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VARIABLE RATE NITROGEN APPLICATION: ERIC ODBERG

Farmer-to-Farmer Case Study Series: Increasing resilience among cereal-based farmers in the Inland Pacific Northwest

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VARIABLE RATE NITROGEN APPLICATION: ERIC ODBERG

By

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Abstract

Eric Odberg farms near Genesee, Idaho, in an area receiving about 22 inches of precipitation annually. In this publication, Odberg discusses his experiences with variable rate nitrogen application and direct seeding.

This case study is part of the Farmer-to-Farmer Case Study project, which explores innovative approaches regional farmers are using that may increase their resilience in the face of a changing climate.

Information presented is based on growers' experiences and expertise and should not be considered as university recommendations. Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement. Grower quotes have been edited slightly for clarity, without changing the meaning.

Readers interested in other case studies in this series can access them at on the [REACCH website](#), as well as in the [WSU Extension Learning Library](#).

Table of Contents

Introduction	3
Getting Started with VRN	3
Odberg's Precision Agriculture System	6
Creating Prescription Maps for Nitrogen Application	6
Nitrogen Application Zones and Rates	6
Moving Beyond Nitrogen	7
Benefits	8
Challenges	8
Managing Risk	9
Learning, Experimenting, and Adapting	9
Looking Forward	11
References	12
Acknowledgements	12

Variable Rate Nitrogen Application: Eric Odberg



Photo: Guy Swanson

Location: Genesee, ID

Average Annual Precipitation: 22 inches

Cropping System: 3-year rotation of winter wheat, spring grain (wheat or barley), and pulses (including lentils and several types of chick peas); he is also experimenting with a 4-year rotation that adds spring canola.

Watch the companion video, [Precision Nitrogen Application: Farmer-to-Farmer Case Study Series](#), introducing Odberg, his production system, and his experience with variable rate nitrogen application.



Map: Kaelin Hamel-Rieken, Washington State University

Introduction

Eric Odberg is a fourth generation farmer who practices direct seeding (also known as “no-till”) and is an early adopter of variable rate nitrogen (VRN) application in the dryland production region of the Pacific Northwest. Odberg currently farms 2,200 acres, with the majority in a three-year rotation of winter wheat, spring grain, and pulses. On smaller acreages, he is also experimenting with incorporating Roundup Ready canola into the rotation to add diversity and weed control options.

Throughout their years of farming, Odberg and his wife, Malia, have been motivated by the desire to pass along an environmentally and economically sustainable operation to their three sons. “I’m fourth generation, and hope to be able to hand it to the fifth generation. Having a sustainable farm is an important part of that. I want to have land to be able to farm, but also want it to be profitable.”

Odberg sees VRN as just one strategy in his ongoing efforts to keep his operation profitable and to provide good stewardship. “You’re applying less nitrogen out there, which is better for the environment because excess nitrogen beyond what the plants need might go into the groundwater and into our rivers and streams. The direct seeding also helps reduce topsoil and nutrients that are going into our waterways. So I really see them working hand in hand, with direct seeding being the foundation.”

Getting Started with VRN

Odberg’s journey to VRN began long before he actually tried it, starting with his transition to direct seeding in 2000, a few years after he took over the management of his family’s farm (Figure 1). “I had a couple of big erosion events when I first started farming, and I could see that wasn’t going to be sustainable. We needed to change, and direct seeding was a good solution.” Direct seeding led Odberg to adopt a series of additional practices, including diversifying his rotations, adding additional classes of wheat, and applying nitrogen at variable rates.

Odberg first began experimenting with VRN, one type of precision agriculture, in 2005. (See the sidebar A Primer on Precision Agriculture for more information.) This was just after he purchased an Exactrix anhydrous fertilizer delivery system for his direct seed drill, seeking to improve the evenness of his nitrogen applications and reduce overall



Figure 1. As a direct seed farmer, Eric Odberg seeds directly into residues, such as his previous garbanzo crop. Photo: Guy Swanson.

