Advancements in Irrigation Agriculture with Implications for Economic and Community Development and Environmental Stewardship in Southern Alberta

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Executive Summary

Recent advancements in agriculture are technological in nature. Global positioning systems (GPS) infrastructure, satellite imagery, and auto-steer and variable rate features on equipment are common examples. These technologies help identify variability in fields to allow for more precise targeting of irrigation water, fertilizer, chemicals, and seed. The term 'precision agriculture' is commonly used to describe these technologies, deemed one of the top ten developments in agriculture in the past 50 years. Precision agriculture can improve crop yield and quality, as well as reduce farm inputs, generating positive implications for the farm economy, other agriculture-dependent broader communities, and the environment. Given that irrigation agriculture is fundamental to southern Alberta, understanding the adoption of precision agriculture in irrigation farming is important. A study of farm practices on irrigation farms in the Taber Irrigation District was undertaken. Based on the data collected, irrigators seem to be embracing precision agriculture. Positive economic impacts should concomitantly bolster broader communities. In addition, reported reductions in farm inputs should beneficially impact the environment.

Twenty-seven percent of district irrigators participated in the survey. Key findings were:

- 81% have adopted some form of precision agriculture;
- yearly crop yields have increased an average 20% and yearly crop quality has increased an average 16%;
- yearly reductions in irrigation water, fertilizer, herbicides and pesticides have ranged from 14% to 24%;
- precision agriculture technologies are being applied largely to specialty crops;
- for 85% of adopters, precision agriculture has affected their overall farm management approach;
- 89% of adopters are highly satisfied with the technology;
- 92% of adopters plan to adopt additional precision agriculture technologies in the future;
- non-adopters indicate small operations, high investment costs, and incompatibility of machines are the main reasons for their non-adoption of precision agriculture technologies.

Table of Contents

Background

(i) Irrigation Agriculture

Southern Alberta is the largest, most fertile and productive agricultural region in Canada (SouthGrow, 2017). It is within this region that the most extensive irrigation farming activity in the country takes place. Southern Alberta has the largest irrigation system in Canada, representing almost 70 percent of all irrigation agriculture area in the country. There are 13 irrigation districts in Alberta irrigating approximately 1.4 million acres of land, through 6,000 producers. An additional 311,258 acres of irrigation takes place on about 3,000 private projects (AAF, 2018). More than 60 crop varieties are grown under irrigation in Alberta, including 28 specialty crops (ARD, 2012). By comparison, crops grown under dryland conditions are mainly cereals and oilseed. Alberta's irrigation storage and distribution system also currently provides water to about 50 towns and villages consisting of more than 42,000 individuals (ARD, 2014).

The benefits of irrigation in southern Alberta are widespread given that a significant amount of economic activity is linked to irrigation. Locally grown crops provide the inputs for major processing industries in southern Alberta. These include Roger's Sugar, Frito-Lay Canada and Lamb Weston, for example. In addition, forage and silage produced under irrigation are used to support the confined feedlot industry, making the region Canada's leader in cattle feeding and processing. A 2015 study of the economic value of irrigation found (Paterson, 2015):

- the irrigation industry contributed about $3.6 billion to the provincial gross domestic product (GDP);
- the irrigation industry generated $2.4 billion in labour income and 56,000 full-time equivalent jobs;
- the irrigation agri-food sector contributed about 20 percent of the total agri-food sector GDP on 4.7 percent of the provinces cultivated land base;
- almost 90 percent of irrigation-related benefits accrued to the region and the province and 10 percent to irrigation producers.

(ii) Agriculture Advancements – Precision Agriculture

'Precision agriculture' is an umbrella term often used to capture many technology-related advancements in agriculture. It involves knowledge-based technical management systems to optimize the application of fertilizer, chemicals, seeds and irrigation water to reduce input costs, enhance crop yield and simultaneously reduce harmful environmental impacts associated with agriculture production (Bora et al., 2012).

Until the advent of precision agriculture, inputs were applied in a uniform rate across an entire field. Such a practice overlooked field variability (Tey & Brindal, 2012). Precision agriculture technologies allow fields to be deconstructed into smaller, more precise sections, based on variability. Based on this variability, allocations of inputs can be more precisely determined than those applied under earlier agricultural practices. Ultimately precision agriculture involves applying the correct amount of inputs, at the correct time, in the correct location in the field, hence the term 'precision agriculture'.

Precision agriculture has been deemed one of the top ten developments in agriculture in the past 50 years (Crookston, 2006). It has the potential to reduce farming inputs, reduce costs and increase farming profits. In addition, collateral damage to the environment can be mitigated. For example, less nitrogen and phosphorus fertilizer can help reduce run-off on the landscape and less irrigation water use can leave more water in the rivers. Precision agriculture has therefore become fundamental to sustainable agriculture.

