Case Study

Adopting Precision Input Management: A Teaching Case Study

Cheryl Wachenheim[a], Erik Hanson[a]
[a]*North Dakota State University*

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Abstract
Students are introduced to a framework for individual-farmer evaluation of the net benefits of adopting precision agricultural technologies (PATs). A young farmer is considering whether to use a PAT bundle. He is advised by a crop consultant. Students adopting the role of the farmer should analyze the basic economics associated with using the PAT. The focus is on identifying what differs from traditional application and that under PAT, finding information necessary to analyze the net effect, conducting sensitivity analysis, and factoring in qualitative considerations. Students should use partial budgeting analysis to calculate net change in profits expected from adopting a single PAT bundle.

"*Farming looks mighty easy when your plow is a pencil, and you're a thousand miles from the corn field*."
—President Dwight D. Eisenhower (Bradley University, Peoria, Illinois, September 25, 1956)

1 Introduction

Dakota Levy and his parents farm 2,400 acres in southeastern North Dakota, growing soybeans, corn, wheat, and sunflowers. His mom, Jacqueline, has a full-time job as a teacher at the local school, and his dad, Arnold, farms and runs a one-man custom welding shop during the winter. Dakota just graduated with a two-year degree in agronomy from the local community college. As he graduated just before Christmas, he is currently helping his dad in the welding shop as he explores his options.

Dakota and Arnold went to a precision agriculture technology (PAT) workshop put on by North Dakota State University Extension staff. In addition to the extension team, there were a PAT equipment manufacturer and two regional PAT data software sales and services firms at the workshop. A crop consultant and dealership who both offer PAT services, including collecting and analyzing drone imagery, soil testing, variable rate application of fertilizers, and variable rate seeding, were also present. Dakota and his dad were excited to learn more about the farming technologies they had heard and read about, and it was good to take a break from the welding shop, as it had been a busy month.

Arnold had kept up on PATs from daily coffee at the local café and reading farm magazines and newspapers, as well as following two farming blogs. Dakota heard quite a bit about the potential of PATs in school over the past year and learned to fly a commercial drone, but did not take any classes that specifically considered the economics of PATs. Hearing about advances in the PATs and talking with other farmers who have had positive experiences increased their interest in considering the use of PATs on their farm.

As they drove home from the workshop, Arnold and Dakota discussed the possibilities. Arnold was particularly curious about how adopting these PATs would affect yields and if spending the extra money on additional soil testing and specialized equipment was worth the cost savings on inputs. "This is a problem that can be addressed using a partial budget," said Dakota. "We learned how to do partial budgets in our farm management course." Dakota went on to explain to his father that the starting point is to identify potential PATs for their operation. They would then compare recent revenues and costs on the land to those they could expect if they adopted a PAT bundle. During the workshop, the North Dakota State University Extension staff indicated they could identify data sources to use in these "what if" scenarios. Dakota was anxious to get started on the problem and share the answers with his father.

2 Farm Background and Plans

Dakota plans to take over the family farm one day although he has two younger brothers, 17 and 13, and a younger sister, 15. His parents are only in their late forties, and his dad has not mentioned any plans to retire. Dakota's parents are supportive of him one day taking over the farm, but have encouraged him to work off the farm for a few years to get some work and decision-making experience, gather new ideas, and otherwise expand his horizons. He has been participating in farm planning and decision making with his parents, increasingly so since he started attending college.

Dakota has been adamant that he wants to farm and has started looking for employment within a forty-minute drive of the farm. He also has hinted to his dad that they might grow the welding business to support two families during the winter. With his parents co-signing his operating loan, Dakota was able to sign a three-year lease on a quarter section of land (160 acres) from a retired neighbor. The farm is adjacent to one of his family's fields and within a mile of the home farm. This farm has some soil variability and moderate topography. Dakota's parents agreed that he can use the equipment from their home farm but will be responsible for paying fuel costs. Another condition is that Dakota must make all production, marketing, and other decisions on his 160 acres. Dakota has been talking with his parents and others as he makes plans for spring planting. So far, he has decided to focus his efforts on one crop this year.

Given current markets and the storage capabilities on the farm, Dakota decided to plant all his acres to corn the first year. He developed a marketing plan, and his plan is to sell portions of his crop at four different times during the year following harvest, unless there are considerable changes in the crop market. He plans to store his corn after harvest and lock in prices with forward contracts with the local elevator.

2.1 Precision Agriculture Technology Adoption Decision

Dakota was finalizing his input purchases as he shared lunch with Joe, who was two years ahead of him in high school and graduated the previous spring from North Dakota State University with a degree in Agricultural Systems Management and a minor in Agribusiness. Joe started working for a local crop consulting firm right out of school. He had interned with them the previous summer, and they are interested in Joe growing the PAT part of the business. It is clear Joe believes in the potential for PATs to allow farmers to, as he repeated several times during lunch, "optimize their input use."

Dakota had a fuzzy recollection from his one economics class that a farmer should optimize input use rather than aim for the highest yield. However, he also knows that his father will be very supportive of getting the most out of the land. Regional farmers generally plant to maintain or improve on their current yields and to maintain their actual production history (APH) yields. Dakota mentioned to Joe that any recommendation would need to include a yield goal similar to the land's APH yield, regardless of input and output prices.

