A Gap Analysis of Broadband Connectivity and Precision Agriculture Adoption in Southwestern Ontario, Canada

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Abstract. *In Southwestern Ontario (Canada), the availability of broadband, or high-speed internet, likely influences the adoption of precision agriculture (PA) technologies and functions of these technologies which enable real-time data sharing between the field and the digital cloud, and back again to the farm-level user. This paper examines the reasons why PA technologies are, or are not adopted, and adoption in relation to varying levels of broadband access. Broadband access is defined here with variables such as availability at download/upload speeds and types of connection. We report the results of an online survey which collected information from field crop producers in Southwest Ontario as of November 2016 on their use of PA technologies. The survey data were cross-referenced to information on broadband within the region. Findings indicate that adoption of PA technologies among crop farmers in SW Ontario varies according to machine, product and service. Internet access (defined by the national standard of the time at five megabits per second (Mbps) download and one Mbps upload) was available on 37% of the farm premises surveyed. Over two-thirds of farmers surveyed lack sufficient symmetrical connectivity anticipated by integrated and cloud-based applications in precision agriculture. Only seven percent of respondents have access to fibre. Those users with access to high-speed internet are all adopters of at least one PA technology identified in this study. Age, farm size and income are relevant factors influencing PA adoption. It does not follow, however, that access to broadband (≥5 Mbps) is required for the adoption of (at least one) PA technology. There is an apparent gap between internet access and use of data generated by PA. Use of wireless-enabled data transfer from PA applications, was found to be low, due to two considerations: a) bandwidth and b) data security. There is an expectation, according to the opinion data collected in the e-survey that the internet is an important factor in future PA adoption and increasingly so for agricultural business.*

Keywords. *broadband, rural broadband, precision agriculture, connectivity, PA adoption.*

Introduction

Precision agriculture (PA) is the term used to encompass a range of digital devices, applications and databases of geospatial techniques and sensors used to identify and analyze variations in the field and to manage them accordingly. Technologies for site-specific agricultural management emerged in the 1980s. By the early 1990s Canadian farms were using PA applications such as the major breakthrough of real-time, non-invasive EM-38 soil sensors produced by Geonics Ltd. In Mississauga, Ontario (Carter, Rhoades and Chesson, 1993 as cited in Mulla, 2013). Producers, particularly farmers of high-value crops such as potatoes, were adopting a range of PA to manage spatially and temporally variable farm information in order to support decision-making for improved productivity and capture efficiencies in time and resource use (Cambouris et al, 2014).

Within the past decade, the Internet of Things (IoT) in agriculture and agri-food systems has meant that an unlimited number of physical objects used in daily farm life are digitally connected and equipped with “smart” technology, including potential artificial intelligence. Such PA can include autonomous vehicles, barn and silo automation systems, energy producing units (e.g. solar) and a vast range of sensor equipped machines, including those used in, on and over ground for monitoring soil, plants and irrigation.

Different devices, products and sensors work together as a data-rich, connected farm system to optimize resource utilization and productivity. The function of a product is optimized on the basis of information and its functionality with other products in the same environment. For example, sensors and drones with associated digital imagery coordinate geospatial information on conditions such as infestations or crop greenness to inform early decision making to reduce crop damage at site, and therefore, optimizing the use of pesticides, if needed. The so-called “connected farm” relays data to other production or processing functions within the farm or off-farm (R2B2 Project, 2018). PA technologies are rapidly increasing data loads, thus generating opportunities as well as challenges on-farm, and off-farm, on broadband networks.

Relevant Literature

Previous studies reveal a number of factors that influence farmers’ decisions to adopt PA applications, including initial cost, return on investment, training and technical skills, and diversity of their operations (Aubert et al, 2012). Information technology (IT) infrastructure capacity, particularly access to broadband internet, however, has probable influence on PA uptake. The amount of data collected, stored, and processed by various instruments, and the software required to enable multiple platforms to interact symmetrically requires significant computing power and bandwidth. A lack of capacity in this regard can override any advantages for a producer considering adopting PA in terms of training, access to funds, etc.

A review of the relevant literature, however, finds few recent studies that have assessed PA applications and their corresponding bandwidth requirements. Ontario Federation of Agriculture (OFA) reports that 67% of its members have unreliable internet service with 94% indicating that internet is essential to their business (Royce, 2015). Aubert et al (2012) identified the lack of infrastructure to support PA applications as a major difficulty for the sector in Canada. Given the expansion of internet access in rural Canada since the late 1990s, PA and the use of big data in agriculture are linked to innovation in the country’s agricultural sector (AAFC, 2016).

It is recognized that the type of connection will influence bandwidth availability and the type of PA technology that can be run at premise. Figure 1 illustrates the required bandwidth for internet and application performance. It includes the most recent layer of 5G technology that is argued to be relevant for evolving digital agriculture innovations (Huawei, 2017).

