An Exploration of how the Relationship between Farmers and Retailers influences Precision Agriculture Adoption

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ABSTRACT

AN EXPLORATION OF HOW THE RELATIONSHIP BETWEEN FARMERS AND RETAILERS INFLUENCES PRECISION AGRICULTURE ADOPTION

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As agricultural production systems attempt to transition to more sustainable practices to increase production and feed a growing world population, technologies such as precision agriculture hold great promise. However, there has been limited research into precision agriculture’s social consequences. This research evaluates precision agriculture’s impact on social relations between farmers and agricultural technology retailers in the cropping and dairy sectors in Ontario, Canada. A mixed methods approach, including analysis of the 2016 Canadian Census of Agriculture and in-depth interviews with farmers and retailers, revealed key trends in adoption patterns, accessibility of technologies, changing social relations, and policy implications of precision agriculture. As precision agriculture innovations continue to be promoted and adopted, this research demonstrates that attention to power relations is crucial in order to make the transition into digital agriculture equitable and sustainable.
DEDICATION

This work is dedicated to my mom, Adam, and Sam – thank you for your love and support.
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# TABLE OF CONTENTS

Abstract .......................................................................................................................... ii
Dedication ....................................................................................................................... iii
Acknowledgements ........................................................................................................ iv
Table of Contents .......................................................................................................... vi
List of Tables ................................................................................................................ vii
List of Figures ................................................................................................................. viii
1 Chapter 1: Introduction ................................................................................................. 1
   1.1 Background ........................................................................................................... 1
   1.2 Research Question and Objectives ..................................................................... 4
   1.3 Thesis Outline ..................................................................................................... 5
2 Chapter 2: Literature Review ......................................................................................... 6
   2.1 Description of Precision Agriculture Technologies ............................................. 6
   2.2 Agricultural Innovation ....................................................................................... 11
   2.3 Critique from Political Economy Theory ........................................................... 14
3 Chapter 3: Methods ...................................................................................................... 19
   3.1 Regional Context ............................................................................................... 19
   3.2 Census Data ....................................................................................................... 21
      3.2.1 Selection of a Specific Region .................................................................. 22
   3.3 Interviews .......................................................................................................... 23
      3.3.1 Data Analysis ........................................................................................... 25
3.4 Summary .............................................................................................................. 26

4 Chapter 4: Results .................................................................................................. 26
   4.1 Adoption ............................................................................................................ 27
   4.2 Accessibility ...................................................................................................... 32
   4.3 Changing Social Relations ................................................................................ 44
   4.4 Policy Implications .......................................................................................... 50
   4.5 Summary .......................................................................................................... 54

5 Chapter 5: Discussion .............................................................................................. 56
   5.1 Agricultural Innovation ..................................................................................... 56
   5.2 Power Relations ................................................................................................ 60
   5.3 Summary .......................................................................................................... 63

6 Chapter 6: Conclusion .............................................................................................. 64
   6.1 Scholarly Contributions ..................................................................................... 64
   6.2 Study Limitations .............................................................................................. 65
   6.3 Recommendations ............................................................................................ 66
   6.4 Concluding Remarks ......................................................................................... 67

References .................................................................................................................... 69

Appendix ....................................................................................................................... 78
   Interview Protocol – Retailer Interviews ............................................................... 81
   Interview Protocol – Farmer Interviews ............................................................... 83
LIST OF TABLES

Table 1: Interview participants by sector and occupation ........................................ 24
Table 2: Descriptive Statistics for Ontario (N=269 CCS Divisions) .............................. 27
Table 3: The relationship between PA technology use and socio-economic factors ..... 31
Table 4: Summary Table of Results ........................................................................ 55

LIST OF FIGURES

Figure 1: Technology Question from 2016 Canadian Census of Agriculture ............. 21
Figure 2: Number of Farms Reporting using GPS Technology in Ontario ................. 28
Figure 3: Number of Farms Reporting using Robotic Milkers in Ontario .................. 29
Figure 4: Patterns of crop technology adoption with examples of brands and 
technologies available in Ontario ........................................................................... 41
Figure 5: Percentage of Farmers using Computers for Farm Management .............. 78
Figure 6: Percentage of Farmers using Smartphones for Farm Management ........... 79
Figure 7: Number of Farmers using Automated Steering in Ontario ....................... 80
Figure 8: Number of Farmers using GIS Mapping in Ontario ............................... 81
Chapter 1: Introduction

1.1 Background

Agriculture is required to sustain the growing population on our planet, however it is also the most environmentally taxing activity that humans do. For instance, agriculture disproportionally contributes to environmental degradation as it is the highest contributor to greenhouse gas emissions (IPCC 2014), it has polluted waterways through the overuse of fertilizers (Tilman et al. 2002), and it is the largest land use activity (Tscharntke et al. 2012). While some scholars argue that we need to increase food production by 70 percent to feed a population of 9 billion by 2050 (Baulcombe et al. 2009; Godfray et al. 2010), arguably, there are a range of solutions for how to solve one of the most pressing challenges of our time. It should be acknowledged that we already produce enough food to feed everyone on the planet (Foley et al. 2011; Godfray et al. 2010), yet we lack a redistributive system to make this food available, and almost one-third of the food produced is wasted (Loos et al. 2014). Therefore, the solution of how to sustainably feed a growing population is not simply a matter of growing more food. So, while there is a suite of reformations necessary to improve the global food system (Fraser et al. 2016), it is clear that we to rethink how we currently produce food and how we will produce more food in the future.

Some authors refer to this shift in production as the ‘sustainable intensification of agriculture’. Sustainable intensification is the strategy to increase the amount of food grown on land currently in production through methods that do not cause further degradation to the environment, nor undermine our ability to produce food for the future (Garnett et al. 2013). Sustainable intensification can be described through four central premises. First is the recognition of the need to increase production, however the amount of increase and what type of production needs increasing is debated by food scholars (Tomlinson 2013). Secondly, new farmland should not be brought into production as this will further exacerbate environmental stresses, therefore, increased production must result from an increase in yields (Foley et al. 2011). Thirdly, context-
specific changes in food production systems are required to attain key reductions in environmental impacts. Finally, sustainable intensification is not a strategy but a goal (Garnett et al. 2013). The goal of sustainable intensification also interfaces with a variety of other issues broadly affecting the food system including: biodiversity and land use, animal welfare, human nutrition, rural economies, and sustainable development (Garnett et al. 2013).

One proposed method to achieve the goal of sustainable intensification is through the use of technology. Specifically, precision agriculture has the ability to allow us to produce more food, on less land, with fewer inputs. Precision agriculture (PA) is a set of technologies that allows farmers to site-specifically manage their farms through tools that gather data (Zhang 2016). These tools began to be developed in the mid-1980s and are now becoming commonplace on farms around the world (McBratney et al. 2005). The three main goals of PA align with the strategies of sustainable intensification. Identified by Gebbers and Adamchuk (2010), the goals of PA include the efficient use of resources to maximize profitability and sustainability of farming, reduction of negative environmental effects, and enhancement of the work environment and social characteristics of agriculture. While academics may focus on the goal of PA to increase the sustainability, farmers are more concerned with returns on investment (ROI) of PA and the ability of new technologies to reduce costs (Batte and Arnholt 2003; Tey and Brindal 2012).

Globally, some countries aim to boost production to meet their domestic food needs, while others seek to become export countries. Canada is one example of the latter, where lately there has been an emphasis from the federal government to sustainably boost agricultural production to enhance Canada’s position as a global leader in food production. The strategy of sustainably intensifying Canada’s agricultural production through innovations, such as PA, has been recommended by the Canadian Government’s Advisory Council on Economic Growth to increase middle-class incomes
and create jobs\(^1\). Additionally, in 2017, the Canadian Agri-Food Policy Institute has advised the federal government to create an industry-led “Agri-Food Growth Council” to strengthen Canadian competitiveness in the global agri-food market to create Canada as an “agri-food powerhouse”\(^2\). In order to meet these domestic goals of increased production, Canadian farmers will need to sustainably intensify their production through new technologies.

While PA may seem like a viable solution to increase agricultural production in an environmentally-conscious manner, technological advances are only sustainable if they are also considered socially acceptable. As PA technologies continue to develop, it is imperative to consider the social consequences of the transition of agriculture into a digital frontier. PA has seen a slow uptake by farmers, although adoption rates are difficult to measure because some studies only consider the use of singular technologies, while others evaluate PA as a system (Kutter et. al 2011). In order to better understand adoption factors for PA, social factors such as the relationship between farmers and agricultural technology retailers must be evaluated.

However, understanding the social implications of PA technologies is a topic that has been relatively neglected by social scientists and food scholars (Carolan 2016; Bronson and Knezevic 2016). Previous studies focused on the profitability of the technologies (Bongiovanni and Lowenberg-Deboer 2004; Griffin et al. 2004; Tey and Brindal 2012), instead of investigating the political and social dimensions of agricultural technology introduction. A few early studies acknowledged that PA allows for the possibility of increased participation from agricultural technology retailers in farm management decision-making (Wolf and Buttel 1996; Wolf and Wood 1997). In recognizing this gap in the literature, the call for research on the social consequences of PA has been


renewed (Carolan 2016, Bronson and Knezevic 2016). As this thesis will focus on the social consequences of PA adoption, analyzing the infrastructural limitations to PA adoption, such as rural connectivity, is beyond the scope of this project (Ruimy 2018, Hambly 2016). Reflecting on how PA and data gathering technologies will affect relationships and power structures in agriculture, Bronson and Knezevic (2016) note: “Big Data is poised to reproduce long-standing relationships between food system players – between farmers and corporations…and thus it deserves scholarly attention…”. Social relationships in agriculture are being influenced by the introduction of PA technologies and therefore require further investigation.

In particular, a more nuanced understanding of the development and promotion of PA technologies by dominant actors within the food system is necessary, in turn, to understand the influence that these technologies will have on this system. One approach to better understand this co-construction of PA technologies is through the relationships between the producers who adopt them and the retailers who promote and sell them. This thesis attempts to fill a gap in human geography literature regarding the connection between adoption of PA technologies and power relations within the agricultural industry.

1.2 Research Question and Objectives

The aim of this research is to shed light on some of the social consequences of the introduction of PA technologies. In order to achieve this aim, this study asks the specific research question of: “How will social relations between PA technology retailers and farmers change, if at all, in light of the introduction of new precision agriculture technologies?” This question will be answered in two contrasting agricultural sectors: cropping and dairy. These two sectors are particularly relevant for analysis because they are two prominent sectors that have been undergoing farm management changes due to the introduction of technology. The reasoning for exploring the cropping and dairy sectors is further explored in Chapter Three, as well as the regional context of Ontario, Canada. Four objectives were pursued to answer the research question:
1. To identify how precision agriculture has been adopted by farmers in Ontario
2. To determine how accessible precision agriculture technologies are to farmers in Ontario
3. To examine how farmers and retailers perceive new technologies changing relationships with other actors in the food system
4. To describe the perspectives of farmers and retailers on the policy implications of precision agricultural technologies

The results of this thesis will address these objectives to ultimately provide insight on changes in social relations between farmers and PA technology retailers due to the introduction of PA.

1.3 Thesis Outline

This thesis is written in the monograph structure and is comprised of the following five chapters. The next section is a literature review which opens with an overview of the relevant technologies evaluated in this thesis. It then continues by providing two bodies of knowledge that contextualize this research and form the conceptual framework and theory used in this study. The subsequent chapter is an overview of the methods used in this thesis including descriptions and justifications of methods and procedures, sampling strategies, and an explanation of the analysis. This section is followed by a results chapter which outlines the initial findings of the PA landscape in Ontario and findings which highlight the implications of PA technologies on social relations within the crop and dairy sectors. Chapter Five is the discussion section which answers this study’s main objective of understanding some of the social consequences of PA technologies by discussing two cross-cutting themes. Finally, the thesis ends with a concluding chapter illustrating the scholarly contributions, recommendations, and finishes with some overall concluding thoughts.
2 Chapter 2: Literature Review

This literature review is structured around an explanation of relevant PA technologies followed by a review of two principle bodies of literature that inform the conceptual framework of this study. The first section explores what PA technologies are and how they work together to form a management system. Then, the first body of literature is a review of agricultural innovations theory. This section is followed by the second body of literature which provides a critique through a political economy lens to understand how power influences the introduction of technologies. Overall, these three sections work together to provide the necessary context for situating this study in the literature.

