔ Establish outreach methods (meetings, word-of-mouth)
✔ Formulate an outreach plan for data sharing
✔ Define audiences for the results

Outreach, education and promotion are important for many reasons. In the start-up phase, you will need a plan for recruiting partners and participants. In the later phases, you will need a plan for educating other non-network participants—such as other area farmers—about the results and knowledge gained from the network. It is very important to conduct outreach and promotion to representatives of other entities in your area who can either benefit from your research or be in a position to contribute funding or in-kind support.

In the beginning stages of establishing a network and collecting data, much of the time and attention is devoted to the "how" and the details of coordinating the timing of the multiple steps involved, and outreach to other partners can easily be overlooked. However, as you accumulate data and have a story to tell from that data, a plan for sharing that data is critical. You are handling what could be considered sensitive data (Chapter 8 for discussions of data privacy) so you will need to define the parameters for sharing aggregate data and ensure the network participants understand those parameters. Farmer identity must be protected, but unless the aggregate data is shared it will be difficult to promote the network and for others to recognize the worth of the network. Therefore, a plan to share that data with others to create and grow support for the network can be developed that is satisfactory to all participants.

First, establish a logical time frame for outreach and project implementation. Begin farmer recruitment well before you want to begin collecting data. The seasonal nature of on-farm research will, to a large degree, dictate your first year's schedule for outreach. Winter meetings are often appropriate for both sharing results and recruiting additional farmer participants, and you may want to piggyback on other regional meetings to announce the formation of the network and its objectives.

Define the various audiences for your messages, and tailor your messages accordingly. It is often useful to shape your messages around how each audience might benefit from a farmer network. University researchers, grower associations, farmers, crop advisors, watershed groups, ag retail outfits or cooperatives, and soil and water districts are just a few of the likely audiences you will want to target. The initial outreach stage is also a good time to ask for input from these audiences and cultivate support and potential partners.

Identify the best medium for your audience. Many potential partners will appreciate initial one-on-one meetings to invite honest input, and then periodic updates via electronic media. Farmers may appreciate a recruitment lunch and presentation, or an invite to your shop over coffee and donuts.Webinars can be effective in sharing aggregate data results, and reports, websites, and social media all may factor into your plans depending on the time and resources at your disposal.

## STEP 5
### Build data management and analytical capacity

✔ Recruit academic assistance or experts
✔ Establish database location and manager
✔ Establish timelines for data collection
✔ Establish clear data handling protocol
✔ Obtain training for data analysis if needed

Data is at the core of on-farm research. Even if you start with just a few field trials, you will need a solid plan for data collection, management and analysis, and it may be helpful to consult academia or another farmer network partner with known database management skills for assistance and advice.

There may be some sensitivity regarding where the data is stored that needs to be taken into account—e.g., can you send the data out of state or will this be an issue for your farmers?

You will need to establish a database to store and manage the on-farm data and identify someone to manage the data. The participating advisors will send their field boundaries and management data to the database manager, who will "clean" the data and be responsible for chasing down missing data and ensuring timelines are met. The research results generated from the on-farm plots will be of little value without oversight during the process to make sure the required data is captured and the data itself is accurate. The network coordinator or database manager must make sure the research plot protocols are followed, and then must ensure that data is gathered at the right times and submitted or entered into the database on time. A delay in one step of the data collection chain can throw off the schedule for analysis and winter meetings, so it is important to ensure that timelines for data collection and entry are met.

Data must be managed and handled carefully. A new farmer network research project team might choose to develop its own internal data storage and management capacity, or use existing databases built for the purpose of storing on-farm research trial data. The ability to extract and utilize the data in a timely way is important, and there are numerous conversations that should take place around how this will be managed and by whom, how it will be extracted and by whom, how and when it will be presented and in what format, and where it will ultimately be stored. For more on this topic see Chapter 8, which discusses data management. Whatever you ultimately decided, it may be useful to write up your data handling protocol for farmers and partners so the parameters are clearly communicated.

Data generated by on-farm research has value, but the value proposition is different depending on the user of the data. For example, farmers value their individual field data as it compares to the aggregate picture. Researchers value the data for how it can show trends and inform agronomics. To a researcher or fertility specialist, the more data, the better. The value of conducting on-farm research through a farmer network is that farmers themselves provide feedback on how they benefit from the data, how it can be improved, and what they want to measure. This ensures greater value back to the farmer, which is the primary purpose of on-farm research.

For farmers, the value of the network is generated through analysis and interpretation of their data. The farmer meetings (often held in the off-season or winter months) are an ideal venue to truly demonstrate the value of the on-farm research to farmers and other partners. There should be a concerted effort to present the data in a way that engages the farmer, enlists the farmer in a dialogue about what the data means, and encourages critical thinking in how that data might be used to support management decisions. It is important to think about who is the appropriate person to stand up in a room of farmers and go over the results of the field trials with them – who can interpret them accurately, elicit questions and stimulate conversation? The task of data presentation may pass from one technical advisor to another with training and coaching, but it is a good idea to have more than one person who will eventually be capable of presenting the data.

Sharing the data is not just about handing out a piece of paper and sending farmers on their way. The network's value to farmers stems chiefly from the presentation of data and the analysis that you provide, and it is critical to structure your data presentation meetings to get the most from them as possible. There is a balance to be struck between giving too little information or too much, because the lattercan be overwhelming and stifle creative thought. You may want to think about structuring the meetings so that you present aggregate data first, and then hold break-out sessions to go over questions or take a closer look at individual farmer data. There is no set formula for this— just adopt a common sense approach that incorporates farmer preferences for how they want to see the data. For more meeting tips, see Chapter 7, Rule #4, which addresses using the power of peer meetings.

# STEP 6
## Develop tools and protocols

✔ Identify partners to help develop protocol (university, extension, etc.)
✔ Ensure field trial protocol can be implemented
✔ Define tools to be used (precision ag tools & technologies)

Protocols already exist for conducting on-farm trials for measuring rate, timing, form and placement of nutrients for corn, wheat and soybeans. Graphics in Appendix D provide examples of such protocols. Trials on fungicides and other products – such as N stabilizers – have been conducted extensively for years, and protocols for such trials closely adhere to the randomized strip trial design that is the established research practice. Other protocols are in development for additional crops like sorghum and cotton.

With the help of university experts or precision ag technology experts, protocols could be developed for anything partners and farmers wish to measure. An individual or team of experts should be assembled who can be available to develop protocol for on-farm replicated strip trials.

Once the protocol is developed, the team conducting on-farm trials must be able to convey clearly how the protocol will be carried out—particularly with farmers in the network—and preferably be in the field during planting and other critical moments to ensure farmers understand and are following the protocol. A forgotten detail can sometimes render an entire dataset unusable. Having a protocol for the data collection process itself can save time and headaches later on. Decide who is ultimately responsible for the quality of the data, what to do if data is submitted with errors or incomplete, and what the consequences will be for faulty data collection. Establish a timeline for the data collection and entry, make sure everyone knows the timeline, and stick to it. A sample timeline is shown below in Table 2; this timeline was used in the data collection process for the Maumee Farmer Network.

Identify the tools you will need to implement the network trials, and understand where to obtain them. For example, the clipper tools used to cut a 10" section of corn stalk for the guided stalk sample had to be specially made so that the tool, when resting on the ground, would cut a uniform sample size at a sample height dictated by the research protocol.

TABLE 2
### Timeline for farmer network rate trials
OH, MI, IN, IL

| | |
|---|---|
| June 15 | ✔ GPS field boundaries—turn in shape files to data manager<br>✔ Lay out and flag strip trials |
| July 15 | ✔ Organize shape files, send to imaging company for flying imagery |
| August 15 | ✔ Sample points picked to ID where to collect cornstalk tests in nitrogen plots/fields<br>✔ Yield monitor calibration clinic |
| November 30 | ✔ Farm management data collection completed |
| December 15 | ✔ All farm management data entered into database |
| January | ✔ QA/QC data: identify errors, clear up missing data, & conduct data analysis |
| February | ✔ Prep data for meetings |
| February or March | ✔ Hold winter meetings |

Soil and tissue tests and other lab samples should all be sent to the same lab so the data is all treated the same way and according to the same protocol. Hand-held GPS devices and other such tools are common, but you wish to employ additional tools. Drones, for example, are new tools that could help advisors and farmers scout fields for multiple purposes. Drones could be ideal tools for a farmer network, with a set of farmers participating to share in the use of the drone and the purchase of camera technology and software. Other tools and technologies can be tested by farmers in a network, and the efficacy of those tools can be reported out to the wider network of farmers for the benefit of the entire watershed.

# STEP 7
## Assemble training materials and plan trainings

✔ Define training methods/identify trainers
✔ Establish plan for ongoing training

Numerous organizations and entities have experience conducting on-farm research (Extensions, USDA, universities, conservation districts, conservation organizations, grower associations, etc.). Some of these same entities may be partners in an on-farm research project, and training should be designed with input from partners and based on mutual goals. In our collective experience, to maintain data integrity and ensure the value of the data going back to the farmer, it is extremely important to train advisors, coordinators, and field staff appropriately, and keep on schedule for timely flow of information and field activity. Any training should also include a contact list of additional soil nutrient and soil health researchers and experts who can be contacted for advice. This manual is intended to help provide the building blocks for a complete program, but more comprehensive training in certain components is needed when starting a network. Just a few examples of training topics might be:

- Use of management data collection sheets
- Equipment calibration
- Proper data entry techniques/on-line data entry
- Use of a corn shearer to collect stalk samples for the Corn Stalk Nitrate Test, as well as marking plots, bagging samples and calibrating yield monitors
- Interpreting aerial imagery to identify collection areas for tissue sampling
- Organizing, advertising and conducting an informational farmer meeting

As mentioned in Step 6, for each project and protocol implemented, it is critical to conduct an agreed-upon set of activitiesaccording to a timeline that is understood by all. This is particularly important for those responsible for collecting information from the farmer, including management data and samples, and for sending information to the data manager. A coordinator, team leader or farmer advisory board member might be responsible for enforcing the deadlines and helping to ensure activities are carried out on time.

Your training plan might also include periodic webinars prior to each activity as a supplement to an in- person training that covers all the bases. For example, just prior to laying out plots in the field, a refresher webinar could be held to remind advisors of the steps needed in laying out the plots. If your network relies on yield monitor data, a yield monitor calibration clinic or webinar prior to harvest is often a good idea. Sometimes the training needed is not always known at the outset, so establish the first year of your farmer network as a somewhat experimental time to allow for mistakes, adjust and refine your schedule, and factor in additional training as needed.

## STEP 8
## Develop data sharing and protection policy

✔ Consult with database manager
✔ Decide who can see the data
✔ Define protection standards and methods
✔ Record policy to share with farmers

The key educational benefits of the farmer network will stem from the quality of the data, so it is important, for the comfort of the farmer in your network, to establish clear protocols for data management, confidentiality and privacy. You may have considered this step in the early stages of establishing the network to obtain funding and partners. Core data management principles might include statements about confidentiality and data handling, plans for how to deliver research results to participants, and restrictions on who will be allowed access to the information generated by the network. Typically, farmer networks share aggregated data, but keep individual farmer data private. Other factors to consider in this regard include:

- **Data-sharing agreements:** an established data-sharing policy may be important to your group of farmers. It is imperative that data is shared in some manner so that those within and outside of the network will benefit, but there can be clear guidelines as to what data is shared and how.
- **Confidentiality:** making sure that when data is shared (whether individually or aggregated), nothing in the information can be traced back to an individual farm operation. This includes map details or other delineators associated with the data.
- **Benchmarking and measuring impact (see discussion in Step 9):** you may require network participants to fill out annual surveys to help track and improve the effectiveness of the network.

This manual also includes a complete chapter on data privacy (see Chapter 8).

## STEP 9
### Implement plan and evaluate

✔ Benchmark and track progress from the beginning
✔ Develop farmer survey
✔ Evaluate, adjust, incorporate
✔ Look back, look forward

One way to check the effectiveness of a network is to determine whether it has benefited the farm community in which it operates. The overarching goal is not to just produce data, but to produce information that will lead to positive economic and environmental change. The economic impact of these changes (e.g., what was the yield response in relation to the change in the input amount?) is much easier to document than environmental impacts.

Measuring benefits is critical to communicate the value of the network to the community at large and to others who are watching the network's activities. However, measuring impact objectively is difficult. Changes in management are not often dramatic or highly visible, particularly in the first year or two. The ecosystems impacted are so large, so complex and affected by so many variables outside of the farmer's control that the environmental impact of such management changes may be imperceptible on such a limited basis. The challenge most networks face is in finding a means of documenting management changes brought about by participation in the network, and documenting that those changes are durable and may extend well beyond the footprint of the field trial.

Given this, you will want to consider the capacity of your network to benchmark a starting point and document changes going forward that result from network participation. What you measure will depend on the goals of the network and what you consider to be a positive impact.

One effective means of measuring impacts from a farmer network is to administer a farmer survey at the beginning of the project and every year after that. You can also consider what management data can be collected automatically that can be recorded in the database to document impacts (e.g., asking farmers to record the amount of N applied on the farm's remaining acres might show an educational impact from N rate trials). An example of a farmer feedback survey is included in Appendix B.

If you have the resources, it can be extremely valuable to consult with a university partner or social science expert to design and administer farmer surveys. Academic assistance may also be helpful in analyzing survey results since, once farmers return their surveys, you will have a stack of them on your desk that you may wonder what to do with! Having a plan for analysis and follow up is essential, particularly if you are using the survey for multiple purposes—e.g., both to measure impact on management in the field and to document feedback on changes farmers would like to see in the network.

Individual interviews or focus groups involving smaller numbers of network participants can also be effective ways to gather feedback and metrics on network effectiveness. This may depend upon the amount of time you have available, and farmers' willingness to participate. Some networks have found it effective to hand out surveys during winter meetings prior to the meal being served, and the survey becomes the "meal ticket" that must be turned in before lining up.

CHAPTER 7

# Harnessing the power of the network

## SOME RULES TO LIVE BY

The power of the farmer network is based largely on the network's ability to generate meaningful data through field trials using sound research protocol, and then using the data to help participating farmers achieve better management, profitability and environmental outcomes. Attempting to implement management changes based upon faulty data has negative consequences, and wastes time and resources. Each year equals one season of data collection, and there are no opportunities to retrace steps once the season is underway. This is why taking the time to formulate a solid plan and timeline early on will pay off down the road. The ability to execute trials and collect, manage, store, access, interpret and present the results of the on-farm research you are conducting is critically important, and takes time and careful planning.

In the initial stages, it can seem that the results of the research are somewhat difficult to interpret. Sometimes what is learned one year may simply show farmers the mistakes that were made, or provide lessons learned in what not to do next year. Each season's experience will instruct participants how to carry out the on-farm research more effectively and efficiently in subsequent years. Each year, after the trials are completed, it is useful to evaluate how the process worked and adjust accordingly for the next year. This chapter offers some straightforward advice to supplement the nine steps provided in the previous chapter's checklist. In later chapters, we will provide more detail on using the data from the farmer networks to teach, learn, and make gradual changes for more efficient farming.

### RULE 1 Make it easy

Field trials should be relatively easy to implement to attract and retain farmer participants, particularly in the startup phase. This is why it is also important to have network members participate in the planning: they are ultimately responsible for implementing the trials, and ultimately responsible for using the results to make adjustments in management. They will be more motivated to make changes if they are participating in trials that are of interest to them.

Examples of making test strips easier to implement include:

- Match plot width with equipment width (planting, spraying, harvesting, fertilizer applicator, etc.).
- Match plot length with field length to avoid having to make changes mid-field
- Consider the mechanics of the data to be gathered – does the farmer have a grain yield monitor, or will a grain weigh wagon be necessary? If harvesting crops other than grain, (i.e., silages or other forages), consider how those will be weighed to document yields.
- Avoid planting time interferences, such as changing starter materials or rates or changing varieties. Such activities take precious time to implement when farmers are focused on getting the crop in the ground. Anything that slows planting increases the chances that a plot will not be established due to last minute field decisions. Strip trials that involve simple

with/without comparisons, pre- or post-planting application variables, or that involve the use of equipment that can make changes on the go (such as planters with variable population controllers) are more likely to succeed.

Aside from making the trials easy to implement, the data generated from the trials should be made relatively easy to understand, and presented in such a way that participating farmers can see how the information can be practically applied.

## RULE #2: Avoid making critical management decisions from one year of data

The first year of data-gathering might be used to benchmark a starting place, but does not usually produce sufficient data on which to confidently change management from the start. Generally, two to three seasons of data can begin to show trends that farmers might apply to management decisions for the following seasons and on into the future.

After accounting for weather variability and other factors that are out of the control of farmers, two to three years of data should begin to produce meaningful information that will stand up to scrutiny.

This doesn't mean that useful information is not gleaned during each year of the process – in fact, many trends are spotted early that can give farmers some indication of what changes might be useful to begin implementing. But caution is in order that one or two year's data does not necessarily show the beginning of a long term trend.

## RULE #3: Aggregate the data for larger effect

Stresses from other production factors (too little or too much rain, compaction, etc.) need to be identified as variables that will impact results, but which will also provide real value. Most everything works well in a good production year without stresses, but farmers are interested in results in stress years because they represent real-world conditions.

Having multiple participants conduct similar trials is helpful in understanding how a variable performs under a wide variety of local conditions, not just one farmer's management. The network collects and aggregates data from multiple fields and farms within a watershed or geographical location. As was mentioned in previous chapters, the initial stages of setting up on-farm research trials may involve just a few trials on a certain topic, to test and adjust the process. Data can be aggregated in many ways – typically it is aggregated across a group of farmers in a given region to examine trial performance under similar conditions and variables like soil, weather and crops.

Many researchers are also keenly interested in the power of large data sets to compare responses across broad geographies and conditions. Such data sets can improve agriculture's ability to make inferences about the 4Rs and establish a greater level of confidence in recommendations on any one of the 4Rs. This concept is discussed in more detail in Chapter 9.

## RULE #4: Use the power of peer meetings to influence learning and change

As discussed in previous chapters, the network can and should provide group meetings designed for participatory learning. The group meeting is a powerful tool for sharing information and can also help the group to coalesce and affirm its purpose. In meetings to present farmer data, the presenter is also often the facilitator of the discussion. When presenting many graphs of aggregate data and the agronomic context for the data, the facilitator should strive to draw out questions from the farmer audience, stimulate discussion and use the data as a basis for dialogue. Farmers are accustomed to asking, "What rate of nitrogen do I use?" The farmer network does not attempt to supply a ready-made answer to this question. Rather, the purpose is to provide a platform for the farmer to be more in control of nutrient management decision-making. Network data can be used to provide the basis for the farmer to make an informed decision about nutrient application rate (or timing, placement and form), but it does not typically provide prescriptive answers or tell the farmer what to do.