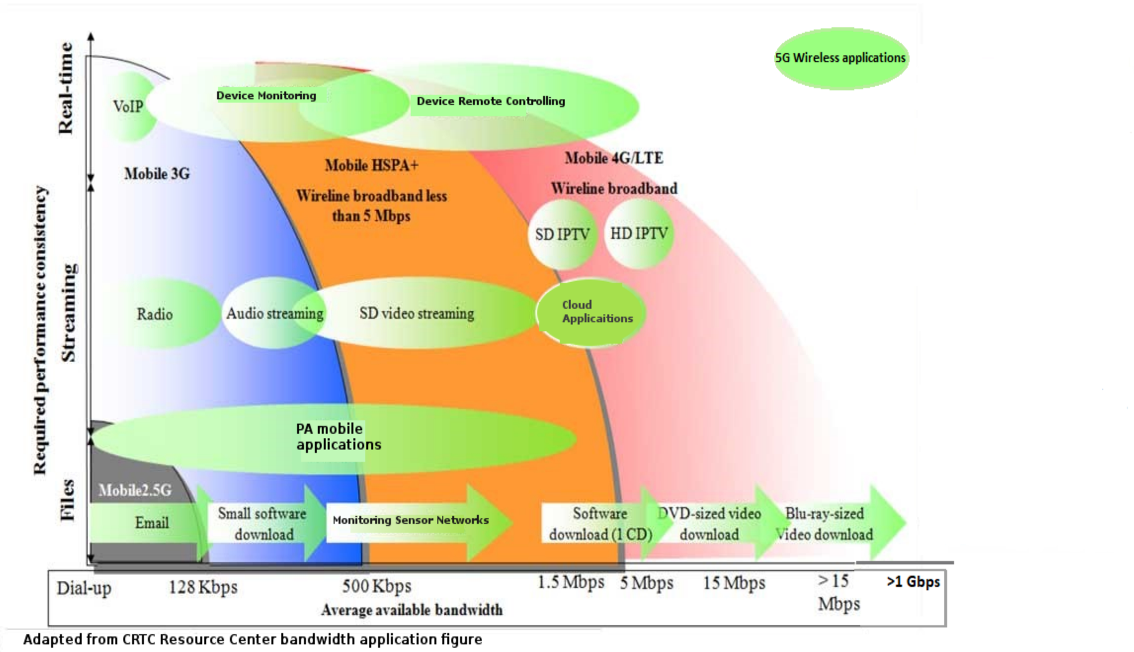

Fig 1. Farm Internet Use and Applications – Bandwidth Requirements

An apparent opportunity lies in filling the gap in the current literature by examining the nexus of rural telecommunications and PA technology adoption. New technologies are of immense importance to the sector, especially in Canada, as a global leader in agriculture and agri-food (CAPI, 2017). The need addressed here is to focus on two sets of new technologies – PA and broadband. We seek to understand the extent to which broadband (defined as high-speed Internet), or its lack thereof, serves as an enabler or a barrier to the adoption of PA applications. Furthermore, what impact, if any, will expanding regional broadband networks and therefore, increasing "last mile" coverage have on the sector?

Methodology

In Canada, one of the leading research projects on assessing rural connectivity is the R2B2 Project, based at the Ontario Agricultural College of the University of Guelph. After conceptualizing the "Connected Farm" based on digital devices used on-farm, we embarked on an initial study, funded by Agriculture and Agri-Food Canada in 2016, to establish a more in-depth understanding of the impacts a lack of high-speed internet has on the adoption of precision agriculture (PA) technologies (AAFC, 2016). The aim of the study was to conduct an analysis of the reasons crop farmers are or are not adopting PA, and examine the geographic distribution of their PA adoption across the region of Southwestern Ontario (hereafter referred to as SW Ontario) which has varying levels of broadband access. The specific research questions are: 1.) What percentage of crop farmers in SW Ontario report: a) using precision agriculture technologies, b) have broadband access? 2.) To what extent do crop farmers in SW Ontario perceive their adoption of precision agriculture technologies is: a) likely to increase; b) be affected by their current level of connectivity (access to internet or quality of services)?

The research questions were addressed using data from an e-survey and compared to connectivity data for the SW Ontario region. These datasets are maintained by the regional broadband network known as SouthWestern Integrated Fibre Technology (SWIFT) Inc. which is currently expanding across SW Ontario, Caledon and Niagara Region.

The e-survey was comprised of a total of 37 questions with a concluding section inviting open ended comments or questions on the study topic. Specific questions in the e-survey covered demographics, internet use and site of service, PA technology use, data management and producer perception of the future importance of PA and big data in agriculture. Table 1 lists the survey variables.

Table 1. Variables Collected on PA Adoption

Category	Variable
Demographic	Postal Code Full / Part-time farm Acreage Crops grown Tillage practices used Average yearly net farm income
Internet use and site of service	Local Access Type Local Access Port Speed (Mbps) Device used for farm business
PA Technology	GPS GPS displays GPS guidance ASC VRT Digital imagery use Using UAVs/drones Using satellite Prescription maps Crop chlorophyll/greenness sensors Soil sensors Yield monitoring equipment
Data	Data management Data transfer Data sharing Management software Ownership
Perceptions of PA & Big Data	Impact Value Reasons for adoption Reasons for non-adoption Challenges of PA Challenges of big data

Social media was used for rapid distribution of the e-survey. A convenience sampling method was used in the study. Completion of the survey was voluntary based on the following criteria: a) respondent is a crop farmer; b) respondent farms in SW Ontario evidenced by postal code; c) respondent is over 18 years of age. Assistance was provided by the Ontario Federation of Agriculture and Christian Farmers Federation of Ontario to share the survey link to their members. Ontario Agricultural College, Farms.com and online groups such as #Ontag also shared the call for participation. In total an estimated 69 social media sites circulated the survey link over six weeks (October 3-November 15, 2016). Additional announcements for the e-survey were possible through special events including “Ag4.0” held in Meaford, Ontario November 2-3, 2016. Ethics approval was provided by the University of Guelph’s Research Ethics Board.

There were approximately 106 responses to the survey with attrition of 9 surveys. Attrition was due to respondents whose postal codes were outside the scope of the study or eligible respondents who started but did not complete and submit the e-surveys. The total number of analyzed surveys was 91. Completed responses varied by questions but values less than 45 were not included. A shorter survey on PA adoption by OFA among its members, but for all of Ontario, yielded 80 surveys (OFA, 2016). Therefore, the sample in our study and its focus on SW Ontario are considered analogous.

The e-survey data was analyzed using Qualtrics reporting with SPSS used for cross-tabulations and graphs. ArcGIS maps were created to visualize survey data and connectivity overlays.

Results

The first section of findings summarizes the results of the e-survey as they pertain to PA technologies. The second section compares variables from the e-survey on connectivity with aggregate connectivity metrics from the R2B2/SWIFT datasets.

The profile of respondents is summarized in Table 2. Age, land size and income are all variables identified in the literature as relevant to PA adoption. We added full and part-time farming status because it is a relevant contextual variable for SW Ontario (Census of Agriculture, 2016).

