GROWER PATHS TO PROFITABLE USAGE OF PRECISION AGRICULTURE TECHNOLOGIES

Douglas G. Tiffany, Karl Foord, and Vernon Eidman

Department of Applied Economics
University of Minnesota
St. Paul, Minnesota

ABSTRACT

First stage adopters of precision agriculture technology growing corn and soybeans in Southern Minnesota were interviewed to learn of their progress in implementing PA techniques. Their attitudes and behaviors adopting the various manifestations of PA technology were noted. A spreadsheet was developed that could represent the magnitude and incidence of farmer investments in alternative bundles of PA technology. The spreadsheet allows one to study the threshold levels of yield enhancement required to justify investments in PA technology as well as attendant hired services. Alternative discount rates, pre-PA crop yields, crop prices, and farm sizes were tested to learn requisite yield improvements demanded for various PA “bundles of technology” selected. Despite low commodity prices, modest yield enhancements for farmers of average size can readily justify many of the typical choices farmers might choose.

Keywords: Precision agriculture, economics, spreadsheet, technology bundles

INTRODUCTION

Use of various techniques to manage small areas of each field individually and to recognize unique qualities should result in more efficient use of land, fertilizer, chemicals, and seed. Efforts to capture these efficiencies by some farmers are called “precision agriculture” or “site specific management.” A U.S.D.A. survey conducted in 1998 found that 11.3% of all farmers in the Heartland farming region utilized one or more types of precision agriculture
This study was undertaken to learn from the experiences of first-stage adopters of precision agriculture techniques. A list of Minnesota corn and soybean producers using PA was selected and subsequently interviewed. In addition, machinery, computer services sales personnel, seed company staff, and crop consultants were also interviewed to help appreciate the choices in technology available to farmers. Later, the behavior of these “first stage adopters” was modeled in a spreadsheet format to determine breakeven thresholds of various PA techniques.

THE SURVEY

The study of first-stage adopters and their experiences was undertaken to learn the following:

1) the aspects of PA they are using
2) their satisfaction and their success with PA
3) their desires for targeted research/education

METHODS

Individual interviews were conducted on-farm in 1998 with five farmers using various PA techniques. The sample of farmers interviewed was not random, but was selected based on the variety of tillage practices and the time they had spent trying to master this technology. Farmers with three or more years of experience with PA were chosen from a larger sample of PA users screened by phone. Other contacts were initiated with machinery manufacturers selling PA accessories, with computer software and hardware vendors, with seed company staff, and with crop consultants to better appreciate the choices in technology and services available to farmers.

PRECISION AGRICULTURE PRACTICES EMPLOYED BY SAMPLE

The sample of farmers interviewed employed a variety of PA practices including combinations of the following:

1) Yield and moisture monitor on combine
2) Yield and moisture monitor on combine with geo-referencing
3) Variable Rate Planting/ Split Seed Sources
4) Grid Sampling/ Nutrient Mapping, GPS-specific nutrient application

How do these systems work? In the case of yield and moisture monitors in a combine, the pressure of grain flow past a curve in a spout is continuously measured after being calibrated to reflect yields of various grain crops.

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Disturbance of electrical current caused by moisture content is also calibrated as volumes of grain pass through the combine. The weight (pressure) of passing grain per second is recorded and multiplied by the time required for the width of the combine to harvest an acre. Data is continuously flashed on display to reflect the yield per acre. In conjunction with the moisture tester, dry grain yields are calculated. Farmers have the opportunity to start or stop the monitor in order to tally yields for specific plots or entire fields.

The next refinement is that represented in the second example, which requires the involvement of a receiver of satellite (GPS) or UHF radio signals in order to determine the place in the field where specific yields are occurring. Including this feature adds the expense of the receiver, but also requires a computer for data storage and manipulation as well as diskettes and software to analyze the data. Yield maps can be generated that guide efforts of farmers in drainage, crop disease, weed infestations, etc. Frequently the involvement of a data-handling consultant comes into play at this stage in adoption intensity.

The third alternative listed is that of variable planting rates or seed sources. In this situation farmers may tactically adjust seeding rates or varieties as they encounter areas of fields with varying yield goals or disease potentials. One farmer had designed his own no-till seeder that was capable of switching varieties of soybeans on-the-go in order to overcome yield-limiting soil pH conditions or soybean cyst nematodes. The technology for varying seeding rates or source can be controlled either manually by the farmer while planting or by geo-referenced data on a computer card.