The meeting or presentation forum you choose will be based on the preferences of your farmer network participants and what will be the best venue for discussion. Each network may choose to hold meetings in a different way, but the basic concept of participatory learning should be applied no matter the venue. Various examples of meeting venues and forms are provided in Appendix A containing farmer network models from the field. The range of options most commonly used includes:

- Two to three meetings per year: post-harvest winter meeting, a pre-planting spring meeting, and/or a pre-harvest yield monitor calibration meeting. The winter meeting should be held prior to the time most of your farmers will be making decisions about the next season, so the data is useful in informing those decisions. These may be larger or small group meetings, but typically involve presenting the aggregate data to the group, while also handing out individual plot data to participating farmers. This way, farmers can see how their fields stacked up against other fields in the program. Some networks also hold summer field days to look at the various research plots and discuss findings during a critical growth stage.
- Small group meetings with one advisor and a few farmer network participants to discuss the groups' plot data. These meetings might be set up to provide farmers with both their individual plot data as well as present data from the aggregate group. The value in smaller groups is ease of communication. Many farmers feel reluctant to "open up" and ask questions in a large group setting, for a variety of reasons including competition with other farmers.
- Webinars to present the aggregate data and smaller group meetings for discussion of individual data.
- Large group meetings, followed by smaller group meetings. These require a bit more planning and time to execute, but are often worth the effort. The large group meeting allows you to present all the data at once, while the subsequent smaller group meetings can provide the more focused, one-on-one dialogue and Q&A needed to clarify information for the farmers.

The meetings should do more than merely present the data from the network. Learning from the data is what the network is all about, and taking the time to set up a positive learning environment is critical. Some of the key questions and discussion points that the facilitator can pose include:

- What can we glean from the data? Are we seeing trends, correlations, or just "noise"?
- What were some personal observations during the growing season? Anything that might provide clues that may correlate with the data?
- What went wrong this year, and why? How can we improve the situation - are changes needed?
- How can we get the work done more efficiently (plot layout ease, sample timing, assistance with gathering information, etc.)?

- Have we learned what we set out to learn (reached goal), and is it time to move on to something else to investigate (set new goal)? Should we reassess our expectations?
- What other factors are emerging that are worthy of research?
- Is our current research indicating there are other things going on that warrant investigation?
- What are the resources needed to continue the current research or expand to other items to explore?

Facilitators have sometimes used the aerial images collected from the networks as a teaching tool and to set the stage for the presentation of the data. Many interesting observations about management practices can be made from close examination of the aerial imagery, such as applicator equipment errors or "skips," drainage issues, differences in cultivars, areas of higher or lower fertility, and other interesting phenomena that are not readily visible from ground level. Sometimes a willing farmer participant will volunteer his imagery for such examination in front of the whole group, which can help other participants open up.

## RULE #5: Keep it fresh

Some members of the network will be anxious to move on to something else as they learn and gain confidence in implementing changes in their operations. Others, who may have recently been introduced to the network, for example, may want to see how that practice works on their farm.

Hopefully this means growth of the network, not only by number of members but by the number of technologies evaluated. Attracting other partners to the network, involving new farmers and asking for new ideas will continue to rejuvenate the network.

## RULE #6: Promote, promote, promote

As mentioned previously, one of the benefits of a farmer network can be to highlight the fact that farmers are actively participating in research projects on their farms that will help them become the best farm operators they can be in terms of their nutrient management, long-term profitability and environmental footprint. Public awareness of what farmers are doing will not happen unless information about the network is shared and its results promoted broadly.

A successful farmer network should also seek to transfer lessons learned to other growers in their area who may benefit from the research, as well as to other neighboring regions and farmers who may see value in producing this type of information for themselves in their locality.

New groups may arise in the same geographic area as existing groups if they want to research practices, products, etc., that an existing group lacked the interest or the resources to study in depth. These groups can certainly complement each other, and may end up sharing resources such as network coordination or expertise in plot management. An example of this may be a livestock feed company that wants to encourage the use of sustainable production practices among their grain suppliers so they can promote their end product as being socially responsible. The company might seek out local farmer cooperatives or groups that are already established to engage with, or look to them asexamples for building a new farmer group. Support might come in the form of funding, meeting space, providing technical assistance or learning opportunities (such as inviting experts to conduct workshops, and by seeking opportunities to increase value and profitability to their grain producers.

Sharing the results of the network research can be done in a variety of ways. Existing networks, as shown by the examples provided in this manual, share information via website postings, presentations, news articles and written reports. Other means of publicizing and promoting the activities and results of your farmer network could include the following:

- Create a logo and name for your network
- Invite reporters from ag journals to your winter meetings
- Provide periodic updates to supporters and partners on network happenings
- Create easily digestible synopses of the research results in annual reports and share via your website and other partners' websites
- Host field tours to participating farms for key partners where you might present the data in charts or have the farmer discuss how the network has helped him or her make management adjustments
- Make presentations at conferences and venues where your key audiences gather
- Distribute field signs with the network name for posting in participating farmer's fields

CHAPTER 8

# Data privacy, data management, data quality

One of the chief assets of on-farm evaluations is the data collected. The goal is to extract knowledge from the data to help farmers make better management decisions.

Farmer networks collect different types of data, including crop yield, aerial and satellite imagery, crop management information, crop budget expenses and input prices, soil drainage data, machinery/equipment-related data, as well as results from soils or plant tissues testing. The amount and variety of the data collected on modern farms can be overwhelming. All these data are valuable in data analyses.

## Data security, privacy and confidentiality

Often, many different partners or stakeholders are involved in implementing a farmer network. This means there may be potential concerns about data privacy, confidentiality and ownership. Farmers usually want to know who owns the data, how data are used and what happens if the data are misused. The recent upsurge of the "big data" trend in agriculture has also fueled discussions about data ownership and the purposes of accumulating large data sets.

Another concern to farmers participating in farmer networks is data security. It is common to hear news about stolen credit card information or compromised consumer data. Farm data can be environmentally or financially sensitive, so participating farmers have a right to understand how their data will be protected.

Data security can be addressed in different ways. Having signed agreements between farmers and parties that collect, process and analyze the data can help protect data from misuse. Another way is to form farmer-owned entities that can store and manage the farmers' data.

Although there have been many discussions pertaining to how farmers' data can be legally protected, there is no clear consensus on which category of the law best describes protection of the data and information belonging to individual farmers. However, current laws protecting intellectual property, trade secrets, trademarks or even patents can be applied in situations where the agreement regarding data ownership and security, or data use, is compromised between farmers and data service providers.

## Collecting, storing and processing data

There are different models for collecting and storing farmers' data. One model is based on group leaders, crop consultants or field agronomists working directly with farmers to collect all management information, in-season observations and yield data. Another model is to use a centralized system in which a dedicated person or group of people manage the data from a central location. In both models, different data collection tools can be used. The many ways in which data are submitted (e.g., paper forms, online data collection tools, phone calls, Internet and wireless data transfer as well as face-to- face meetings with farmers and agronomists) complicates both storage and privacy protection.

On-farm visits are often used to collect and verify information. During such visits, an agronomist or crop consultant can download data from equipment monitors and make notes.

The field data collection sheet (also called a field information form, management data collection sheet, and other names; see example in Appendix C) is a tool used to capture the essential individual and field-specific information needed to successfully complete on-farm studies, analyze data and interpret results.

Electronic data collection has become quite common as well. The Iowa Soybean Association On-Farm Network® uses an online data entry tool to collect management data for different on-farm studies. The online form allows collection of specific management data (sometimes sensitive) for each individual field.

These forms can include several dropdown options to help users easily select the necessary options without typing the information. Because of different types and brands of products tested by farmers in different regions, online forms may need to be modified to specific geographic locations or specific on- farm studies. These forms should be flexible enough so that users can modify or add important information.

Use of wireless technology to transfer farmers' data is rapidly evolving, too. Farmers working with most major equipment manufacturers can transfer both management and spatial data from their equipment in the field to their computers or to data storage managed by crop advisory or farm management groups.

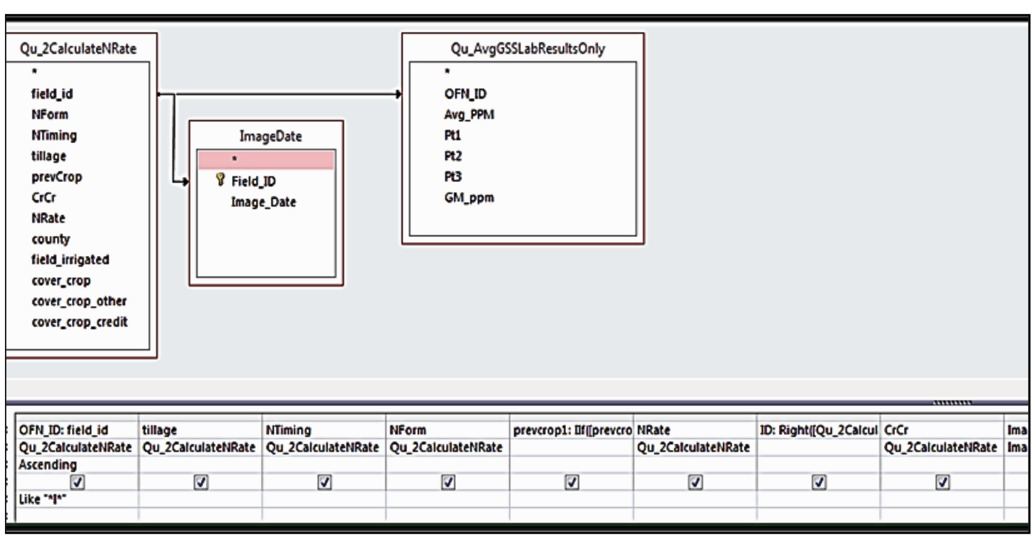
These data are usually stored on a server owned by a providing company or on secured cloud storage, so data is automatically backed up.

## Data management

Management of different types of data—such as lab results from soil and tissues samples, management data, and spatial data—can be done in various ways. A common method is to use a database platform such as Microsoft Access or SQL. Employing databases allows better management of these various data. Open Data Connection Protocol (ODBC) is commonly used

FIGURE 5

### Sample data window



to retrieve and connect varies types of data, including lab soil and tissue analyses, management data and spatial data.

Figure 5 (page 41) depicts a Microsoft Access window showing different data sources and layers used in management farmers' data. This snapshot illustrates how different data tables (management information, aerial imagery date, results of lab analyses) can be joined in a query. ODBC connections to online data ensure that data for producing individual field reports or conducting group level analyses is always the most current.

## Data quality control

Quality control is critical in ensuring that data used to create individual field summaries and conduct group level data analyses are free of errors and mistakes. There are numerous ways to identify and remove errors and bad observations from spatial data. Commonly used tools include current and historical aerial imagery, farmer and agronomist notes, information about machinery speed, grain moisture, and many others.

Private companies have developed and employed a variety of GIS tools to clean yield data. Most errors can be avoided if farmers properly calibrate yield monitors, onboard sensors and application equipment.

Some errors can be spotted by using simple exploratory statistical analysis and verifying the extreme values. Others can be identified by using specifically designed GIS or statistical tools. Controlling data quality should be a two-way communication between group leaders and farmers. Often, many errors can be explained by merely discussing the data with growers or agronomists, or simply overlaying different spatial layers.

CHAPTER 9

# Putting the data to use

Farmer data can be used to build important decision-support systems. As more data is collected in a geographical region over longer periods of time, farmers gain more confidence that the data represents the range of environmental and agronomic conditions under which they operate. There are many ways to utilize farmer network data, ranging from running very simple individual or aggregate reports showing nutrient application, yield and tissue test results, to creating more complicated hierarchical analyses.

As you weigh the possibilities of a farm research network, it is important to consider the amount of data you will be collecting, and that handling and working with that data will require some basic level of expertise. You'll need to decide early on:

1. How will you handle data from observational studies (surveys) vs. on-farm experiments or trials?
2. Who will summarize data, interpret results and make decisions using aggregate data from
   - Nutrient status surveys with remote sensing?
   - On-farm replicated strip trials?
3. Who will present the data to farmers in winter meetings? Who will analyze, summarize and interpret data?

As shown in the other chapters of this publication, farmers involved in local groups or networks usually work with different private and public consultants, scientists, extension personnel, agronomists and technical providers.

Different models for data collection, data summary and results interpretation are used. Farmers have been collecting data in the form of plant tissues test values, soil grid sampling and yield maps for many years. Unfortunately, studies show that only a small percentage of spatial yield data or other forms of data are being analyzed, summarized and used by farmers and agronomists to make management decisions.

With ever-larger amounts of data being collected on modern farms, farmers often need help to handle and summarize different types of data. This is also relevant for data from on-farm studies. While historically one of the main objectives of field extension agronomists was to educate growers about best management practices, the question is whether they should also help farmers analyze, summarize and interpret agronomic data.

Although time will show how data will be handled in the future, currently many groups across the country are working on developing decision support systems that incorporate on-farm site specific data, analytical tools, crop, soil and weather modeling, and risk and economic analyses. Organizing farmers into groups allows centralization of many processes related to data analysis, and makes it easier to utilize the expertise of university scientists or consultants. One key feature of the centralized data management is that farmers can discuss and learn from their data as well as data of other farmers during grower meetings. A centralized model of handling farmer data also enables the development of management decision support systems.

## Nutrient status surveys with remote sensing

Farmers involved in networks can participate in survey studies or conduct on-farm replicated strip trials. As more spatial layers become more accessible, nutrient status surveys can be guided by aerial or satellite imagery, historical yield data, and/or current or historical management zones within fields.

When conducting survey studies, it is important to clearly define the survey target area. For example, in many cases, a survey will target specific management practices or conditions across a watershed, a cropping district or a state. After the target area is defined, a sampling design is implemented to effectively sample the target practices or conditions. It is also important to consider how the fields are selected in the survey. It is often recommended that fields be selected randomly within a target area, but stratified or cluster random sampling is often more efficient for reducing the cost and variability in the data.

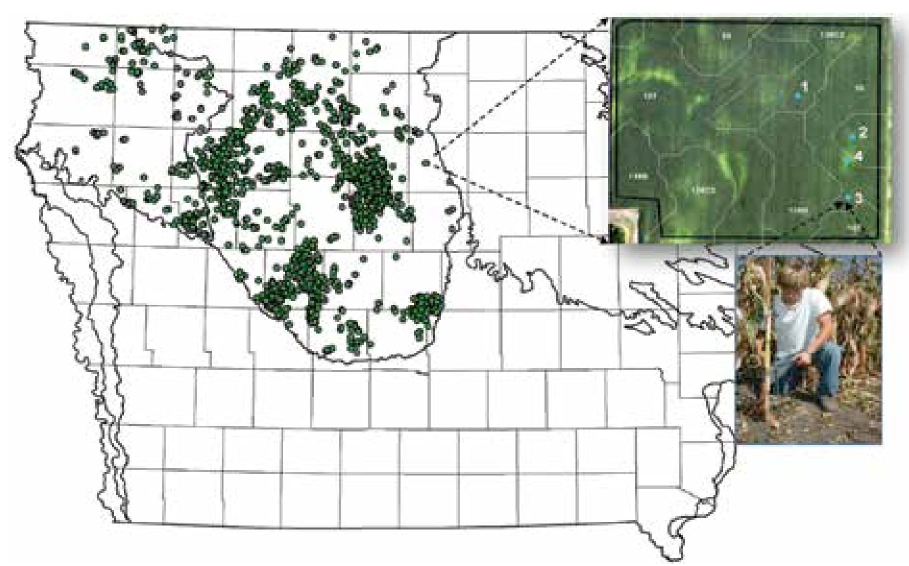
An example of the end of the season corn N status survey guided by aerial imagery in Iowa is illustrated in Figure 6. The main target area for this survey was identifying the major farmer N management practices across the state. Corn canopy imagery and digital soil types were used to guide the selection of sampling areas within each field. The four sampling areas were located using handheld GPS. Three predominant soil types were used to better represent the average field N status and reduce unexplained spatial variability in the corn canopy and to avoid areas of the fields where there might have been application errors.

There are many ways to summarize data from observational studies. Appendix E provides more technical and detailed examples of analyses for observation studies and replicated strip trials. For additional examples, as well as the individual reports associated with the analyses, please visit the Iowa Soybean Association On-farm Network webpage: http://isafarmnet.com/onlinedb/gss/index.php.

FIGURE 6

### Example of the late-season N status survey

Guided by aerial imagery of corn canopy conducted by the Iowa Soybean Association On-Farm Network




Approximately 1600 corn fields were sampled using the corn stalk nitrate test within the Des Moines Lobe and North West Plain Landform areas of Iowa from 2006 and 2013. The imagery and digital soil types were used to select three sampling areas, one within each predominant soil type to represent the average field N status. The fourth sampling area was chosen where corn canopy showed the potential for nitrogen stress.

## On-farm replicated strip trials

There are different definitions of on-farm replicated strip trials. Throughout this manual we discuss on-farm trials that are conducted by farmers with the help of scientists, local agronomists or consultants. In addition, we emphasize that treatments applied in strips by farmers are always replicated and experimental units that span the length of farmers' fields. In the majority of situations, farmers use their common application equipment, tillage implements, sprayers and grain combines equipped with onboard GPS and yield monitors. Some farmers can use weigh wagons if yield monitoring technology is not commonly adopted for crops such as corn for silage, forages or cover crops.

On-farm replicated strip trials share characteristics of both observational studies (surveys) and controlled field experiments. The data collected from on-farm trials can be used to draw cause and effect relationships between factors measured at different scales.

When planning small-plot controlled field experiments, scientists should clearly define the target population (target area), replicate treatments at least three or four times within fields, and assign the treatments randomly (if possible or practical) to available experimental units. The experimental units, often called strips or passes, are those that receive individual treatment applications. The number of available experimental units defines the number of replications within the field.

The target population/area should represent all possible management and soil conditions of interest within a geographic area, watershed, and county or farmer group area. The method of selecting fields within the target area is often more important than assigning the treatments to experimental units within a field. Random, stratified or cluster selection of fields within a target area is commonly used. The last two methods often require a fewer number of fields than the random selection. Working with farmer groups enables researchers to select enough fields to adequately represent the target area.

Replications are critical to adequately quantify the variability among experimental units with the same treatments. Replications are needed to separate the treatment effect from the experimental error or noise. The latter often arises because of error in measurements and spatial variability in soil properties.

Randomization helps avoid potential bias arising from previous management practices, such as manure application, tillage, tile drainage or crop residue position within fields. In addition, scientists commonly use randomization to ensure that the experimental units are statistically independent as well as to utilize a wide range of statistical tools to neutralize the effect of spatial variability during analyses.

However, a common objective of many on-farm replicated strip trials is to quantity spatial variability in yield response to evaluate or develop site-specific management recommendations.

Analysis of data is another important piece of executing on-farm studies. Appendix F offers a more thorough and detailed discussion of data analysis using replicated strip trial data from the Iowa Soybean Association On-Farm Network®.