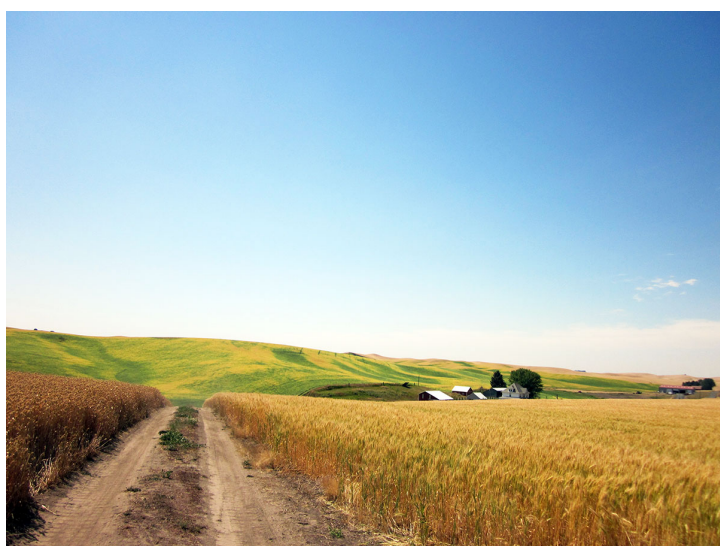


Figure 2. The rolling landscape of the Palouse has led to important differences in soils at various landscape positions. For example, in many places, higher erosion rates on hilltops has led to thinner soils and lower production potential compared to lower areas. On the hillside in the back of this photo, you can see different rates of crop maturity. This is related to variation in soil factors that influence how much water the soils hold. Photo: Tabitha Brown.

nitrogen use. (See the Odberg's Equipment sidebar for more information.). As Odberg looked for strategies that would further reduce nitrogen fertilizer use, Guy Swanson, a mentor and the owner of Exactrix Global Systems, suggested that he try VRN application. Instead of applying nitrogen at the same rate across the field, based on average yields, he could probably reduce nitrogen applications on hilltops, where the soil was thinner and production was lower (Figure 2).

While this made sense, Odberg wanted to see it for himself—and participation in the USDA-NRCS [Conservation Security Program](#) gave him that chance. He used funds from the environmental enhancement program to purchase a yield monitor. During his 2006 harvest, he was surprised to learn

A Primer on Precision Agriculture

Precision agriculture is a term used to describe a number of different technological tools that can be used to improve the precision of agricultural operations. Some commonly used pieces of equipment include:

GPS guidance (also called “auto-steer”). Guidance systems use the Differential Global Positioning System (DGPS, a highly accurate satellite system) to detect the location of equipment and steer it across the field in a way that reduces overlap in passes across the field. Auto-steer systems can generally be retrofitted onto existing equipment.

Section controllers. Section controllers are mechanisms that automatically shut down operations (often of a “section” of a piece of equipment) at locations (edge of field, overlap with previous passes) to reduce the amount of inputs used, such as seed, fertilizer, and herbicide due to overlap. Section controllers can be retrofitted onto existing equipment.

Variable rate fertilizer systems. Variable rate fertilizer systems are able to apply fertilizers at different rates across a field. This technology is suited to fields with a wide range of yield potentials, or in fields where residual levels of nutrients are quite variable. Though nitrogen is the nutrient most commonly applied at variable rates, phosphorus, sulfur, and other nutrients can also be applied in this way.

Yield monitor. Yield monitors record the yield at different locations within a field. With several years' data, this information can be used to generate prescription maps that divide fields into different “zones” for variable rate fertilizer application.

Aerial infrared crop images. Prescription maps for fertilizer application can also be developed using aerial images. In infrared images, the most dense and vigorous vegetation is shown in bright red, whereas less vigorous plants are shown in lighter red and grey tones. Photos taken during crop growth can thus be used to delineate zones of higher and lower yield.

Spatial soil mapping. Soil electrical conductivity measurements document variations in many soil properties including clay and water content across the field. This is another method that can be used to develop prescription maps for variable rate fertilizer application.

Odberg's Equipment

Drill and Fertilizer Application. Odberg direct seeds with a John Deere 1895 direct-seed drill, fitted with an Exactrix liquid anhydrous fertilizer delivery system (Figure 3). Odberg has made several modifications to his drill to improve performance over the years. After breaking discs and hubs in hard, dry conditions, he changed to bigger, heavier hubs for the single discs on his drill. To ensure consistent seed depth and good contact with the soil, he uses Keaton seed firmers, which have given him better results than firming wheels. He also uses Exapta (or Thompson) closing wheels (Figure 4). Under his conditions, he has found that the spiked wheels work better for closing the seed trenches than the factory packer wheels, especially when soils are wetter.



Figure 3. Odberg's drill and fertilizer delivery system. Photo: Guy Swanson.