Table 2. Profile of Respondents

Characteristic	Finding
% of respondents over 45 years of age	56%
Farming full-time	63%
Land size farmed - average	793 acres
Land size farmed - range	85-4000 acres
Income less than $75,000/yr	46.3%
Income more than $200,000/yr	15%

Precision Agriculture Technologies Used

Crops grown by the respondents to e-survey are identified in Figure 2. The main “other” crops were hay/alfalfa (n=15), tree crops (nuts, maple syrup), and other grains including quinoa, spelt, triticale and wheat.

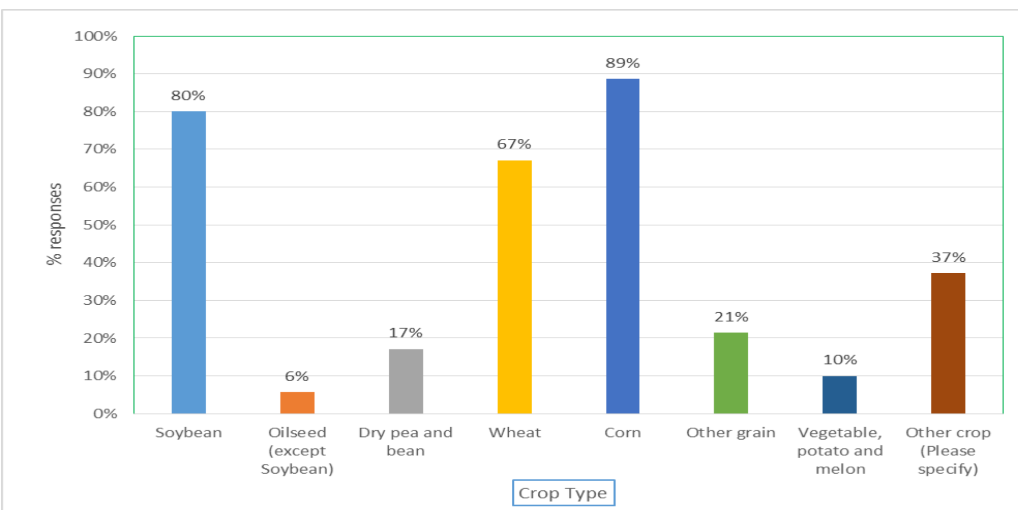

Fig 2. Crops Grown

Note: n=70

Tillage options listed by respondents indicate that no-till cultivation predominates (53%). This is followed by intensive tillage (40%), reduced tillage (35%), conservation tillage (31%), rotational tillage (21%), strip till (12%) and zone tillage (7%) and mulch till (1%).

According to the e-survey (n=63) crop farmers in SW Ontario growing various grains and vegetables have adopted at least one PA technology. Soy bean and corn are major crops in the region. Technologies such as VRT are particularly relevant to soy bean and corn growers.

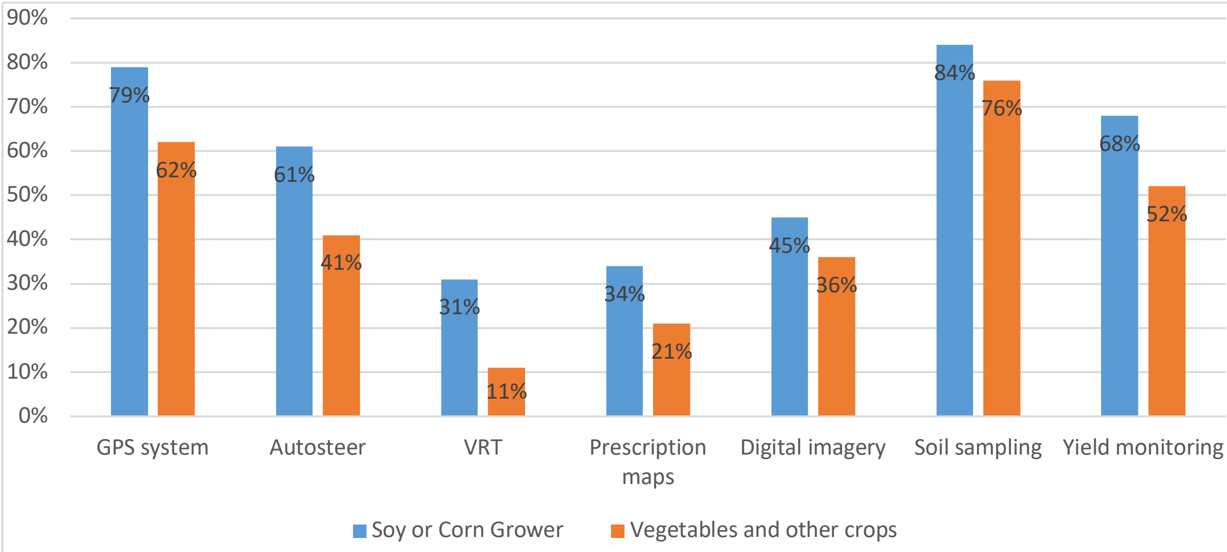

Fig 3. Crops Grown and Use of PA

Note: n=63

Respondents were surveyed on a range of PA technology uptake. Approximately one-quarter of respondents do not use any PA technology. The most popular technology used is GPS (Figure 4). The most popular display is LCD/screen view (95%) followed by light bar (46%) and 3-D perspective (17%). Use of GPS covers a range of operations and is primarily used for fertilizing/crop protection (95%), spraying (93%), planting/seeding (85%), tillage (61%) and harvesting (49%).

Over 45% of respondents report that they do not use auto-steer. Variable-rate technology is infrequently used. Over 70% of respondents report that they do not use VRT.

Approximately two-thirds of respondents do not use Auto Section Control (ASC) which can automatically turn the boom/nozzle section and/or turn planter units on or off. This avoids overlap or minimizes misses of spraying or spreading product. As well, ASC manages the boom sections around obstacles within the field, across headlands or whenever the operator would control the switches of the boom section.