Data analysis does not need to be complicated, however – and not every network advisor or data interpreter will have the capability to perform these types of analyses. Often, simple summary reports can help farmers make important decisions. For example, summaries of individual replicated strip trials across Iowa are publically available at the ISA On-farm Network® database of replicated strip trials at: http://isafarmnet.com/onlinedb/index.php. The online tool allows users to search individual trial reports by crop type and category of trials within Iowa counties or watersheds. This tool also allows users to perform a simple return on investment analysis by entering their own input costs and crop prices when using aggregate data for a specific category of trials.

CHAPTER 10

# Farmer network funding models and options

Farmer networks require funding because they involve time, use of tools, and a commitment to year-round schedules and deadlines for data entry and analysis. This chapter will examine options for funding of farmer networks, existing models and potential avenues for funding that may not have been fully explored by others yet.

There are various farmer network structures that can guide your thinking on how to set up a network. Similarly, there are different funding models that might work in your region. The first place to start might be to contact the farmer network partners that are geographically nearest to your location to find out if there may be existing capacity or components related to their network functioning that you might tap into. For example, many farmer networks order aerial imagery to be flown at certain times during the season. Ordering bulk acres can increase efficiency for the imaging company and lower costs, so it's a good idea to try to coordinate with an existing flyover schedule that may occur in your region if you plan to use aerial imagery as a tool. Of course, there are other options for obtaining aerial imagery and you will want to research the best option for your network objectives.

Whatever funding model is used at the outset will set up expectations for the future. If you start by asking farmers to contribute a small amount toward network functioning through membership fees, for example, it will be easier to adjust those fees as expenses either go up or down according to economy of scale, as well as to continue charging a fee, even if that fee is a small amount.

If a network is fully funded by sources other than farmer participants from the start, it will be much more difficult to begin charging farmers in the future for benefits they've received for free. In fact, this is a fundamental question that might be posed to your nascent group of farmers and partners: "should we charge farmers to participate?" Even if the answer you receive is "no," then at least the conversation has established a collective awareness around operating costs, and around the fact that other funding sources will be needed.

In this chapter, we offer some concrete cost and benefit figures that may help you make a case for establishing and funding a farmer network. Please note that these costs and benefits may vary dramatically from region to region and from year to year, and are used to illustrate a broad-brush scenario that can serve as a guide to set up your own cost categories.

Table 3 (page 47) shows some of the cost categories and considerations associated with running a network.

It is important to keep in mind that some of these costs are fixed and some are variable. Adding more farmers and trials will increase equipment, aerial imagery and plot layout costs, but should not add to the costs of a coordinator, for example. Once you have laid out cost categories and assigned a cost (or no cost) to each of these, you will have a better idea of how much is needed and what to prioritize.

A network may not want to collect aerial imagery, for example, or may want to try using drones or satellite imagery instead. A network might not have much in the way of product costs if it is not testing products.

A coordinator might double as a data manager, or a consultant might also serve as a data manager or coordinator. Combining roles will save money, as long as it is feasible given existing

TABLE 3
### Network costs and considerations

| Coordination costs | To consider |
|---|---|
| Coordinator (oversee tasks, timeline, functioning of network, partner engagement) | Undertake as part of existing job duties? Hire coordinator? |
| Data manager (ability to manage all data coming in to the database) | Some technical expertise required to manage data, generate reports, order imagery, collect field boundaries |
| Data base (housed where?) | Could entail significant cost if database is housed externally (some universities have this capacity) |
| Website | Where will you publish results/will you allow farmers access to their data on-line? Who will populate and maintain the website? |
| Meetings | Planning meetings with partners, winter farmer meetings (meals served?), larger meetings to share research/gather partners |
| Surveys: survey development, administration/interpretation | Academic assistance required? What will you do with the results? |
| Travel | Will mileage be required for the team leader/consultant/coordinator? |
| Data analysis/interpretation | Will you require assistance from an expert or a grad student in assembling and interpreting the data? What will that cost? |
| Reports and communication | Printing reports for meetings, promotional materials, brochures, newsletters, presentations |
| **Field costs** | **To consider** |
| Equipment | GPS, sampling equipment, yield monitors |
| Lab analysis | Soils, tissue tests, shipping |
| Aerial imagery | Generally a per-acre fee |
| Plot layout, management data collection, yield monitor data, consultation and technical in-field support to farmer, recruit farmers | Consultant or advisor costs—these are important categories as the quality of all data coming in will hinge on whether these tasks are performed well |
| Product costs | Who will supply the products for product testing field trials? |

human resources. This analysis might be broken down into a per-acre or per-trial cost to quickly assess the additional costs associated with adding farmers, trials or acres to the program.

## Estimating farmer benefits

A fundamental question is how to quantity the benefits of farmer networks to show that the money invested in it ultimately translates into more profit or more benefit. It is beyond the scope of this manual to assign a dollar value to the soil, air and water benefits resulting from improved fertilizer management. Instead, we will focus on how the benefits of improved nutrient use efficiency (NUE) through better fertilizer management might pencil out for the farmer. This information can then be communicated to farmers and potential funding partners.

One way in which networks have improved farmers' profits is by improving farmers' NUE. Results of some surveys conducted by EDF of farmer networks in the Midwest and North

Carolina estimate that the networks have helped farmers reduce N inputs by 20% or more without reducing yields.

Of course, nutrient use efficiency is not about reducing N inputs, it is about increasing efficiency. As a result of increased efficiency, farmers are decreasing N losses to the environment. While this is impossible to accurately measure for a given field or farmer without the expensive edge of field monitoring equipment, we can get meaningful information using the data from farmer networks. With this data, we can make a comparison between acres where farmers have decreased N use (because more N wouldn't lead to higher yields in those areas), and acres where they have increased N use (because those areas of the field could utilize the additional N), achieving an overall efficiency in N use while also reducing average per acre N use. This amounts to increased profits and less losses of N to the environment. These benefits are shown in real dollars in Table 4.

TABLE 4

### Nitrogen savings

N efficiency benefits in $/acre

| | |
|---|---|
| Farm size (acres) | 1,000 |
| N rate (lb/acre) | 180 |
| N use (total lbs) | 180,000 |
| N price ($/lb) | $0.50 |
| N cost (total $) | $90,000 |
| Typical N savings (%) | 20% |
| Typical N savings ($) | $18,000 |
| Typical N savings ($/acre) | $18.00 |

These price assumptions are based on corn and N prices for fall 2014, and can be adjusted to reflect current prices and different N rates, since fertilizer prices and corn prices fluctuate daily. This example is offered as a simple analysis for showing how a 20% increase in efficiency can translate into a savings and greater profit for the farmer.

These calculations can be useful to consider the general scale of benefits from increasing NUE on the farm, and how different variables such as farm size, prices, rates, yields and improvements all affect those benefits. These can also be used to promote or build a case for farmers to pay participation fees to join a network.

## Supply chain companies as funding partners

One potential source of funding is companies in the agricultural supply chain. There are few existing models for this type of funding arrangement, because supply chain sustainable sourcing projects that involve a variety of partners are just beginning to take hold. But the potential exists for such models to succeed.

Companies may be convinced to support farmer networks for several reasons:

- Grain buyers may realize a benefit for each percentage increase in corn they purchase locally, either due to increases in local yields or increases in their share of market for local grain purchases.
- Grain aggregators or processors may also benefit by increasing their throughput of local grain. Each percentage increase of throughput may increase their profits.
- Grain purchasers can develop a closer relationship with their farmer suppliers by offering to help fund value-added programs like farmer networks, increasing likelihood of loyalty and thus ensuring more consistent supply.

Grain buyers also want to be assured that in the sustainable sourcing arena, they are able to account for some simple continuous improvement metrics and report those up the chain to companies selling products made from that grain. A farmer network provides field data, quantifiable measurements (provided benchmarking occurs early on) and value back to the farmers—a combination that can make for a robust sustainable sourcing program.

CHAPTER 11

# Conclusion

We hope this manual provides sufficient information and motivation for the reader to feel comfortable forming a farmer network or discussing the concept with potential partners. As farmer network practitioners, we have devoted significant time and energy into our own networks: learning from farmers, learning from each other, learning from mistakes and continuing to improve the network models. Undoubtedly, there are many improvements still to be made, and we invite you to experiment and be creative in applying the concepts in this manual to your own set of circumstances.

The rewards from establishing and running a Farmer Network are numerous. A final framing of the major benefits in terms of public and private benefits is offered in Table 5 below.

TABLE 5

## Public and private benefits of farmer networks

| Private benefit (to the farmer) | Public benefit (to the ag community and society) |
|---|---|
| Assistance optimizing yields while minimizing nutrient losses and increasing nutrient use efficiency (NUE)—which often means increased income for the farmer | Improved management of nutrients and less losses to water and air |
| Decision support in a safe environment where peer-to-peer learning can take place | Improved air quality, reductions in greenhouse gases, and improved water quality resulting from lowering nitrate and phosphorous loading to water bodies |
| Greater confidence in management and decision-making | Greater awareness around local nutrient issues of concern and how to ameliorate impacts |
| Support for current management or changes in management that can be communicated to the public as an improvement | Awareness of farmer stewardship and meaningful actions toward environmental improvement |
| New data that is specific and relevant to the farmer's operation, while combining data from others for greater value and comparison | Scientific data that will contribute to the growing body of knowledge on nutrient management |
| Leadership opportunities for local farmers—a chance to chart a path toward improvement | A structure and model that can be duplicated anywhere and used to test any number of scenarios |
| Opportunities for the local farming community to change and progress, and greater confidence in adopting new technologies based on solid information | A platform for agencies to quantify economic and environmental benefits of programs |

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## APPENDIX A

# Farmer network models from the field

As mentioned previously, there are many different models of farmer networks. Each network design will vary depending on resources, capacity and goals.

On the following pages are examples of farmer networks operating today that were designed for on- farm research in nutrient use efficiency (NUE) for commodity crops, such as corn and soybeans. These networks implemented protocols from which consistent data could be collected from one field or farm to another, and analyzed to reach meaningful conclusions regarding performance.

Components from these models can be combined, and new components added, to meet the particular needs and issues in a local area.

While each farmer network is unique, most of the examples on the following pages have certain elements in common:

1. Advisors work with farmers to collect on-farm data through plot research according to scientifically developed protocol.
2. Data collected is entered into a database and used to inform participating farmers and assess potential results from management changes made as a result of the research.
3. The information is shared with the participants and other farmers through grower meetings, websites and reports.

The primary differences between networks relate to organizational structure, funding and diversity in field trials. For the benefit of the user of this manual, each network model is presented in summary along with details about the structural makeup, and each example is written by the coordinator or manager of that network.

The examples include the following elements:

- Summary of the network operations—trials, crops, funders, roles and partners
- Outreach and communications
- Lessons learned
- Future plans

## MODEL Iowa Soybean Association's On-Farm Network®

By Peter Kyveryga and Suzanne Fey
Iowa Soybean Association
http://isafarmnet.com

The On-Farm Network®, a program of the Iowa Soybean Association, conducts on-farm replicated strip trials and nutrient surveys with remote sensing to help participating farmers collect meaningful data related to crop, integrated pest, nutrient, and soil and water management. Precision agriculture systems, global positioning systems (GPS), remote sensing, geographic information systems (GIS), and the Internet are the fundamental tools used by the On-Farm Network staff, participants and partners in planning, implementing and evaluating cropping system practices and the use of different inputs.

In 2000, the Iowa Soybean Promotion and Iowa Soybean Association boards initiated the "On-Farm Nitrogen Network" to organize and involve farmers in data collection specifically for improving nitrogen management and water quality. Replicated on-farm strip trials were conducted studying nitrogen rates, forms, timing and fertilizer placement. The protocols, methodology and quality control procedures were developed, and interns contracted for sampling and scouting.

The On-Farm Network team works closely with other Iowa Soybean Association departments including Analytics, Environmental Programs & Services and Communications.

The Analytics Department assists the On-Farm Network in identifying research topics, and developing tools for data collection, analysis and summary. Analytics publishes technical and scientific articles and coordinates joint research projects with university and industry partners.

The Environmental Programs & Services team's focus is in on water quality. The team helps farmers install nitrogen treatment practices like bioreactors, assists in environmental planning, and collects thousands of water samples in major Iowa watersheds from edge of fields monitoring sites. The team also manages its own in-house water quality laboratory.

The Iowa Soybean Association On-Farm Network works closely with the ISA Communication Team to provide weekly agronomic research newsletters (www.isafarmnet.com/Advance/advance.php), and other relevant farmer-friendly and technical publications.

### Farmer groups

On-Farm Network farmer participants conduct research in organized groups covering topics of local interest. Organizing and aggregating localized credible on-farm data within a geographic area such as a county, watershed or crop district provides value to farmers in making informed data-driven decisions. The Iowa Soybean Association On-Farm Network has served as a model for developing trials on soybean and corn focused on product comparisons and management practices. With support from industry partners, more than 100 products have been tested over the years.

Over the last 15 years, Iowa Soybean Association On- Farm Network research projects have blanketed the nine Iowa crop districts and all 99 counties, and have included:

Establishing a side-by-side manure replicated strip trial after soybean harvest in Iowa.

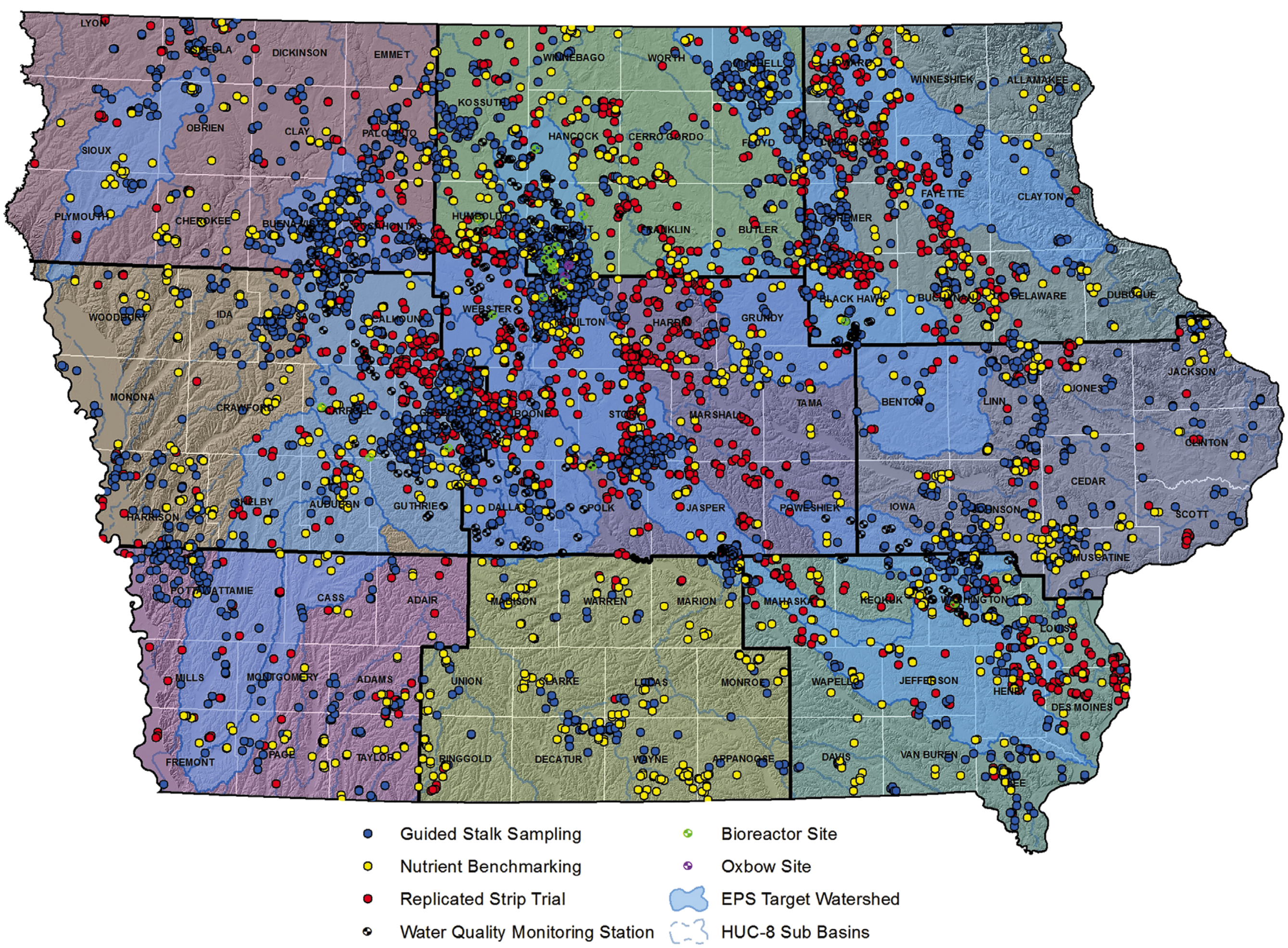
- More than 1000 corn and soybean fields and 500 Iowa farmers in the nutrient benchmarking survey collecting baseline soil and tissue samples.
- More than 3500 fields and 750 Iowa farmers using the corn stalk nitrate test and aerial imagery for guided stalk sampling.
- More than 600 Iowa farmers in approximately 4000 on-farm replicated strip trials focused on continuously improving efficiency and profitability of environmentally sound cropping systems.

Today, the On-Farm Network team is staffed with a program director, research logistics coordinator, two operations managers, two GIS specialists, and three field research specialists. The ISA On-Farm Network team has also helped other farmer networks—in Pennsylvania, Delaware, Maryland, Ohio, Virginia and North Carolina and in the Mississippi River Basin with programs in Illinois, Indiana, Minnesota, and Missouri – with data collection, processing, analytics, automation and reporting tools, and aerial imagery acquisition.

### Key partners

Current partners include Environmental Defense Fund (EDF), Iowa Agriculture Water Alliance (IAWA), Iowa Department of Agriculture and Land Stewardship (IDALS), INfield Advantage

FIGURE A.1
## ISA research and program sites



(formerly Indiana On-Farm Network), Iowa State University (ISU), USDA Natural Resources Conservation Service (NRCS), National Corn Growers Association's Soil Health Partnership, the Nature Conservancy (TNC), United Soybean Board (USB) and multiple agribusinesses.

### Replicated strip trials

Participating farmers utilize On-farm Network protocols to compare products or management practices in "real world"—or production scale—soybean or corn cropping systems. Product studies have included: cover crops, crop sensors, hydraulic down force, foliar fertilizers, fungicides, herbicides, insecticides, nutrient stabilizers, seed treatments, soil amendments and starter fertilizers.

Evaluations of management practices have included: nutrient rate, form, timing and placement; planting date, planting rate and row spacing, manure management, rollers and tillage.