2.1 Description of Precision Agriculture Technologies

The three main precision agriculture technologies identified by the 2016 Canadian Census of Agriculture for crop technologies include automated steering, global position systems (GPS) technologies, and geographic information systems (GIS) mapping, and for the dairy sector, robotic milkers were identified as a key technology (Statistics Canada 2017). This section details how these technologies work. While innovations in these technologies began in the 1980s, it was not until the 1990s that many of these technologies were commercially available (Stafford 2000).

The technologies of automated steering and GPS technologies are interconnected, as guidance systems for automated steering rely on GPS. GPS technology was initially developed for U.S. military purposes and became available for civilian use in 1983 (Lowenberg-DeBoer 2015). This satellite-based navigation system was then modified for agricultural purposes by allowing farm machinery, such as tractors and combines, to be equipped with an automatic steering system that self-directs machinery along GPS-coordinated crop rows. Wolf and Buttel (1996) highlight that the use of GPS technology in agriculture had less to do with a demand for this technology within the sector, but rather discovering and promoting new uses for existing military technology. GPS technology allows farm equipment to be used more efficiently because overlap of crop
rows is avoided, rows are seeded and harvested straight and precise, and soil compaction is lessened. Even skilled machinery operators often overlap their passes on fields, especially in irregularly shaped areas, which can result in over spraying chemical inputs or over seeding (Lowenberg-DeBoer 2015). Therefore, one potential benefit of GPS technology is decreased pollution through a reduction in over-application of nutrients, while simultaneously increasing cost-effectiveness of machinery operation.

The most common PA technology is the yield monitor, which is a small computer screen in the cab of combine harvesters connected to sensors that determine the yield of a crop as it is being harvested. Yield monitors can be associated with both GIS mapping and GPS technologies. Adoption rates for yield monitors have steadily risen, especially for corn and soybean production, so that now it is considered standard equipment on the majority of harvesters in Europe and North America (Griffin et al. 2004, Lowenberg-DeBoer 2015). As the crop is harvested by the combine, an algorithm converts the amount of crop into a known measure, such as bushels per acre or tonnes per hectare. The yield monitor color codes these quantities and places them on a field map according to their GPS location of harvest to visually represent variations in yield (Lowenberg-DeBoer 2015). Therefore, yield monitors rely on GPS technologies in order to create yield maps through GIS.

The role of yield monitors is crucial to precision agriculture management because by understanding variations in yield, farmers can individually manage underperforming areas of the field, thereby increasing profitability. In one early study on yield monitoring in Britain, a significant majority of the farmers interviewed explained that they adopted a yield mapping system due to encouragement from their machinery dealers (Tsouvalis et al. 2000). This study demonstrates the importance of investigating how precision agriculture alters the relationship between farmers and agricultural retailers. With the addition of novel technologies to agriculture, retailers seeking to capitalize on these new streams of profits advocate for the adoption of these technologies to farmers. Within the same study, farmers stated that since their adoption of yield maps, they were not consulted by the manufacturer about their experiences using that technology. Farmers
desired a continued discussion about the implementation of new technology on their farms, while manufacturer’s interests focused primarily on sales. Farmers expressed that they wished that they would have been consulted on the development of yield mapping technologies for their own use (Tsouvalis et al. 2000). While this example may be from 2000, this was the time when these technologies, such as yield maps, were first being developed and increasingly in use. Therefore, it is still relevant because it is important to recognize that when these technologies were first developed, farmers were excluded from the development process. This example highlights the issue that PA technologies are top-down innovations, created by agricultural manufactures, which farmers are expected to learn and implement on their own. This example informed the development of my interview question to farmers asking, “If you could make suggestions to a technology developer, what would change about the precision technologies that you use?”

In addition to yield monitors, another component to GIS mapping is sensing applications for agriculture, which have developed significantly over the past twenty-five years. Remotely sensed information can be gathered through aerial, satellite, or real-time sensing technologies mounted on farm machinery, also known as proximal sensing (Gebbers and Adamchuk 2010). Essentially, remote sensing is the data received from reflected electro-magnetic radiation on plant or soil material. This data can help farmers gather more information about a variety of factors within the fields such as crop yield, biomass, nutrients, water stress, weeds, insects, diseases, and soil properties (Mulla 2013). The most common application for remote sensing in agriculture is the creation of NDVI maps through GIS mapping. NDVI is an acronym for ‘normalized difference vegetative index’ and is an indicator for plant health.

Recently there has been an increase in the use of UAVs, unmanned aerial vehicles or drones, for remote sensing in agriculture (Phillips 2014). UAVs are often considered more efficient than satellite imagery which can be obstructed by cloud cover. They are more cost effective than hiring a plane for aerial imagery and can be flown more often. Drones are another example of military technology being re-appropriated for agricultural
use. It is predicted that drone use will continue to grow as they provide an efficient way for crop and soil sensing, precise application of inputs, and a timely way to make observations over large areas of fields (Freeman and Freeland 2014). Remote sensing applications are often used in conjunction with variable rate technology, as described in the next section. While the use of UAVs is not explicitly documented in the 2016 Canadian Census of Agriculture, the imaging that UAVs collect is pertinent to the use of GIS mapping.

The technology associated with the “right time, right place, and right amount” catchphrase of PA is variable rate technology (VRT) (Gebbers and Adamchuk 2010). VRT technologies are often the last PA technology adopted by farmers as they require both GIS mapping and GPS technologies, as well as several years of data to be implemented efficiently. First, management zones are developed by evaluating data from yield maps or remotely sensed images. Then unique prescriptions are created in decision support software (DSS) for each zone based on varying productivity. These prescriptions are then loaded into the monitors on planters and sprayers and using hardware tools such as automatic shut-offs, they know when to plant the right seed, or apply the right fertilizer as the machine moves over each exact location based on GPS. Using VRT, farmers can seed fields with the right population for a specific soil type. For instance, corn can be planted in a higher density in low yield areas and a lower density in high yielding areas for maximum possibility of yield. Additionally, VRT allows for multi-hybrid planting of seeds. For example, areas of the field with low productivity can be planted with less expensive low-yielding hybrid varieties, and areas with high productivity can be optimized with high yielding varieties (Fountas et al. 2006). Variable rate application (VRA) of inputs allows for specific amounts of applications, such as fertilizer or pesticides, to treat each management zone as needed. In addition to economic motivations, a driver for the use of this technology is increasing environmental legislation regarding agricultural pollution. In the European Union (EU), there has been the introduction of pesticide taxes in several countries including France, Denmark, Norway, and Sweden (Stafford 2000; Böcker and Finger 2016), which demonstrates
that VRT is a response to increasing pressure on the agricultural community to better address environmental concerns.

While the 2016 Census of Agriculture may have only identified automated steering, GPS technologies, and GIS mapping as the predominant crop technologies for agriculture, it is clear that these technologies are comprised of a variety of PA tools that farmers may adopt. Automated steering and GPS, yield monitoring and mapping, remote sensing, and VRT technologies are the main examples of PA technologies for crop production. These PA technologies create a detailed management system for farmers based on data. Understanding how these technologies work and interact with each other as part of a precision management system is important for understanding their role in Ontario PA adoption and how they affect social relationships within the cropping sector.

As technologies have continued to develop in the crop sector, there have also been advancements in the precision dairy industry. Robotic milking systems are often referred to as voluntary milking systems or automated milking systems in the literature, however to use the same terminology as used by the participants in this study, we will refer to these systems as robotic milkers or robots. Data gathering technologies have been used in the dairy sector prior to the introduction of robotic milking systems. In tie-stall barns, rotary parlours, or double parlours, farmers use technologies such as activity monitors to detect heat in cows for breeding purposes (Eastwood et al. 2017). A simple description of how robotic milkers operate entails that cows roam freely in a ‘free stall’ barn and when they feel the necessity to be milked, they approach the robot milker which is housed in a ‘box’. The machine scans the cow’s identification collar and determines whether it should be allowed to be milked. If so, the gate opens and the cow steps into the robotic milker and is given feed pellets. The robotic arm cleans and prepares the teats and then attaches the milking machine. While the cow is being milked, large amounts of data are being collected. Some examples of the types of data collected by robotic milker are amount of milk produced by each quadrant of the udder, somatic cell count, a camera make take a picture of the cow’s body for her body score,
weight, and frequency that each cow comes to the robot. This study focuses on specifically the use of the data-gathering technologies of robotic milkers for two reasons. Firstly, robotic milkers collect vast amounts of data about each cow passively, with many more parameters than traditional monitoring systems, and secondly, they were a specific technology described in the 2016 Canadian Census of Agriculture. The technologies described in this section are the essential PA tools that will be discussed throughout this thesis.

2.2 Agricultural Innovation

Since the mid-twentieth century, modernization theory, which seeks to explain how society develops and transitions towards 'progress' (Castree, Kitchin, & Rogers 2013), has informed agricultural innovations theories. Specifically, Rogers (1962) developed the diffusion of innovation theory, which sought to explain how and why new innovations are dispersed and adopted. This theory is useful to understand the preliminary aspects of this study which aims to understand the landscape of technology adoption in Ontario. First, this body of literature is important as it provides five attributes of innovations that impact the rate of adoption. Secondly, there are certain characteristics of adopters that can be categorized on the basis of innovativeness. This early work still informs the diffusion of technology, however a broader review of the agricultural innovation theory approach, including some critiques, is also useful for understanding the current state of PA technology adoption.

Rogers (1962) developed diffusion of innovations theory to better understand how certain ideas and technologies are spread. His seminal work developed a standard classification scheme for defining the main qualities of innovations in universal terms. The five attributes that impact the rate of adoption are: 1) relative advantage 2) compatibility, 3) complexity, 4) trialability, and 5) observability. Furthermore, each of these traits can be evaluated in relation to PA because innovations that embody these traits can be predicted to be easily adopted. When assessing these five attributes, and their relation to PA, they demonstrate that there are some challenges to adopting this
innovation, which is one potential reason for why adoption rates in Ontario have been slow.

Relative advantage refers to the “degree to which an innovation is perceived as being better than the idea it supersedes” (Rogers 1962). PA has a clear relative advantage because it is easy to say that site-specific management of agricultural resources is preferable to a homogenous treatment of land or animals. However, relative advantage is often expressed in terms of economic profitability, and the profitability of PA has yet to be fully determined (Griffin et al. 2004). The profitability of PA is dependent on a number of variables, such as which PA technologies are adopted, if the data from PA technologies is used to make more profitable management decisions, and the extent to which there is heterogeneity in the land or livestock that needs to be uniquely managed (Griffin et al. 2004).

Secondly, compatibility is understood as the degree to which innovations are “perceived as consistent with existing values, past experiences, and the needs of potential adopters” (Rogers 1962). Overall, the goals of PA are consistent with the socio-cultural values of farmers to increase production and to be good stewards of the land (Burton 2004). Yet, some of the requirements of PA clash with previously held notions of what it means to “do farm work”. Farmers rarely perceive time spent on the computer analyzing data to be real labour; however, such desk based work is necessary to reap the benefits of PA management.

Thirdly, complexity – or the extent to which innovations are perceived by the user to be challenging to understand and use – has a negative correlation to adoption rates (Rogers 1962). This attribute is highly connected to PA adoption rates as the use of new technologies requires learning new skills to operate machinery, as well as a new approach to management.

Additionally, trialability, defined as the “degree to which an innovation may be experimented with on a limited basis” (Roger 1962), is limited for PA technologies.
Farmers may be able to view demonstrations of PA technologies at retail locations, farm shows, or on neighbouring farms, but they cannot fully experiment with these technologies at their own locations without large capital investments.

Finally, observability, which is described as the “degree to which the results of an innovation are visible to others” can only be partially attributed to PA technologies (Rogers 1962). A technology such as auto-steer allows farmers to plant straight and precise rows, which is a source of pride to many machine operators who have field located along roads. However, the gains in production from using these technologies is information that farmers would have to choose to share and is not easily visible to others.

While understanding the attributes of innovation and their correlation to PA is important to understanding rates of adoption, it also important to characterize the farmers who are using these technologies. Another component to diffusion of innovations theory is the five categories of adopters: 1) innovators, 2) early adopters, 3) early majority, 4) late majority, and 5) laggards. These categories are defined by the degree of “innovativeness”, which Rogers (1962, p. 247) defines as “the degree to which an individual is relatively earlier in adopting new ideas than other members of a system”. Innovators are defined at one end of the spectrum as being a risk-taking group, enthusiastic to try new ideas and apply technical skills, and are the gate-keepers for the flow of new ideas into a social system. At the other end of the spectrum are the late majority and the laggards, who will only adopt new ideas because it has become an economic necessity and are often suspicious of new ideas or agents of change.