The fourth alternative of PA technology involves the use of grid sampling of soil nutrient levels with greater intensity, so that each sample represents either 4.4 or 2.2 acres. With soil samples at this level of resolution recorded in a geo-referenced fashion, maps of nutrient or pH levels can be produced with a computer and the right software. Crop consulting or fertilizer sales companies then prepare a computer card, which is read by a fertilizer spreader equipped with variable rate technology (VRT). As such a machine crosses a field it dynamically adjusts fertilizer blends to treat each grid of the field based on the grid sampled soil tests.

While conducting the pre-interviews, it became evident that the farmers were using various combinations of these dominant PA techniques. Several farmers mentioned using PA to guide their application of herbicides by using the satellite receiver to alter rates while going across a field, based on the presence of “target” weeds or the activity of the herbicide in specific soil groups. One farmer mentioned that GPS (global positioning systems) could also be used in conjunction with some hardware to guide him in straight rows with no gaps while applying herbicides.

**ADOPTION AND USE OF PRECISION AGRICULTURE TECHNIQUES**

A common progression in the use of PA technology is for farmers to advance to ownership of yield monitors and position receivers after being introduced to grid-sampling of nutrients by their fertilizer supplier or crop consultant. The first hardware purchase for farmers using PA techniques is to buy and install a yield monitor on their combine. Some of those interviewed had
several years of experience with yield monitors that would continuously display and record yield and moisture levels. The data can be summarized by field or sub-field, but not geo-referenced. The next step in PA intensity is to add geo-referencing, allowing the farmer to create yield maps. All operators that were interviewed had yield monitors and position receivers so that yield maps could be created. One of the farmers also had one year of experience with variable rate planting technology, one was getting ready to use it for the next year, and a third had the capability of seeding either of two varieties of soybeans in different areas of a field on-the-go. As mentioned previously, this individual was switching varieties in order to remedy iron chlorosis problems, but could also switch varieties of soybeans to overcome field areas infested with soybean cyst nematodes.

Farmers using yield monitors with position receivers are able to produce yield maps for their fields and readily admit that they never realized that there was such a range of yields in individual fields. The farmers focus on the obvious causes for yield differences and see the need for additional drainage and measures to reduce weed competition. Though they have nutrient levels mapped for the same fields, the interviewed farmers indicated that the linkages between yields and nutrient levels are not as profound as effects of poor drainage and weed pressure. Many of the farmers observed inexplicable yield variations. Some speculated that herbicide carryovers related to soils of particular pH ranges may be a possible explanation. One respondent uses his yield monitor to compare corn and soybean varieties across the varied soils of his farm to provide more information on the unique herbicide tolerance and yield capabilities of the crops.

Several of the respondents said that they share reports and maps with their landlords to facilitate negotiation of equitable rents and to identify areas where improved drainage would enhance yields. One farmer uses data collected by his yield monitor to help calculate rental payments to be made on his variable cash lease. Some farmers appreciated having the ability to accurately measure corn moisture levels so that they could make tactical decisions regarding which varieties to harvest on a particular day, an advantage for farmers trying to maximize through-put of their corn dryers.

A crop consultant mentioned the use of PA technology in prescribing liming to help overcome corn and soybean herbicide carryover effects in sugar beets, which are quite sensitive in this regard. In this fashion they expected to make the herbicide more subject to degradation or less available on the more acid soils of a field.

**OPPORTUNITIES AND CHALLENGES NOTED BY FARMERS**

None of the farmers interviewed felt that they had fully captured the opportunities of PA, in fact some were cautious about making further investments in the technology until they could identify more uniformity in system specifications between yield monitor and geo-referencing systems. In general, most farmers interviewed recognize they will need to store data from several seasons to be in a position to utilize the full potential of PA. Many had the previous season’s data on disk that they had yet to convert to maps even though the next harvest was a month or two away.
All respondents expressed concern about the time and effort required to edit, store, and use the data that is produced. In addition they admitted that they had suffered loss of significant data due to machine or human error. All respondents expressed concern for the amount of time required to “clean-up” the raw data they had collected before producing maps. All respondents expressed some frustration at some time with systems and their ability to contact someone who could help them with data transfer. Some respondents used a crop consulting company to produce their yield maps from the data they had collected from their combine yield monitor. From grid-sampled soil nutrient data, crop consulting firms produced a “computer card” to geo-direct the VRT (variable rate technology) fertilizer spreader.