Digital imagery from drones or satellite systems is one of the fastest growing PA tools used by farmers in SW Ontario. Results found 22 incidences of using digital imagery in crop farming operations. “Other” uses include measurement, planning and manure spreading. The preferred source of images is satellite (remote sensing) at 78% of users. Drones or UAVs account for 39% of digital imagery use.

Prescription mapping is used by one-third of respondents (n=18). Among these crop farmers most are using software such as John Deere’s APEX, Farmworks, etc. available from their dealership or cooperative which also sells the application (41%). Other users are downloading and using the software independently of support from their dealership or consultant (35%). Prescription mapping is used for a range of management tasks (Figure 5).

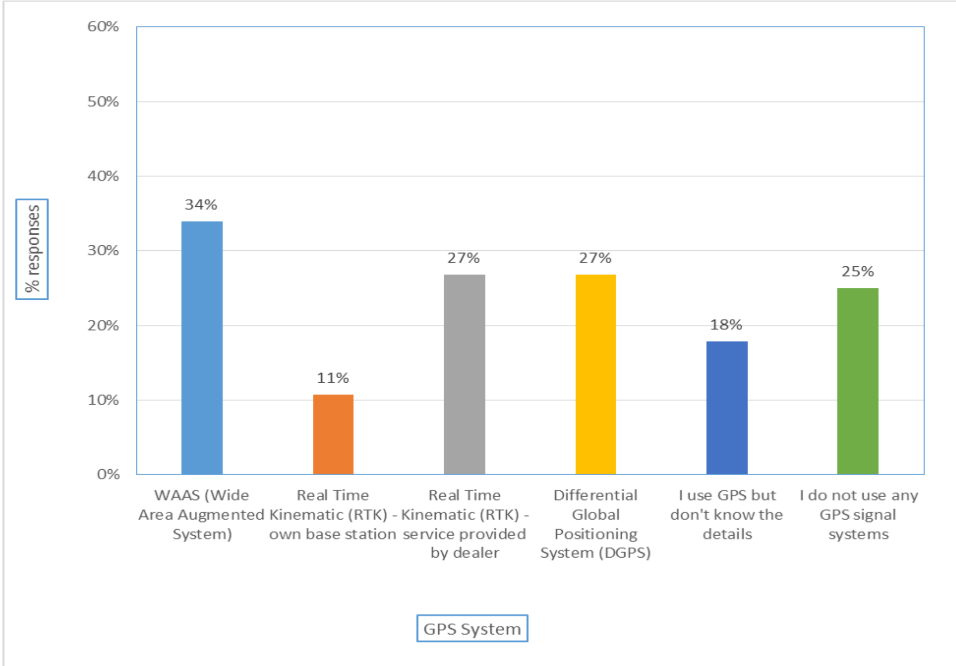

Fig 4. GPS Systems Used

Note: n=56

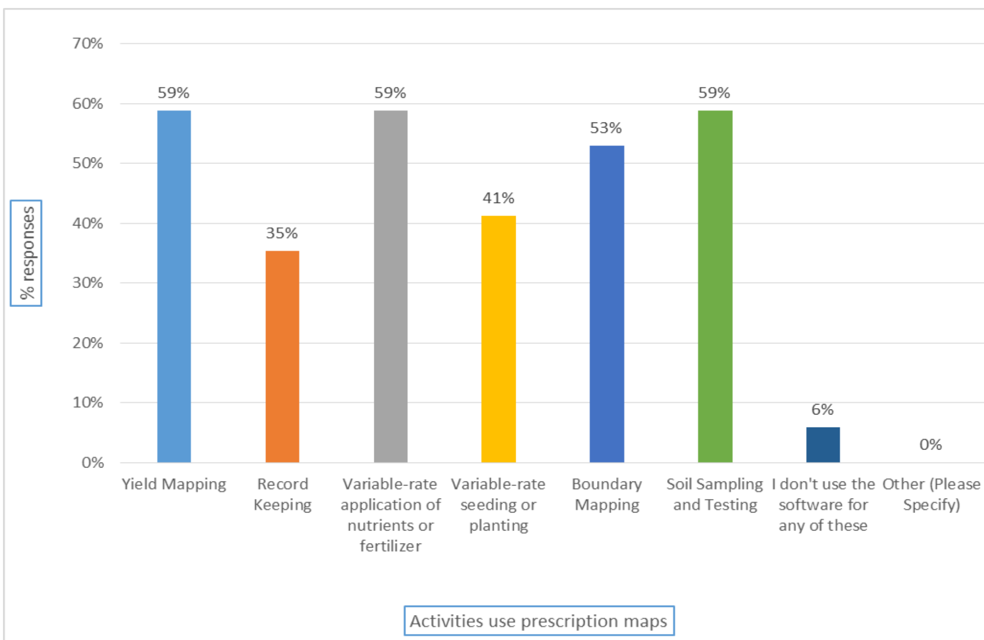

Fig 5. Use of Prescription Mapping

Note: n=17

Sensors used for monitoring chlorophyll or greenness of plants are rarely used by respondents. Only 7 out of 55 respondents answered affirmatively to the use of sensors. In comparison, a variety of soil sampling techniques are used by respondents.

Yield monitoring is used in conjunction with GPS maps among 36% of respondents. Nearly the same number (35%) do not use any yield monitoring equipment.

Social Factors Influencing Precision Agriculture Technologies Adoption

We considered if adoption of PA technologies examined in this study were influenced by age. As Figure 6 (n=64) indicates farmers younger than 44 years of age are more likely to use PA.