### Nutrient surveys with remote sensing

The network has emphasized use of guided stalk sampling, which uses the corn stalk nitrate test and aerial imagery of the corn canopy as a method to evaluate nitrogen use efficiency. These post-season evaluations of nitrogen status are being used to develop a nitrogen risk calculator that is also accessible on the On-Farm Network website.

In disseminating results, farmers receive custom reports for each of their replicated strip trials that integrate aerial imagery, sampling and scouting results, management information, weather data, yield summary and statistical observation. Individual trial reports are published anonymously online in a searchable database (www.isafarmnet.com/onlinedb/index.php).

### Conference and communications

Group meetings provide an opportunity for farmers and others to discuss the results in a participatory learning environment. Participating farmers that become champions help communicate ways to improve efficiency and profitability of environmentally sound cropping systems to their communities. Participating and nonparticipating farmers and the agriculture industry benefit from On-farm Network publicly available research results.

The Iowa Soybean Association conducts an annual conference reaching 500–600 attendees. This conference features presentations from On-farm Network, Analytics and Environmental Programs & Services staff, industry professionals and academia. Seasonal topics and research results are published weekly in the Advance newsletter reaching more than 3,000 subscribers. Articles are widely disseminated to members and the general public in other Iowa Soybean Association newsletters and publications, social and external media.

### Scientific contribution

Since 2010, a dozen peer-reviewed papers have been published in scientific journals. These publications advanced the current body of knowledge related to fungicide use on soybean, adaptive nitrogen management, statistics and remote sensing. The full list of publications is available at: http://www.isafarmnet.com/PeerReviewed/peer_reviewed.html.

The latest research is focused on: advancing statistical methodology for multilevel analyses of on- farm replicated strip trials; risk assessment; calibrating crop, soil and weather models; and identifying factors and management practices affecting water quality. The success of the adaptive management approach became evident when ISA and other partners worked with the NRCS to include adaptive management in the NRCS practice standard for Nutrient Management (590 Code) – which made it available to farmers across the country through the

Environmental Quality Incentives Program (EQIP). Farmers interested in adaptive management can enroll in the EQIP practice and receive funding support from NRCS to work with an advisor and implement replicated strip trials.

### Funding

On-farm Network projects are supported via public and private grants and contracts that leverage Soybean Checkoff funding. These projects specifically address priority resource concerns assisting farmers directly with improving efficiency and profitability of environmentally sound cropping systems.

### Lessons learned

- The most valuable information for individual farmers is the information gathered from their research trials.
- Participating as part of a group increases the value of an individual trial exponentially and accelerates what one farmer can do alone.
- There is not a one-size-fits-all answer. The aggregation of data from multiple years of On-farm Network research has demonstrated that field variability requires individual assessment, planning, adoption of practices and reevaluation —the cycle of continuous improvement.
- Identifying and empowering Farmer Champions is invaluable in communicating ways to improve efficiency and profitability of environmentally sound cropping systems in their communities.

### Future plans

The main goal of the On-farm Network now and in the future is to improve the competitiveness of Iowa's soybean farmers. The primary strategy is to increase farmer engagement, both in terms of scope, scale and active value. Tactics include using multidisciplinary and integrated research that is coordinated internally with Iowa Soybean Association departments and externally with farmers, agronomists, certified crop advisors, service providers, industry partners, universities, government agencies and other collaborators.

In addition, On-farm Network will focus on projects that:

1. Address management and help farmers improve efficiency and profitability of environmentally sound cropping systems.
2. Test the impact of evolving cropping systems (such as cover crops) on profitability, soil health and water quality.
3. Employ crop, soil, and weather modeling and predictive analytics to develop decision management tools for farmers and agronomists.
4. Increase technical communication and dissemination of study results.

## MODEL The North Carolina Agricultural Inputs Management (AIM) Program

By Deanna Osmond (North Carolina State University) and Maggie Monast (EDF)

The Agricultural Inputs Management (AIM) Program began in North Carolina in 2013. AIM is a voluntary program that is designed to help farmers in eastern North Carolina optimize nutrient and water management. The farmer network component of AIM focuses on efficient nitrogen and phosphorus fertilizer use. The network is led by North Carolina State University and funded by EDF.

AIM is advised by representatives from EDF, NC State University, NC Department of Agriculture, NC Farm Bureau, the U.S. Department of Agriculture's Natural Resources Conservation Service, NC Division of Soil & Water Conservation, NC Foundation for Soil & Water Conservation, and the NC Association of Soil & Water Conservation Districts. Dr. Deanna Osmond of the NCSU Soil Science Department leads the network, in coordination with a team of NCSU staff, students, and several crop consultants.

### Network operations and results

AIM is the first farmer network of its kind in the Southeast. The agricultural system of North Carolina's coastal plain is characterized by a warm climate, multiple soil types, and a diverse cropping system. Farm rotations may include cotton, corn, peanuts, soybeans, tobacco, sorghum and winter wheat. The long growing season and multiple cropping options mean that many farmers double-crop and are in the fields from February through November. For this reason, AIM implements nutrient trials on three crops: corn, winter wheat and sorghum.

Farmers participate in the network with one or two of these crops. Unlike many farmer networks in the Midwest that run nitrogen trials in corn, the AIM network does not use corn stalk nitrate tests (CSNT) because their value in the Southeast has not been demonstrated. This is likely because of the high mobility of nitrate-nitrogen in Southeastern soils.

### Day-to-day operations, functions, database management

The NCSU team assists farmers to install and calibrate yield monitor technology, lays out strip trials and applies varying rates of nitrogen on farmer fields, collects and analyzes farmer data, and holds farmer meetings to share and interpret trial results. EDF receives aggregate program results that are stripped of farmers' identifying information.

In 2013, 33 farmers participated in the AIM Farmer Network. The NCSU team and crop consultant conducted 73 nitrogen strip trials on corn, winter wheat, and sorghum. The trials covered over 145 acres in seven counties. Strip trials were conducted with three nitrogen rates: the farmer's preferred rate, 25% less, and 25% more. 2013 was an unusually wet year in North Carolina, which proved advantageous for some crops and problematic for others. Results and yield maps were shared at a farmer meeting led by NCSU in February of 2014.

- **Corn:** The AIM corn trials had uniformly high yields for North Carolina (average was 190 bushels per acre), and the different nitrogen rates did not impact yield. Soils in the region can be very droughty, so require more frequent rainfall to produce high corn yields—a condition that was met in 2013. Many of the farmers' rates were above university fertilizer rate recommendations and fully half of the participating farmers could have applied less nitrogen, harvested the same yield, and saved on fertilizer costs. However, only one year of data in an exceptional rainfall year does not confirm the appropriate range of economic nitrogen rates.
- **Wheat:** The AIM wheat trials suffered due to the uncharacteristically wet conditions. Unfortunately, the resulting late harvest, sprouting, and some complications during harvest confounded the data collection.
- **Sorghum:** Similarly, the wet weather, late planting and harvesting caused half of the sorghum fields to go unharvested. Of those that did produce data, the farmers' preferred fertilizer rate was best in half the fields with trials and the higher fertilizer rate was best in the other half of the fields.

## Lessons learned

Several important lessons were learned in the first year of the AIM Farmer Network. These are included below under subheadings:

**Finding the right people to work with farmers**

It was challenging to find people with the right combination of agronomic and technical skills required to work with farmers and implement the trials. North Carolina appears to have fewer independent crop consultants than the Midwestern states, and there were additional challenges in managing technology transfer to farmers and data transfer from farmers to the research team. The AIM Farmer Network was fortunate to have a team from NCSU that was capable of handling many of these roles.

**Fluidity of crop rotations in the southeast**

Crops chosen can tend to vary widely, based on commodity prices. Some farmers dropped out of the network as they shifted out of wheat and corn into soybeans, cotton, sweet potatoes and other crops.

**Technology transfer**

Many of the farmers who participated in the AIM Farmer Network either did not have yield monitors on their combines or they did not have their yield monitors connected and capable of producing yield maps. In 2013, 16 of the participating farmers received some form of yield mapping equipment as part of the program.

**Wheat protocol**

An unanticipated challenge in harvesting the wheat trials was the tendency for combines to drift into adjacent strips. This "combine creep" meant that some wheat fertilized with different nitrogen rates was harvested at the same time, confounding the strip trial data. In the 2014 season, a larger field area was used to ensure buffer strips between N rate strips to prevent harvest issues.


North Carolina corn farmer.

**Data analysis**

Analyzing spatial data can be challenging, requiring skills and understanding beyond that of a typical owner-operator farm. Grower networks would benefit from having a central, trusted repository to handle the data collection, management and analysis tasks.

## Future plans for the network

In 2014, the AIM Farmer Network expanded to include five more crop consultants throughout eastern North Carolina and at least 30 more farmers. In addition, one crop consultant will conduct phosphorus trials on corn. As in 2013, farmers received yield maps and the recommended nitrogen rates based on their tests. In general, the best nitrogen rate for wheat was the farmer rate, which was very close to the university-recommended rate in another exceptionally wet year. This rapid expansion of the network will provide exciting opportunities for additional farmers to participate, as well as new challenges in program implementation.

## MODEL The INfield Advantage (INFA) Program

By Meg Leader, Indiana State Department of Agriculture http://INfieldAdvantage.org

The Indiana Farmer Network began in August 2010 when the Indiana State Department of Agriculture (ISDA) was awarded a Conservation Innovation Grant (CIG) by the USDA Natural Resources Conservation Service (NRCS). The purpose of the CIG was the formation and implementation of The Indiana On-farm Network® within the Mississippi River Basin. The Indiana Farmer Network was modeled closely on the ISA On-farm Network®. The CIG application anticipated that at the grant's conclusion, the Indiana network would engage about 50 growers with a total of 150 fields in three HUC eight (Hydrologic Unit Code) watersheds.

In the first year of the project, ISDA worked with the Jasper County Soil and Water Conservation District (JCSWCD). JCSWCD acted as a local agent and engaged a group of 17 farmers in a pilot project, conducting aerial imagery and guided stalk sampling on 39 fields.

Additional local groups have been added every year. At the grant's conclusion in 2014, the network included 22 local groups in 19 watersheds within the Mississippi River Basin. In addition, there were two local groups outside the CIG grant supported through the Indiana Corn Marketing Council/Indiana Soybean Alliance's (ICMC/ISA) checkoff funds. All told, over 260 Indiana farmers were engaged in the participatory learning process.

The Indiana program was recently rebranded "INfield Advantage." INfield Advantage is supported through a partnership with the Indiana Corn Marketing Council, Indiana Soybean Alliance, Indiana State Department of Agriculture, Indiana Association of Soil and Water Conservation Districts, the United States Department of Agriculture–Natural Resources Conservation Service, Purdue Cooperative Extension Service and the Indiana Conservation Partnership.

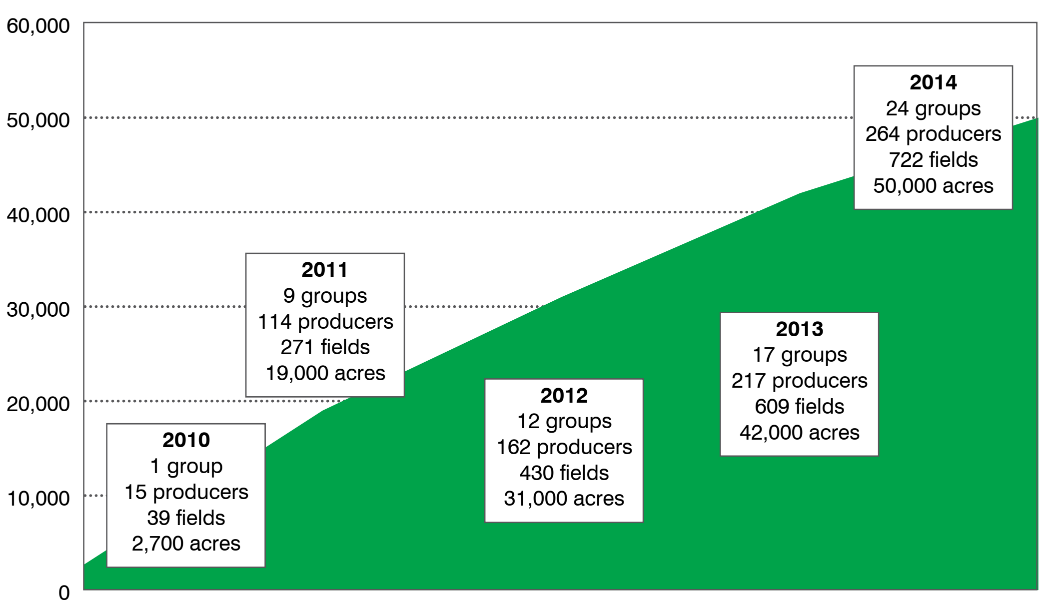
### Network operations and results

INFA uses aerial imagery, guided stalk sampling and replicated strip testing to monitor nitrogen yield response on participating cornfields. In addition, meetings are conducted, both one-on-one and in small groups, to engage participating producers, potential producers and many key stakeholders (grower organizations, state agencies, conservation districts, NRCS state and local staff, regulators and others). Most participants plant corn in two- or three-year rotations and in the off years, plant some combination of soybeans or wheat. Seed corn and popcorn are planted in regions of the state. A significant percentage of the fields are planted in continuous corn.

All of the participants enroll fields for guided stalk sampling. Many INFA growers do not have the technology (or interest) needed to install replicated strip trials, so INFA usually has very few fields each year with strip trials. Local groups organize year-end field reports, and then each local group's data is analyzed for regional responses and trends. INFA still contracts with ISA to analyze and prepare the bulk of the data presented at the meetings. Each local group holds a winter meeting to present the aggregate results and to discuss individual reports. The winter meeting is restricted to participants, the local group leader, the ISDA state coordinator and a respected agriculture consultant. The coordinator and consultant lead the participants in a facilitated discussion. Our experience has shown that by keeping the local group to no more

FIGURE A.2

**InField Advantage program growth**



Hans Kok, INField Advantage consultant, leads a discussion during a winter grower meeting.

than 20 participants, most growers are comfortable enough to share detailed information about their operations and management.

While ISDA coordinates INFA, the program is a project of the Indiana Conservation Partnership (ICP) and supported by all eight of the ICP membership organizations: ISDA, USDA/NRCS, the USDA Farm Service Agency, Indiana Department of Environmental Management, Indiana Department of Natural Resources, Purdue Cooperative Extension Service, the Indiana Association of Soil and Water Conservation Districts and the State Soil Conservation Board. It is through the ICP that the Indiana network has been able to expand the reach of the program to a much larger share of the state's growers than originally anticipated. Most of the ICP organizations contribute administrative or field staff time to the local groups as in-kind labor.

Nearly all local group leaders are SWCD staff who offer the program to their growers as part of their other work responsibilities. They are supported by the Purdue Extension Ag Educators, USDA/NRCS District Conservationists and ISDA Resource Specialists who serve their counties. With this arrangement, the only INFA expenses that need to be funded are the direct expenses related to offering the program. With the conclusion of the USDA CIG grant, ICMC/ISA funds all aerial imagery, lab work, analysis, report generation and consultant's expenses with checkoff funds.

## Lessons learned

Many components of the Indiana network have worked well, including:

- the working partnership between the Indiana State Department of Agriculture, the Iowa Soybean Association, the Indiana Corn Marketing Council/Indiana Soybean Alliance and EDF;
- development of new local groups and the enrollment of additional growers;
- training and support of local group leaders so they were comfortable with the network's established protocols and understand their role in the management of group dynamics and farmer participatory learning;
- the development of meeting facilitators capable of leading the participatory learning process needed to deliver effective producer engagement and adoption of adaptive nutrient management;

- presentation of data results and analysis to both participants and the wider stakeholder community, while protecting farmer confidentiality;
- education of participants on the environmental issues impacted by the lack of effective nutrient management, thereby encouraging broader adoption and implementation of best management practices;
- engagement of farmer participants who do not normally participate in most conservation initiatives; and,
- media engagement and other information dissemination about the project beyond active participants.

The Indiana network had several issues that needed to be addressed.

1. Staff turnover within three of the four primary contributors to the CIG led to aspects of the program being modified or lost over the grant period.
2. As the Indiana program expanded beyond the initial local groups, new local group leaders struggled to understand the protocols required for successful replicated strip trials. This resulted in growers installing strip trials that were not being considered adequate for full analysis. After problems became apparent, better support materials were developed and training was provided to the local groups that wanted to have replicated strip trials.

## Future plans for the network

ISDA and ICMC/ISA plan to continue expanding INFA and offering the program to more corn growers across the state. In 2015 the program expanded to 33 local groups and engaged over 400 growers in studying their nutrient management. Current plans are to expand even further in 2016. This will come not from adding growers to existing groups, but by expanding the number of county Soil and Water Conservation Districts staff and Purdue Extension Agriculture Educators leading new local groups.

In 2015, INFA worked with JCSWCD to offer their growers a chance to participate in a pilot soybean project focusing on soybean cyst nematodes and micronutrients. Working with Purdue University Extension and Agronomy, INFA is looking at using aerial imagery with soil and tissue sampling at the winter meeting to help participants understand their soybean fields better.

Some of the participants and a crop consultant listen to the discussion while considering the impact of their variable rate application.

Off-loading corn in Indiana.

As part of the 2015 program rebranding, the INfield Advantage Advisory Council was established with representatives from ISDA, ICMC/ISA, ICP, Purdue University, School of Agriculture professors, local group leaders and participants. The INFA Advisory Council will help guide the future of the program to make sure that it continues to be viable and valuable to Indiana growers.

## MODEL The Maumee Farmer Network

By Karen Chapman, EDF

The Maumee Farmer Network, formerly the "Adapt" Network, began in 2008 in the Maumee watershed of northwest Ohio, northeast Indiana and southern Michigan. At that time, Environmental Defense Fund (EDF), a nonprofit conservation organization, partnered with the ISA On-farm Network® and obtained support through an NRCS Conservation Innovation Grant to start an adaptive management farmer network. The initial work to establish the network was done in collaboration with independent crop advisors, primarily Nester Ag Management—an independent crop-advising firm in northwestern Ohio.

When the program started, participating consultants conducted 14 on- farm nitrogen rate trials. By 2013 the program had grown to include some 100 producers in the Maumee and Grand Lake St.

Mary's watersheds in Ohio and Indiana, the Raisin River watershed in Lenawee County, Michigan, and in the Southwest Michigan counties of Cass, Kalamazoo and Van Buren.

Today, the program largely focuses on nitrogen (N) and phosphorus (P) trials in Ohio and Indiana with support from the Ohio Corn Marketing Association and the Ohio Small Grains Marketing Association, the Joyce Foundation, and the Walton Family Foundation. The Indiana Soybean Association provided some funding for the Maumee watershed trials that were located in Indiana during 2012–2014. The primary crops grown in the region are corn, soybeans and wheat.