Several respondents were cautious about spending money on grid sampling, but liked what they were learning about the land they managed from the yield and moisture monitor and resulting maps. One farmer, who refused to pay for grid sampling across his entire farm, had this service performed on the fields that had been high recipients of manure for many years. This grower expected that the grid-sampling would define for him areas of fields that require no additional nutrients for many years into the future.

One farmer concluded that the yield maps and nutrient level maps were telling him that some of the most “profitable” areas of his fields were of areas of medium to low productivity. This was a bit of a revelation for him, having previously thought that the highest producing soils were also his most profitable. Instead he witnessed that he had not been applying his fertilizer where it would result in the highest amount of marginal product.

Livestock producers seem to be more eager users of grid sampling and nutrient mapping as an aid to more fully utilize the nutrients in manure. Nutrient level maps revealed areas to avoid and areas to target for additional manure. Most respondents liked the opportunity to note and geo-reference weed infestations, rocks, or broken tiles by simply hitting a button while they are combining.

**DATA FARMERS SEEK TO UTILIZE IN PRECISION AGRICULTURE**

PA users desire research by universities or seed companies in determining useful strategies to alter site-specific populations of corn and soybeans with variable seeding rate technology. They wish to vary seed populations of soybeans in order to overcome poor plant development due to iron chlorosis. In the same manner, they seek guidance on altering plant populations to reduce white mold prevalence by allowing more air movement in areas of fields prone to white mold.

One PA user suggested that geo-referenced field elevations could be more useful and cheaper than grid sampling of nutrients for determining yield potential of land. Other tools, such as scheduled aerial photography or remotely-sensed data that are of low investment with high potential payoff would be welcomed as an alternative to the expenses associated with grid-sampling and geo-referenced fertilizer application.
ECONOMIC ANALYSIS OF INTENSITY LEVELS OF PA ADOPTION

An Excel spreadsheet, originally designed by Karl Foord, Extension Educator from Dakota County, Minnesota, was modified to illustrate how one could estimate the possible economic impact of alternative levels of PA implementation or intensity. By stating assumptions about discount rates, crop yields before implementation of PA technology, crop prices, and farm size it is possible to use the spreadsheet to test the financial performance of alternative “technology bundles” among machines and services purchased. Review of the spreadsheet on the following page can readily acquaint one with its workings.

Starting near the bottom of the sheet, there are six alternative assumptions that can be made to specify "bundles" of PA technology and also characteristics of the farmer to be modeled. In the example one can observe that PA capital investment of $17,500. This would represent an individual purchasing a yield monitor for the combine with a GPS receiver as well as a $2,000 computer at home to store data and also variable rate seeding equipment on his planter. The same individual would also purchase $10 per acre additional soil analysis every four years, $6 per acre additional soil spreading expenses every other year, and $3 per acre consulting fees to manage data and produce yield maps each year. The farmer attributes are expressed in the 40% marginal tax rate reflecting federal, state, and social security taxes as well as his discount rate of 10 percent or whatever else he might deem appropriate. **Numbers in bold print are those that can be modified.** With initial assumptions of technology bundle and farmer attributes made, one should go to the area labeled “Crop Enterprises” to specify the number of crop acres of corn and soybeans to be grown as well as appropriate “Pre-PA” yields and projected crop prices. Appearing to the right of the “Crop Enterprises” area is a cell for Revenue Change Assumptions, which may result from yield increases or fertilizer expense reductions. The factor of “Revenue Change” is expressed as a decimal and can be entered (imposed) or generated based on other assumptions. Below the bold factor of increase, annual revenue changes by crop are recorded. Slightly below and to the left, “B.E. Yield Gains Needed” records the changes due to PA strategies consistent with the “Revenue Change Assumption.” The numbers appearing at the top in the table all flow from the assumptions entered. Expenditures before crop production are assumed made in “Year 0.” After that the incidence of expenditures and depreciation all appear in the table. Cell D14 contains the sum of all the discounted present values of the years 1-7. Cell D15 contains the net present value of the precision agriculture strategy modeled. By using the “Goal Seek” tool in the Excel spreadsheet one can set Cell D15 to equal zero by changing the value of Cell N19. In this fashion it is possible to determine breakeven revenue increases or expense reductions that need to be obtained consistent with the PA technology bundles and also the discount rate selected.