Joe recommended that Dakota try using variable rate application of fertilizers and a variable seeding rate based on yield monitor and soil sampling data.[1] He suggested that the first year, Dakota hire out the soil sampling and zone mapping, and custom hire the variable rate application of fertilizers. Joe knew that Dakota's parents had a variable rate seeder so he could use digital prescription maps to variable rate seed using their own equipment.

Joe used the National Agriculture Imagery Program (NAIP) and Normalized Difference Vegetation Index (NDVI) imagery along with yield and soil sampling data the neighbor provided from prior years of operating on his 160-acre tract to create five management zones for the quarter-section (Figure 1). Joe explained that the NAIP is a U.S. Department of Agriculture program that captures digital imagery. And that the NDVI uses graphics to identify plant locations and characteristics, allowing for example, the

[1] Variable application is designed to optimize inputs such as fertilizer and seeds based on variable crop needs throughout the field rather than apply a constant rate across the field.

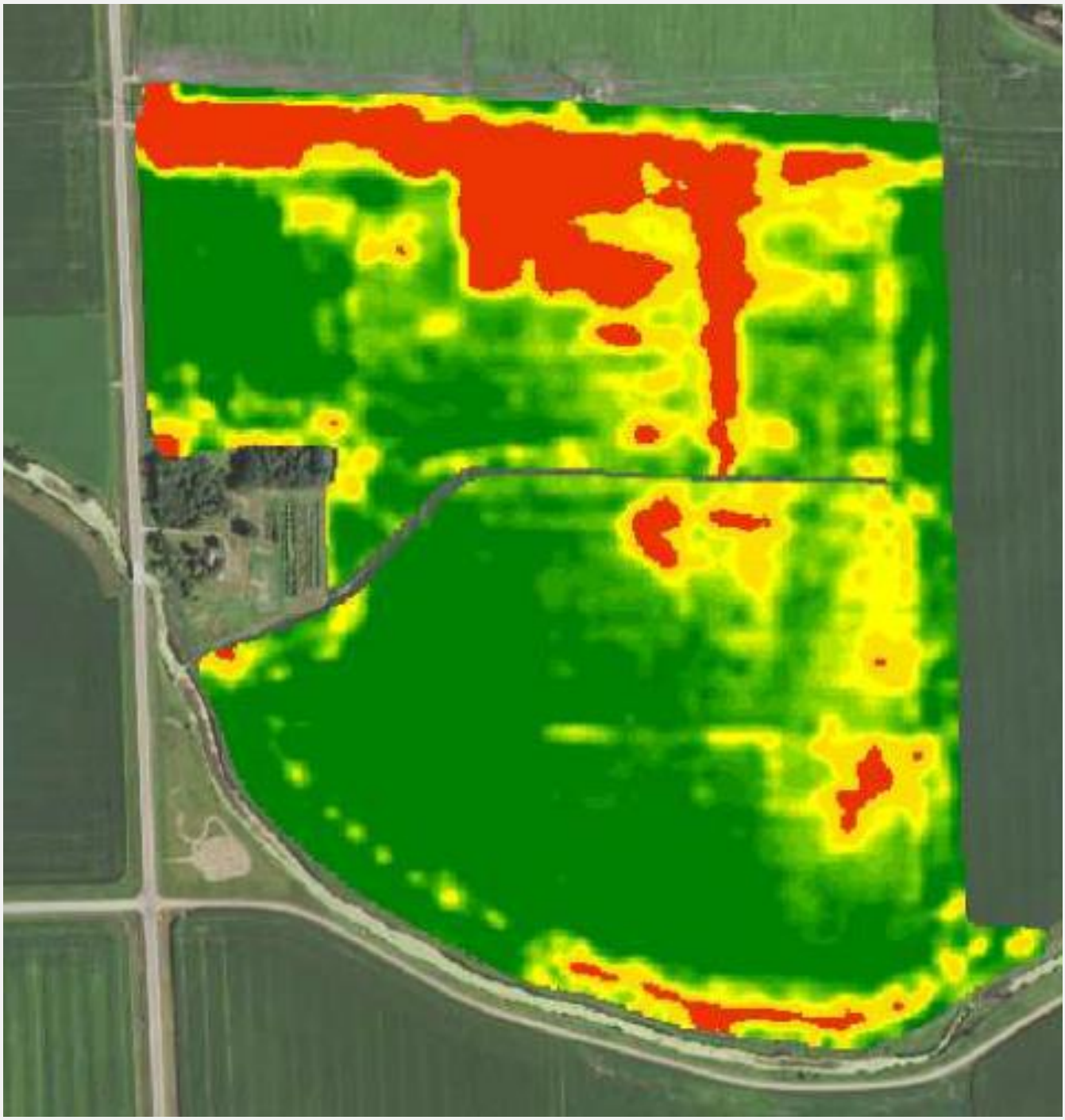

Figure 1: Recommended Zones for Variable Rate MAP Application[2]

monitoring of crop health and yield predictions. He proposed he would then more aggressively soil sample each management zone after harvest to refine fertilizer and seeding recommendations for the following year.