Figure 4. Exapta (or Thompson) closing wheel (spiked wheels on far left). Photo: Guy Swanson.

By keeping the pressure higher than many other application systems, the Exactrix system maintains anhydrous ammonia as a liquid as it is injected into the soil. Before he purchased this system eight years ago, Odberg struggled with gaseous losses of ammonia nitrogen, especially under hard, dry soil conditions and during cold, wet spring weather. He also found that the cold ammonia gas in his old system was causing the discs to freeze up, resulting in plugging problems with his drill. Though he is pleased overall with the way the system works, he notes that one drawback is that the system is complicated and requires a skilled operator.

Odberg has also made several modifications to his system, which he feels has improved performance. For example, having the closing wheel right behind the outlet for the liquid anhydrous ammonia is key. As the anhydrous ammonia leaves the pressurized system, it tends to convert to gas, and closing the soil over it quickly reduces atmospheric exposure and losses.

Odberg has found that the Exactrix system works well for applying nitrogen at variable rates (though many other systems can be used with VRN). The ammonia manifold and accumulator allow the system to easily vary the rate of application. Odberg finds he can vary the rate from 50 to 120 lb of nitrogen per acre without changing orifices.

Variable Rate Application Controller. To vary the rate of nitrogen as he goes, Odberg uses a Trimble FmX variable rate controller (Figure 5). While his old controller was only able to vary the rate of one product, the newer Trimble system he purchased in 2013 can vary up to four products at a time. For auto-steer and guidance, he uses a Raven Envizo Pro.



Figure 5. Trimble FMX controller (screen on the right) which can independently control the rate of up to four products. Raven Envizo Pro (smaller screen on the left) carries out auto-steer and provides guidance. Photo: Guy Swanson.

just how much winter wheat yields varied across his fields, from less than 50 bushels per acre on hilltops to over 150 bushels per acre in the draw bottoms. This convinced Odberg that VRN applications would be beneficial.

Odberg's Precision Agriculture System

Creating Prescription Maps for Nitrogen Application

The prescription maps Odberg uses for nitrogen applications divide the field into four different zones that receive different levels of nitrogen (Figure 6). These maps were developed from his yield maps with the help of a precision agriculture specialist, Dave Barton. Odberg has found that his yield patterns are fairly stable from year to year, so his zones are likewise consistent. Working with a consultant has been a key part of his strategy and, in his case, he feels the expertise has been worth the added cost. Without established guidelines that dictate how to translate the yield maps into fertilizer prescription zones, having the support of someone with practical experience was particularly helpful when he was learning how to use this technology.

Though he is generally satisfied with his current zone delineations, Odberg continues to make refinements in small areas. He has also been mapping new fields that he is farming. In doing this, he has been experimenting with supplementing, or even replacing, the information from his yield monitors with

infrared crop canopy images taken during the growing season. So far, Odberg has found that these images correlate well with his yield monitor data. This has increased his confidence that he can use the infrared images when his yield maps are incomplete. (Of their two combines, only one has a yield monitor.)

Nitrogen Application Zones and Rates

Odberg's system includes two separate controllers: one to vary fertilizer application as prescribed by his application map as he drives across the field, and the other to auto-steer the tractor. In 2013, he updated his controller so that he can apply multiple products at variable rates—a feature he is using to vary the rates of seed and nutrients other than nitrogen. (See the Moving Beyond Nitrogen section for more information.) Odberg typically uses four zones for nitrogen application, as shown in Table 1. The lowest yielding areas receive 50–55 lb of nitrogen per acre, two middle zones receive 80–90 lb and 100–110 lb, and the highest producing areas receive 120–130 lb.

To fine-tune his decisions about nitrogen rate, Odberg takes composite soil samples for the entire field shortly before planting. He previously tried sampling management zones separately, but found it difficult to make sense of the results he was getting. So he went back to sampling by field, and uses that information to adjust his application rates for all zones upward or downward, based on the amount of residual nitrogen.