Examples of five hypothetical farm operators with the same land base (1500 acres split between corn and soybeans, and a discount rate of 10%) but choosing various bundles of PA techniques and equipment illustrate the versatility of the spreadsheet described above. The farmers were all given nicknames to help distinguish between the bundles.
Bundle 1 Farmer (No Gadgets) owns no computer and chooses not to buy any new equipment. Instead he hires a crop consulting firm to grid-sample his fields. The consulting firm prepares maps of soil fertility levels for him and creates a “card” that will guide a variable rate spreader as it makes application to his field. This strategy will yield a 10.0% rate of return on money invested in PA with yield increase of 3.05%.

Bundle 2 Farmer (Monitor Man) owns no computer but feels he could learn more about his fields as he watches as the yield and moisture monitor flash levels of yields and moisture levels of the crops as he rumbles across the field in his combine. The yield monitor he purchased for $4000 can summarize yield data by field or sub-field, which he dutifully records in a notebook that he always carries. He has no electronic record of his yields and nothing but his memory to guide any change in management strategies. He purchases no additional PA services. By improving his yields by 0.24%, he will produce a 10% rate of return on PA investment.

Bundle 3 Farmer (No Trespassing) decides to get a yield monitor on his combine with a satellite receiver, and buys a nice computer totaling investment of $11,000. He hires a consulting firm to produce some nice yield and grain moisture maps. However, he is reluctant to pay the $10 per acre in additional fees necessary for grid-samplers to drive their four-wheelers on his fields, not to mention the additional $6 per acre that variable rate fertilizer spreaders require every other year. He would rather apply fertilizer based on his own sampling and apply all nutrients himself with common rental application equipment. A yield

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### Breakeven Returns Worksheet for Precision Ag. Strategies

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</thead>
<tbody>
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<td>Change in Expenses</td>
<td>$15,000</td>
<td>$13,500</td>
<td>$12,000</td>
<td>$10,500</td>
<td>$9,000</td>
<td>$7,500</td>
<td>$6,000</td>
<td>$4,500</td>
</tr>
<tr>
<td>Profit Before Depreciation</td>
<td>$7,230</td>
<td>$7,730</td>
<td>$8,730</td>
<td>$9,730</td>
<td>$10,730</td>
<td>$11,730</td>
<td>$12,730</td>
<td>$13,730</td>
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<tr>
<td>Profit Before Tax</td>
<td>$5,230</td>
<td>$5,730</td>
<td>$6,730</td>
<td>$7,730</td>
<td>$8,730</td>
<td>$9,730</td>
<td>$10,730</td>
<td>$11,730</td>
</tr>
<tr>
<td>Less Tax</td>
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<td>$2,592</td>
<td>$3,092</td>
<td>$3,592</td>
<td>$4,092</td>
<td>$4,592</td>
<td>$5,092</td>
<td>$5,592</td>
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<tr>
<td>Profit Depreciation</td>
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<td>$2,500</td>
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<td>$2,500</td>
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</tr>
<tr>
<td>Cash Flow</td>
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<td>$7,638</td>
<td>$7,638</td>
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<td>$7,638</td>
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<tr>
<td>PV Cash Fl @10.0%</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
</tr>
<tr>
<td>PV Cash Fl Yr(1-7) @10.0%</td>
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<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
<td>$7,638</td>
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<tr>
<td>NPV of Precision Ag. Strategy</td>
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<td>$0</td>
<td>$0</td>
<td>$0</td>
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### Crop Enterprises

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pre-PA</th>
<th>Projected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>100</td>
<td>130</td>
</tr>
<tr>
<td>Soybeans</td>
<td>500</td>
<td>40</td>
</tr>
</tbody>
</table>

### Farm Size in Tillable Acres

1500

### Change in Revenue


### Change in Expenses

| Change in Expenses | $15,000 | $13,500 | $12,000 | $10,500 | $9,000 | $7,500 | $6,000 | $4,500 |

### Profit Before Depreciation

| Profit Before Depreciation | $7,230 | $7,730 | $8,730 | $9,730 | $10,730 | $11,730 | $12,730 | $13,730 |

### Profit Before Tax

| Profit Before Tax | $5,230 | $5,730 | $6,730 | $7,730 | $8,730 | $9,730 | $10,730 | $11,730 |

### Profit After Tax


### Profit Depreciation

| Profit Depreciation | $2,500 | $2,500 | $2,500 | $2,500 | $2,500 | $2,500 | $2,500 | $2,500 |