Current partners include the University of Connecticut, Brookside Labs, Inc., Iowa Soybean Association, Simplified Technology Services, G&K Concepts, Nester Ag Management, and Haselman Ag Management. Database services were in the past provided by SureHarvest in California, and are now provided by Iowa Soybean Association. The Mennel Milling

Dr. Tom Morris explains results of the N rate trials to Maumee farmer network participants in the 2013 winter meeting.

Company in Fostoria, Ohio also funded a portion of the trials in 2014–2015 for participating wheat farmers.

### Network operations and results

The Maumee Farmer Network conducts replicated nitrogen rate strip trials, aerial imagery, and soil and stalk testing, as well as leaf tissue tests for phosphorus trials. The results of the trials are presented as individual data and as aggregate data to the farmers in winter meetings. EDF helps coordinate and fund the infrastructure to support the farmer networks and conducts outreach and education to promote the work and findings of the networks associated with EDF.

The Maumee River is a major contributor of sediments and nutrients to Lake Erie, which suffers from summer algae blooms caused by fertilizer and urban storm water runoff. Research shows that legacy phosphorus, phosphorus leaching through tile drainage and phosphorus applied to the surface of fields all contribute to the problem. Partners in the Maumee Farmer Network have tested P drawdown thresholds in soil to measure against current recommended phosphorus rates, and are working with Ohio State University to conduct on-farm trials for both N and P.

The operations of the network are largely coordinated by an independent ag technology consulting firm in NW Ohio, Simplified Technology Services (STS), with support and oversight from EDF. Independent consultants are responsible for collecting and entering field management data using a data collection form. Consultants usually fill out the form in consultation with the farmer, then enter the data themselves.

Consultants mark and lay out plots and collect yield monitor data from each farmer as well. STS orders aerial imagery for the project, receives and processes all aerial imagery and field boundary files, and requests and receives data from the database housing entity. A private database management and sustainable agriculture firm in California, SureHarvest, housed data for the project until 2015. STS and the University of Connecticut (Dr. Tom Morris) analyze and prepare the data in individual and aggregate reports for winter farmer meetings.

Winter meetings are held in a large group setting to present the aggregate data and provide education about nitrogen and phosphorus in crop production. Consultants meet with individuals or smaller groups of farmers to discuss individual data reports. Partners found this approach works well in a region where farmers are in competition with each other and unwilling to speak openly about their operations and management. Consultants convene and manage the small group setting themselves, as they are more familiar with their farmer clients.

## Lessons learned

The Maumee Farmer Network began as a collaboration with the ISA On-farm Network,® but established its own separate identity in 2012. The initial startup phase of the network and the transition to a network with its own infrastructure taught partners several important lessons:

- **Reaching beyond N rate while maintaining ease of trial implementation is not easy.** The Maumee Farmer Network used ISA's tried and true protocol for implementing N rate trials using precision ag tools. Other entities in the Lake Erie basin, however, are largely concerned about dissolved phosphorus losses from agriculture, due to the algae problems in recent years in Lake Erie. Network partners struggled to establish a protocol for testing P applications that was easy to implement and would not slow farmers down during planting. One of the great advantages to on-farm research – the ability to show what happens on a farmer's own field – can also be a disadvantage in that it can be difficult to control variables like planting and nutrient application timing windows. Only a few P trials were able to be implemented on certain fields where consultants had more control.

- **Benchmarking is important to establish early on, and survey methods or means of measuring impact should be established.** Several years into the program, partners realized that farmers perceived the network as valuable, because more continued to join the program every year. However, since partners had not established a means of tracking management changes in the field as a result of network participation, it was difficult to quantify the network's impact. The network is not designed to be a decision-support platform upon which "yes" or "no" decisions can be made, or a 50 lb. application rate difference can be decided,from one year to the next. Rather, it is designed to convey the subtleties of the impacts of a management decision given the variables present in that year, and to help farmers apply that nuanced information to next year's crop. This does not translate well into a clearly quantifiable impact of pounds of N saved per acre—only the farmer can tell what actually happened with the information gained. To better

Long time farmer network participant Todd Hesterman in his field discussing the network with EDF.

track the impacts of farmer network participation, we eventually developed a farmer survey to deploy during winter meetings. We realized later that it would have been even more useful to have surveyed farmers from their very first year of participation in the network, as management changes can only be fully captured if a baseline is known and measured against.

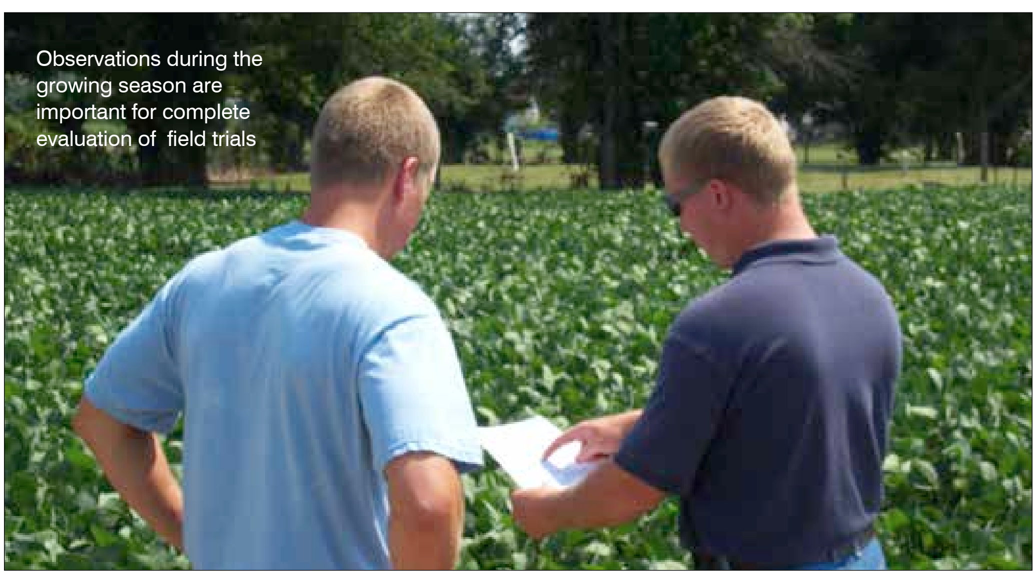
- **Communication to a broader audience is critical.** Networks that are just getting underway will not have much to share in the way of trial data or measurable impacts, but it is still important for them to communicate to the regions's broader ag, conservation, and public audience about what a farmer network is and the network's goals and objectives. This will help the network to gain support early on.

- **Network structure and administrative needs must be solidified.** Tasks like establishing the protocol, identifying participating farmers, setting up trials, identifying database capacity and many others can take precedence over cultivating support from outside of the core team, but this support will be important to gaining acceptance for the concept of on-farm research in general and in applying that research more broadly.

## Future plans

The Maumee Farmer Network will continue to implement limited N and P rate trials in collaboration with Ohio State University, and to support efforts to update the tri-state fertility guide. Going forward, most of the participating consultants—as well as an expanded set of consultants that are members of the Association of Brookside Consulting Professionals (ABCP)—will be engaged in testing new models, technologies and products for the NutrientStar program. The NutrientStar program, developed by EDF with the help of an expert team of NUE scientists, evaluates and certifies NUE tools, technologies and products through a rigorous review of data from studies and field testing. These trials will be called NutrientStar Network trials and will initially involve 20 ABCP consultants and 100 trials in five to six agro ecoregions across eight to 10 states, with growth expected in future years.

Measuring the results of the farmer network and of the NutrientStar Network trials is of critical importance. Farmer surveys as well as consultant surveys will continue to be administered and collected to gain knowledge about the use of the new technologies and their


Observations during the growing season are important for complete evaluation of field trials

impacts, to inform the NutrientStar evaluation, and to provide information to other farmers, advisors and companies in the agriculture and food company supply chain.

The Network provides a platform for farmers to understand how to increase NUE, and to report back on how they successfully did so. It also provides a venue through which partners can communicate those results – backed by concrete trial and farmer survey data – up the supply chain to the retail food companies interested in those results to meet their sustainability goals.

For example, EDF is partnering with the Mennel Milling Company, General Mills, the Ohio Small Grains Marketing program and Haselman Ag to deliver metrics to Mennel about NUE improvements made through the farmer network. Mennel sources the wheat grown by those farmers and sends it to General Mills to be made into bakery products that are sold in Walmart retail stores. More such partnerships can be formed, with the farmer network model at the core of these sustainability efforts.

## MODEL Cornell University's Nutrient Management Spear Program

By Quirine Ketterings, Cornell University

http://nmsp.cals.cornell.edu/NYOnFarmResearchPartnership/index.html

The Nutrient Management Spear program coordinated at Cornell University's College of Agriculture and Life Sciences aims to improve field crop nutrient management on New York State farms. Its motto: "Relevant questions and sound science for agricultural profitability and protection of the environment."

This On-farm Research Partnership involves producers, PRODAIRY, Cornell Cooperative Extension, crop and nutrient management consulting firms, and other farm advisors and agencies. The group aims to establish a statewide research partnership that can pose relevant questions (based on farmer and farm advisor priorities) and answer them efficiently through on-farm replicated trials. Those trials aid in the development of science-based guidance and implementation of both field-based and whole-farm improved nutrient management practices.

The Nutrient Management Spear Program (NMSP) vision is to "assess current knowledge, identify research and educational needs, conduct applied, field and laboratory-based research, facilitate technology and knowledge transfer, and aid in the on-farm implementation of


Grain silo.

strategies for field crop nutrient management, including timely application of organic and inorganic nutrient sources to improve profitability and competitiveness of New York State farms while protecting the environment."

NMSP partners believe that keeping farms sustainable is critical to the economy of the state, particularly in rural areas, and that sustainability can be achieved through an adaptive management strategy that includes applied research to address knowledge gaps. The program uses knowledge gained from the applied research to create improved management practices and Cornell guidelines for field crops management that can be used by farms of all sizes.

The NMSP extension program aims to improve communication, information exchange and knowledge transfer among Cornell University's research programs, Cornell Cooperative Extension field staff, agricultural consultants, field crop dealers and regulatory agencies. It also exists to develop joint applied research projects that address current and future challenges.

Further, the NMSP teaching and mentoring program prepares Cornell undergraduates and graduates in agricultural sciences, animal science and plant science to better address environmental issues impacting the farming community now and in the future.

The NMSPs goals are three-fold:

- **Extension program:** Improve grower and agricultural industry awareness of field crop nutrient needs, crop quality, management of organic amendments, environmentally sound nutrient management practices, and overall soil fertility management in New York State. Provide methods and tools to integrate and apply accumulated knowledge about field crop nutrient guidelines to optimize yield and quality while minimizing risk to the environment.
- **Research program:** Improve understanding of nutrient dynamics, development of risk identification tools and best management practices that reduce runoff, leaching and volatilization losses from inorganic and organic amendments as affected by soil type, hydrology, time and rate of application, and use of specific soil and fertilizer amendments.
- **Teaching and mentoring program:** Prepare Cornell undergraduates for careers in agriculture focusing on increasing farm income while protecting the environment. For Cornell graduate students with a major or minor in soil science, instill the skills, attitude and enthusiasm needed to conduct sound science using interdisciplinary and integrated approaches to address environmental issues related to soil science and nutrient management.

## Operations and results

The NMSP is housed in Cornell University's Department of Animal Science, under leadership of Dr. Quirine Ketterings, professor of nutrient management in agricultural systems, in close collaboration with Karl Czymmek, senior extension associate with PRODAIRY.

The campus-based team currently includes: a research support specialist, for field-based work; a research associate, for laboratory management and analyses; a research aide who coordinates two statewide projects on yield potential for corn and double cropping with winter cereals grown as forage in corn silage rotation; three postdoctoral researchers, leading projects on nutrient mass balance assessment, phosphorus index evaluation, greenhouse gas emissions from fields, and crop sensor technology use for corn and sorghum; and, two graduate and six undergraduate students.

Off-campus collaborators include an independent consultant for writing support (for farmer impact stories), two retired cooperative extension educators for regional projects, and Cornell Cooperative Extension educators, agricultural consultants, Soil and Water Conservation District (SWCD) and NRCS staff, agricultural companies, and other agencies and farm advisors, in addition to farmers themselves. Funding for the program is provided on a project basis by various funding agencies including the New York Farm Viability Institute, NRCS Conservation

Innovation Grants program, the Northern New York Agricultural Development Program, and Northeast Sustainable Agriculture Research and Extension.

Database storage and management is provided in-house.

The NMSP consults with partners to identify relevant questions, discuss progress on projects, educate/inform about project findings, and set priorities for future work. Many of the projects that NMSP implements are informed by and involve a variety of partners.

The program is unique in that the LGU is engaged both in conducting research on commercial farms and in conducting research on experiment stations, with the on-farm research informing LGU guidelines. The value of on-farm research in informing and validating university nutrient recommendations is often overlooked, seen as competitive, viewed as too risky to conduct (risk of trial failure), or considered to be too limited in scope (with fewer treatments comparisons than could be handled on research stations where the university staff controls what happens in the fields). But the NMSP recognizes the importance of on-farm research conducted in a research network approach (i.e., many locations implementing the same trials so datasets can be combined) as critical in the development of science-based, statewide guidance, with a key role for the LGU.

The NMSP conducts a variety of trials each season that are decided upon through a combination of formal and informal processes that include inviting feedback, holding discussions, and ongoing personal interaction with partners. Sometimes farmers initiate the trial ideas and engage the larger partnership in the ideas. Other times, consultants and campus partners work out a project idea and identify and approach the farmers whom they think would be interested in participating. The results of each trial are shared with participating farmers in a research summary with a cover sheet that includes the main findings of the trial, along with data that are presented in easily digestible form. Aggregate data from like trials are used to inform university recommendations and produce reports that are shared broadly on the NMSP website.

The NMSP research trials are broadly diverse, targeting issues of importance to New York farmers. One example of a recent research project focused on conducting a study on double crop nitrogen needs at dormancy break in the spring.

After New York suffered a drought in 2012, more farmers became interested in growing winter cereal crops like triticale after corn silage harvest to provide soil protection in winter months and forage for harvest in May. The objective of the research was to both promote double cropping and find out how much nitrogen was needed for the winter cereal, in essence developing a new LGU guideline for a new crop rotation.

Given the diversity of soils in New York and differences in weather patterns within the state and among years, the project included 65 on-farm trials. Results to date show that about 45% of all sites experienced increased yields after using additional N fertilizer, while one third of the sites did not increase yield with N addition. The data will allow the research team to analyze the field data further for possible correlations of N response to soil fertility status and crop management practices.

Participating farms reported great interest in, and satisfaction with, the project. Commenting on their participation in the study, a crop advisor for a cow operation said: “Participating in a project like this is really worthwhile. In a year when we opt to harvest or sell some of the winter rye as silage, we benefit from knowing the N rate that provides the best economic return. Whether it is from fertilizer or manure previously applied, we’d just be guessing on the N needs without research like this.”

## Access to results

The Cornell NMSP provides program participants with easy access to protocols, field design and management data collection forms. It also shares impact stories about other farms and projects that make it easy for users to assess the results of the program and to access the materials needed to participate. Having updated, relevant success stories and articles for posting is an excellent way to publicize the networks' findings, highlight participating farms, share information and continue to obtain support.

The program seeks to use research findings to inform and update LGU guidelines, as well as nutrient management policies. Agronomy fact sheets on the program's website are updated to reflect findings from the field studies where sufficient research has been conducted to warrant it.

For example, Agronomy Fact Sheet 78 allows farmers to go beyond the Cornell yield database to determine yield goals/N needs themselves over multiple years of conducting adaptive management field trials. Farmers who can document a need in certain parts of the field for higher N applications due to soil fertility potential, and can also show corn stalk nitrate test (CSNT) values maintained at or below an acceptable range, may continue to use higher than recommended N rates for those parts of the field.

The experiences in New York have shown that there are key principles of effective and active adaptive management, as implemented by the on-farm research partnership:

1. Research projects should have direct relevance to the farmer; therefore, his or her involvement in trial selection, implementation, and data collection is essential.
2. Topics should focus on the combination of economic sustainability and environmental protection (win-win situations);
3. The on-farm trials need to be simple but scientifically sound (small number of treatments, at least four replications per farm field), and include sufficient participation to generate statewide guidelines;
4. Annual trial summary reports are important and ideally are followed by farm crew meetings to evaluate data, draw conclusions and decide on follow-up.

In addition, current work on whole farm nutrient mass balances shows that such balances can be great monitoring tools, allowing farmers to gain confidence that changes can be made to improve the overall performance of the farm.

The NMSP continues to seek funding for projects, engage more stakeholders, and move forward with a greater focus on precision agriculture, whole-farm and field-based assessments of nutrient use according to the 4R strategy, and use of field-based technology. All of these initiatives are based on the same motto: "Relevant questions and sound science for agricultural profitability and protection of the environment."

## MODEL Kansas State University Extension On-Farm Research Program

By Ignacio Ciampitti, Crop Production and Cropping Systems Specialist, K-State On-farm Research Project Coordinator
email: ciampitti@ksu.edu
https://webapp.agron.ksu.edu/agr_social/eu_article.throck?article_id=162

A relative newcomer to on-farm research, Kansas State University Extension, known as K-State, began implementing trials with Kansas farmers in 2014. Their research involves cooperating farmers, agriculture specialists, area agronomists, and county/district extension agents in establishing on-farm and large-scale research plots.

The program's broad goal is to improve yields and/or minimize input costs, increasing overall efficiency at the local level. This will be accomplished by establishing "a network of on-farm research collaborators with the main purpose of providing research results on production practices at the regional or local scale, under a wide set of growing conditions and soil types."

The benefits that K-State seeks from the trials are to provide information back to farmers, involve farmers in conducting and learning from the research, and help K-State agronomy researchers check the validity of previous scientific findings conducted in small plots and in more controlled environments. In addition, K-State wants to help producers learn the best ways to design an on-farm test so they can obtain reliable information on a specific question related to their farms.

Ignacio Ciampitti, K-State On-Farm research program coordinator.

### Operations and results

Farmers who enroll in the program are responsible for implementing the trials according to protocol and for collecting the data. Extension agricultural agents are the "gatekeepers" of the project, working very closely with the farmers and assisting with trial implementation. Data is stored in-house at K-State.

The program does not have a dedicated source of funding. It is implemented in collaboration with K-State faculty, agents and farmers. A team at K-State Extension collects the information from the farmers, prepares maps, and interprets the information from the trials.

FIGURE A.3

## Sample plot layout for seeding rate trial

Extension agents in the counties where farmers are participating in the network work with the farmers to help them establish the experimental trials. The university prepares research protocols and schedules for collecting data from the trials including stand counts, phenology data and yield.

K-State has several different approaches to data sharing. The first is to work one-on-one with farmers in small meetings. Staff schedule a workshop for 510 farmers in each of the regions involved in the program, to share trial results, go through some calculations and review the maps. The format provides a good opportunity for K-State Extension and producers to discuss topics and ideas on how to make the best use of the on-farm research.