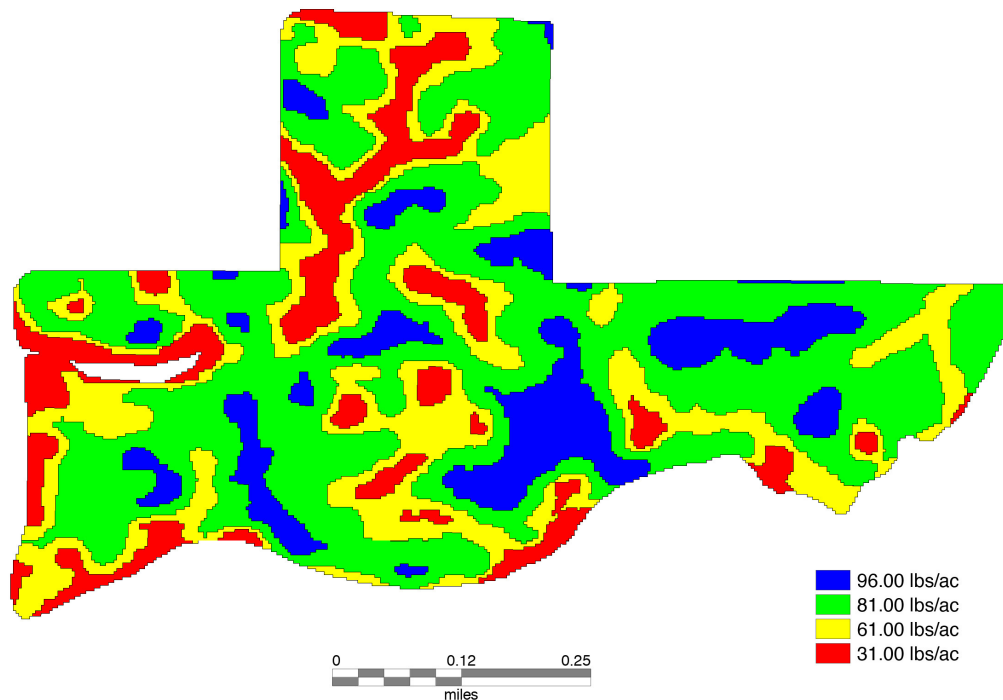


Figure 6. Fertilizer application map for one of Odberg's fields, showing four zones. Map: Dave Barton.

Table 1. An example of Odberg’s fertilizer application rates for soft white and hard winter wheat, and average yields by zone, under normal conditions. Additional nitrogen may be added in the spring depending on soil test results and yield potential.

Zone	Initial Application Rate (lb/acre)	Average Yield (bu/acre)
Low	50–55	35–55
Medium Low	80–90	80–90
Medium High	100–110	100–110
High	120–130	130–150