### Cash Flow

| Cash Flow | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 |

### PV Cash Fl @10.0%

| PV Cash Fl @10.0% | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 |

### PV Cash Fl Yr(1-7) @10.0%

| PV Cash Fl Yr(1-7) @10.0% | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 | $7,638 |

### NPV of Precision Ag. Strategy

| NPV of Precision Ag. Strategy | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |

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**Bundle 1 Farmer** (No Gadgets) owns no computer and chooses not to buy any new equipment. Instead he hires a crop consulting firm to grid-sample his fields. The consulting firm prepares maps of soil fertility levels for him and creates a “card” that will guide a variable rate spreader as it makes application to his field. This strategy will yield a 10.0% rate of return on money invested in PA with yield increase of 3.05%. **Bundle 2 Farmer** (Monitor Man) owns no computer but feels he could learn more about his fields as he watches as the yield and moisture monitor flash levels of yields and moisture levels of the crops as he rumbles across the field in his combine. The yield monitor he purchased for $4000 can summarize yield data by field or sub-field, which he dutifully records in a notebook that he always carries. He has no electronic record of his yields and nothing but his memory to guide any change in management strategies. He purchases no additional PA services. By improving his yields by 0.24%, he will produce a 10% rate of return on PA investment. **Bundle 3 Farmer** (No Trespassing) decides to get a yield monitor on his combine with a satellite receiver, and buys a nice computer totaling investment of $11,000. He hires a consulting firm to produce some nice yield and grain moisture maps. However, he is reluctant to pay the $10 per acre in additional fees necessary for grid-samplers to drive their four-wheelers on his fields, not to mention the additional $6 per acre that variable rate fertilizer spreaders require every other year. He would rather apply fertilizer based on his own sampling and apply all nutrients himself with common rental application equipment. A yield
increase of only 1.78 %, will provide a 10% rate of return on the money he invests in PA.

Bundle 4. Farmer (Welcome Wagon) has the same equipment as Farmer III., worth $11,000 and also hires a consultant to produce some nice maps of yields and moisture. His nickname is “Welcome Wagon” because he decides to spend money for consultants to do grid-sampling and for geo-referenced variable rate fertilizer application. He may have a number of strangers tramping around on his farm as opposed to “No Trespassing”. If he is able to enhance yields by at least 4.83%, he will achieve a 10% rate of return.

Bundle 5. Farmer (First Class) has the latest in equipment with a yield monitor with a satellite receiver on his combine and also variable seeding rate equipment on his planter and a radar gun to measure his planter speed. His investment in equipment is $17,500. He has a computer at home, but hires out some of his data transfer projects. He pays a consultant to perform grid-sampling and to produce nutrient level maps for him. The consultant prepares a “card” to guide the variable rate fertilizer spreader. If “First Class” achieves yield increases of 5.22%, he will have a 10.0% rate of return on money spent for this PA technology bundle.

The following graph contains breakeven yield increases (or expense decreases) for the five technology bundles required to produce a 10% rate of return when assuming seven year depreciation on equipment, a 40% marginal tax bracket, and farm size of 1500 acres, as described in the five nick-named farmers. The graph also compares the returns needed by the 1500 acre farms and contrasts those with the returns required by farmers with 750 acres. Threshold breakeven levels are generally higher on the smaller farm example because the depreciation
of capital purchases is spread over a smaller acreage base. The notable exception is Bundle 1, which represents fee payments for grid sampling and geo-referenced fertilizer applications. Bundle 1 is a scale-neutral choice, meaning that farms of any size enjoy the same advantage in purchasing PA services.

The following graph contrasts breakeven yield increases required on a 1500 acre corn and soybean farm, contrasting discount rates of 10% and 15%. Note that the higher discount rate requires the operator to seek even higher yield increases or expense decreases from his investments in precision agriculture technologies.

**SUMMARY**

The survey revealed a financially conservative approach to precision agriculture technology by the interviewed farmers. The first-stage innovators that were interviewed represent practical operators seeking competitive rates of return on PA investments even though they admit that they have not yet realized the full potential of this technology. Most expected a time of learning, data collection, and product improvements before reaping the full benefits of PA. The spreadsheet was designed to portray the alternative paths to adoption of PA technologies. By testing alternative assumptions and technology bundles, it was possible to learn about the threshold levels of yield improvements necessary to capture specified rates of returns depending upon the technology bundle chosen and the costs the farmer might encounter in implementing the various paths to profitable use of PA technologies.