The second approach is to hold largescale meetings for audiences of 50 or more farmers, where aggregated data and results are shared through K-State's Crop Schools. Third, project results are communicated via social media (Twitter and Facebook) and written reports shared in online newsletters such as e-Update Agronomy Newsletter, which reach a broader audience around the state.

K-State's on-farm research and protocol includes seeding rates, planting dates, row selection for corn, soybeans, sorghum and winter canola. Protocol call for evaluation of only one or two variables at a time, with up to five "levels" or rates (e.g. seeding rates) laid out in at least three field-width replications.

Figure A.3 (page 69) shows an example of a 2014 plot showing corn seeding rate protocol layout in the field.

A summary of corn plant population response to three on-farm locations allowed the program team to visualize the complex yield response to plant population, and conclude that on-farm research efforts are critical to properly identify optimal corn plant population.

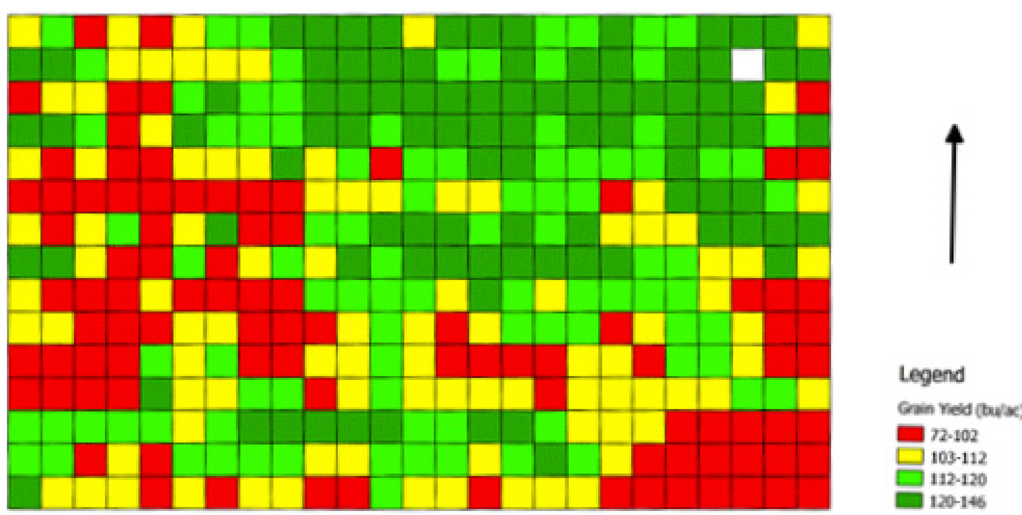
For 2015, researchers and growers involved in the Kansas program worked in:

1. Corn, soybean, and sorghum seeding rate trials.
2. Twin-row trials in corn.
3. Row spacing trials in soybeans.
4. Sorghum seeding rate x fertilizer N rate interactions.
5. Soybean and sorghum maturity group and planting dates.

FIGURE A.4

## Field variability

Reflected by the yield monitor information collected at harvest time for one location



Ciampitti and farmers in cornfield.

The team also worked with farmers again in 2015 to conduct corn seeding trials and build on previous seasons' research.

Participating farmers say the K-State On-farm Research Program is helping them learn better nutrient management, and is more effective than past similar programs. For example, Mr. Pettijohn, a farmer network participant, has conducted nutrient management research on his farm for a number of years. "I've had about 25 on-farm experiments on my operation. They were all side-by-side tests. I thought it would be nice to have a collaborator on these tests, so I welcomed the chance to work with Dr. Ciampitti and K-State in getting a test designed for my farm."

Pettijohn says tests were more carefully constructed than in his previous on-farm trials, and the results were more interesting and useful in a number of ways. He liked the follow-up meeting to discuss the results and overall analysis of the study with participating growers.

"The whole learning experience of being part of this K-State project was quite an honor. I'm looking forward to working on more on-farm tests in the future," Pettijohn concluded.

A publication with comments like this from other farmers and agents is being developed to help promote the program to other farmers.

### Goal for the next five years

The program aims to establish a network of on-farm research trials with the purpose of fine-tuning crop production recommendations to local environments. The end result will hopefully be to generate practical information that will either improve yields or minimize input costs.

## MODEL Mackinaw Farmer Network, Illinois

By Terry Noto, consultant, and Maria Lemke, The Nature Conservancy
http://mcleancountyswcd.com

The Mackinaw Farmer Network, formerly On Farm Network and Adapt Network, began in 2011 in the Lake Bloomington watershed in central Illinois. It is comprised of two groups of farmers: the Lake Bloomington group (i.e., farmers located within the portion of McLean County that

Treatment wetland, Mackinaw Watershed.

drains into Lake Bloomington reservoir) and the McLean County group (i.e., farmers throughout McLean County who are participating in the USDA-NRCS Conservation Stewardship Program). The Mackinaw Farmer Network is part of the Mackinaw River Drinking Watersheds Project that seeks to protect local drinking water by addressing nitrogen/nitrate loading using a combination of small, strategically located wetlands that dramatically reduce nitrates in tile drainage water and infield nutrient management. At the time, Environmental Defense Fund (EDF) obtained funding from Walton Family Foundation to partner with Iowa Soybean Association (ISA) On-Farm Network to start an adaptive nutrient management farmer network. This initial work to establish the network was conducted in collaboration with McLean County Natural Resource Conservation Service, McLean County Soil and Water Conservation District (SWCD) and the City of Bloomington (City).

Lake Bloomington serves as the primary drinking water supply reservoir for 80,000 people in the City of Bloomington and several surrounding townships. Lake Bloomington was formed by impoundment on Money Creek. The primary designated use is drinking water, and recreational and residential development are second and third priority designated uses. The roughly 43,000-acre Lake Bloomington watershed consists predominantly of row crop agriculture in corn/soybean rotation with extensive tile drainage. Lake Bloomington has Total Maximum Daily Loads (TMDLs) in place to address nitrogen and phosphorus loadings and comply with numeric nutrient water quality criteria (10 ppm for nitrates). The Lake Bloomington Watershed Planning Committee drafted the existing Lake Bloomington Watershed Plan in 2008, and is currently working on revising and updating the plan. Nutrient management is a key implementation strategy in the Lake Bloomington Watershed Plan.

In the first year of the farmer network (2011), the program achieved a strong response. A total of 31 producers enrolled 90 fields for corn stalk nitrogen testing (CSNT). This included 14 producers and 44 fields in the Lake Bloomington watershed group, and 17 producers and 46 fields in the McLean County group. Participation was significantly lower in 2012: 10 growers and 29 fields in CSNT in the Lake Bloomington group, and 27 growers and 65 fields in CSNT in the McLean County group (results were higher in the McLean County group due to CSP participation). This was due to a severe drought and the partners' decision to impose a cap of two fields per producer.

In 2012, The Nature Conservancy (TNC) partnered with EDF to obtain funding from the USDA-NRCS Conservation Innovation Grant (CIG) program and the Walton Family Foundation, which supported the farmer network through 2016. The City has each year paid for additional fields that exceed the enrollment goals in the CIG. In addition, in 2013-2014, the World Wildlife Fund (WWF) provided funding from Coca-Cola to SWCD to fund five additional replicated strip trials and to TNC to construct a small tile-treatment wetland in the watershed. The current Mackinaw Farmer Network program is administered through a partnership among NRCS, SWCD, the City, TNC, and EDF.

### Network operations and results

The Mackinaw Farmer Network conducts replicated nitrogen rate strip trials, aerial imagery, and soil and stalk nitrogen testing. A local crop consultant, funded through the CIG, coordinates with SWCD and other partners to hold two group meetings per year for new enrollment and to present group data analyses. The crop consultant is also responsible for collecting field management data, entering data into a collection form with the producer, collecting soil and corn stalk nitrogen samples, and conducting replicated nitrogen strip trials annually at five locations.

Data collection and analyses for digital aerial imagery are coordinated between the local crop consultant and EDF's Adapt Network analysts, Simplified Technology Services (STS), an independent agricultural technology consulting firm in NW Ohio. Strip trial and field management data are analyzed by Dr. Tom Morris of the University of Connecticut.

Winter meetings are held with the participating producers to present and discuss the aggregate data and to provide individual data to each producer. At these meetings, consultants are also available to meet with individuals to discuss their data and answer questions.

Participation in the Mackinaw Farmer Network has continued to be strong. Participation in 2013 included 25 growers and 49 fields in the Lake Bloomington group, and 25 growers and 45 fields in the McLean County group (50 producers and 94 fields total). In 2014, 43 growers (92 fields) participated in the Lake Bloomington group, and 13 growers (18 fields) participated in the McLean County group. Participation in 2015 included 34 growers (88 fields) in the Lake Bloomington group, and three growers (seven fields) in the McLean County group.

Replicated strip trials assessing a variety of rates began in 2013 with five producers participating. In 2014, this number doubled to 10 rate-replicated strip trials. A protocol was developed for time and rate-replicated strip trials. A combination of time/rate and solely rate-replicated strip trials were conducted in 2015.

### Lessons learned

The Lake Bloomington Farmer Network has been through several transitions. This network began in collaboration with the ISA On-Farm Network during its start-up years (2011–2012). In 2013, we transitioned to working with the Adapt Network infrastructure and an Illinois crop consultant. In 2013, after TNC received CIG grant funding, we began work with a local crop consultant, Don Brucker of Brucker Crop Services LLC. The partners have learned several important lessons from the start-up phase, through these transitions, to the present.

- Decades of conservation working with McLean County SWCD, NRCS, the City of Bloomington and TNC, and a strong farm stewardship culture in the Lake Bloomington watershed and McLean County, helped pave the way for strong participation in the farmer network.
- Working with a local independent certified crop consultant helped farmer network succeed and lessened some of the burden of implementation on SWCD.

- Farmers are interested in the results and analyses, but prefer straightforward reporting and less reliance on grower meetings; combining with a field day demonstration might be preferable.
- Participating farmers were generally not over-applying nitrogen; nitrogen losses are more likely attributable to timing concerns (i.e., fall application). Shifting from rate to rate/timing strip trials was helpful and the results are of interest to participating farmers, but more must be done to address barriers to shifting from fall applications.

### Future plans

Data from the last five years show that producers in the watershed generally are not over-applying nitrogen, and that nitrogen loss in the watershed is most likely a function of application timing (i.e., fall application). An advisory group has recently been formed comprised of producers, landowners, farm managers, SWCD, TNC, and the City with the purpose of promoting large-scale adoption of conservation practices that are good for the environment and the agricultural bottom line. Discussions with this agricultural advisory group have revealed that there is a growing interest among producers to move from fall to spring application, but reservations exist with regards to availability of side dress equipment. We are working on innovative approaches to address this initial barrier to adoption.

APPENDIX B

# Sample farmer feedback survey

The farmer network team would like to understand how the program is working and what suggestions you might have. We are requesting your help in filling out this information sheet about your use of nutrient management practices and your participation in the farmer network. It should take you less than 15 minutes.

By completing this form, you are helping us to inform funders and program supporters what the benefits of the program are from your point of view, and are also telling us what you think of the program. Your ideas for improvements to the program are welcome!

The following questions are **optional** and **your responses are completely anonymous.** If you are comfortable sharing the name of your consultant/advisor, please do so below. If not, you may leave that question blank. **Thank you for your participation!**

**Advisor/consultant name (optional) ______________________________________________**

**1.** How many years have you participated in the program? ____ years

**2.** How many acres do you farm? (Check one):

☐ 0-500 ☐ 501-1000

☐ 1001-2000 ☐ More than 2000

**3.** Please rate the following parts of the farmer network on a scale of one to five according to the extent to which you think they are useful. Use the scale below to answer. Rate the usefulness of each part of the network by writing the number in the space to the right.

| Did not use | Not useful at all | Not very useful | Somewhat useful | Very useful |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

Corn stalk nitrate test (CSNT): _____

Aerial imagery: _____

Strip trials with different fertilizer rates: _____

Crop yield maps: _____

Winter meetings: _____

Other (write in): ________________________________ Rating: ____

**4.** How much has your participation in the farmer network influenced your selection of your nitrogen fertilizer rate?

- ☐ The farmer network has not influenced my selection of my nitrogen fertilizer rate.
- ☐ The farmer network has somewhat influenced my selection of my nitrogen fertilizer rate.
- ☐ The farmer network has substantially influenced my selection of my nitrogen fertilizer rate.

**5.** Please fill out the table below for each of your 2015 rotations. We know you may not know the exact amounts of fertilizer or acres, so an estimate would be fine if you or your consultant cannot remember the exact numbers.

| | Corn after soybeans | Corn after corn | Corn after wheat |
|---|---|---|---|
| 2015 acres in this rotation | _________acres | _________acres | _________acres |
| Please check the box to show which commercial fertilizer you used on this rotation in 2015. | ☐Anhydrous<br>☐28%<br>☐Side-dress<br>☐Starter<br>☐Strip till/injected<br>☐Fall broadcast<br>☐Spring broadcast<br>☐Did not use | ☐Anhydrous<br>☐28%<br>☐Side-dress<br>☐Starter<br>☐Strip till/injected<br>☐Fall broadcast<br>☐Spring broadcast<br>☐Did not use | ☐Anhydrous<br>☐28%<br>☐Side-dress<br>☐Starter<br>☐Strip till/injected<br>☐Fall broadcast<br>☐Spring broadcast<br>☐Did not use |
| Please check the box for which type of manure you used on this rotation in 2015. | ☐Poultry<br>☐Hog<br>☐Cow<br>☐Did not use | ☐Poultry<br>☐Hog<br>☐Cow<br>☐Did not use | ☐Poultry<br>☐Hog<br>☐Cow<br>☐Did not use |
| Did you incorporate commercial fertilizer? | ☐Yes<br>☐No | ☐Yes<br>☐No | ☐Yes<br>☐No |
| Did you incorporate manure? | ☐Yes<br>☐No | ☐Yes<br>☐No | ☐Yes<br>☐No |
| For **commercial fertilizer**, what was the total nitrogen fertilizer rate for corn in this rotation in 2015 (adding all applications together)? | ______ lbs/acre<br>or<br>☐ not sure | ______ lbs/acre<br>or<br>☐ not sure | ______ lbs/acre<br>or<br>☐ not sure |
| For **manure,** what was the total amount applied to corn in this rotation in 2015 (adding all applications together)? | _____tons/acre<br>or<br>☐ not sure | _____tons/acre<br>or<br>☐ not sure | _____tons/acre<br>or<br>☐ not sure |
| **Compared to 2014**, did you increase, decrease, or maintain nitrogen fertilizer rates for corn in this rotation in 2015? | ☐ increase N<br>☐ decrease N<br>☐ maintain N | ☐ increase N<br>☐ decrease N<br>☐ maintain N | ☐ increase N<br>☐ decrease N<br>☐ maintain N |
| On how many acres did you **increase** your N rate for corn in this rotation in 2015? | ______ acres | ______ acres | ______ acres |
| If you **increased** your nitrogen fertilizer rate on corn in 2015, by how much did you change your N rate? | +_____lbs/acre<br>or<br>☐ not sure | +_____lbs/acre<br>or<br>☐ not sure | +_____lbs/acre<br>or<br>☐ not sure |
| On how many acres did you **decrease** your N rate for corn in this rotation in 2015? | ______ acres | ______ acres | ______ acres |

| | Corn after soybeans | Corn after corn | Corn after wheat |
|---|---|---|---|
| If you **decreased** your nitrogen fertilizer rate on corn in 2015, by how much did you change your N rate? | - _____ lbs/acre<br>or<br>☐ not sure | -_____lbs/acre<br>or<br>☐ not sure | - _____lbs/acre<br>or<br>☐ not sure |

**6.** If you either increased or decreased your fertilizer rate on corn in 2015, what were your main reasons for the change?

**7.** What improvements could be made to the farmer network?

**8.** We are interested in learning more about your opinions. Please rate the following statements on a scale of one to five according to the extent to which you agree or disagree with them. Use the scale below to answer. Rate your agreement with each statement by writing the number in the space to the right of each statement:

| Strongly Disagree | Mildly Disagree | Neither Agree nor Disagree | Mildly Agree | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

I feel a responsibility to steward the land. Rating: _____

Farming is a business and it all comes back to economics. Rating: _____

It is important to me to reduce the impacts of agriculture on the environment. Rating: _____

Keeping the land healthy and clean is the right thing to do. Rating: _____

My farm management may impact my ability to sell my crop. Rating: _____

I want people to view my farm positively. Rating: _____

**9.** Is there anything else you would like to share with us?

**Thank you for your response!**

## APPENDIX C

# Sample field data collection sheet

| GROWER INFORMATION | | | |
|---|---|---|---|
| First Name: | MI: | Last Name: | Company Name: |
| Mailing address: | City: | State: | ZIP: |
| Home Phone: | Mobile Phone: | Email: | |

| FIELD & EQUIPMENT INFORMATION | | | |
|---|---|---|---|
| Field Name: | Acres: | | |
| County: | Township: | Section: | Quarter Section: ☐NE ☐SE ☐SW ☐NW |
| Tillage: ☐ No Till ☐ Fall Only ☐ Spring Only ☐ Both Fall and Spring ☐ Strip Till | Planting Date: / /2012 | | |
| Hybrid/Variety: | 2011 Crop: _____________; 2010 Crop: _____________; 2009 Crop: _____________ | | |
| If this field is corn following corn, how many years has this field been continuous corn including 2012? __________ | | | |
| Is this field irrigated? _________ | Rotational N Credits lbs/ac: _________ Crop Year: ________________ | | |
| Cover Crop: ____________________ Date seeded? ______________ How seeded? ____________________ N Credit lbs/ac___________ | | | |
| How Killed off: ☐ Chemical burn down ☐ Plowed or Disked under ☐ Harvested ☐ Other ________________ Date killed off? ___________ | | | |
| Were different management practices used on this field? ______ (i.e., West has manure, East commercial N, etc.) Please illustrate on back of form.<br>Please describe:______________________________________________________________ | | | |

| **Fertilizer Applications** | | **Manure 1** |
|---|---|---|
| Field received variable rate N, P, K? | Yes No | Manure: ☐ Swine ☐ Beef ☐ Dairy ☐ Layer ☐ Broiler ☐ Turkey<br>☐ Layer pullet Other ______________ |
| Fall N ____ %; Rate ______ lbs; gal N/A | Incorp: Y N | ☐ Surface Applied ☐ Incorporated ☐ Injected |
| Fall NPK ___-___-___; Rate _____ lbs/A | Incorp: Y N | Time to incorporate: ______________ Hours Days (Circle)<br>Assumed N availability (credit) from manure: _________ lbs N/acre |
| Fall NPK ___-___-___; Rate _____ lbs/A | Incorp: Y N | Manure Application Timing: ☐ Fall ☐ Spring ☐ Both |
| Preplant NPK ___-___-___; Rate _____ lbs/A | Incorp: Y N | Gallons or Tons Manure/Acre: ____________ ☐ Liquid ☐ Solid |
| Type Pre-emerge N: Liq; Granu; Anhy | Incorp: N I D | **Manure NPK** _____-_____-_____ |
| Preplant N ____ %; Rate _____ lbs; gal; N/A | Incorp: N I D | **Manure 2** |
| Starter NPK ____-___-___; Rate _____ lbs; gal/A | | Manure: ☐ Swine ☐ Beef ☐ Dairy ☐ Layer ☐ Broiler ☐ Turkey<br>☐ Layer pullet Other ______________ |
| Type Pre-emerge N: Liq; Granu; Anhy | Incorp: N I D | ☐ Surface Applied ☐ Incorporated ☐ Injected |
| Pre-emerge N: _______ %; Rate _____ lbs;gal;N/A | Incorp: N I D | Time to incorporate: ______________ Hours Days (Circle)<br>Assumed N availability (credit) from manure: _________ lbs N/acre |

| | | | | |
|---|---|---|---|---|
| Variable rate used to apply dry fertilizer? | | Yes No | Manure Application Timing: ☐ Fall ☐ Spring ☐ Both | |
| Variable rate used to apply other forms of N? | | Yes No | Gallons or Tons Manure/Acre: ____________ ☐ Liquid ☐ Solid | |
| N Serve, Instinct, Nutrisphere or Agrotain used on this field? | | Yes No | **Manure NPK** _____-_____-_____ | |
| | | | Number of years in the last 5 manure was applied: _______ | |
| Type of Sidedress N: Liq; Granu; Anhy | | | Received manure 8 of last 10 years: Y N Don't know | |
| Sidedress N: ______ %; Rate ______ lbs; gal; N/A | | Incorp: N I D | Is field managed under a CNMP? Y N | |
| Lbs N from UAN with irrigation: lbs N/A ________ | | | **Is this the first year this field has been in the Adapt-N Network® stalk sampling program?** _______ | |
| PSNT date: | PSNT test: ______ ppm | PSNT Rec: ________ lb N/acre | | PSNT applied: __________ lb N/acre |
| *All fields are subject to approval. Grower agrees to allow field access to service providers for stalk sampling.* | | | | |