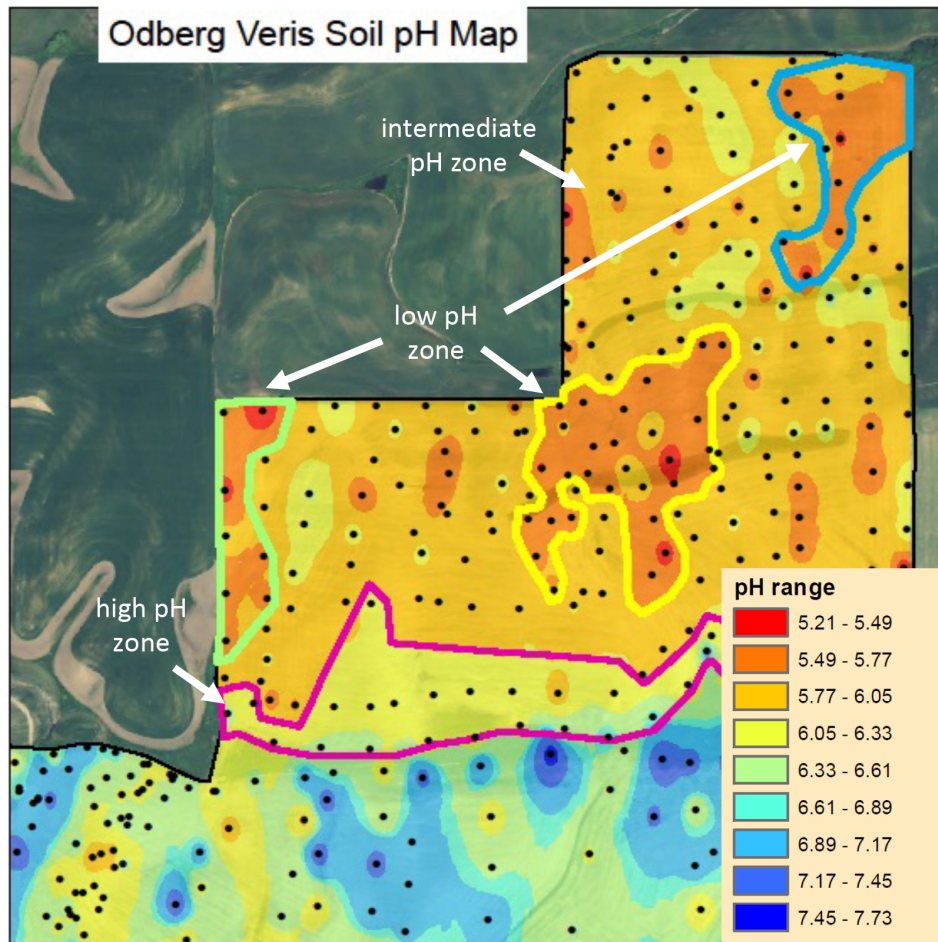


Figure 7. A pH map for one of Odberg’s fields generated as part of the study on variable rate liming carried out by the Latah Soil and Water Conservation District (and funded by a Conservation Innovation Grant from the Idaho Natural Resources Conservation Service). Colors show pH as indicated by Veris pH detector; these pH maps and lime requirement tests were used to guide lime application rate decisions. Map: Tabitha Brown.

Moving Beyond Nitrogen

Odberg is starting to explore the impacts of using precision agriculture tools to apply other products at variable rates. In 2013, he began participating in a study on variable rate lime

applications led by the [Latah Soil and Water Conservation District](#) (Figure 7). Because lime is an expensive product, he feels this has good potential to be cost effective. On his own, he has also begun to apply potassium and phosphorus at variable rates, with higher rates on eroded hilltops where these

nutrients are deficient. Though he is just beginning, he is eager to see his results.

Odberg is also excited to begin experimenting with applying seed at variable rates. “It’s all related to water and soil depth. I think we have been over-seeding our south slopes and hilltops,” he says. “In those locations, we just don’t have the water-holding capacity, so we really don’t need so many plants out there. Maybe we have been under-seeding our north slopes and draw bottoms, where we have more available water longer in the growing season.” And with seed becoming more expensive, he thinks the cost savings could be important.

Benefits

Since implementing variable rate technologies, Odberg has reduced his overall nitrogen use by 15%, while achieving equivalent yields. Of his savings, about 7% comes from using auto-steer, which reduces overlap in nitrogen applications. (See the Odberg’s Fertilizer Cost Savings Using Precision Agriculture Tools sidebar for more information.) An additional 8% savings comes from the use of variable zones. The savings, according to Odberg, is enough to benefit his bottom line, and he is optimistic that there is still room for future improvement. In research settings, the savings and yield impacts have varied widely, suggesting that results are quite dependent on both physical and management contexts. (See the Impacts of VRN Application on Fertilizer Application Rates and Wheat Yields in the Inland Pacific Northwest sidebar for more information.)

From a practical standpoint, Odberg says he sees a lot less downed or lodged wheat than he used to, which he attributes to fewer areas receiving too much nitrogen. This makes his

harvest go more smoothly and makes his direct seeding easier, since the residue is standing rather than lying down.

Odberg also sees environmental benefits from his use of VRN. Though it would be possible to use variable rate technology in a conventionally tilled field, Odberg finds that these technologies work together to reduce the loss of topsoil and nitrogen.

“I think there is a great environmental gain with variable rate. You’re putting less nutrients out there. It’s not a lot less, but that’s just less that is going into our environment. And it’s using less of a petroleum-based resource that we’re not going to have forever. So it’s a win for me as a producer with the cost savings, and it’s a win for the planet and general population with less nitrogen going into our environment, whether it’s in the atmosphere or our waterways.”

Meanwhile, direct seeding and diversified rotations complement his VRN and work together to increase organic matter, reduce compaction, and improve soil quality. His overall weed issues also seem to be relatively manageable, with the exception of a growing problem with rattail fescue.

Challenges

For Odberg, the biggest challenge with precision nitrogen application has been the expense associated with the technology. High equipment costs make purchasing decisions critical. Early on, he purchased a controller that would only apply one product at a variable rate, rather than the multiple products it advertised. This limited him to varying the rate of nitrogen only.