However, categorizing farmers into one of these categories of adopters simply based on their personal tendencies to be innovative is too simplistic. Criticisms of diffusion of innovation theory included that this framework did not question the appropriateness of technology, economic constraints to adoption (e.g. some farmers may simply not be able to afford to adopt technology), and a lack of attention to opposition to innovation (Ruttan 1996). Additionally, diffusion of innovations states that the push to adopt
specific technologies is based on their features, whereas critiques where quick to acknowledge that innovations can be pushed by powerful actors within a system (Lyytinen and Damsgaard 2001). Building upon these critiques to diffusion of innovation theory in the 1990s, agricultural knowledge and information systems theory (AKIS) emerged and is important for understanding this social research on PA is agricultural innovations theory (Klerkx et al. 2012). Röling (1990) made significant contributions to developing a more holistic lens for understanding agricultural innovations, recognizing the role of individuals and organizations and the synergies between them that helped to facilitate the spread of innovations. Agricultural innovation is more than just a technological solution but can be considered an idealized concept of what the future should be and requires shifts in several spheres of practice (Klerkx et al. 2012). Broadly, agricultural innovation further develops diffusion of innovations theory by understanding that innovation is not linear, but a co-evolutionary process (Röling 2009). This framework understands innovation to be simultaneous technical, social, economic, and institutional change, which underscores its relevance to understanding the social implications of PA technologies (Klerkx et al. 2012). To summarize these critiques, the next section will focus on how political economy theory can provide a broader perspective beyond diffusion of innovation for the adoption of PA technologies.

2.3 Critique from Political Economy Theory

A political economy framework evaluates how economics influences social and political systems and is useful as a general framework for exploring complex problems by examining the intersection of political and economic factors for change. Particularly, Friedland’s notion of political economy theory is beneficial for understanding current shifts in agriculture due to technology (Friedland et al. 1991). In the past, this theory has been used to investigate the transition from “local farming practices to concentrated corporate-capitalist agricultural production” (Friedland et al. 1991 p. 3). Using this lens, it can be applied to understanding how corporate-capitalist agricultural production is shifting towards the use of PA technologies. Political economy theory attempts to
address the challenges in understanding relationships between agriculturalists, agri-capitalist businesses, the state, and non-agricultural institutions (Friedland et al. 1991 p. 26). Therefore, it is relevant to this study which examines the relationship between farmers and agricultural technology retailers. By looking beyond the superficial purposes for PA technologies and understanding some of the political and economic drivers, political economy theory provides a lens to understand the trajectory of PA and how it can affect power relations within the agricultural sector.

In considering the use of political economy in this conceptual framework, it is necessary because we need to think beyond the attributes of technologies and adopters. It is important to consider how the introduction of new technologies intended to increase production and profitability are integrated with political decisions and can have extensive social consequences. In response to agriculture’s impact on the environment, sometimes technological solutions, such as PA, can be viewed as an alternative to political reforms by those in power (Griffin 1974). Additionally, as political economy is a lens to understand the relationship between power and technology, it is also important for understanding the process of ‘elite capture’, where the benefits of new technologies are more easily captured by powerful actors (Hornborg 2001).

Building an understanding of social relations and PA can be informed broadly by the discipline of Science and Technology Studies (STS), which explains that technology and society cannot be viewed separately. The relationship between society and technology is one of co-evolution and co-construction. Society does not simply develop technology to fulfill specific needs, but political and economic factors also influence its inception (Castree, Kitchin, and Rogers 2013). Moreover, there is not a linear understanding that technology can actively drive social changes, nor that social, economic, and environmental problems can be solved solely through a technological solution (Castree, Kitchin, and Rogers 2013).

Specific political trends are apparent for driving the adoption of PA technologies, the most obvious being the need for the agricultural sector to respond to “environmentally
based socio-political opposition” (Wolf and Wood 1997, p. 181). This trend specifically refers to the unease of the general public towards industrial agricultural techniques, particularly the use of chemical inputs. Farmers are increasingly facing challenges of social license to continue practices that are unsustainable. Examples of this include the government pressure in some European countries to impose restrictions on the use of chemical inputs through the implementation of pesticide taxes (Stafford 2000; Böcker and Finger 2016). These types of regulations create drivers to develop PA technologies that can assist in meeting these environmental rules, such as through variable rate application of fertilizers.

Another political trend that is consequential to an investigation of the social implications for PA is decreased investment from public institutions in agricultural innovation. Research and development has been relegated to the private sector, and the majority of PA technologies have been developed by corporations (Wolf and Buttel 1996; Piesse and Thirtle 2010). The development of data-gathering technologies by the private sector “reflects and propels the resulting trends of privatization of agricultural technology and information transfer” (Wolf 1997 p.108). Data collection through PA tools in an emergent form of agricultural capital, therefore creating a greater incentive for private sector development of the tools that can capture this form of capital.

Agricultural economic trends that are embodied through PA technologies is the productivist model of agriculture. “Productivism” can be defined as through the primary goal of producing more, no matter the costs (Burton 2004). This productivist lens has is still prevalent in modes of agricultural production today, and PA technologies support that view. PA has been promoted by academics and industry alike as rationally managed, more efficient, profit-driven, highly mechanized, and focused on increased productivity (Burton 2004; Bronson and Knezevic 2016; Kutter et al. 2011).

 Particularly, productivism has been a key component in the political economy of Canadian agriculture. As industrial agricultural has continued to develop in Canada, this has resulted in both ecological and social changes. Trends in Canada have
demonstrated declining levels of on-farm diversity, including crop types and varieties, in order to suit capital-intensive production and processing methods (Rotz and Fraser 2015). The social and political forces behind these trends include subsidies, crop insurance programs, market liberalization, and market concentration – all of which pressure farmers to specialize and reach economies of scale (Rotz and Fraser 2015). Increasing capital-intensive production has led to both overproduction of commodities and Canadian farmers have incurred massive amounts of debts (Rotz, Fraser, and Martin 2017). This has led to a ‘cost-price squeeze’ where the costs of inputs and production have increased dramatically, while commodity and farm-gate prices have remained relatively stagnant (Galt 2013). This method of farming is commonly referred to in Ontario as ‘conventional agriculture’.

However, it must also be acknowledged that as a response to this rise in industrial agriculture in Canada, there has also been a proliferation in the growth of agro-ecological methods of farming (i.e. alternative agriculture, such as organic farming). There has been a rise in the number of organic farms in Ontario, despite an overall declining number of farms for the province (Blay-Palmer 2005). Nevertheless, the difference in sustainable organic versus corporate commercial organic which embodies many of the same characteristics of conventional production (e.g. monocultures and capital-intensive production) should be noted (Gliessman 2013; Hall and Mogyorody 2001). Given this dual system of agricultural production in Ontario, conventional and agro-ecological, creates a complex political economic system for agriculture in Ontario.

Due to this complexity, pressures to adopt PA are apparent for the production system in Ontario. As conventional farmers attempt to reduce the ‘cost-price squeeze’, PA technologies that allow them to allocate resources more efficiently will be more attractive for adoption. As well, Canada’s drive to become an ‘agricultural powerhouse’ through increased production as well as neoliberal political policies such as market liberalization and export orientation, will influence the adoption of PA, which has been promoted to increase yields. On the other hand, organic farmers who prioritize sustainable practices could be also be drawn to PA, particularly dairy farmers who might
consider adopting robotic milkers for increased cow comfort and easier adherence to organic standards.

In conclusion, both these conceptual frameworks, agricultural innovation theory and political economy theory, are necessary to understand how PA is influencing social relations between retailers and farmers in the cropping and dairy sectors in Ontario. These two bodies of knowledge, agricultural innovation theory and political economy, work together to provide a thorough conceptual framework for understanding the current technological landscape for PA adoption in Ontario and its impact on . Agricultural innovation theory is able to particularly address the first and second objective of understanding how PA have been adopted and how accessible they are to farmers. Meanwhile, political economy theory will provide insights toward the third and fourth objectives of understanding how PA is changing social relations and what are the policy implications of technology adoption. This conceptual framework, jointly informed by these two bodies of knowledge, will be applied to analyze PA broadly.
3 Chapter 3: Methods

This chapter will detail the methodology used in this study. The initial section will describe the regional context of Ontario as a prime location for understanding the social impacts of PA. As this study implemented a mixed-methods approach, the following section will describe the data collection and analysis of the quantitative data. This chapter will conclude with the quantitative data discussing sampling strategies and analysis procedures.

3.1 Regional Context

The regional context for this thesis is southern Ontario. The agri-food sector in Ontario contributes approximately $36 billion to the province’s gross domestic product. Additionally, the agri-food sector is responsible for 11.4% of total employment and exported over $14.1 billion of agri-food products in 2015 (OMAFRA 2016). Ontario is specifically a leader in the two sectors that are the focus of this study: crop and dairy production.

These sectors have been selected because they are the leading sectors that use PA technologies that gather data for farm management. PA cropping and dairy technologies are similar in that they both require a capital investment and require learning new skills for farm management. Both sectors have seen PA technology adoption rates increase dramatically in recent years, thus presenting an opportune time to investigate the social implications of these technologies (Kutter et al. 2011). Additionally, the PA tools related to these sectors were explicitly asked about in the 2016 Census of Agriculture, providing a specific dataset for analyzing the cropping and dairy sectors. The reasoning for selecting two sectors, rather than focusing more in-depth one specific sector, is that it allows for comparison and demonstrates important differences in perceptions, opinions, and practices held by farmers and agricultural technology retailers. The contrasts between the cropping and dairy sectors will be
explored more thoroughly in Chapter Four, but overall creates a more robust analysis of the diverse outcomes involved with unique PA technologies.

The most typical tools associated with PA are the cropping tools already discussed in Chapter Two, therefore the cropping sector in Ontario is an important area for study. Corn, hay, and soy are the leading crops produced in Ontario in terms of acreage (OMAFRA 2016). Furthermore, southern Ontario is a prime area to understand the relationship between farmers and technology retailers as new actors and PA products have recently become available. One prime example of this is The Climate Corporation, owned by Monsanto, has made its leading agricultural data analytics platform commercially available prior to the 2017 growing season (Monsanto Canada Inc. 2016). As new products become available and new agricultural retailers move into the PA market space, it presents a novel opportunity to better understand the role of retailers and their relationship to farmers within the cropping sector.

In addition to the cropping sector, dairy production is a key component of Ontario’s agriculture sector. In terms of market receipts, dairy products are the leading commodities produced by the province, and it is the largest agricultural sector (OMAFRA 2016). There are 3,439 dairy farms in Ontario, with an average herd size of 78 cows (Statistics Canada 2016). In terms of the relationship between dairy production and PA, “new technology” has been one the leading challenges facing producers as identified by the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA 2016). The number of robotic milking systems has boomed in the last three years, increasing by over 400% (Linnington et al. 2016). This widespread adoption of technology by the dairy sector presents a prime opportunity to investigate how new technology, like robotic milkers, has impacted the retailer-farmer dynamic within this sector.

Ontario presents an interesting landscape as the most productive and diverse agricultural region in Canada to explore the adoption of PA in both the cropping and dairy sectors with a particular focus on the relationship between farmers and retailers.
This dynamic regional context provided valuable quantitative and qualitative data for this study.

### 3.2 Census Data

In order to better achieve my first objective of understanding the current landscape of precision agriculture technology use in Ontario, data from the 2016 Census of Agriculture was qualitatively analyzed. The Census of Agriculture is a census form that is filled out by farmers about their farm operation gathering demographic and socio-economic information. This Census of Agriculture data was particularly relevant because in 2016, Statistics Canada added the question to the census of: “What type of technologies were used in this operation?” (See Figure 1). The answers that I focused on for the cropping sector were the responses based on what I refer to as “smart tractor technologies”, including the use of auto-steer, GIS mapping, and GPS technologies. For separate analysis of the dairy sector, I focused on the response of “robotic milkers”. The responses of use of smartphone and computer technologies for farm management were evaluated for both sectors.