Source: Grainnews

Given the potential benefits of precision agriculture, gaging rates of adoption, identifying the factors influencing adoption, and identifying factors preventing adoption are of considerable interest. A 2017 study of adoption of precision agriculture in western Canada found a large percentage of farmers, 84 percent, were using precision agriculture technologies (Steele, 2017). The data indicated that almost 100% of farms use GPS technology, 84% have combine yield-monitoring capability, 79% use GPS auto-steer equipment guidance and 75% use farm management software on a computer, for example

(Steele, 2017). Higher adoption rates were found on farms with larger acreage and higher revenue. Reasons for not adopting included: high price of the technology, internet speeds and/or cellular data coverage, lack of knowledgeable people, continuously evolving technology, and incompatible older farm equipment (Steele, 2017). A 2018 study focussed specifically on adoption of precision agriculture on southern Alberta farms (Nicol & Nicol, 2018). It was found that between 63% and 86% of farmers implemented precision agriculture technologies, depending on the levels of advancement of the technology. The most basic forms of the technology had a higher adoption rate than more advanced technologies. The study considered factors motivating farmers to adopt. It was found that the adoption factors included increased crop yield and crop quality, reduced farming time and reduced work load. Non-adopters cited high investment costs, small operations and high time requirements as the reasons for not adopting (Nicol & Nicol, 2018).

No study has explored the adoption of precision agriculture specifically on irrigation agriculture farms in southern Alberta. To maintain the extensive benefits of Alberta's irrigation agriculture, the industry's adoption of such advancements is important. The intent of this study is to fill this knowledge gap by exploring the adoption of precision agriculture in the Taber Irrigation District.

Study Area, Objectives and Methodology

The southern Alberta region is recognized for its entrepreneurial and progressive farm culture and practices. New speciality crops, equipment and land management practices have emerged where 'the business of agriculture is shifting from food producers to agri-business' (SouthGrow, 2017). Within this region are 13 irrigation districts, one of which is the Taber Irrigation District (TID). The TID consists of between 115 to 120 irrigators, irrigating 80,370 acres (personal communications, Chris Gallagher, September 21, 2018; AAF, 2018). Among the 13 irrigation districts, the TID has one of the highest concentrations of speciality crop production. Almost 40 percent of irrigation acres in the TID is devoted to speciality crops, including potatoes, sugar beets, canola seed, beans, peas, corn, sunflower, and onions. The remaining irrigated acreages are devoted to cereals (32.6%), forages (24.3%), oil seeds (2.7%) and other (0.7%) (AAF, 2018). The TID infrastructure also delivers water to the town of Taber, several communities and many individuals.

This study explored adoption of precision agriculture by irrigators in the TID. The objectives of the study were to determine:

(a) the extent to which technologies are being adopted, the type of technologies adopted; satisfaction with the technologies; motivations to adopt; what type of land and crops precision agriculture is primarily applied to; any future additional adoption intentions; farm and personal characteristics of adopters; and

(b) the extent of non-adoption of precision agriculture technologies; the reasons for non-adoption; any future adoption intentions of non-adopters; motivations to adopt in the future; farm and personal characteristics of non-adopters.

Data collection was based on a survey questionnaire developed and uploaded on a Qualtrics survey platform (Qualtrics, 2019). The survey questions drew on previous published studies, tailored to local conditions in the TID, and the study's objectives. A draft of the survey questionnaire was provided to the TID Manager and the TID's board of directors. Recommended changes were then incorporated into the final version of the questionnaire. Ethics approval to conduct the study was received from the University of Lethbridge Research Ethics Committee on July 31, 2018.

There are many precision agriculture technologies available. This study identified twenty. The technologies were grouped into the following three categories:

- Basic Technologies - auto-steer technology, yield mapping, soil moisture monitoring, weather monitoring, variable rate fertilizer application, variable rate irrigation application, GPS soil sampling, developing management zones
- Soil Mapping Techniques - terrain mapping/analysis, spatial variability of available water-holding capacity, electric conductivity mapping, satellite imagery, unmanned aerial vehicle mapping, establishing field boundaries/ low spots/ unfarmable land
- Data Management – studying/analyzing yield data, using hydrological modeling and forecasting to predict soil moisture status, developing dynamic water management zones, using precision agriculture data management software or services, using precision agriculture technology for records and analysis, using precision agriculture for on-farm research

Survey participants were recruited through the TID's head office via an invitation from the Manager of the TID. The invitation was sent via e-mail and text messaging. TID irrigators were given from October 9, 2018 to November 13, 2018 to participate in the survey. Thirty-two irrigators participated in the survey, representing 27% of irrigators in the TID. Data were summarized on a question-by-question basis. Cross tabulations were conducted to determine differences in adoption and non-adoption across personal and farm characteristics. The data analysis was alert to the emergence of common findings to ascertain if there are common characteristics amongst adopters as well as non-adopters. For non-adopters, the reasons why they have not adopted were useful in determining, if possible, what measures can be taken to assist with adoption.