Odberg’s Fertilizer Cost Savings Using Precision Agriculture Tools

Odberg finds that precision agriculture allows him to save about 15% per acre on his anhydrous nitrogen costs (Table 2). Of this, about 7% results from his use of auto-steer, which reduces overlap on each pass as well as on the field borders. Variable rate application saves him about another 8%. For example, assuming an application rate of 90 lb per acre of anhydrous nitrogen, he would save about 6.3 lb of nitrogen with auto-steer and about 7.2 lb from VRN application. Assuming an anhydrous price of \$0.63 per lb, auto-steer saves \$3.97 per acre and VRN saves \$4.54 per acre, for a total savings of \$8.51 per acre. Over several thousand acres, the savings are substantial and help pay for precision agriculture upgrades. Reducing nitrogen runoff and leaching with variable rate application are additional benefits.

Table 2. Nitrogen cost savings by type of precision agriculture technology for 90 lb per acre application.

	Nitrogen savings (%)	Nitrogen savings (lb)	Price, anhydrous N	Savings (\$/acre)
Auto-steer	7%	6.3	0.63	\$3.97
Variable rate	8%	7.2	0.63	\$4.54
Total	15%	13.5	0.63	\$8.51

Impacts of VRN Application on Fertilizer Application Rates and Wheat Yields in the Inland Pacific Northwest

Given the range of conditions across the inland Pacific Northwest, it is perhaps not a surprise that the impacts of VRN applications on wheat yields and fertilizer application rates have been quite variable. While no systematic survey of impacts has yet been done, semi-structured interviews with four growers on the Palouse (including Odberg) indicated that impacts on yield ranged from no impact to small positive impacts (Wavrin et al., unpublished data). While most growers noted a reduction in nitrogen application, this result was not quantified.

Research results across the region also give an indication of the variability in impacts of adopting VRN. Research at the Cook Agronomy Farm (in Pullman, WA) showed that optimum soft white winter wheat yields could be achieved with less overall nitrogen using VRN as compared to a uniform nitrogen application. This led to a 40% decrease in nitrogen usage for the field, down from an initial rate of 92 lb per acre, while increasing the average yield by 12 bushels per acre (Brown and Huggins 2011). This “double positive” result is largely due to the high spatial variability at this site. In some other cases, VRN application has led to higher nitrogen application, if more nitrogen is applied to regions with higher yield potential.

In general, having patterns in yield that are consistent over time makes VRN management easier, and more likely to be beneficial (Huggins et al. 2014). In particular, spring wheat yields tend to be less stable than yields for winter wheat, and therefore may benefit less from precision nitrogen management (Huggins et al. 2014).

In Davenport, WA, Jake Wavrin and colleagues developed low-, medium-, and high-precision nitrogen management zones based on one year of yield data and electrical connectivity data (Huggins et al. 2014). VRN was applied during seeding of hard white spring wheat. Results from 2012 found similar yields and protein at the field level when comparing VRN management with uniform management. The overall nitrogen application rate was 5% lower on the portion of the field where variable rate application was used.

Given this variability in results across the region, growers implementing VRN are strongly encouraged to evaluate the impacts on yields and nitrogen rate through methods such as a series of uniform rate check strips (D. Huggins, personal communication).

Managing the technology has also been a challenge. Odberg has a certain level of comfort with technology, but he does not see himself as an expert. Using the services of a precision agriculture specialist has made all the difference, but it has also made him dependent on that person. When his original precision agriculture specialist moved to another job, Odberg had to find a new specialist.

Despite the challenges, Odberg thinks using variable rate technology has been worth it for him. “Of all the production areas in the United States, we probably have the greatest variation out there because of our hills,” he says. “The Palouse is just screaming for this technology, and I think everyone will probably be doing it eventually.”

Managing Risk

While farming is never risk free, Odberg feels his production strategies combine to reduce his overall risk. His production risk is lowered and his system is more resilient due to direct seeding and diverse rotations. Meanwhile, using VRN technology reduces his reliance on fertilizer, contributing to decreased risk from fluctuations in input prices. “Variable rate is just another component...it’s not big, but it’s part of a tool belt,” he says.

Odberg also feels that two key strategies reduced the risk of adopting a new, complex, and expensive technology: participating in cost-share programs and utilizing the services of a precision agriculture specialist.

Learning, Experimenting, and Adapting

Especially when he was first transitioning to direct seeding, mentors were an essential resource. For example, when he was first direct seeding, Odberg asked many questions of his neighbor, Russ Zenner. He also interacted with other experienced direct-seed farmers through his participation in the [Pacific Northwest Direct Seed Association](#), which sponsors hosted breakfast meetings for growers during the winter months. Funding through federal government programs such

as the USDA-NRCS's Environmental Quality Incentives Program and the Conservation Security Program also provided financial resources that made it easier to explore new practices.