![Figure 1: Technology Question from 2016 Canadian Census of Agriculture](image)

The variable of ‘technology-use’ based on this question was then compared with responses to other questions asked in the 2016 Census of Agriculture. These variables
included: age, total gross farm receipts, total farm capital per farm, value of all machinery, farm size in acres, number of tractors used, cost of tractors, and cost of grain combine harvesters and swathers. To understand the relationship between technology used and these variables, I ran a Pearson correlation test in SPSS. I chose to use the most detailed level of data, which was aggregated at ‘Census Consolidated Subdivision’ (CCS), which is the smallest census division. The size of each CCS varies across Ontario, but they are smaller than county size.

3.2.1 Selection of a Specific Region

The specific region selected for interviews in the province of Ontario was based on the data provided from the 2016 Census of Agriculture. For ease of using known borders in sampling, Census Divisions (CD) was chosen as the scale for sampling because CD boundaries align with county boundaries in Ontario. The top five counties with the highest users of cropping PA technologies, including automated steering, GPS technologies, and GIS mapping, and the top four counties with the highest users of dairy PA technologies, specifically robotic milkers, were selected. In the cropping sector, these counties included: Perth, Oxford, Huron, Chatham-Kent, and Elgin. In the dairy sector, these counties included: Perth, Oxford, Durham, and Stormont.

I determined the counties with the highest users by taking the number of farms reporting for each answer the aforementioned 2016 Census of Agriculture technology question and dividing it by the number of relevant farms for each response. For example, the number of farms reporting using a robotic milker in each CD was divided by the number of farms reporting as dairy farms. This gave me the percentage of farmers using each technology in each CD. In Ontario, there are 49 CDs reporting for the technology

---

3 One farmer interview participant was from Norfolk county; however, he often did custom work for neighbours in Oxford county.
question of the 2016 Census of Agriculture. Therefore, I first took the highest quartile of farms reporting using the technology, 12 CDs, and then re-ordered them by looking at the highest percentage of farmers using each technology. From there, I selected the top CDs with the highest percentage of technology users. Finally, the most technologically advanced CDs were translated into their associated counties to comprise the selected region of Perth, Oxford, Huron, Elgin, Chatham-Kent, Durham, and Stormont counties for interviews.

3.3 Interviews

To collect qualitative data through interviews, I began with the first group of participants which was agricultural technology retailers. Based on the nine counties with the highest number of users, I searched online for agricultural stores that sold precision agriculture equipment or services. I then contacted these outlets via email or phone to find the respondent within their organization that focused specifically on the sale of precision agricultural tools. All retailer interviews occurred over the phone and lasted approximately thirty to forty-five minutes.

The second group of participants for interviews was farmers who used precision agricultural technologies in the nine selected counties. I initiated the search for these participants through snowball sampling. Snowball sampling finds an entry point and then contacting some members of the group (Secor 2010), so some retailers were able to put me in contact with farmers that they work with. At the end of the interview with technology retailers, I would ask if they had suggestions for how to contact this group of farmers. If the retailer offered to connect me with customers of theirs, I would ask them to either pass along my contact information or to give me the information of their customers (with their consent) to contact them for an interview. My next method to recruit farmer participants was to create a poster to be distributed on social media, specifically Twitter, as it is the most popular social media platform among the farming
community. By following various farmer organization pages and retailer pages on Twitter, I was able to see public posts by farmers who used precision agriculture tools. I then sent these individuals private messages to ask if they would be interested and send them more information via email. Additionally, I also asked various farmer organizations to promote my research to farmers, such as the county level organizations for the Ontario Federation of Agriculture and the Ontario Soil and Crop Improvement Association. Interviews with farmers took place either over the phone or in-person and generally lasted forty-five minutes.

All interview participants were provided with an information sheet and were required to fill out a consent form as per regulations set out by the University of Guelph Research Ethic Board, which approved this research. All interviews were recorded by an audio device and were later transcribed by myself. The total interviews conducted can be observed in Table 2 with participants divided by occupation and sector. Interviews were conducted until a point of theoretical saturation was reached. This style of qualitative research is when the researcher continues to interview and collect data from new participants until they start to hear the same themes repeated in interviews and there are well-defined links between themes that have emerged. At that time, no new data are required as the point of theoretical saturation has been reached (Glaser and Straus 2012). This methodology follows along similar protocol to Carolan’s (2016) study on precision agriculture, where his study used interviews with 18 farmers who were using PA technologies and 14 interviews with retailers of technology to better understand what socio-technical forms are engendered by these technologies. My study implemented a similar methodology to better understand how the implementation of new forms of agricultural technologies can alter power relations.

Table 1: Interview participants by sector and occupation

<table>
<thead>
<tr>
<th>Dairy Sector</th>
<th>Crop Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retailers: 6</td>
<td>Farmers: 7*</td>
</tr>
<tr>
<td>Retailers: 14</td>
<td>Farmers: 6</td>
</tr>
<tr>
<td>Total interviews: 33</td>
<td></td>
</tr>
</tbody>
</table>
3.3.1 Data Analysis

The interview transcriptions were then uploaded into the qualitative data analysis software, NVivo. The first round of coding for the interviews was based on grounded theory analysis. Grounded theory provides a useful mode of data analysis because the impact of PA technologies on social relations, particularly between farmers and retailers, in agriculture is an under-explored phenomenon. Grounded theory allows the researcher to hold theory loosely while new concepts are explored deductively through the information provided by participants, and then this data are used to inductively explain the observed trends (Baxter 2010). While some theory, such as agricultural innovations systems theory and a political economy conceptual framework, were hypothesized at the beginning of the data analysis, grounded theory allowed the data from this study to be explored openly and to refine how these concepts fit into the reality of PA use in Ontario.

Grounded theory analysis begins by asking a question, for example: “What are dairy farmer’s perspectives on agricultural data sharing?” Then the entire set of qualitative data was reviewed, and concepts relating to the answer to the specific question were grouped under an individual code in NVivo. The process was repeated for a multitude of sub-questions that would ultimately answer to the larger research aim of understanding the how PA impacts the relationship between farmers and retailers. Then the codes were able to be grouped into categories that are presented in the results chapter, and how these categories interact with the theories presented in the literature review is detailed in the discussion chapter.
3.4 Summary

To conclude, the census and interview approach was particularly appropriate for this study for two reasons. First, the analysis of census data provided a broad overview of the topic of PA in Ontario, a region that has yet to be fully analyzed for PA adoption. This type of quantitative research helps to support the reasoning for selecting specific regions for more in-depth qualitative research, such as interviews. Secondly, semi-structured interviewing was selected as an appropriate methodology to accompany the census analysis as it allowed for a more detailed exploration of social relations as they are a key method for gathering information about opinions and experiences that would unlikely be captured by observation or a survey (Dunn 2010; Aitken 2001). Primary interview questions began with descriptive questions regarding role of the individual and descriptions of their retail or farming operation, then proceeded to opinion and structural questions to ascertain impressions, assertions, ideologies, and assumptions regarding the role of technology (Dunn 2010). Secondary questions were used as necessary to prompt respondents to elaborate or provide more information (Dunn 2010). During the interview process, sometimes respondents would state “don’t quote me on this”, letting me know that they were revealing information of a sensitive nature that would likely not have been captured through other methods than a one-on-one interview. The combined use of a census and interview methodology yielded significant results that will be described in the next chapter.

4 Chapter 4: Results

This chapter follows the four objectives of the thesis. In particular, this chapter begins by describing how PA technologies have been adopted in Ontario based on the 2016 Census of Agriculture. These statistics are followed by more detailed statistics on the relationship between certain PA technologies and socio-economic factors also measured by the COA. The aim of these sections is to achieve the first objective of this study, which is to identify how PA technologies have been adopted in the dairy and cropping sectors.
The second section of results demonstrates the key findings from the interviews with agricultural technology retailers and this, therefore, fulfils the second objective, which is to determine how accessible PA technologies in Ontario are. This section is followed by two separate sections that are informed by the results from interviews with farmers. Namely, these final two sections address objectives 3 and 4, which are to explore the changing social relations in agriculture due to PA and the perceived policy implications, respectively.

4.1 Adoption

In order to understand the PA technological landscape of Ontario, the 2016 Census of Agriculture was used to quantify the use of certain technologies. The data presented include the use of computers and smartphones, however it is recognized that these technologies might just be used for farm management purposes that are not affiliated with the use of PA technologies, such as bookkeeping. In addition, when filling out the census, farmers also had the option of “other” and to fill in another technology than the ones analyzed here. There were 250 responses in that category, however those responses are not publicly available data. The data was analyzed at the smallest census division, the CCS – census consolidated subdivision, for the most detailed representation of technology use. Table 2 provides a general overview of technologies used in the province.

Table 2: Descriptive Statistics for Ontario (N=269 CCS Divisions)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Total number of users – Farms Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers</td>
<td>27,904</td>
</tr>
<tr>
<td>Smartphones</td>
<td>19,532</td>
</tr>
<tr>
<td>Automated steering</td>
<td>6,851</td>
</tr>
<tr>
<td>GPS Technology</td>
<td>13,851</td>
</tr>
<tr>
<td>GIS Mapping</td>
<td>5,436</td>
</tr>
<tr>
<td>Robotic Milkers</td>
<td>337</td>
</tr>
</tbody>
</table>
Communication technologies, such as computers and smartphones, have been widely adopted. However, their application for farm management is growing and as displayed in the spatial presentations of Figures 3 and 4 (See Appendix), they are most commonly used in areas of high agricultural production in Ontario. Computers and smartphones were technologies evaluated by the agricultural census, yet they can be considered more support tools for PA. The following maps (Figures 2 and 3) depict the adoption of technologies such as GPS for crop farms and robotic milkers for dairy farms, respectively. Maps depicting the other census-evaluated crop technologies such as GIS and autosteer are also featured in the Appendix.

**Percentage of Farmers using tech in Ontario (CCS Division)**

| Percentage | 56% | 39% | 16% | 32% | 12% | 9.8% |

**Figure 2: Number of Farms Reporting using GPS Technology in Ontario**
Figure 3: Number of Farms Reporting using Robotic Milkers in Ontario

In an attempt to characterize what type of farms are using PA technology, the correlation between PA technology use and other socio-economic factors measured by the 2016 Census of Agriculture was tested as shown in Table 3. Most relationships proved to be statistically significant. There was a weak negative correlation between age and technology use, as it might be assumed that older generations might not be as well adapted to PA technologies, however there are more significant barriers to PA adoption than age, thus a weak correlation. Moderate positive correlations were demonstrated for gross farm receipts and total farm capital and technology use indicating that PA is more likely to be adopted by wealthier farms and are highly capital-intensive. In addition, there was a strong positive relationship between value of machinery, specifically tractors, combine harvesters, and swathers for crops, again highlighting the capital-intensive nature of PA. Farm size and technology use had a
moderate positive correlation for crop farms, but not for dairy farms, as acreage is less likely to influence the adoption of a robot because not all dairy farms produce their own feed. The relationship between gender and PA technology use could not be determined based on the data in the census, however this relationship presents an interesting line of future research to understand the connection between gender and technology in agriculture.
Table 3: The relationship between PA technology use and socio-economic factors

<table>
<thead>
<tr>
<th>Technology</th>
<th>Relationship between age and technology use (p-value)</th>
<th>Relationship between gross farm receipts and technology use (p-value)</th>
<th>Relationship between total farm capital per farm and technology use (p-value)</th>
<th>Relationship between value of all machinery and equipment per farm and technology use (p-value)</th>
<th>Relationship between farm size (land in crops) and technology use (p-value)</th>
<th>Relationship between average number of cows per farm and dairy technology use (p-value)</th>
<th>Relationship between number of tractors used and crop technology use (p-value)</th>
<th>Relationship between value of tractors and crop technology use (p-value)</th>
<th>Relationship between cost of grain combines and swathers and crop technology use (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers</td>
<td>-.119</td>
<td>.537**</td>
<td>.550**</td>
<td>.545**</td>
<td>.351**</td>
<td>.363**</td>
<td>.316**</td>
<td>.476**</td>
<td>.523**</td>
</tr>
<tr>
<td>Smartphones</td>
<td>-.173**</td>
<td>.604**</td>
<td>.602**</td>
<td>.640**</td>
<td>.356**</td>
<td>.378**</td>
<td>.317**</td>
<td>.564**</td>
<td>.589**</td>
</tr>
<tr>
<td>Auto-steer</td>
<td>-.265**</td>
<td>.565**</td>
<td>.671**</td>
<td>.785**</td>
<td>.531**</td>
<td>N/A</td>
<td>.445**</td>
<td>.773**</td>
<td>.744**</td>
</tr>
<tr>
<td>GPS Technology</td>
<td>-.294**</td>
<td>.530**</td>
<td>.635**</td>
<td>.740**</td>
<td>.534**</td>
<td>N/A</td>
<td>.445**</td>
<td>N/A</td>
<td>.716**</td>
</tr>
<tr>
<td>GIS Mapping</td>
<td>-.099</td>
<td>.419**</td>
<td>.497**</td>
<td>.577**</td>
<td>.309**</td>
<td>N/A</td>
<td>.282**</td>
<td>.582**</td>
<td>.566**</td>
</tr>
<tr>
<td>Robotic Milkers</td>
<td>-.190**</td>
<td>.066</td>
<td>.110</td>
<td>.161**</td>
<td>.102</td>
<td>.205**</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