Joe showed Dakota the yield goals and recommended input use values he had come up with in Table 1. He pointed out that the first two rows identify the zones and the target yield for these zones. The following rows list average seeding rate and fertilizer input recommendations for each zone. He

[2] "MAP" abbreviates monoammonium phosphate fertilizer (NH4H2PO4). It is used as a source of nitrogen and phosphorous.

noted that applications and seeding rate would vary within each zone as well, but that level of detail can be left up to the planter, sprayer, and spreader custom operations. The overall average yield goal, seeding rate, and fertilizer application level was calculated as a weighted average over the five zones. The last column shows the retiring farmer's historic rate of fertilizer application and seeding rate on this land. Dakota was pleased to see that the proposed yield goal was slightly higher than the land supported previously.

Table 1: Sample Corn Input Recommendations per Acre by Management Zone*

Value/Zones	1	2	3	4	5	Weighted average	Traditional
Acres	3.7	14.1	27.8	51.2	62.2		
Yield goal (bushels)	120	150	160	195	210	189.0	185
Seeding rate (1,000)	24	27	29	31	35	31.7	32
Nitrogen, urea (lbs)	195	215	268	270	295	272.8	325
Phosphorus, MAP (lbs)	0	19	50	100	140	97.4	100
Potassium, potash (lbs)	0	0	70	74	75	65.4	100
Sulfur, AMS (lbs)	20	47	51	60	66	58.7	75
Pop-up fertilizer, 6-24-6 (gallon)	3.0	3.0	4.5	4.5	5.0	4.5	5.0

3 Economics

Dakota was excited about the possible yield gain while at the same time using a lower seeding rate and applying less fertilizer. He asked Joe what this would all cost. Joe motioned him to the table and emphasized that the primary cost savings would be in the form of reduced application of fertilizers and reduced overall seeding rate. He noted that savings by applying less fertilizer should really pay off this year because fertilizer prices are high. Joe ambitiously pointed out that eventually expanding use of precision agriculture to the overall family operation would increase savings even more because of its greater soil variability and the higher input costs. He recommended that Dakota use costs from December 2020 when he calculates out the net effect of adopting the precision agriculture bundle recommended because of recent dramatic increases in the market (Table 2), providing a more conservative estimate of the value of adoption.

Table 2: Fertilizer, Seed, and Corn Prices ($), December 2020

Input/Output	Cost/Price
Corn (bushel)	$4.14
Seed (1,000)	$3.00
Nitrogen, urea (lbs)	$0.28
Phosphorus, MAP (lbs)	$0.27
Potassium, potash (lbs)	$0.18
Sulfur, AMS (lbs)	$0.20
Pop-up fertilizer 6-24-6 (gallon)	$2.69

Note: Unless indicated, input use is noted in pounds.

Dakota liked the potential for significant cost savings but reiterated his question about what this would cost. He wanted to know what additional costs he would encounter by adopting this PAT bundle. Joe indicated that those were easier to estimate because Dakota would be hiring custom applicators.

Additional or higher costs associated with transitioning to the PAT bundle include those due to smaller-grid soil sampling, zone mapping, fertilizer recommendations, dry fertilizer application, and a hydraulic pump. Joe provided a per acre estimate of new or increased costs

Joe's proposal seems like it might work, but Dakota will have to run the numbers and think about his options. He also wonders if any other costs Joe didn't mention might change and how that might affect the decision. He remembers something was said in the workshop about how harvest and post-harvest costs may change with yields.

Dakota is thankful for the agricultural management and finance classes he had at the community college. They learned how to set up a problem in Excel and calculate profit and other financial indicators. He wants to have a plan ready when he approaches his parents with his proposal, although ultimately the decision is his for the 160 acres he rented.

To get started, Dakota reviews his notes from his courses about developing a partial budget. His instructors emphasized that an analysis can only be as good as the assumptions and data it uses. Dakota will use assumptions and costs provided by Joe as a starting point. Should it turn out that adopting PAT is likely to be profitable and his parents support the change, Dakota is ready to implement this in the spring on a trial basis.

Table 3: Cost Differences Between Precision Agriculture and Traditional Application Rates ($/Acre)

Costs	With PAT[a]	Without PAT
Soil Sampling	2.5	1.25
Zone Mapping	3	-----
Fertilizer Recommendation	6	-----
Dry Fertilizer Application	10	8
Hydraulic Pump	1	-----

[a]PAT is "Precision Agriculture Technology."

About the Authors: Cheryl Wachenheim is a Professor of Agribusiness and Applied Economics at North Dakota State University (Email: cheryl.wachenheim@ndsu.edu). Erik Hanson is an Assistant Professor of Agribusiness and Applied Economics with North Dakota State University.

CRediT author statement:
Cheryl Wachenheim: Conceptualization, methodology, formal analysis, investigation, data curation, writing-original draft, writing-editing and review, visualization, supervision, project administration, funding acquisition. Erik Hanson: Conceptualization, methodology, formal analysis, investigation, data curation, writing-editing and review, and testing.