Odberg has also learned by jumping in and doing things on his own. About variable rate technology, he said, "It just seemed very obvious to me. That's why I just went into it head first, and really haven't looked back. But it is a leap of faith. And I don't have all the answers." Over time he has built a base of knowledge that he can draw on to solve problems as they arise, both through learning from others and his own experimentation.

Odberg sees variable rate as just one strategy in his ongoing efforts to improve his practices. He continually evaluates what he does, identifies areas for improvement, and talks with other growers about their strategies. He reads both the monthly newsletter and the print magazine, *No-Till Farmer*, to get ideas from other regions that he can adapt for use here. Lastly, participating in research studies has helped Odberg stay on top of cutting-edge techniques. Currently, he is a grower-cooperator in WSU's Site Specific Climate Friendly Farming Project. (See the Research on Improving Management of Precision Agriculture sidebar for more information.) Beyond contributing to the development of new knowledge, he hopes he will be able to evaluate and improve the nitrogen application zones he is using and learn more about his soil compaction, soil quality, and nutrient management.

Research on Improving Management of Precision Agriculture

David Brown, Department of Crop and Soil Sciences, Washington State University

Erin Brooks, Department of Biological and Agricultural Engineering, University of Idaho

Through the Site-Specific Climate-Friendly Farming project, scientists at Washington State University, University of Idaho, and the USDA-ARS are working to understand how growing conditions vary within fields at different locations on the Palouse. The project is improving understanding of variations in physical, chemical, and biological processes, and translating this into information that farmers can use to implement and improve precision management.

To better understand these processes under real management conditions, the project established four

research areas in small catchments on grower-collaborator fields. Sites include Odberg's farm near Genesee, ID, as well as farms near Colfax, WA, Leland, ID, and Troy, ID. The sites span a range of climatic, soil, and topographic conditions across the Palouse.

At each site, scientific instruments have been installed to capture a range of measurements. At twelve carefully selected locations within each site, soil moisture and temperature are measured hourly at five depths up to 60 inches (150 cm). Grain yield and protein, crop biomass, carbon, nitrogen, and nitrogen mineralization rates are also being measured. Hydrologic flumes monitor water and nitrogen outputs. Weather information is collected with weather stations.

The project relies heavily on both direct measurement of the spatial variability of soil and hydrologic properties and on the development and refinement of remote and field-based sensing technologies that can be used for rapid and inexpensive characterization of variability within fields. Soils are mapped across the catchment using cutting-edge soil-sensing instruments, and important crop parameters (e.g., biomass, nitrogen content, and water stress) are mapped repeatedly during the growing season using RapidEye satellite infrared imagery.

While this research is ongoing, preliminary results suggest that lower yielding areas of Odberg's fields have high clay content or have a shallow clay layer below the soil surface. Soil moisture data indicates that these shallow soils are very "flashy," wetting up and drying quickly (Figures 8 and 9). Overall, the prescription maps

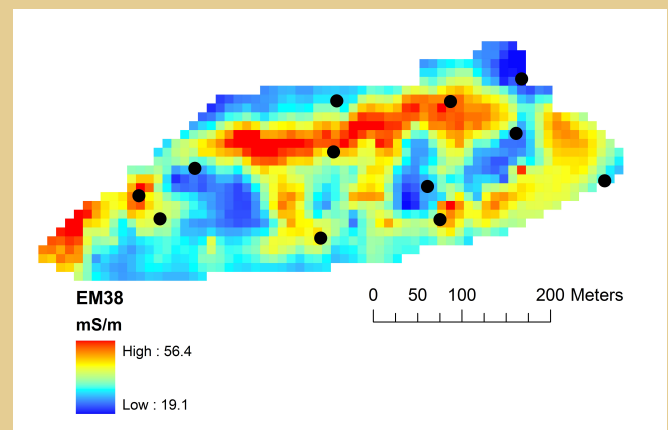


Figure 8. Soil electrical conductivity measurements document variations in clay and moisture content of the soil across the field. Map: Erin Brooks.

developed by Odberg and his precision agriculture specialist indicate a strong understanding of variability within Odberg's fields. Drying patterns and crop yields matched well with fertilizer application rates, suggesting that nitrate losses were minimized by variable rate application of fertilizer (Figure 10).