** Correlation is statistically significant at the 0.01 level (2-tailed)
The technological landscape of PA in Ontario is evolving but some characteristics can be summarized from this analysis. The first result is that PA technologies are not overwhelmingly used by farmers in Ontario; it remains a small proportion of farmers who have adopted these technologies. This data was only collected for the 2016 census, therefore the precise growth rates in adoption cannot be determined from this data. However, retailers agreed that in the past five years there has been a dramatic increase in sales of PA products. Thus, discussions about the impact of PA on sustainable intensification need to be tempered by the fact that these technologies have yet to be widely adopted. Secondly, it is typical that farms that are already capital-intensive with high values of machinery are more likely to be using PA technologies based on the census information. Considerations into what type of farms are able to adopt these technologies (i.e. capital-intensive, large acreage) are also important when analyzing how the social relationship between farmers and retailers will be affected by technologies, as some farmers will be excluded from this technological landscape. Finally, understanding exactly what components of PA are currently widely available to farmers will have an influence on adoption, therefore, the next results section focuses on accessibility of PA.

4.2 Accessibility

Objective two was to determine how accessible PA technologies are to farmers in Ontario. In terms of results, accessibility of technologies is a key result because while the previous section shows that PA is being adopted to some extent, by analyzing the accessibility of the technologies presents further information on adoption trends. The results from this section are primarily comprised of the data received from interviews with agricultural technology retailers. This section begins by describing the training models offered by retailers and characteristics of adopters, because these two factors also impact accessibility. It then further examines how the factors driving adoption of PA influence accessibility. Finally, this section analyzes the data collected on the
pattern of adoption, particularly noting the differences of in adoption between cropping and dairy PA technologies.

According to the farmers and retailers interviewed, retailers were the primary source of information of how to implement precision agriculture tools on their farms. Retailers described their various strategies for during the adoption process, which typically entailed some training before installation of a new system (whether a robotic milker or yield monitor with a decision support system), on-farm consultation during start-up, communication over time, and refresher “clinics” during less busy times of the year (i.e. winter). What differed greatly between retailers was the amount of assistance with interpreting data collected from precision tools into farm management decisions. Depending on the brand of robotic milker, retailers took different approaches to data management and decisions support – some had dedicated staff for this role and some were uninvolved. In the cropping sector, there was similar variation as the more advanced precision retailers did have a role in data management and interpretation, however the majority of retailers said that they did not have a role in data management and advised their customers to get have their data interpreted by crop advisors. The disconnect between the retailers selling the tools of precision agriculture and those who are the ones interpreting the data will be further explored in the discussion.

In order to understand accessibility of PA technologies, outlining the characteristics of PA adopters provides information on who these technologies are available to. The results show that in understanding what adopters of PA have in common, it is quite variable. In the cropping sector, a common factor of crop farmers interviewed was farm sizes of ranging from 585 to 2500, with an average acreage among participants of approximately 1600 acres of land farmed, including both owned and rented land. This is dramatically higher than the average crop farm size in Ontario, which is 249 acres (OMAFRA 2017). Farmers tended to grow the typical rotation of corn, soy, and wheat, with the occasional crop such as beans or forage mixed into the rotation. Generally, retailers struggled to describe their “average” customer.
In analyzing the characteristics of dairy farmers adopting robotic technologies, there were also a variety of considerations. Here again, age was not a particular factor, and neither was herd size. Most retailers described that a common installation was two robots, which is typical of the average herd size of 78 in Ontario (Statistics Canada 2016). However, they also described a growing trend that larger dairies are installing robots. Previously, it was described that small family farmers would be partial to robotics; however, it was noted that it is a growing trend for larger dairy farms to be adopting robotics as exemplified by this quotation:

Kyle (dairy retailer): …personally I always felt that the robots are for small family farms. That was kind of always my mindset, and part of that is because that is where 99% of all the robots have been sold with the different colours have gone into those family farms. But in the last little while I have really seen that the signs are there that there has been a lot of farmers that are going to adopt on a larger scale…So I think that is going to be the same kind of theme that we are going to start seeing here…I think that will probably be the biggest change that we will be looking at – is this larger herd mentality for robots…Yeah I think that the large farmers are going to become quite common. Like it wasn’t that long ago that I would have argued against it, but it really – yeah it costs a little bit more to maintain a robot and costs a little bit more to feed for a robot because you are feeding pellets instead of farm-grown feed. But a lot of the other benefits, you know out weight those costs - some of the best cost per liter, or lowest cost per liter are robots farms.”

Overall, the characteristics of dairy farms adopting PA according to the census agree with the results found in interviews. However, it is interesting to note the growing trend of robotic milkers being adopted by larger dairy farms. In addition to characterizing farms using PA, the factors driving adoption also play an influential role in accessibility of technologies. In addition to characterizing who is adopting PA and how they are
adopting these technologies, why farmers are adopting precision agriculture is also an important result of this research. The main factors driving adoption that were discussed during interviews included: age, profitability, changing work environments, a lack of labour, and competition and growth in farm size.

Age was often cited by farmers and retailers as an influencing factor to do with the adoption of precision technologies. Interestingly, it contributed both a factor both encouraging and discouraging adoption in both the cropping and dairy sectors. For example, farmers would say the advent of new technologies helped them to continue farming for longer as it made some of the repetitive tasks on the farmer easier.

“Ben (dairy farmer): One is our age. My brother Steven is about say 64 and my other brother Glenn, he farms with us too, and he 49, and I am 66 of course. We didn't feel like we were ready to quit farming, but we were feeling like we were ready to quit milking cows. We were milking in a parlour that was kind of antiquated. We did as much as we could to make it comfortable for ourselves but still it took its toll on backs and knees and shoulders and stuff. That was the biggest factor...And it really wasn’t that expensive when you factor over the number of cows that can milk in a day and how many years it will operate. It is just another on-going cost that is all. We have a lot better backs and knees too.”

On the other hand, farmers and retailers also cited age being a barrier for farmers to understand and use the technologies.

“Henry (crop retailer): I think it comes down to education, and also the age of the farmer...I am sure you have probably found that your older generation farmers are less accustomed to picking up precision ag technologies. It’s more complex and something new for them to learn. So, a lot of our customer base is of the younger generation farmers up
until 40 or 50 years old. But again, those are the guys that have the bigger acres and are looking for precision agriculture technologies to help with their decisions and to essentially increase their yields which in turn is more dollars in their pocket. There is definitely a certain demographic that is looking for this type of technology and a bit of a push back from the older generation as it is not something that they are needing or wanting in their farming practices.”

As demonstrated by these varying quotations, age is a factor in adoption of PA technologies, but it can be a driver of adoption or sometimes a deterrent. While age is a commonly cited as a factor for PA adoption, it is a shallow factor in determining the adoption of PA, which is why this study also investigates some of the political and economic factors influencing adoption.

One of the key factors that farmers and retailers stated for adoption of precision technologies was the desire to increase profitability in farming. One distinct finding in this area was that increasing profits did not necessarily translate into increasing yields or production for all farmers, but that sometimes it resulted in a cost-savings instead. When asked about return on investment for precision technologies, farmers were unclear about when or if they had achieved a good return for these technologies, despite the fact that most retailers stated that the main way they promoted these technologies to farmers was through increasing profitability.

“Christine (crop retailer): the benefits so you have to stress to customers are profitability and yield.”

“Eric (crop farmer): The main reason I guess at first, we are just trying to gather data to learn what is going on in the field and as we gather that data we are identifying areas we can improve. There is couple…I guess everything has a couple of reasons. One is to reduce our costs and with that increase profitability. Minimize use of fertilizers, like
To give some context for the cost associated with the adoption of precision technologies, dairy farmers interviewed reported a range of $1.2 million – $3.2 million for changing their systems to robotic milking machines. Factors influencing the total costs for robot adoption are whether they had to rebuild a new barn or install new feeding or manure management systems, but overall according to the various retailers all for brands of robots where comparably similar costs of typically around $200,000 for a single box robot. The technologies in the crop sector are often adopted piece-meal. However, beyond the monetary values associated with adopting precision technologies there are also less quantifiable benefits, such as changing the work environment of the farm.

One overall agricultural trend that has been observed is the decline in the number of farmers. One perception is that farming does not have an attractive work environment and that many of the tasks are monotonous and repetitive. PA technologies help to alleviate some of these challenges associated with the farm work environment and are therefore a strong driver of the adoption of precision agriculture as exemplified in this quotation:

Courtney (dairy farmer): “But the problem was we were milking 3 times a day, so the shifts would start at 4 in the morning, and roughly at 12 in the afternoon, and then at 9 at night. The one at night would end at midnight or 1AM, so you can imagine that hiring people for 4 in the morning or midnight is very difficult. There are very people that were motivated to do it, and if they were they saw it more as shift work. And so, near our farm we also compete with the Toyota factory and we had GM. And they offer fairly high wages and more appealing shift hours, so we were constantly in competition with them. So, we were also looking for a lifestyle change where you wouldn’t be tied to having to...”
milk cows at set times. And milking robots basically take care of that. There are still all other aspects of farming that you have to take care of but at least the most labour intense part, the most repetitive part – the robot does. Our goal with switching from the parlour to the robots was that we could hire more skilled people because they wouldn’t just be milking, they would be in charge of more animal health and animal welfare. And that you could offer a better working environment for them. We have completely changed the way we hire and train and the way we have our work schedules for our team.”

Changing working environments for farmers is a key driver of adoption of PA technologies. There is often a fear that technologies will replace jobs, however in this case PA just alters the labour requirements of the same job allowing farmers to focus on the more important aspects of farm management. Associated with the need to provide engaging work environments for employees, dairy farmers in particular noted the that growing trend of a lack of labour in rural areas is a driving trend for the adoption of robotic milkers. The following quotations from dairy farmers exemplify how robotic milkers have been useful in addressing a labour shortage:

Jessica (dairy farmer): “And the labour force, I mean that is just a huge bottleneck that is only going to get worse. I find here, it is very very hard to get reliable help. And it doesn’t matter what you seem to pay.”

Gary (dairy farmer): “I think of the robotic technology, and maybe this would be the same over the last 100 years, but I think of robotics milking had proven itself 10 years earlier, we would have a lot of farms that wouldn’t have quit. Because there are also farmers that quit because of labour. The next generation wasn’t coming. It was tough to get people to help milk, but the robotics wasn’t proven yet, so they got out.”
Contrasted to the cropping sector, crop farmers did not note that they were facing a shortage of labour for farm work, so this factor influencing adoption of PA might be unique to the dairy sector. It is clear that robotics is not replacing jobs in the dairy sector but providing more highly skilled jobs and better work hours. By improving the work environment of agricultural labours, PA technologies are simultaneously addressing the issue of a lack of labour.

One of the trends that can be observed in Ontario is an increase in the size of farms – in terms of number of acres in the cropping sector and in terms of number of cows being milked per farm in the dairy sectors. For instance, the 2011 Census of Agriculture reported that the number of farmers with $500,000 or more (at 2010 constant prices) of gross farm receipts increased by 5.8% since the last census, and farms with less than $500,000 decreased by 10.7% in Ontario (Statistics Canada 2016). This statistic demonstrates the trend towards an increase in farm size and smaller farms leaving the market. Additionally, the average area per farm increased from 233 acres to 244 acres in 2011, confirming that farms are growing in size in Ontario (Statistics Canada 2016). Another example from the dairy sector shows that in the past seven years, the number of cows per farm has risen by approximately 12.1%, with the average Canadian dairy farm now having about 85 cows (Canadian Dairy Commission 2017).