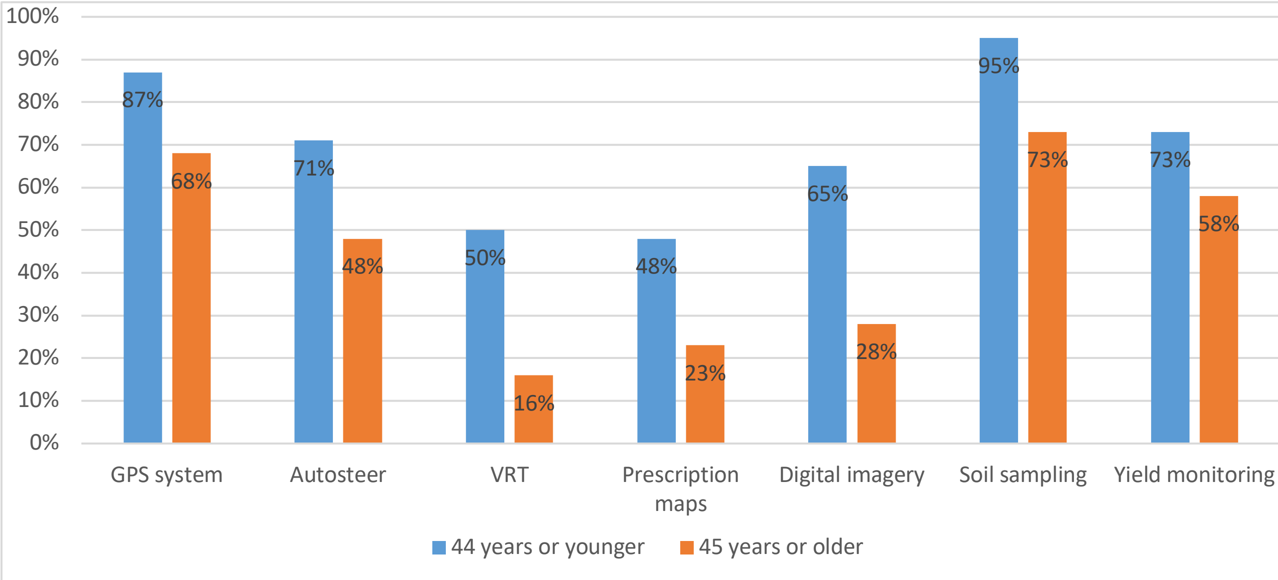

Fig 6. PA Adoption Over/Under 44 Years of Age

Note: n=64

Except in the case of soil sampling and yield monitoring technologies, producers farming larger acreages are more likely to adopt PA (Table 3).

Table 3. PA Adoption by Acreage

Farm Size	GPS system	Autosteer	VRT	Prescription maps	Digital imagery	Soil sampling	Yield monitoring
500 acres or less	27%	13%	2%	8%	12%	34%	20%
More than 500 acres	51%	44%	15%	24%	29%	50%	43%

Note: n=63

The influence of farm income levels on the adoption of PA has been identified in the literature. The findings of this study indicate that only some PA technologies such as GPS systems and VRT are less likely to be used by respondents reporting a lower farm income level (Table 4). Cost of individual PA technologies adopted by users was not a survey variable. There is no indication, however, that more costly PA technologies are used only by farms with an annual income over CAD$75,000. Data on PA adoption does not appear to be influenced by full or part-time farming (Table 5).

Table 4. PA Adoption by Income Level

Income	GPS system	Autosteer	VRT	Prescription maps	Digital imagery	Soil sampling	Yield monitoring
$75,000 or less yearly income	63%	53%	17%	23%	37%	70%	60%
Over $75,000 yearly income	90%	63%	37%	42%	32%	90%	74%

Note: n=63; CAD$

Table 5. Farming Status and Use of PA

	GPS system	Autosteer	VRT	Prescription maps	Digital imagery	Soil sampling	Yield monitoring
Full time	80%	69%	27%	32%	40%	79%	66%
Part time	67%	38%	29%	33%	46%	83%	58%

Note: n=63

Questions in the e-survey on data management among respondents (n=40) indicates that very few respondents are using cloud-based applications for data analysis and storage. The vast majority of users (92.5%) are using an external drive. Others (17%) are using wireless transfer. Two-thirds are not using any specialized farm management software, and where it is used Farmworks is the most popular programme.

Cost is the most-often cited challenge for PA adoption followed by IT infrastructure. Regulatory barriers and lack of investment are not major obstacles to PA according to respondents. Under 'other reasons' the lack of knowledgeable dealers and training are cited. The major reasons, of which cost is the most significant, are listed in Table 6.

Table 6. Reasons for Not Adopting PA

Question	Very important		Somewhat important		Not very important		Total
High initial investment cost	78%	40	22%	11	0%	0	51
Lack of training/technical skills	25%	12	48%	23	27%	13	48
Lack of IT infrastructure/access to broadband internet	40%	19	33%	16	27%	13	48
Lack of consultants, service suppliers, or equipment dealers in my area	21%	10	49%	23	30%	14	47
Other (Please specify)	17%	1	17%	1	67%	4	6

Connectivity Influencing Precision Agriculture Technologies Adoption

Respondents connected to the Internet using DSL (26%), satellite (21%), fixed wireless (21%), mobile wireless (11%), fibre (12%) dial-up (2%) and cable (2%). The relationship between PA and connectivity as indicated in Table 7 suggests that non-PA users have low capacity internet connection types.

Table 7: Connection Type by PA User and Non User

Connection Type	PA User	PA Non User
Telephone line - Dial-up Connection	0%	100%
Telephone line - DSL (digital subscriber line)	93%	7%
Cable Modem	100%	0%
Fixed Wireless	92%	8%
*Mobile Wireless	83%	17%
Satellite Service	75%	25%
Fiber Optic	100%	0%
Other (Please specify)	100%	0%

Note *includes 'uses the mobile data network and has an adapter such as a turbo stick'. Sum of the percent column may exceed 100% as the individual percentage figures are rounded to a nearest whole number. Other includes use of another person's access. Note: n=57

For the purposes of using PA, respondents access broadband with a range of devices but primarily through laptop/tablets (46%) with 4% reporting the use of their smartphone and the balance working from desktop computers.