Findings

(i) Adoption

The study found 81% of survey participants have adopted some form of precision agriculture technology. However, the adoption rate varied depending on the technology category. According to the three categories of technologies – basic, soil mapping and data management – the adoption rates were:

- 75% have implemented one or more basic technologies
- 50% have implemented one or more soil mapping technologies
- 44% have implemented one or more data management technologies

Across the 20 technologies, an average of five technologies per adopter have been implemented. The five most often used were: auto steer technology: 85%; studying/analysing yield data: 50%; weather monitoring: 50%; using satellite imagery: 38%; and GPS soil sampling: 35%.

When asked if precision agriculture has affected crop yield, crop quality and input utilization, the results indicate positive effects. Respondents reported that precision agriculture has on average increased annual crop yield by 20% and crop quality by 16%. Precision agriculture technologies have also reduced input utilization, including irrigation water, fertilizer, herbicides and pesticides by an annual average of between 14% and 24%

(details contained in the table below). These positive effects are also expected to continue in the future, with annual crop yield expected to increase by 18% and crop quality by 15%. Annual reductions in irrigation water, fertilizer, herbicides and pesticides are anticipated to be between 16% and 24%. A summary of these findings is contained in the table below:

Annual Average Change by Factor		
Factor	**Current Annual (%)**	**Future Annual (%)**
Increase in crop yield	20	18
Increase in crop quality	16	15
Reduction in irrigation water	24	23
Reduction in fertilizer	21	16
Reduction in herbicides	14	23
Reduction in pesticides	19	24

The study explored motivations for adopting precision agriculture and found there are a multitude of factors driving adoption. The factors rated highly (4 or 5 on a scale of 5) were to: reduce energy costs: 77%; increase annual crop yield: 62%; reduce machine time: 58%; increase annual crop quality: 57%; and reduce annual irrigation water: 54%. Other major reasons related to: reduce labor hours: 50%; reduce annual fertilizer: 50%; and manage environmental impacts: 46%.

Almost all adopters, 85%, indicate precision agriculture has impacted their overall farm management approach. Many adopters report impacts on: fertilizer strategy, method and/or depth: 71%; quality of seed: 58%; amount or type of soil moisture testing: 54%; and amount or type of soil nutrient testing: 46%.

When asked to rate their satisfaction with the technologies, across adopters a high percentage, 89%, were highly satisfied (rating of 4 or 5 on a scale of 5). Only 6% rated the technologies as neither negative or positive (a rating of 3), and 6% somewhat or extremely negative (a rating of 1 or 2).

In the future (specified as the next five years), most adopters plan to continue precision agriculture technology implementation. Of the respondents, 92% indicated they plan to adopt additional technologies, with 39% of respondents indicating they would adopt basic technologies, 35% data management and 26% soil mapping.

The study, not unexpectedly, found the technologies are being applied primarily to irrigated land – 92% to irrigated land versus 8% to dryland. When asked which crops benefited most from precision agriculture, 86% of those who responded indicated speciality crops, most notably sugar beets followed by potatoes, canola seed and corn. The remaining 7% indicated cereals, 7% oil seeds, 0% forages.

When asked if they use a precision agriculture consultant, 69% of respondents indicate they do not, 31% indicate they do. Of those who use a consultant, about one-third indicated the purpose for doing so was for field mapping and approximately 20% indicated consultants were used for either building variate rate prescriptions or unmanned aerial vehicle mapping or data management.

Source: spudsmart.com

(ii) Non-adoption

The study found 19% of respondents did not implement any precision agriculture technologies. When asked to check off from a list of the reasons why, the respondents noted: their operation is too small: 32%; high investment costs: 28%; incompatibility of machines of different manufacturers: 12%; techniques are too complicated or complex: 12%; high time requirements: 8%; too many unknowns regarding the technology: 4%; and lack of advisory services: 4%.

When asked if they plan to adopt any of these technologies in the next five years, the majority, 82%, indicated they would not. The small percentage that plan to adopt indicated they would adopt primarily basic technologies. All identified three reasons to adopt - to reduce energy costs, increase crop yield and increase crop quality.