This trend has an explicit influence on why farmers are choosing to adopt precision technologies – the data that these technologies collect makes farming easier for one person to manage a larger operation. A few select quotations here illustrate this trend:

*Ben (dairy farmer)*: “I think they [PA technologies] are coming down the road for sure and farmers get to be fewer and fewer, they are going to be working the same amount of farmland as farmers are working now only they are going to have more of it. There are going to be less farmers working the same number of acres. I am quite satisfied that because of these large acres you begin to lose touch with your fields. It is just another piece of property that you are going to put crop in and
you lose the ability to actually see what that field does, and crop technology will replace that. The young farmers that are farming hundreds of thousands of acres, like they do out west now, they are going to need that technology to just be able to function. In the old days, farmers like my dad and my grandfather, they knew their fields individually...I think because they are moving away from farming as a way of life to farming as a business, they are going to be needing these products to keep that business afloat.”

(emphasis added)

Andrew (dairy farmer): “…once we get over 225 cows, I think that will be critical mass for us to be able to compete against, with the American style operation. I hope all these trade negotiations will work its way out but anyway – in a quota system that is capital intensive just by its very nature and then the technology that is very capital intensive puts a strain on progress. We are trying to reach that size and volume that it makes sense to go that way and it is a struggle.”

The pressure to grow in farm size in order to remain competitive in the agricultural industry is clearly a factor that is influencing the adoption of PA technologies. Additionally, the cost-price squeeze, often referred to as the increasing costs of inputs, such as fertilizer and seeds, and the decreasing or unstableness of prices on commodity crops, is a driver of farmers to be more judicious in their use of inputs, which PA technologies have the potential to assist with.

Lastly, the patterns of adoption are influenced by the aforementioned factors, such as training, age, profitability, work environments, labour, and competition. This study collected data on the brands and types of technologies that were accessible to farmers in Ontario. Then from this data, the patterns of typical adoption strategies were discerned. Adoption of PA crop technologies differs greatly from the adoption of dairy
technologies. Crop farmers typically will start at one end of the PA spectrum of tools in terms of complexity and after experiencing benefits from this technology, they will then seek to adopt more PA tools. In this sense, trialability is the most important feature of crop PA innovations. This pattern is described in Figure 4. Whereas dairy farmers, on the other hand, reported relying on stories of success by other farmers in adopting a robotic system in deciding which system to adopt. In this case, observability is the predominate quality that will assist in the diffusion of PA dairy innovations.

Figure 4: Patterns of crop technology adoption with examples of brands and technologies available in Ontario

To further quantify the types of PA technologies available in Ontario, Figure 4 displays the typical adoption trend for PA technologies in Ontario with respect to the cropping sectors. There is less of a pattern for adoption in the dairy sector, as the transition from other types of milking systems to robots is one swift transition that usually involves barn construction. The examples of brands available for robots in Ontario include Lely, DeLaval, Gea, and Boumatic, with Lely being by far the most widely adopted. In
comparison, there is much more selection in the cropping sector for PA tools. Figure 4 is intended to give a preliminary sense of what is available on the market currently, however there are likely other crop dealerships offering more products that were not included in this study. In terms of dairy technologies, the robotic market is currently limited to four brands of robots but there is other dairy herd management software also used by farmers that is not necessarily limited to robotic systems, such as the commonly used software DairyComp305. As technologies continue to develop, the information in these tables will likely change dramatically in short period of time.

As illustrated in Figure 4, it is important to note that with precision cropping technologies, there is a certain pattern to adoption. For farmers, the first foray into PA typically starts with some type of steering control. Retailers reported that this was the most common piece of PA technology sold, and as seen from the census data this is the most widely used piece of technology. Once farmers have adopted auto-steer, this usually coincides with using a yield monitor. Farmers interviewed who were more advanced in their PA usage noted that GPS and yield monitors were the technologies that they had been using the longest. Retailers mentioned that almost all new harvesting equipment came standard with yield monitors. Once yield data has been collected for several seasons and soil sampling has been conducted, then farmers are able to move into the more advanced usage of PA by creating management zones and treating these areas of the field site-specifically. This can be done through variable rate seeding or variable rate fertilizer.

An important result from this flow chart of adoption is that PA technologies should be considered separately rather than an overall system of management because there are layers to adoption. If farmers are only using auto-steer and yield monitoring, then they have a limited ability to use data for site-specific management decisions. The technology adoption pattern is well described by one farmer in the following quotation:

_Toby (crop farmer): “I also view it as a stepping stone system where…maybe not a stepping-stone, but maybe a tier system – where_
you can’t do step 8 if you don’t have 1 to 7 done. And this is where there has been some failure in the industry, where you know people can build a planting prescription and can make it work but if they didn’t have fertility and zones accurate, it really didn’t show a return… and if you haven’t really checked the fertility, all those plants can run out groceries pretty quick. So, it needs a tier system where you look at accurate zones, not just zones for the sake of making zones, then you actually have to build those zones into a bit of a classification, whether it’s on potential or how you are going to manage it, and then fertility, seeding, nitrogen, imagery if you get that far, and then it helps if it is kind of full circle.”

The way that crop technologies are adopted differs quite considerably from the adoption of PA dairy technologies. As explained, PA crop technologies are added in a piece-meal style, whereas to install robotics often requires the addition a new barn and complete overhaul of the system. Dairy farmers may have been using some data-gathering technologies previous to the installation of robotics, however with a new milking system the data management system is also likely to change. In this case, it is important to recognize that PA can come in the use of a single technology, a whole systems approach, or it can be considered a separate management approach as well (Kutter et al. 2011).

Building on the results provided by analyzing the technological landscape of PA in Ontario, there are evident challenges to the accessibility of PA technologies. While characteristics of PA adopters might vary, there is a typical pattern in how PA technologies are adopted, and similar training models used by retailers. Additionally, there are a number of factors driving adoption, including: age, profitability, changing work environments, labour needs, and competition and growth in farm sizes. Overall, two typical adoption patterns have been expressed in these results. The first is incremental adoption of PA, such as the pattern of adoption from crop farmers described in Figure 4. Secondly, there is the adoption pattern is in the dairy industry
where a new technology isadopted by one swift transition to a new system. Exploring beyond the adoption of PA is necessary to understand how these technologies are changing social relations, particularly between retailers and farmers, therefore, the next section of results focuses on the role of the agricultural data that PA technologies collect.

4.3 Changing Social Relations

The third objective of this study is to examine the role that data-gathering precision technologies have on social relations in agriculture. As will be described below, there were four main perceptions described by farmers and retailers. The first was that the data gathered by agricultural technologies is vastly underutilized for decision making, which has relationship-changing consequences. The second important result is that one of the biggest barriers to using precision technologies are compatibility issues because competition in the PA market influences farmers’ abilities to adopt new technologies. Thirdly, farmers described their perspectives on data sharing, data ownership, and privacy concerns. Fourth, it is important to note that agricultural data from precision technologies is not only relevant to farmers and agricultural retailers, but there are other actors within agricultural networks and the food system that are interested in agricultural data, and thus there is a need to examine those relationships as well.

One of the most significant findings of this thesis is that the data that is being collected by farmers using agricultural technologies, especially in the cropping sector, is vastly underutilized. While the aforementioned findings on the growing rates of adoption of precision technologies are important, it does not present the full case that while more of these technologies are in use – they are not being used to their full capabilities. It cannot be assumed that just because numbers are rising in the adoption of these technologies that the data being collected by precision technologies is resulting in a
change in management decisions. Both retailers and farmers alike stated that precision technologies are rarely used to their full capabilities, which is exemplified in the following selected quotations:

John (crop farmer): “Honestly, I know a lot of guys that have all this fancy equipment on the tractors and they don’t even have a clue to make it work. They just look at the maps and say, ‘yeah that is a pretty map’ and that is as far as it goes. I know a lot of people aren’t utilizing it nearly as much as they should be.”

Ryan (crop retailer): “No. Less than 10% are actually utilizing the cherry on top even yeah, we are at the tip of the iceberg really. I would say very few people are utilizing 100% of the capabilities of what they have. Even my most technically advanced customer is just scratching the surface. There are so many capabilities of what people can do. Across the board, it is not even tapping into its full potential.”

Andrew (dairy farmer): “I’m sure there is lots of stuff that I haven’t used yet. Mostly I just watch for herd health reports…On the data software stuff, I am sure I am not utilizing the full potential of the system.”

These are just a few quotations, but almost nearly all participants interviewed echoed a similar sentiment that PA data were not used to their full potential. This result is important for understanding PA use in Ontario because while the previously reported results show that PA is being adopted in Ontario, the promised outcomes of using PA, such as profitability and sustainability, are likely to not be achieved if farmers and retailers alike are unable to make better management decisions based on data. Recognizing that there is a vast underutilization of data in agricultural decision making demonstrates that there need to be improvements in technology design and in capacity building. It also raises the question that if farmers are not able to use the data they are collecting, then who will they trust to interpret the data and help to make those
management decisions? The underutilization of agricultural data provides an opportunity for new relationships related to PA technologies to be formed.

Secondly, the most common challenge associated with using data for management decisions is the fact that there are often compatibility issues between technologies, particularly in the cropping sector. As exemplified by the previous section, there are a wide range of precision agriculture products available in Ontario. However, many farmers stated that in different types of machinery that were from different brands, they struggled to amalgamate the data. Here is a quotation that demonstrates this frustration:

Dylan (crop farmer): “What would really be nice is if all brands could kind of get along a bit better… There are just certain limitations and I know why they put the limitations in. It is a proprietary thing. They just make life difficult if you don’t want to go all in their program. I am not in all in on any one program. That is the biggest hurdle is getting everybody to get along. I don’t know if you have heard of ISOBUS. That is kind of the biggest joke going. They said it going to make everybody work with everybody else. The problem is a lot times, by the time you make an ISO component compatible you are going to spend the same amount of money as if you bought their whole system because they kill you with unlock codes. Unlock codes are kind of the big dark demon of the compatibility world. I know I have priced some out and just for codes I was going to spend five or six thousand dollars. And all that is to unlock a feature within the system.”

Certain decision support system platforms have been marketed to be “colour-blind”, in other words able to accept data from a variety of brands or technologies, such as Climate Fieldview. However, farmers stated that this is one of the biggest challenges limiting the adoption in precision agriculture.
Eric (crop farmer): “For example our sprayer, it has a great rate controller on it, but it doesn’t talk to anything else. So, we really can’t utilize that information, the integration is not very smooth, so we probably should have done our homework more…I’m not sure if we should have invested more, just in a different platform to make that work…because everybody wants to own the space…so it is like a free for all and then this company buys that company and then this thing works with that thing. And everybody is updating their systems, but the compatibility issues are always a problem, for sure. Even for example, Climate doesn’t work on our combines. They are getting closer, so I am convinced it will, but waiting is sometimes hard when the money dished out is the same whether you have it on everything or just on a couple of things…We upload it into Climate manually but that is not the idea. We bought Climate, so it would be a seamless transfer and live - like when the guys are planting I can see it on my iPad, where they are, and how far they are with the field, and with the combine I can’t.”

In regard to data compatibility in the dairy sector, this is less of a challenge, but still many farmers use more than one data platform for farm management. Before adopting robotic milkers, most dairy farmers noted that they were collecting data through other types of management systems by having technologies such as pedometers for heat detection. Due the fact there is strict regulation of dairy quality, there is a need for robotic milking platforms to also be able to produce the data that can be used for these dairy herd improvement (DHI) checks which are used for official milk recording records by the Canadian dairy industry.

Jessica (dairy farmer): “I like DairyComp305, it is definitely the one that is most broadly adopted by farmers regardless of their management software, their environment, their anything. I think is ridiculous that I have to pay $1800 to make it interface, and I think it is even more ridiculous that I have to pay a monthly fee to keep that happening. Like
I would pay the $1800 if that was all I paid, and I was done with it knowing that you now have access to all my information, but you’re going to still charge me every month? No dice. Sorry.”

Compatibility issues are often referred to in the literature as interoperability issues. These results demonstrate that compatibility is a significant limitation in the use of PA technologies. Overcoming this challenge will require collaboration on the part of PA technology developers and a strengthening of social relations to create systems that are able to interface with each other. However, due to proprietary development of technology, compatibility issues are likely to persist.