**OTHER NOTES:** Grower Signature: ________________________________ Date: ________________________________

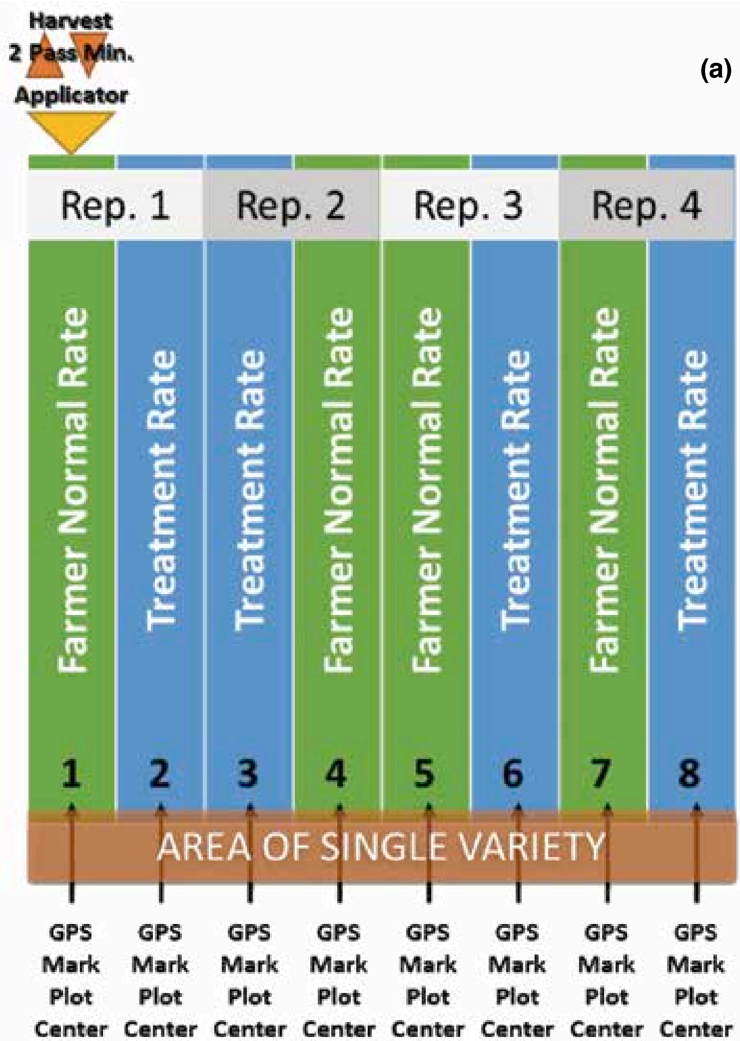
APPENDIX D

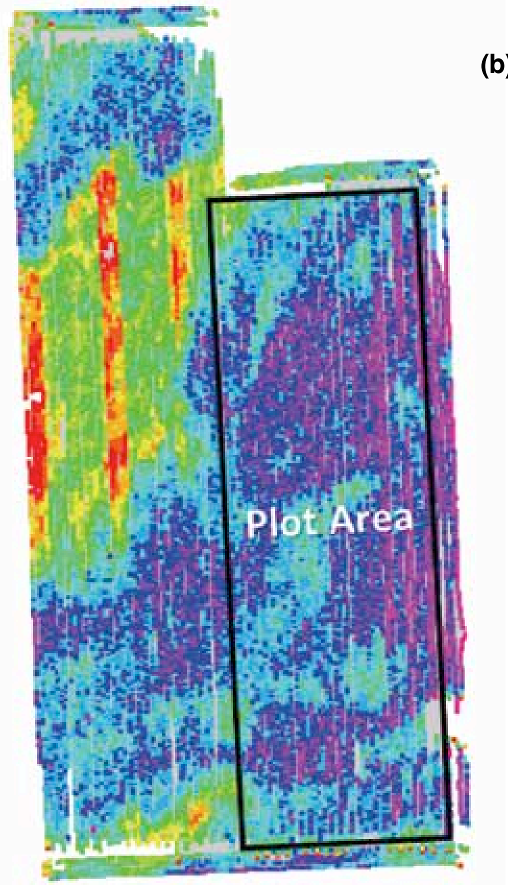
# Sample replicated strip trial protocols

FIGURE D.1

## Plot with two treatment

No VRT applicator equipment



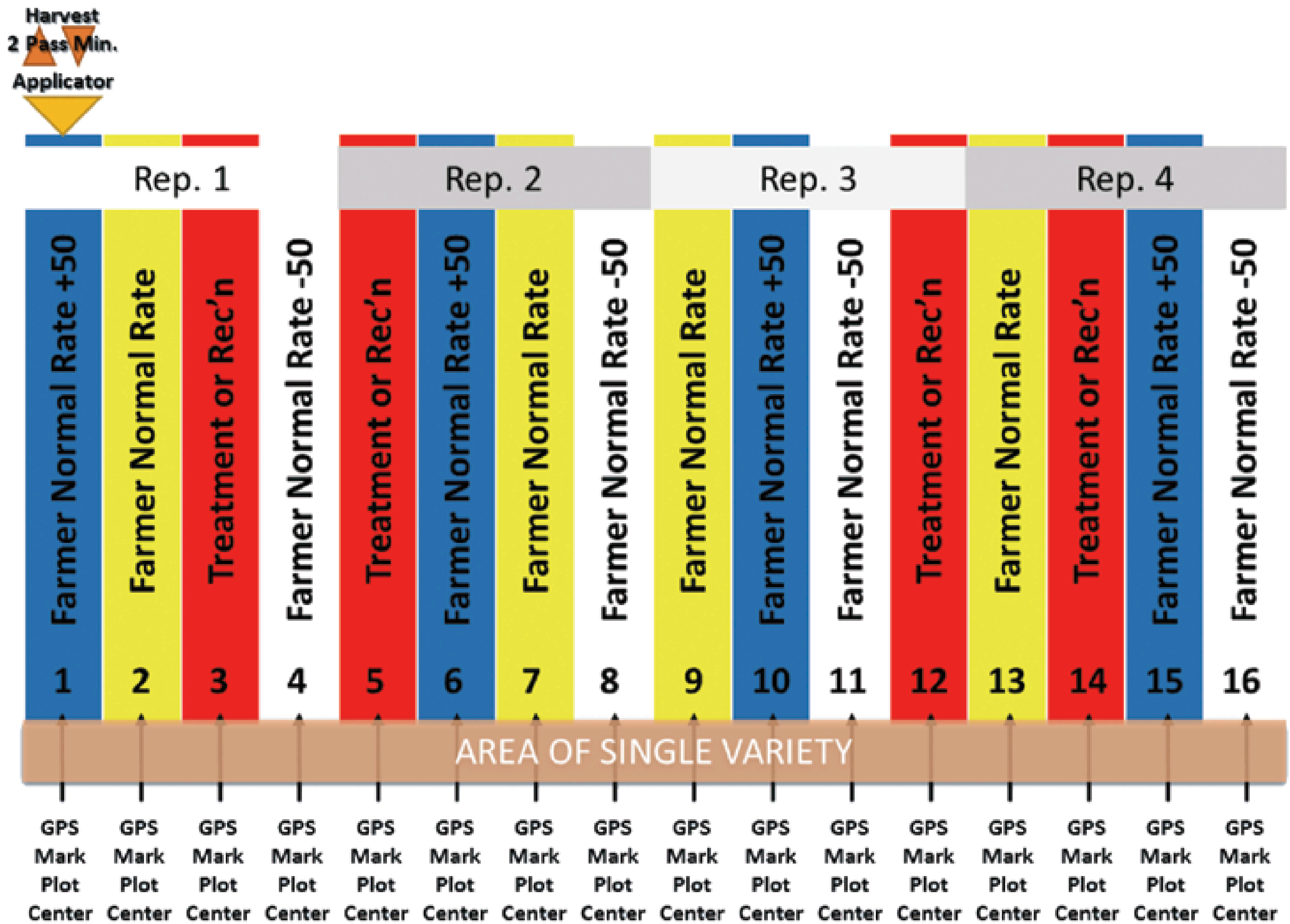




**This is not a great field for a trial like this because of the variability in soil type, but if it is your only option then place the trial to the east side.**

FIGURE D.2

## Plot with four treatment

No VRT applicator equipment



## APPENDIX E

# Examples of data summaries

## FROM OBSERVATIONAL STUDIES AND REPLICATED STRIP TRIALS

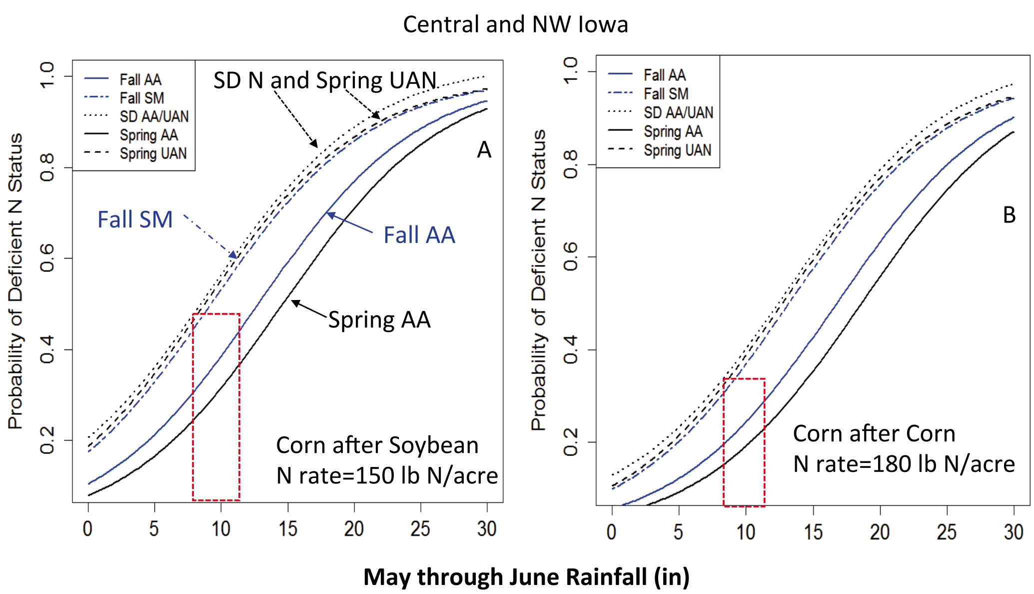
Using the aggregate data of many fields surveyed over time can yield a better picture of how corn N status, crop rotation, management and rainfall interact. Here we present examples of how we have used the aggregate data to help farmers better manage nitrogen inputs.

Figure E1 depicts another type of analysis used to identify factors that impact the probability of deficient or low corn N status. Because stalk nitrate values are extremely skewed and the stalk nitrate test indicates categorical classes of N sufficiency (N supply relative to demand), the agronomic risk of deficient corn N status was determined by combining the four stalk nitrate test categories (Deficient, Marginal, Optimal and Excessive) used in Iowa into binary categories: Deficient vs. Sufficient (Marginal, Optimal, Excessive).

Figure 1 also gives a snapshot of the complex relationship between plant N status, rainfall, form and timing of N application. Although the "S-shape" probability curves represent the

FIGURE E.1

### Probability of corn N deficiency




Probability of deficient corn N status as affected by May through June rainfall: a combination of N form and timing of application (Fall AA; fall-applied anhydrous ammonia; Fall SM, fall-injected liquid swine manure; SD UAN/AA, sidedress anhydrous ammonia or UAN; Spring AA, spring applied anhydrous ammonia; Spring UAN, spring-applied UAN; previous crop (corn after soybean vs corn after corn) within the Des Moines Lobe and North West Plain Landform areas of Iowa from 2006 and 2013. Nitrogen rates were fixed at 150 and for corn after soybean and 180 lb N/acre corn after corn. The red rectangle shows a range in long-term average rainfall from May through June.

TABLE E.1

## Example of risk matrix used to identify the probability of deficient corn N status

| N rate (lb/acre) | May-June rainfall (in) | | |
|---|---|---|---|
| | 5 | 11 | 16 |
| | | Spring AA | |
| 130 | 0.19 | 0.40 | 0.60 |
| 150 | 0.16 | 0.35 | 0.56 |
| 160 | 0.15 | 0.33 | 0.53 |
| | | Spring UAN | |
| 130 | 0.39 | 0.64 | 0.81 |
| 150 | 0.35 | 0.59 | 0.77 |
| 160 | 0.32 | 0.57 | 0.74 |
| | | Sidedress UAN or AA | |
| 130 | 0.36 | 0.61 | 0.79 |
| 150 | 0.33 | 0.57 | 0.76 |
| 160 | 0.31 | 0.55 | 0.74 |

Examining N application rate and form in the context of below average, average and above average rainfall categories can help farmers assess the risk of deficient corn N status.

average trends observed across seven years, the results clearly suggest a greater risk of deficient N status with an increase in cumulative May through June rainfall and lower risk of deficient N status when anhydrous ammonia (AA) was used as the predominant N form, especially for corn after corn. The graphs clearly indicate an overwhelming effect of early season rainfall on N loss and corn N status in Iowa. Using the data to show these relationships can help farmers visualize the impacts of rainfall on N status and assess how to apply that knowledge toward their planning and management decisions for upcoming seasons.

An example of a decision support process using the farmer network data from Iowa can be described by considering Table E1. A farmer can look at the data in the table to make decisions about nitrogen application timing, form and rate, based on May through June rainfall. For instance, a grower can choose to apply 130 lb/acre of Spring UAN, based on an assumption of average May through June rainfall. During the growing season, if May through June rainfall is normal or below (about 11 inches), the grower can be confident the risk of N deficiency has either remained unchanged or decreased.

However, if May through June rainfall is above normal the grower can see a change in N deficiency risk category from moderate to high. Each scenario allows the farmer to make adjustments in N application, knowing the risk factors and likelihood of either running short or having sufficient nitrogen for the plant.

Additionally, if a farmer decides that the risk of N deficiency is too high, the likelihood of economic or above break-even yield response to additional N observed in on-farm trials should be considered. For example, should above average May through June rainfall shift in-season N deficiency risk from moderate to high, a grower may consider supplemental N applications. Previous on-farm trials with farmers' normal N rates and rates that were 30% below or above the normal rates in Iowa between 2007 and 2010 showed that the probability of an above break-even yield response (greater than five bu/acre) to additional 50 lb N/acre was within a range of 0.60 to 0.70.

APPENDIX F

# Data analysis and interpretation

## USING ISA ON-FARM NETWORK® DATA

Below we discuss potential challenges when summarizing individual trials and aggregate data of many trials within a target area. The on-farm trials shown in Table F.1 had two treatments: the farmer's normal rate of injected liquid swine manure, and the normal rate plus 50 # N/acre. All fields had liquid swine manure injected in the fall before corn. The target area of this study was the whole state, but here we show only trials located within the Des Moines Lobe of Central Iowa. The Des Moines Lobe has a unique topography, with an artificial tile drainage system and large variability in soil organic matter and soil pH within fields.

Table F.1 shows total N rates used with the injected swine manure for normal rates and yield responses to the additional N. Statistical inferences from individual trials analyzed separately are shown in the last column, suggesting these conclusions: no evidence, some evidence or strong evidence of yield response. Approximately half of the trials had statistically significant yield response; the other half did not meet the criteria of statistical significance.

The statistical inference for individual trials is important, but the inferences from a group of trials within the target area are more useful for making management decisions. Using quick

TABLE F.1

### Summaries of nine on-farm replicated strip trials

with “normal manure rate” and “normal manure rate plus 50”

| Trial ID | Number of treatment replications | Manure total N rate lb N/acre | Average yield response to the additional 50 lb N/acre bu/acre | Standard deviation | Evidence of significant yield difference at 10% significance level* |
|---|---|---|---|---|---|
| ST2009050A | 3 | 180 | 7.7 | 2.6 | some evidence |
| ST2009064A | 3 | 180 | 28.5 | 6.0 | some evidence |
| ST2009122A | 5 | 193 | 7.2 | 3.0 | some evidence |
| ST2009128A | 4 | 168 | 4.0 | 8.8 | no evidence |
| ST2009143A | 6 | 194 | 5.6 | 3.2 | no evidence |
| ST2009145A | 10 | 194 | 1.8 | 2.3 | some evidence |
| ST2009268A | 3 | 180 | 4.3 | 9.5 | no evidence |
| ST2009269A | 3 | 180 | 6.6 | 1.7 | no evidence |
| ST2009373A | 4 | 210 | 3.9 | 8.5 | no evidence |
| **Across trial (pooled)** | | **186** | **7.1** | **8.0** | some evidence |

Conducted within the Des Moines Lobe, Central Iowa, i 2009. Statistical inferences from analyses were done independently for each trial an pooled across the sites.
*; p-values from a paired t-test; no evidenc e if p-values >0.15; some evidence, 0.01–0.15; strong evidence, p-value <0.01.

calculations and assuming that a pooled average yield response across all trials was about seven bu/acre, with a standard deviation of about eight bu/acre, a yield response of 28.5 bu/acre observed for strip trial ST2009064A (the second row in Table F.1) looks unrealistically large.