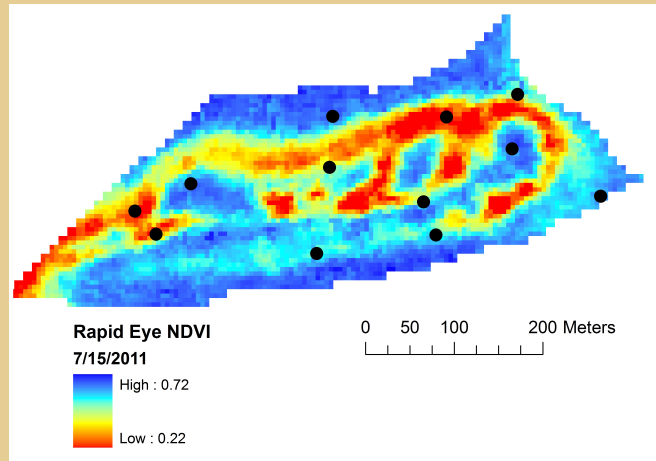


Figure 9. RapidEye imagery indicating drying patterns. In this image, red areas are dry, while blue areas are actively growing. Notice that these patterns match well with the soil electrical conductivity measurements shown in Figure 8. Map: Erin Brooks.

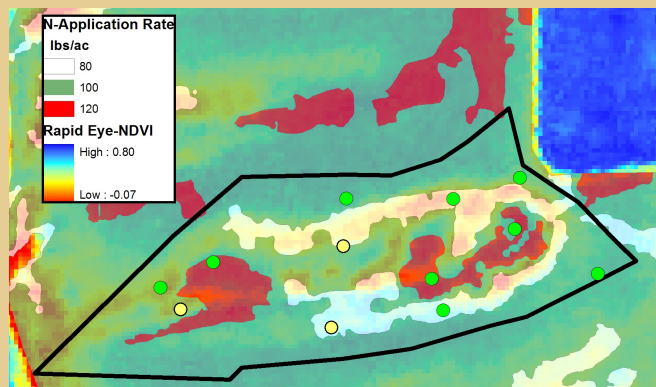


Figure 10. Fertilizer prescription maps draped over the RapidEye imagery (shown in Figure 9). Notice the close correlation between zonal boundaries shown in the overlay here and drying patterns (red areas, underlay, and Figure 9). Figure: Erin Brooks.

Looking Forward

Odberg looks forward to the new opportunities that precision agriculture will create for future generations to be involved in agriculture. He anticipates that these new technologies will make farming more appealing to his sons, since sitting on a tractor is combined with sophisticated tools that make it more interesting and challenging. In a broader sense, Odberg feels optimistic that the future may provide more management tools for dryland growers, including precision agriculture, improved crop varieties, and cover cropping.

Reflecting on the climate, Odberg says that growers in the inland Pacific Northwest are lucky. "We're very blessed here in the Pacific Northwest to have a fairly consistent climate." But over the years he has also noticed more weather extremes like longer dry or wet periods. His sense is that these extremes are here to stay, but that given the overall resiliency of his direct-seed system, he will be able to manage around them. In some cases, changes in his equipment have been key to managing new conditions. For example, he has added bigger, heavier hubs for the single discs on his drill, improving its ability to seed through hard, dry soils during extended dry periods in the fall. He also thinks that growing new winter wheat varieties, such as the early maturing types, will be important in the future.

Advice for Others

Odberg was asked what advice he would give to other growers who are interested in trying precision agriculture.

Take the plunge. "Don't get hung up on the details of how much you should be reducing and how much you should be changing things. Just get started doing it... But don't make changes that are too drastic."

Have realistic expectations. "Have realistic expectations that you're not going to have huge savings, but you're going to have savings."

There are more equipment options now than ever before, but purchasing decisions are still critical. The number of equipment options has grown since Odberg first started. The technology has also generally been better tested and developed, in some cases specifically for the terrain of the inland Northwest. However, even with these ongoing technology developments, Odberg cautions, "Whether you are deciding to buy your first

system or update to a new system that has potential to do more, you want to make sure that it can actually do what you want it to do.”

Do not be intimidated by the technology. Odberg does not consider himself to be particularly tech-savvy, but having a precision agriculture specialist and other knowledgeable resource people to turn to has allowed him to successfully adopt VRN application. He finds that some growers think they need to be more knowledgeable about technology than is really required.

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