In addition to compatibility issues, proprietary development of PA technology also has impacts on agricultural data ownership and sharing. One surprising result of this study was the lack of concern by farmers over privacy and data ownership concerns. Most farmers seem unperturbed by the fact that their data might be shared with others, in fact some knew that they had signed and agreed to let companies to use their data when they adopted their specific decision support software. Farmers often compared their agricultural data to banking or credit card data and stating that banking information had to be strictly protected because others could benefit from that data, but they did not see how someone could benefit from their agricultural data and therefore, were not concerned about data privacy. While farmers were aware of cybersecurity risks, they also seemed uncertain of how to mitigate those risks.

George (dairy farmer): “I’m not afraid to share my information but I am always afraid that we are going to get attacked by viruses and lose a lot of our information. I am probably not going doing a good enough job of backing up some of my information on the cloud or on the memory sticks. So, every once in a while, I have to get on my kid’s case that we have to back some of this stuff up so that I don’t lose all my information. Honestly I don’t know how to back it up.”
In terms of openness to sharing data, farmers often felt that they would benefit from sharing their data with agricultural companies in the long-term through benefits such as improved technologies or better decision-making power. During interviews, several farmers acknowledged that for data to be meaningful it had to be pooled and aggregated to have large enough datasets for decision making. Therefore, they could perceive the benefits from data sharing with agricultural companies. However, there were some concerns about whether farmers were actually receiving tangible benefits compared to other actors who might be benefitting from the use of data. Farmers were aware that the companies that creating PA technologies are greatly benefitting from the data that is being generated on their farms. The trade-offs between investing in the technology and contributing to the research and development of new technologies through agricultural data were questioned by several respondents, as suggested by the following quotation:

*Jessica (dairy farmer)*: “That is a tricky one right, because they have access to everything, yet we still get the bills all the time. When do we get to issue a bill and get a little bit of a kick-back for the information that we are generating on a daily basis? Because you know, the supplier companies are like “we worked that into it, well we need to find our R&D programs, to make it better for you guys” – but every time you make a new investment, then the price of your equipment just went up because now it is the newest, latest, greatest, so you figure you can charge another 10% or another 5% or whatever amount it might be. So, you took all my information to do that…”

Finally, data sharing goes beyond sharing with the companies that create PA technologies and other farmers. This study found that agricultural data was often shared with various actors beyond the farm. In the dairy sector, these actors often included veterinarians and nutritionists who used the data collected by robotic milkers to make improved animal health and performance decisions. In the cropping sector, agricultural data was often shared with agronomists and seed/input dealers. There is a
need to understand more about how these other actors are benefitting from the on-farm production of agricultural data by PA technologies.

Overall, the data that is being generated by PA technologies has a powerful role on social relations, especially the relationship between farmers and retailers. From the results presented in this section, it is clear that farmers are starting to become more aware of the issues surrounding data privacy, ownership, and sharing. At the same time, it is important to recognize that at this time it is only a small percentage of farmers in Ontario who are actually using these technologies, and an even smaller percentage of farmers who are making decisions based off the data. The use of data is limited by compatibility issues as well. There is a need for policy interventions to address some of these challenges. The next section explores a specific relationship between the state and farmers, and includes some of the recommendations made by participants in terms of what the role of the government should be in relation to PA.

4.4 Policy Implications

Through a political economy lens of understanding the social implications of precision agriculture, the role of the state in promoting these new technologies was explored with participants. There were three broad categories of responses discussed in terms of the government’s involvement with precision agriculture: 1) incentives to adopt, 2) regulations informed by agricultural data, and 3) education and capacity building.

There were mixed opinions of whether incentives to adopt precision technologies are the best approach for the government to support farmers in the adoption of new technologies. Some reported having financed their adoption of technologies through the equipment customization management practice supported through the GLASI program – the Great Lakes Agricultural Stewardship Initiative organized by the Ontario Soil and Crop Improvement Association. In addition, during the time of interviews for this research, there was a brief funding window opened by Agriculture and Agri-Food
Canada for farmers to apply for funding to adopt robotic milkers through an initiative called the Dairy Farm Investment Program. According to retailers, this led to a boom in farmers getting quotes for upgrading barns and installing robotic milkers. Some farmers were supportive of initiatives such as these because cost has been cited as main barrier to the adoption of precision technologies. However, not all farmers thought that these incentives directly benefit farmers, as demonstrated by the following quotation:

Jessica (dairy farmer): “In my personal opinion, the further you can stay away from the government the better it is because they never do anything good in the long run. It is never really a true investment because they are always asking for something back or it is always at an expense… They are offering different grants - it is who has got the deeper pockets and who has the better banker...Funding is one way that they can do it (incentivize adoption), I guess - how they choose to execute that funding is a whole different ball game. I don’t want to be subsidized, all that does is allows everyone on the dairy supply side of things to up their margins because “Oh well you are getting subsidized, so we can get this money back and we can get more money for ourselves.” That is all that that did. That didn’t help the farmers at all in adopting technology. It just took the [technology retailers] and they said, “Okay so we need our 15% or our 25% margin on everything so let’s just inflate the price and submit that on your application and if you get it back, well then maybe we will work it back.” It doesn’t do anything for the farmers. It helped the dairy supply companies, that is it.”

This sentiment was echoed by other farmers that grants were one option to incentivize farmers to adopt technology but that they were inefficient, did not fully benefit farmers, or that they only incentivized farmers who planned to adopt these technologies anyway and did not garner new interest in PA.
While farmers reported that they would favour a “carrot” approach to precision technology adoption by the government, many feared a “stick” approach. There was a reluctance to share agricultural data with the government for fear that they would be reproached for management practices, particularly regarding field inputs.

Adam (crop retailer): “Where I see the government actually coming in is going to be, it is going to come down to the variable rate and the application because I guess where I see them as being worried about the environment … And making sure that farmers are being responsible as far as not overapplying fertilizers and manure management… It is definitely going to become more and more that the farmer is going to have to adopt it… In manure management scenarios, it is going to be a requirement of the government that you have GPS maps of where your applications are for environment reasons.”

Larry (crop retailer): “I would say probably the easiest one to think of would be with the nutrient management side of things, with the phosphorus issues in Lake Erie and all that, the GLASI programs and everything. There is a lot of grower perception that the government is going to be putting out some strict rules in the next few years on where and when you can apply nutrients such as phosphorus. I think that is kind of the easy one, but they will be looking more towards precision ag practices to help know where we can place that fertilizer and where it is going to get the most use, where it is going to run off, where it is most likely to just be wasted. Really on the nutrient side of things, I think that is going to be the biggest part in the near future.”

No regulations that require the use PA generated data have been established in Ontario, but there is a need for farmers to improve sustainability practices. As pesticide taxes and other regulations are increasing in Europe, for example (Böcker and Finger 2016), it is not a far-fetched idea that similar regulations could be implemented here.
Thus, the final recommendation of increasing PA education and capacity building is vital to increasing sustainability in the future.

Ultimately, a key point that was raised in regard to the role of the state and PA was that there needed to be more education on the use of these technologies for incoming workers to the agricultural sector and the government should offer extension services that would help increase farmer’s capacity to use PA. Suggestions included offering courses in college and universities to help future farmers become more “precision minded”.

Ben (dairy farmer): “We have suggested it several times at our local community college to have a course on agricultural electronics. We need somebody who is trained on how these systems are put together. The techs out there at the dealership, they are good, but they have never had a whole lot of training in agricultural electronics. I believe, it should be a big uptake for something like that. Even the robot, there are electronics on that have never given a whole lot of trouble, but there are sensors that do fail and our principal dealer he has had training on what sensors fail and he knows exactly where to look. He is looking for a guy to help him and he hasn’t found anybody yet. He basically has to train the right person himself.”

Jessica (dairy farmer): “I think that something really that the precision ag dealers really need to look at if they want to push the adoption of these technologies further is there is huge huge lack on the education side of the farmer. Huge. I really do think that is a crutch for pushing it a lot further than we are or pushing it. The more educated you are about a risk, the more likely you are to take that risk, than to not take that risk. So, if you at least have a better understanding of what is going to be brought back to you, then you are more willing to take that risk.”
This section highlights that there is a need for more education and capacity building for farmers, especially given the previous result that the vast majority of data is underutilized. This responsibility should be a role of public institutions, not just the private retailers who are selling PA tools. While incentives and regulations may prove to be contentious policy issues, farmers and retailers alike agree that education is key to moving PA forward in Ontario.

4.5 Summary

This results section has highlighted the key findings from the quantitative dataset in the COA and the qualitative dataset from interviews with farmers and PA retailers. These results focused on the 1) adoption of PA, 2) accessibility of PA, 3) PA’s impact on social relationships, and 4) the role of policy regarding PA. The results are summarized in Table 4. The following discussion section will analyze how these results are able to answer the four objectives of this study and answer the larger thesis question of how PA is impacting the social relationship between farmers and retailers.
<table>
<thead>
<tr>
<th>Theme</th>
<th>Sub-Question</th>
<th>Overview</th>
<th>Summarizing Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption</td>
<td>How has PA been adopted by farmers in Ontario?</td>
<td>- Low levels of PA technologies adopted</td>
<td>- Less than 10% of dairy farms in Ontario have adopted robotic milkers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Correlation of adoption with socio-economic characteristics</td>
<td>- Less than 12% of crop farms in Ontario are using GPS technologies</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Adoption of PA is concentrated in areas of prime agricultural land</td>
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<td></td>
<td></td>
<td></td>
<td>- Large, capital intensive farms are more likely to adopt PA</td>
</tr>
<tr>
<td>Accessibility</td>
<td>How accessible are PA technologies to farmers in Ontario?</td>
<td>- Training models for farmers</td>
<td>Logan (dairy retailer): “…typically here in Eastern Ontario, you have family run farms. They own and operate the farm. They are milking anywhere from 80 to 100 cows. They do have acreage where they do harvest crops to feed their cows and they are probably doing some cash cropping on the side. So, what makes that unique, where robots are such a nice fit is now the automatic milking takes away the milking task from the family that is running the farm and they don’t have to hire any additional outside help to get that done.”</td>
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<td></td>
<td></td>
<td>- Factors driving adoption (age, profitability, work environments, labour, competition)</td>
<td>Gary (dairy and crop farmer): “Now we are getting more and more data. I think the variable rate will come and as fields get bigger, the variable rate will come more into play for fertilizer and nutrient application.”</td>
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<td></td>
<td></td>
<td>- Differences in adoption patterns</td>
<td></td>
</tr>
<tr>
<td>Changing Social Relations</td>
<td>How do farmers perceive new PA technologies changing relationships with other actors in the food system?</td>
<td>- Underutilization of data</td>
<td>Scott (crop retailer): “But I have a lot of systems out there that have a ton of capability and they are not being utilized to the full potential. I have got a lot yield monitors, even things like that – that I don’t even think the maps are being pulled off them and being analyzed. I have seen planters that will give you an endless amount of as-applied data and that data just sits in the monitor and doesn’t get pulled out. There is a lot of data that is being collected but it is not being utilized to its full potential.”</td>
</tr>
<tr>
<td>Policy Implications</td>
<td>What are the perspectives of farmers and retailers on the policy implications of PA technologies?</td>
<td>- Incentives for adoption</td>
<td>Ryan (crop retailer): “We need to find a way to develop people in agriculture that are precision minded. Either a college or a technical course in college, or even more university focused entirely on precision agriculture components… I think academia needs to catch-up or surpass, not surpass, industry but at least you catch up and help to provide us with some human resources with some people that actually can you come out of school and be ready to go to help this industry succeed in the world-wide frame. We are competing against the world, so we have to utilize technology in Canada to be competitive against other countries.”</td>
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<td></td>
<td>- Regulations</td>
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Table 4: Summary Table of Results
5 Chapter 5: Discussion

Standing back from the results of this study, there are two cross-cutting themes that return to the initial conceptual framework. The first is the theme of diffusion of innovation, and the second theme is power relations. The results from this study demonstrate that social relations, such as the one between farmers and retailers, in Ontario agriculture are changing significantly due to the introduction of PA technologies, with some clear social challenges that have yet to be explored in the literature. New technologies are shaping an evolving technological landscape that the results section has documented, which has a strong correlation to the literature described through diffusion of innovations theory. Additionally, there are new roles for retailers as PA technologies are increasingly being adopted in terms of providing data management services, which will have an effect on power relations within the agricultural sector. This redefines former relationships between farmers and retailers both in the cropping and dairy sectors. The summary of these findings is relevant for both policy implications and future research.