This illustrates a common dilemma when analyzing field trials: separate vs. pooled analyses of yield response data. Separate analyses of individual trials do not often provide enough statistical power to claim that treatments had significant effects in each field, while the pooled analyses ignore the inherent differences among the trials.

Another important practical question is how to use the results of the separate analyses shown in Table F.1 to make management decisions for farmers who participate in on-farm studies, as well as for those who do not participate but are still interested in the results.

One of the solutions to this dilemma is to employ hierarchical (multilevel) analysis to partially pool information between trials considering the observed variability within and across fields. The main assumption in this analysis is that the distribution of the trials is exchangeable, meaning that changing the order of the trials in Table F.1 does not substantially affect observed yield responses.

The exchangeability assumption is often reasonable because even with the additional information (e,g. rainfall, tissue, soil test results, previous crop and other) collected from farmers, it is very difficult to explain the observed yield responses. In the example above, it seems intuitive to expect that the yield responses should decrease with the larger total amount of N applied with the manure. However, the total manure N rate does not correlate with yield responses in Table F.1.

Hierarchical analysis is often done with Bayesian statistics to better quantify the uncertainty and make predictions for unobserved situations. An example of partial pooling at two levels

TABLE F.2

## Example of hierarchical analysis of data

from "manure plus 50" trials conducted in Central Iowa

| | | Percentiles for partially pooled yield response | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Trial ID** | **Within field standard deviation** | **2.5th** | **5th** | **10th** | **Median 50th** | **90th** | **95th** | **97.5th** |
| | | | | | **bu/acre** | | | |
| ST2009050A | 2.0 | 3.1 | 3.6 | 4.3 | 6.8 | 9.6 | 10.4 | 11.0 |
| ST2009064A | 8.0 | 6.4 | 7.3 | 10.0 | 23.4 | 32.2 | 34.6 | 36.2 |
| ST2009122A | 2.1 | 2.6 | 3.2 | 4.1 | 6.7 | 9.4 | 10.4 | 11.3 |
| ST2009128A | 4.1 | -3.8 | –1.3 | 0.8 | 5.9 | 10.2 | 12 | 13.8 |
| ST2009143A | 2.3 | 1.3 | 2.0 | 3.2 | 6.1 | 8.7 | 9.7 | 10.7 |
| ST2009145A | 2.2 | –1.4 | –0.4 | 0.4 | 3.7 | 6.3 | 6.9 | 7.4 |
| ST2009268A | 4.1 | –3.6 | –1.4 | 0.9 | 5.9 | 9.8 | 11.7 | 13.6 |
| ST2009269A | 1.5 | 3.3 | 3.9 | 4.5 | 6.4 | 8.2 | 8.9 | 9.3 |
| ST2009373A | 4.0 | –2.5 | –0.2 | 1.8 | 6.2 | 10.0 | 11.9 | 14.2 |

Level 1 (within field): percentiles for partially pooled yield response and standard deviation for individual trials. For trial ST2009373A: 80% chance that yield response will be between 1.8 and 10.9 bu/acre; 90% chance, betweeb –0.2 and 11.9 bu/acre; 95% chance, between –2.5 and 14.2 bu/acre. Intervals that include a zero ot negative numbers would indicate a no or little evidence of significant yield response.

TABLE F.3

## Hierarchical analysis of data

from “manure plus 50” on-farm trials

| | | Percentiles for partially pooled yield response | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trial ID | Between field standard deviation | 2.5th | 5th | 10th | Median 50th | 90th | 95th | 97.5th |
| | | | | | bu/acre | | | |
| Field-level yield response | 2.0 | 2.8 | 3.2 | 4.0 | 6.2 | 8.1 | 9.3 | 10.1 |

Level 2 (between field): percentiles for partially pooled yield responses and standard deviation. 80% chance that the field level response will be between 4.0 and 8.1 bu/acre; 95% chance between 2.8 and 10.1 bu/acre. The probability of above break-even yield response (>5 bu/acre) is about 55% when using corn price of $4/bu and N price of $.40/lb.

is shown in Tables F.2 and F.3. At level one for within fields, yield responses from experimental units from each trial are modeled as normal (bell shaped) distributions with specific means and variances. At level two across fields, the means and variances of within field distributions are modeled separately as new random distributions (not necessary normal) with another set of means and variances (Table F.3). Knowing mathematical formulas of these distributions, scientists can estimate the probability of yield response in new or unobserved situations. This is much more useful than just indicating that the yield response is or is not statistically significant.

Using hierarchical analysis and the idea of partial pooling, the adjusted median (50th percentile) yield response for trial ST2009064 changed to 23 bu/acre (Table F.2) compared to 28 bu/acre (Table F.1), suggesting the shrinking to the overall mean. The variability in median yield response across other trials has also decreased, indicating a more reasonable range in potential yield responses than in Table F.1. The “shrinking” shown in Table F.2 depends on the number of replications, observed variability and prior information used in the analyses. Trials with less data and small variability are pooled more than those with more data and large variability.

Unlike separate analyses in Table F.1, partially pooled analyses in Table F.2 show nicely the expected uncertainty in yield response for each trial. A user can select the desired confidence interval: 95%, 90 or 80%. The narrower the interval, the higher the uncertainty in estimated yield responses for individual trials. For example, for the last trial ST2009373A in Table F.2, there is 80% chance that yield response would fall between 1.8 and 10.0 bu/acre; 90% chance, between 0.2 and 11.9 bu/acre; 95% chance, between 2.5 and 14.2 bu/acre. Intervals that include zero or negative values would indicate “no or little evidence” of a significant yield response.

Table F.3 shows adjusted across field yield responses and their standard deviations (level two). Table F.2 shows that most common median yield response was between four and six bu/acre. More accurately, Table F.3 indicates that the adjusted across trial median yield response for the Des Moines Lobe in 2009 was about 6.2 bu/acre, with a 90% chance that the median response will fall between 3.2 and 9.3 bu/acre. The adjusted across field standard deviation was two bu /acre.

Users can choose Table F.2 (level one) or Table F.3 (level two) to help in the decision process. Farmers who conduct trials on their farms would be more interested in results in Table F.2, and farmers who do not conduct trials would be more interested in the results in Table F.3.

APPENDIX G

# A study of aggregate data from the Maumee Farmer Network

As indicated, years of data collected from established farmer networks shows that there is much room for improvement in N management across much of the Corn Belt. One example is shown in data from the Maumee Farmer Network (OH, IN).

Partners conducted 210 replicated strip trials between 2008–2013 on farms in NW Ohio and NE Indiana, using the treatments described in Table G.1.

Farmers and consultants collected the management and harvest data for the strip trials. Corn stalk nitrate test (CSNT) samples were collected for each strip at the end of the season. Corn was harvested by combines equipped with GIS and yield monitors that recorded yield observations every second. The corn yield data was processed using Ag Leader SMS software. Individual yield observations were aggregated in 25-m quadrants, and yield changes were calculated as differences between yields at two rates in each quadrant. Different sites had different numbers of quadrants as a result of different lengths of the strip trials.

Farmers managed their fertilizer or manure applications and used GPS to locate treatments. Typical forms of nitrogen for the treatments including UAN, AA, and other forms of nitrogen, for example: urea, AMS, or manure, were also used. Typical timing of applications was sidedress or spring. Most of the sites were corn after soybean (118) with some corn after corn (two) and a smaller number of corn after wheat fields. Most of the sites were not manured.

Summaries of the results are show in Figures G.1 through G.4. Figures G.1 through G.3 show the yield responses and returns to N by site for 50-lb. increases in N rates. Both the yield response and return to an application of 50 lb N acre$^{-1}$ was greatest when the application rate was increased from 100 to 150 lb N acre$^{-1}$ (Figure G.1). Greater than 80% of trials had a positive yield response and 60% of trials had a positive net economic return to N when the N rate was

TABLE G.1

## Trial statistics

| Year | Number of sites | Number of treatments | Treatments | Number of replications |
|---|---|---|---|---|
| 2008 | 12 | 5 | 50 100 150 200 250 | 3 |
| 2009 | 16 | 4 | 100 150 200 250 | 3 |
| 2010 | 38 | 4 | 100 150 200 250 | 3 |
| 2011 | 21 | 3 | –50 normal +50 | 4 |
| 2012 | 60 | 4 | 100 150 200 250 | 3 |
| 2013 | 63 | 4 | 100 150 200 250 | 3 |
| Summary | 210 | 3–5 | 3–5 | 3–4 |

increased from 100 to 150 lb N acre$^{-1}$. A similar percentage of trials had positive yield responses when the N rate was increased from 150 to 200 lb N acre$^{-1}$, but the percentage of trials with a positive return to N was reduced and the amount of dollars returned was substantially reduced (Figure G.2). When the N rate was increased from 200 to 250 lb N acre$^{-1}$ about 50% of trials still had a positive yield response, but only a small percentage of trials had positive net economic returns because most of the yield increases were fewer than five bu acre1 (Figure G.3).

These data clearly show the tremendous amount of variability in yield response and economic return to additional N applications in fields in the Maumee Valley. To improve NUE will require field-specific information about the probability of a yield response at individual fields.

Figure G.4 displays the data from the 160 trials in a format similar to the way the MRTN database shows the distribution of EONR rates. This display of data also shows that the potential for improving NUE is tremendous with an opportunity to both lower N rates on many fields and increase N rates on other fields to harvest more corn and improve profits. These data demonstrate a critical need to determine the sources and the significance of the variability optimum N rates to increase the accuracy of N applications and to make the best field-specific decisions on N management.

FIGURE G.1

**Frequency distribution of change in yield (bu·acre$^{-1}$) and return to N (\$·acre$^{-1}$)**

for 160 strip trials as a result of increasing N rate from 100 to 150 lb·acre$^{-1}$

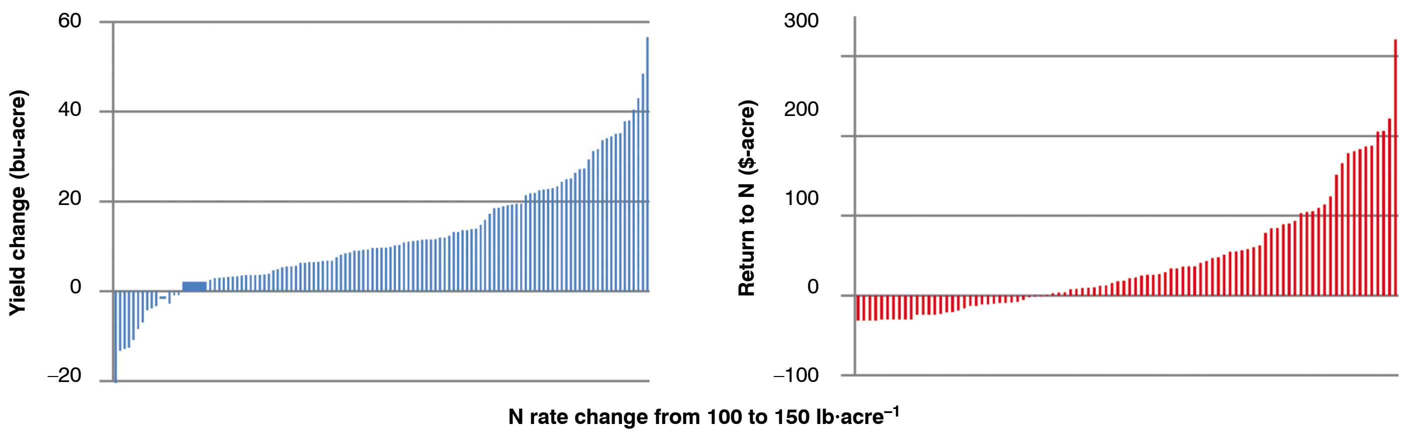



FIGURE G.2

**Frequency distribution of change in yield (bu·acre$^{-1}$) and return to N (\$·acre$^{-1}$)**

for 160 strip trials as a result of increasing N rate from 150 to 200 lb·acre$^{-1}$

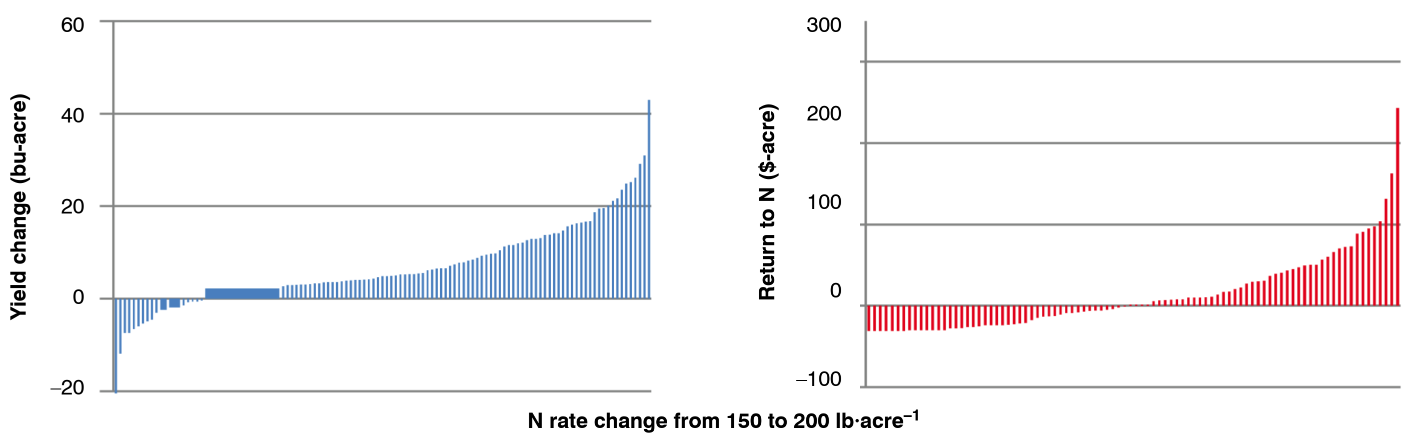


FIGURE G.3

## Frequency distribution of change in yield (bu·acre$^{-1}$) and return to N ($·acre$^{-1}$)

for 160 strip trials as a result of increasing N rate from 200 to 250 lb·acre$^{-1}$

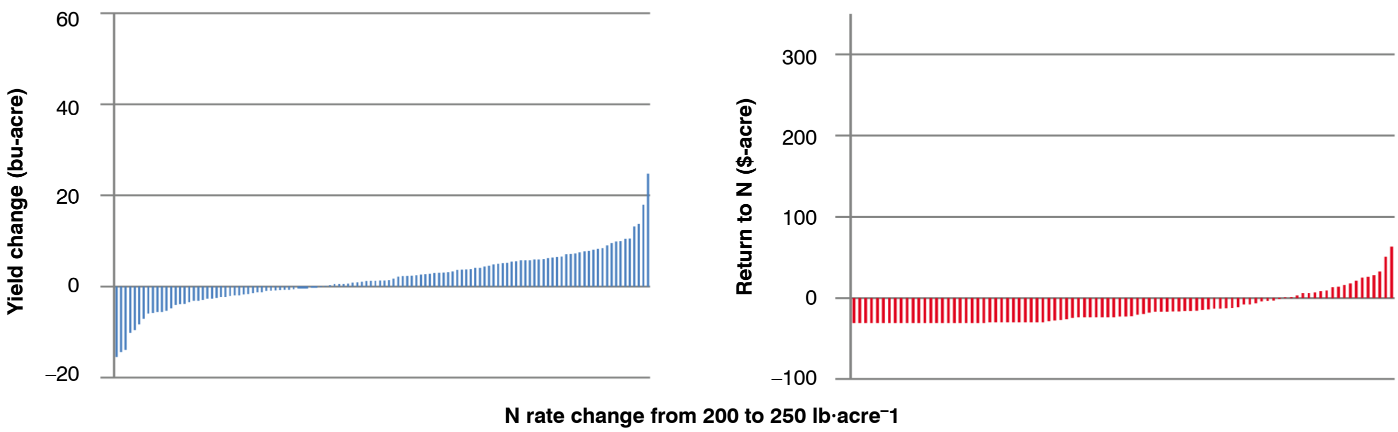
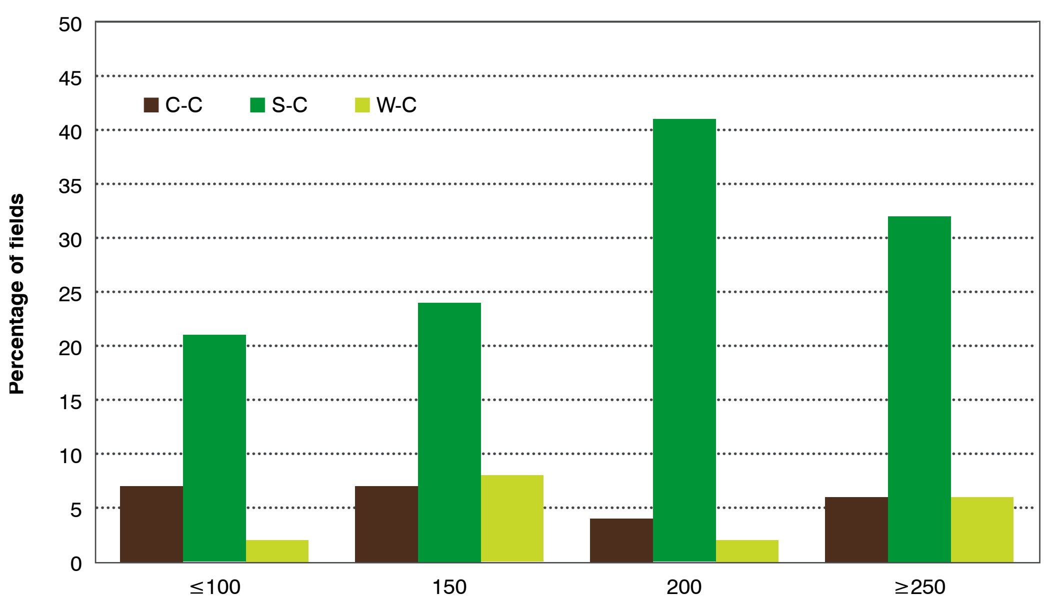



FIGURE G.4

## Percentage of fields at estimated economic optimum N rates (EONR)

for corn for 160 trials in the Maumee River watershed




Estimated Economic Optimum Nitrogen Rate (lbs N/acre). C-C: Corn after corn. S-C: Corn after soybeans. W-C: Corn after wheat,

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