Respondents were asked to conduct a speed test as part of the e-survey. Results were available for (n=51). Half of respondents reported download speeds of 4.9 Mbps or lower. Broadband, as defined in this study, is download speeds ≥5Mbps. The highest speeds reported were 150 Mbps (symmetrical). Download and upload speeds reported by respondents are summarized in Figures 7 and 8.

Using R2B2/SWIFT datasets we attempted to visualize geo-spatially the survey respondents who report having access to broadband (according to the national standard as of August 2016 as internet access ≥5Mbps). We compared this to high-speed internet services using fibre (wireline) and fixed wireless within areas of the region. The mapping indicates broadband gap areas within the region (Figure 9).

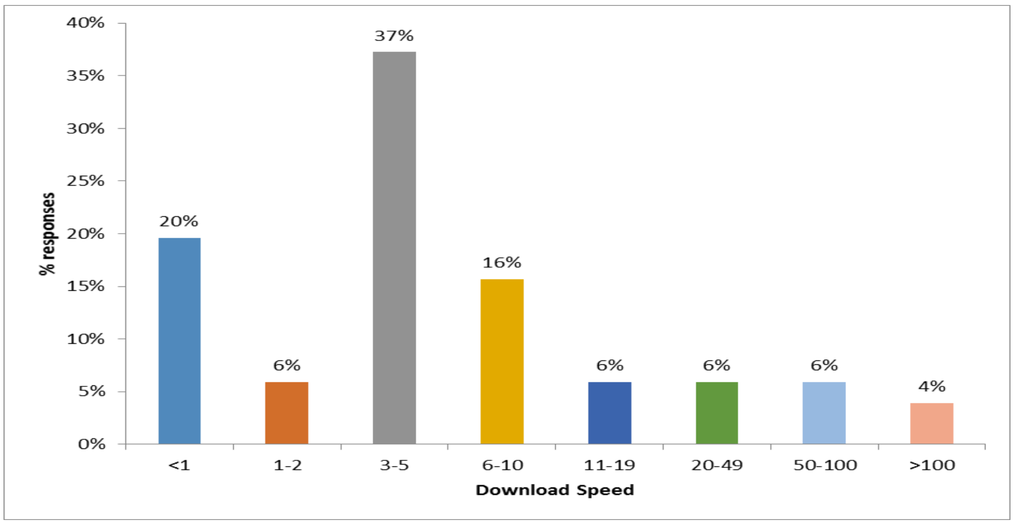

Fig 7. Download Speeds (Mbps)

Note: n=51

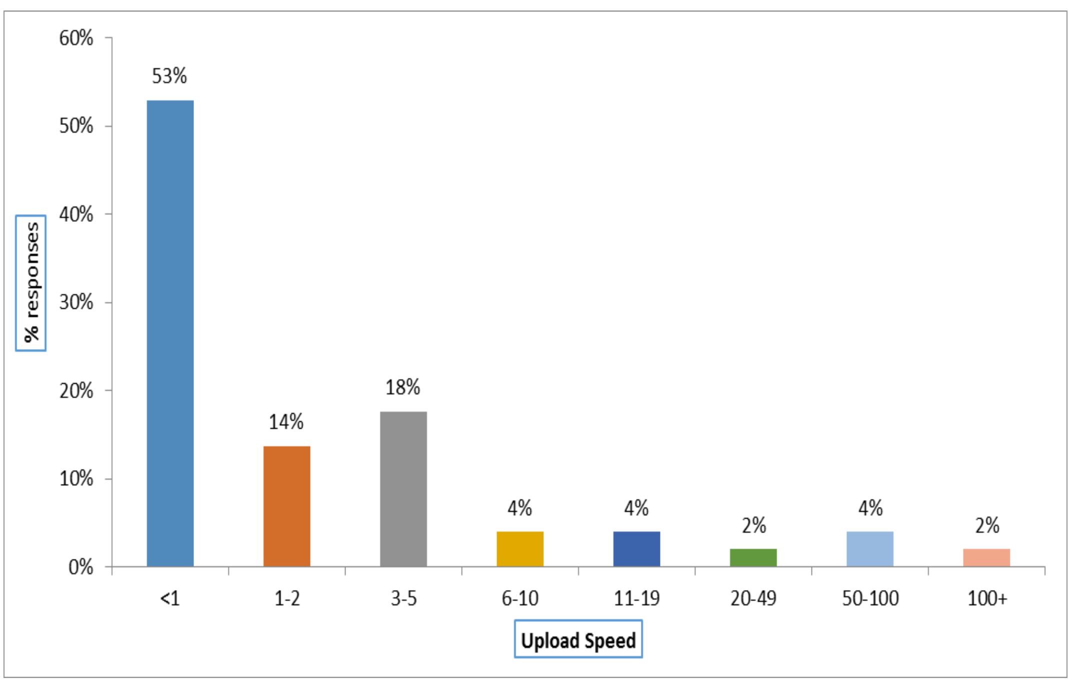

Fig 8. Upload Speeds (Mbps)

Note: n=51

It was found that 67% of e-survey respondents who reported that they do not have broadband access (defined at 0-4.9 Mbps) are located in gap areas. The use of mobile wireless technologies is widespread among respondents with approximately 20% respondents in these areas reporting access to higher-speed 4G or LTE service. In contrast, the majority of wireless users in this survey are on 3G or lower connections.