(iii) Farm and personal characteristics of adopters and non-adopters

In terms of age range, based on the survey results, adopters are generally younger - a greater percentage of them are in the '20 to 34' year age range (8%) compared to non-adopters (0%) and a smaller percentage of adopters are in the 'over 55 years' age range

(46%) compared non-adopters (55%). Adopters are also relatively newer to farming, having spent less years making farm management decisions than non-adopters. While 62 percent of adopters have been making farm management decision for over 20 years, 73 percent of non-adopters have been making farm management decision for that period. Also, farm size of adopters is larger than non-adopters. Forty six percent of adopters have farm size of 2,000 acres and larger compared to zero percent of non-adopters. In other words, all non-adopters have farm size less than 2,000 acres. Concomitantly, adopters have a relatively high number of people working on the farm than non-adopters with 46% having five or more workers compared to 9% of non-adopters having five or more workers. In terms of education levels, adopters tend to have higher levels of formal education: 69% of adopters have a college diploma or university degree compared to 54% of non-adopters. The comparative data between adopters and non-adopters are enumerated in the table below:

Farm and Personal Characteristics, Adopters and Non-Adopters (%)			
Characteristic		**Adopters**	**Non-Adopters**
Age	Less than 20 years	0	0
	20-34 years	8	0
	35-55 years	46	45
	Over 55 years	46	55
Years making farm management decisions	1-5 years	0	9
	6-10 years	8	9
	11 to 20 years	31	9
	Over 20 years	62	73
Farm size, acres	Less than 499	31	45
	500-1,999	23	55
	2,000-5,000	31	0
	Greater than 5,000	15	0
Number of people working on the farm	1-2	23	73
	3-4	31	18
	5-10	23	9
	Greater than 10	23	0
Highest level of education	High school	31	46
	College diploma	31	36
	University degree	38	18
	Graduate degree	0	0

Summary and Conclusions

The study of TID irrigators provides a glimpse into the agricultural practices of irrigators with respect to the adoption of precision agriculture technologies. Caution should be used in extrapolating the results to larger irrigation populations but based on the results of the 27% of the district's irrigators who participated in the survey, it appears the progressive farm culture of southern Alberta is being reinforced through the adoption of precision agriculture technologies. Between the three categories of technologies – basic, soil mapping and data management – 81% have adopted one or more of the 20 technologies enumerated in the study, an average of five per adopter. Applied primarily to irrigated specialty crops, the evidence indicates noticeable, favourable effects on crop yield and crop quality. The application of agricultural inputs, including irrigation water, fertilizer, herbicides and pesticides, have decreased by a noticeable amount. Furthermore, irrigators expect these beneficial effects to continue in the future.

Based on the study results, precision agriculture has impacted the overall management approach to, and strategies used in, farming in the TID. Many economic factors are motivating adoption, including increasing crop yield and quality, reducing costs (especially energy), reducing inputs (especially irrigation water), and reducing machine time. However, irrigators are also motivated by environment concerns with close to half of adaptors citing 'manage environmental impacts' as a factor. The majority of adopters are highly satisfied with the technologies and most plan to continue implementation in the future.

Source: lethbridgenewsNOW

For non-adopters the study found small operations, high investment costs and incompatibility of machines to be the main reasons for not adopting. The majority of these irrigators do not plan to adopt in the future. Those who do plan to adopt will mostly be adopting basic technologies. When comparing the characteristics of adopters and non-adopters, adopters are generally younger, are newer to farming, have larger farms with a greater number of workers and have higher levels of formal education relative to non-adopters.

These results suggest irrigators are embracing precision agriculture and as such, are experiencing the benefits. However, beyond the economic benefits to irrigators, there are positive implications for economic and community development as well as environmental stewardship. As a main driver of the southern Alberta economy, adoption of precision agriculture technologies is improving the quantity and quality of irrigated crops vital to the region. Based on the findings of this study, this is especially true for speciality crops which are the primary inputs to processing industries in the region. These crop effects, coupled with reduced inputs of irrigation water, fertilizer, herbicides and pesticides will enhance the profitability of irrigation agriculture. Economic spin-offs should continue to positively impact communities through the many forward and backward linkages of the irrigation agriculture industry. Finally, reducing farm inputs should benefit the environment. Results suggest environmental stewardship should continue to occur given irrigators seem to be highly motivated to reduce inputs for economic reasons as well as their desire to manage environmental impacts.

The potential for non-adopters to become adopters may be limited, given 82% do not have plans to adopt in the future. Small farms size and the cost of agricultural technologies are currently a main deterrent. However, given there is a tendency for small farms to increase in size over time as well as a tendency for the cost of new technologies to decrease over time, those factors may become less of a deterrent in the future.

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