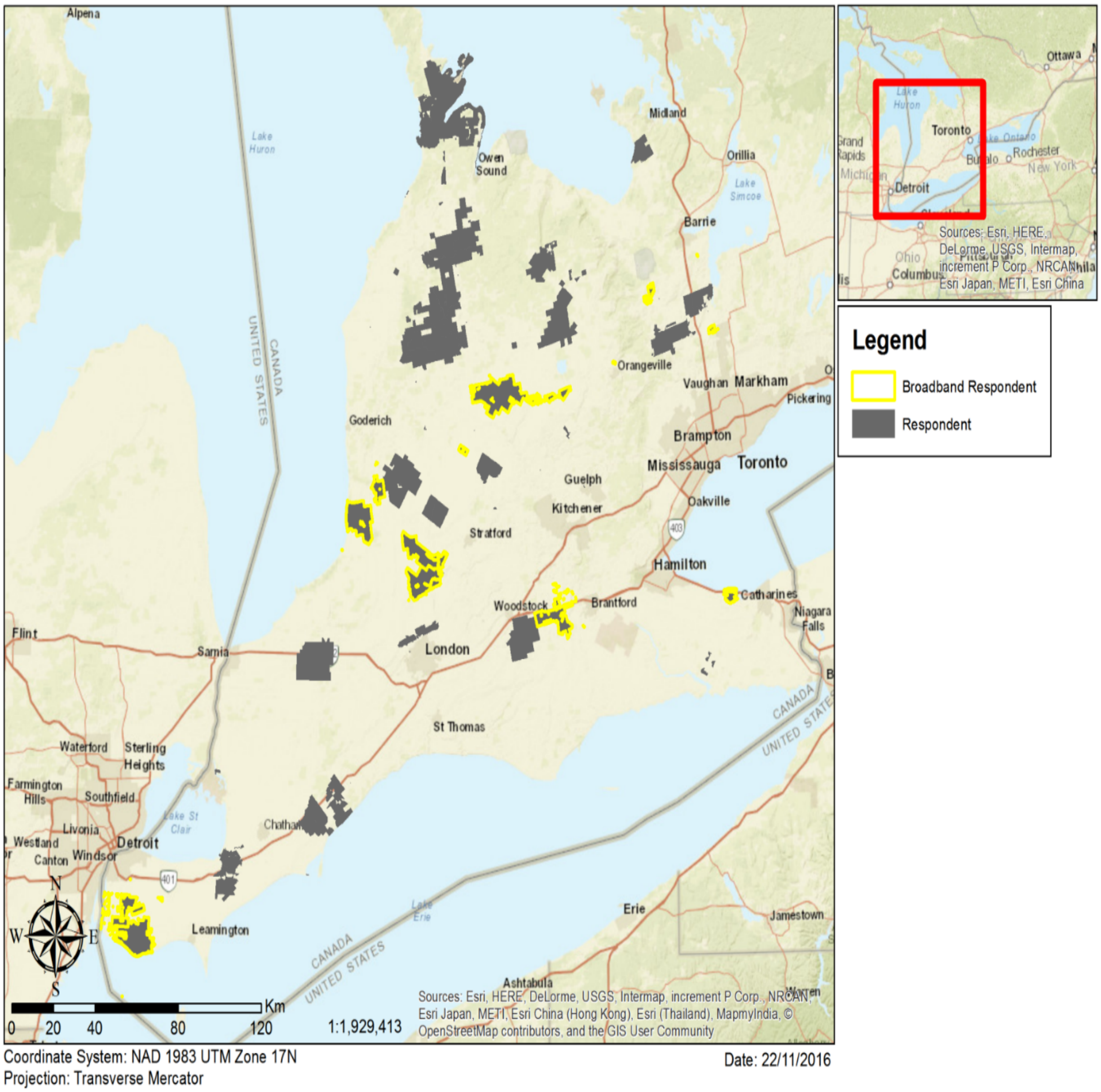

Fig 9. E-Survey Respondents with Broadband Access

Finally, connectivity is relevant to the use of more data-intensive applications, and those that are based in cloud computing. The use of big data has apparent obstacles associated with it, some of which are related to connectivity while others are not (Figure 10). As decision-makers some respondents do not want more data ranking information overload as a concern (32%). This is followed by the obstacle of ineffective IT/internet infrastructure on which data can be managed.

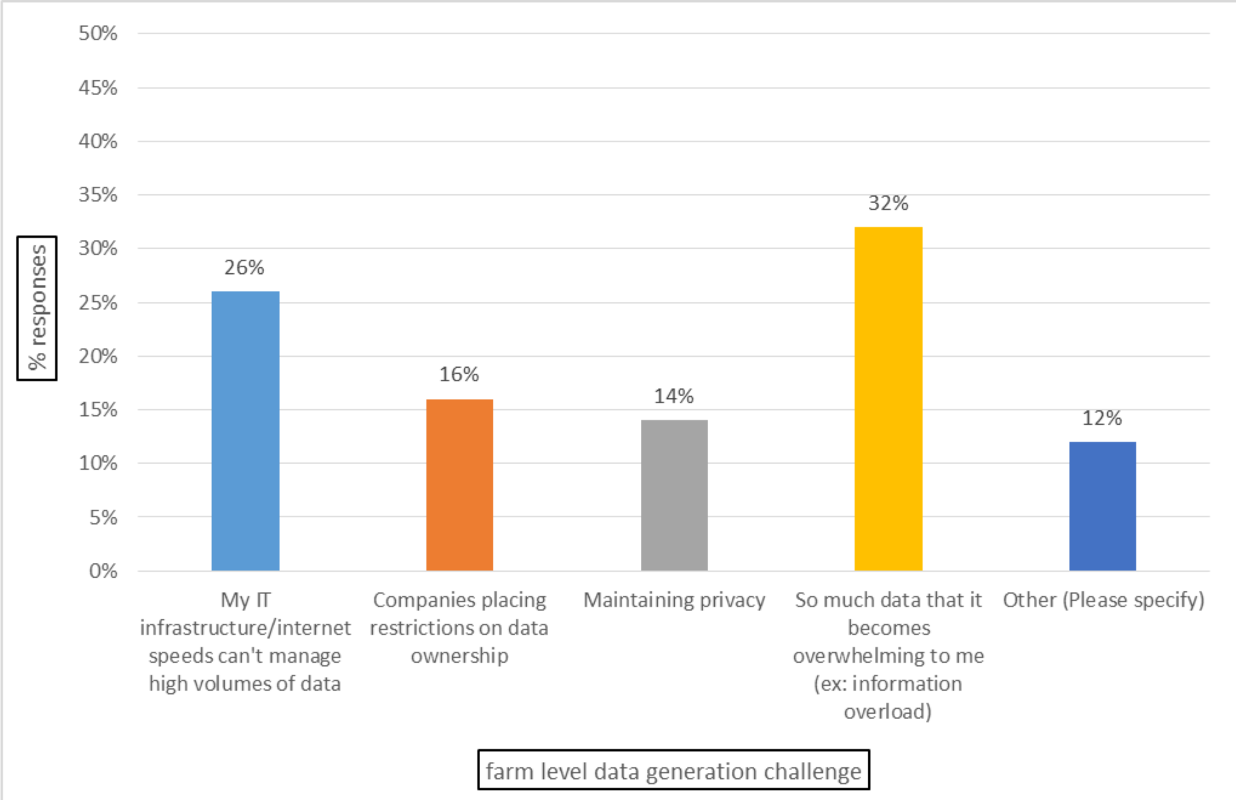

Fig 10. Obstacles to Data Management

Note: n=50

Discussion

There are apparent limitations due to lack of connectivity in SW Ontario on the adoption of PA. This study finds that many crop farmers (approximately 78%) are using at least one PA technology. It is important however, not to generalize PA because the machines, products and services vary widely. For example, 65% of respondents are not using any software-related to PA for farm management. Except in the case of soil sampling and yield monitoring technologies, producers farming larger acreages are more likely to adopt PA. Adoption of PA technologies, as observed in this study is influenced by age. Farmers younger than 44 years of age are more likely to use PA.

PA and broadband access are interdependent according to the results of this study. The findings of the survey indicate that crop farmers across SW Ontario lack access to broadband to support PA technology adoption, and certainly data transfer and management. Upload speeds are less than 3 Mbps among 67% of the respondents and less than 10Mbps among 88% of the sample. Security of data transfer and sharing is a concern to respondents in this study. Most users are transferring files with an external drive/USB (92%) and only 10% are using wi-fi. Real-time 'big data' transfer is well out of the reach of many farmers with only 3% of respondents in this study having access to the highest recorded download speed of 150 Mbps. It is likely that give cloud-based computing and bandwidth-intensive digital applications in agriculture are not currently within the grasp of many crop farmers in SW Ontario. One might expect that larger farms invest more in connectivity. We observe however, that there is less difference in internet access among smaller and larger crop farms than expected.

Table 8. Comparing PA Users by Internet Access

Variable	PA Users	PA Non-Users
% users high speed internet	84	7
% users wireless access only	3	33
% users with ≥1 Gb bandwidth	34	0

*includes urban and rural; SWIFT dataset (2016 figures)

Overall, the results of this study suggest that adoption of PA technologies among crop farmers in SW Ontario varies according to machine, product and service. Overall, PA adoption is found to be influenced by age and farm size. The following are apparent characteristics of the PA adoption across the region.

- Users of PA technologies are not necessarily located in areas with higher internet speed access;
- Higher bandwidth users are located in areas with higher availability of fibre and DSL, with benefits from higher download and upload speeds offered by available service providers;
- In some areas of the region, lower speeds/bandwidth and lack of higher speed internet availability are evident and these will limit PA applications, even when potential user populations are relatively high.
- One can reasonably expect however, that increased bandwidth on -farm will increase the trial and long-term adoption of PA technologies.

It has been argued elsewhere in the literature that they would be willing to invest in supportive information and communication technologies, including WLAN, as long as they are competent, timely and cost-effective (McKinion et al 2004). Further analysis of reported obstacles to adoption – specifically cost data for PA and high-speed internet, are needed. The survey did not collect specific one-time or monthly-recurring cost data for either PA or internet use.

Our results point to an apparent distinction in the gap between internet access and use of data generated by PA. Use of wireless-enabled data transfer from PA applications, is currently low, due to two considerations: a) bandwidth and b) data security. There is an expectation, according to the opinion data collected in the e-survey, that the Internet is very important factor in PA among 40% of respondents. Crop farmers recognize that PA and internet are relevant for their business. As a result, some farms have opted to build wireless systems or alternatively, use more than one device or subscribe to more than one provider to ensure mobility/improved reliability of their Internet access, a trend observed elsewhere in rural Ontario.

There are recognized limitations to this study which can be addressed in future research. We relied primarily on e-survey data and the sample size is small. The convenience sampling method using social media for survey distribution is non-representative. At the farm level, in-depth interviews should be conducted to understand non-adoption of PA technologies and to discuss connectivity requirements. The limited focus of this study on crop farming suggests that other technologies are used in other farming operations including barn automation and security. A similar analysis of barn systems in key sub-sectors such as dairy, poultry and pork.

Conclusion

This study from SW Ontario supports notions of changes in rural connectivity that suggest that IT infrastructure on-farm should be assessed as an integrated and interactive system with important connections off-farm. The IoT and bigger data on-farm demands such an approach. More generally, further discussion and analysis of quality of service for PA use and future uptake is needed within the agricultural industry. Innovations are possible to address the trends identified in this study that implicate a gap between PA and internet access and Quality of Service. Farm IoT and cloud-based computing are adversely affected by low bandwidth and concerns regarding quality of service. Despite evidence of possible higher QoS available through proximity to fibre backhaul within some areas of the region, some producers are apparently not aware of, or not accessing these services. Agricultural and agri-food industries are encouraged to use their collective voice to ensure improved access to bandwidths higher than 100 Mbps (down).

Further studies should be possible. The following areas are recommended including an assessment of PA cost-benefits. PA and broadband access will be a focus of future study by R2B2 Project, ideally involving key partners such as SWIFT and OFA and CFFO. We expect that new data capture in 2018 for SW Ontario by SWIFT will compare across telecommunications service providers. The trend apparent in the results of this study is that crop farmers realize the importance of PA and internet technologies for improved management, including efficiencies in input use, increased yields and environmental benefits. Furthermore, SW Ontario producers recognize the obstacle of existing broadband access to their adoption of PA technologies.

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