5.1 Agricultural Innovation

In addressing the first two objectives of understanding the PA technological landscape through adoption and accessibility in Ontario, this study has revealed some key findings. Referring back to the literature on categorization of adopters and the degree of innovativeness, it is clear that Ontario is in the first category of innovativeness with the majority of farmers using PA being classified as “innovators” or “early adopters”. In finding participants for this study, it was particularly difficult in the cropping sector as there were very few farmers who were using the full gambit of precision agriculture technologies as described in Figure 4. While precision agriculture may be broadly promoted by academics, government, and industry as a promising solution to production issues surrounding agriculture, this research demonstrates that prime
farmland in Canada’s most productive province is not being managed by precision

technologies.

Past studies have focused on the barriers to adoption such as cost, compatibility issues, complexity of DSS, and user confidence (Kutter et al. 2011; Van Meensel et al. 2012; Lindblom et al. 2017; Rose et al. 2016). This study generally agrees with these findings, as farmers and retailers alike mentioned some of these challenges. Additionally, the factors driving adoption also correlate with the findings of this study including age, profitability, changing work environment, and lack of labour.

While many respondents spoke to age being a factor influencing adoption of technologies and there was a negative correlation between age and PA technology adoption according the COA, this does not quite capture the full nuance of the trends that are influencing the adoption of precision technologies. Other studies, such as (Rose et al. 2016), promote age as a barrier to adoption, yet this study found that PA technologies helped older farmers continue to work on the farm longer through improved work environments while also supporting findings from the literature that some technologies would be more difficult for older farmers to learn. Overall, even though the average age of farmers in Canada has continued to increase from 47.5 to 54 years from 1991 to 2011 (Statistics Canada), there needs to be more attention given to other factors and the changing nature of relationships in the agricultural industry from PA technologies in order to understand the broader scope of adoption trends.

While profitability was one of main reasons that participants said that farmers adopted PA technology, many of them could not state the return on investment of their PA tools. This finding suggests that more research is needed in terms of profitability mapping and helping farmers to understand the true return on investment of PA technologies. However, it should also be observed that many of the PA technologies might not have a quantifiable return on investment, but they impact the farming work environment quite significantly and that value also needs to be taken into account.
Overall, the findings in this study are supported by the literature that there is a lack of labour in agriculture. Farmers reported that by adopting PA technologies they were able to redirect their labour to other more important farm tasks than the more menial ones, such as milking or steering. This leads into further questions about the nature of work for agriculture in the future. If menial tasks are being replaced by technologies, then there will likely be a shift in the demand for unskilled labour and a transition to more highly skilled labour required for agriculture. The Ontario Agricultural College recently found that there are four jobs for every agriculture graduate entering Ontario’s agri-food sector\(^4\). This study corroborates that statement by the fact that several participants mentioned the need for there to be more highly skilled people to assist with PA technologies. Based on these findings, this study suggests that PA technologies are not putting people out of work but creating different opportunities for agricultural workers by creating more comfortable work environments and requiring highly skilled workers. However, more research needs to consider the impacts in other more labour intensive agricultural sectors, such as horticulture, and the differential impacts that PA might have on farmers versus farm labourers, particularly migrant workers (in preparation Rotz 2018).

By reviewing the 2016 Census of Agriculture data, the initial assumption that technology adoption has a positive correlation with farm size, gross farm receipts, and capital investments was fulfilled. This data coupled with the qualitative data from farmers discussing costs and pressure to grow in size to remain competitive speaks to the economic factors that motivate PA adoption. In this case, it is important to question whether the adoption of these technologies will fully benefit the sector as the will only be adopted by those with the means to do so. This runs the risk of creating a less diversified farming system and the hollowing out of rural communities. Some more recent studies have started to question what the social impacts of PA adoption will be

and based on this study it demonstrates that there is this risk (Rotz, Fraser, & Martin 2017).

Finally, in understanding the diffusion of PA innovations in Ontario it is also important to consider which technologies are available and how that has influenced adoption. In the cropping sector, there are multiple brand and platforms available creating an overwhelming amount of choice for farmers. In the dairy sector, there is one leading company, with other brands moving into the market. The literature shows that there is a wave of stakeholders interested in developing PA technologies, from agri-business giants like Monsanto and John Deere, to venture capital firms, start-ups, and tech companies (Wolfert et al. 2017). During the recent development and promotion of PA technologies, there have also been the trend of acquisitions and mergers within the agricultural sector with some of these technologies being a driver of this trend (Clapp 2017). For example, the Bayer and Monsanto merger in 2016, the Dow-Dupont merger in 2017, John Deere’s acquisition of Blue River Technology in 2017, and the Dupont purchase of the decision support start-up Granular, are just a few of the mergers and acquisitions that have influenced the PA market. Due to the rapidly changing nature of what technologies are available, this has serious implications for compatibility of platforms for farmers. Given the trends in agriculture and the rate of mergers and acquisitions in the PA sector, this will not be an issue for long, however this research suggests that if left to the private sector, compatibility problems will persist. While many studies have focused on the low adoption rates of decision support systems by farmers (Lindblom et. al 2017; Oliver et al. 2017), they have yet to consider the macro-economic factors that have influenced compatibility in the sector. More research is needed to characterize the rapid shifts and implications in the PA sector due to mergers and acquisitions.

The challenges such as compatibility caused by the domination of private industry in the PA market present an opportunity for public institutions to become more involved in PA. For instance, public institutions can work with farmers and industry to help develop more open-data tools and address some of the governance issues surround agricultural
data in terms of ownership and privacy (Wolfert et al. 2017). In asking participants how public institutions might be involved in PA, responses could be categorized into three categories: incentives to adopt, fear of regulations, and support through education and capacity building. The most important role for public institutions would be education and capacity building. As previous research has found that agricultural technology firms are considered the most important source of information on PA, and that government advisory services are the least informative (Kutter et al. 2011), this study definitely confirms those finding in this regional context. If public institutions work to build capacity in PA data analysis, this type of intervention would have a significant impact on social relations within the agriculture industry.

Overall, PA needs to continue to strive to embody the five key attributions of innovations to further adoption. As competitiveness and a pressure to increase profitability in agriculture continues as a trend, the relative advantage of PA will help drive adoption. Additionally, more support from public institutions for training and capacity development will aid in reducing the complexity of adopting PA systems. As some of the ‘innovators’ interviewed for this study continue to demonstrate their successes in using PA, observability of PA innovations will increase. However, the influences of relationships and policy will also determine future trajectories of PA in Ontario.

5.2 Power Relations

The second theme emerging from this study is an analysis of power relations, particularly through a characterization of the social relations of specific actors in relation to PA – farmers and agricultural technology retailers. Wolfert et al. 2017, in discussing PA and big data, states that “the literature suggests major shifts in roles and power relations among different players in existing agri-food chains.” This section of the discussion aims to explore what those roles are for these actors and how PA is altering those roles.
Previous studies have touched on how the relationship between farmers and advisors has had implications for adoption, such as the fear of decision support systems replacing advisors (Lindblom et al. 2017), farmer-advisor compatibility as a main factor for an effective decision support system (Rose et al. 2016), and the rejection of PA machinery by local sellers and advisors as a constraint for the adoption of PA (Kutter et al. 2011). While this study did not focus on the relationship between farmers and advisors, but rather the relationship between farmers and PA retailers. This different perspective is an important contribution because it has highlighted a major gap between ‘precision agriculture’ and ‘precision agronomy’. This study agrees with previous findings that the majority of PA data is analyzed off-farm due to time and knowledge constraints but contrasted to PA in Germany where consultancy and data processing were often provided by the retailers of PA technologies to the farm (Kutter et al. 2011). In Ontario, there is a disconnect between the retailers who are selling PA products and the ability to process the data that is generated by them.

The implications of this separation between precision agriculture and precision agronomy in Ontario is that there will likely be a new line of services beginning to be offered by retailers who are selling PA technologies. In two cases of the retailers that I interviewed, they were already beginning to offer these services. In addition, there will also likely be a rise in consulting agencies that focus specifically on the data management aspects of PA without retailing the hardware – one participant for this study specialized in this type of consulting. However, this type of service presents a challenge as there are a variety of PA systems available in Ontario currently that it is difficult for one individual to be proficient in all of them. In terms of the dairy sector, companies that did not offer data management services in addition to the sale of the robotic milkers were the least best-selling brands in the province. Overall, trust and the strength of the relationship between farmers and retailers is confirmed by this study as a determining factor in which type of service or PA product farmers will choose (Kutter et al. 2011).
Trust and social relations are also key to understanding farmer’s concerns over privacy and data ownership. Kutter et al. (2011) found that fears of agricultural data misuse were widespread. However, our results show that farmers have limited concerns over the security and uses of their agricultural data. This finding highlights that there are risks for agricultural data in Ontario, as practices surrounding cyber-hygiene and data sharing need to be better established. Farmers generally had a positive attitude towards data sharing as long as it provided some benefit to themselves, such as using tools on some dairy decision support systems to benchmark themselves against other farms of similar size and management practices.

However, some farmers found it problematic when other actors or companies were benefitting from the data they are generating with unclear benefits to themselves. One particular example that was raised was the artificial insemination industry benefitting from the generation of production data from robotic milkers without a direct payback to the farmers who have invested in the technology that creates that data. In understanding the social impacts of PA, relationships beyond the farmer-retailer nexus need to also be categorized as there are other actors involved in using agricultural data. Further research is required to understand how networks within the agriculture industry are using data to improve services.

Additionally, some crop farmers even admitted to switching to different crop advisors because their previous advisor was unfamiliar with processing PA data. This highlights the importance of these technologies and their influence on impacting social relations. Not only is there an impact on consulting agents, but also on the producer-processor relationship. More research is needed into how processors and buyers of agricultural commodities might use the data generated by PA in the future. As processors attempt to differentiate their products through sustainability claims, such as using less inputs than other brands, the necessity of generating digital agricultural data through PA technologies will become increasingly important. The social impacts of pressure from processors to adopt PA technologies will influence what type of farms are able to continue to be viable in a changing market.
5.3 Summary

In summary, to characterize how social relations between farmers and retailers are changing due to the introduction of PA technologies, it is clear that there are widespread impacts beyond the farmer-retailer relationship that requires further research. Nevertheless, this relationship has undoubtedly been impacted as this study has shown that due to farmers grossly underutilizing PA technologies and the data generated by them, this has resulted in a new line of services offered by technology retailers and advisors that helps farmers to process and understand their agricultural data. It has also demonstrated the gap in understanding between those who sell the tools to gather the data and those who interpret the data. This finding is critical as more recent literature has started to recognize that advisors are more likely to be the ones interpreting agricultural data (Van Meensel et al. 2012; Lindblom et al. 2017). What does this mean for the role of farmers, if technologies are collecting the data and others (retailers and advisors) are interpreting it and making farm management decisions? From this study, some farmers have rejected the use of services and learned to interpret and manage their own data – the “innovators”. However, this will likely not be the case for the majority of farmers as PA technologies continue to become more detailed and specialized. This is likely why farmers interviewed generally reported that they felt that those selling PA technologies had benefitted the most from them, rather than themselves. This does not negate the benefits of PA state were found in terms of labour saving and changing work environments, but it is the realization that the ability to retail technologies and provide services for data interpretation is where the majority of PA benefits lie. Therefore, for farmers to be able to fully capture those benefits there is a need to support them in using the full abilities of their PA technologies and be able to interpret data for themselves.
6 Chapter 6: Conclusion

6.1 Scholarly Contributions

One of the aims of this thesis was to fill a gap in the literature on the social aspects of PA as previous studies have focused on how PA technologies work. As Carolan (2016) achieved with his study to “reshape the debate around agro food-based technologies, from one that asks what technology is to one that looks at what these socio-technical forms engender,” (pp.135) this study aims to move that debate forward in a similar direction as there is still more research that needs to be pursued in this line of questioning. This study presents a unique case of Ontario agriculture which can be compared to other areas of PA adoption to understand how social relations between farmers and retailers might differ in areas with alternative political and economic contexts. Additionally, few studies have considered how the social implications of PA have manifested differently in diverse agricultural sectors. By looking jointly at the cropping and dairy sectors, this study is uniquely able to contrast differences between the influence of PA technologies, but also recognize the generalities that apply to PA in different contexts.

Future research should build on this preliminary work of outlining the impacts of PA on social relations across agricultural networks and even through the agricultural supply chain. More research is needed on agricultural data governance as data management roles continue to shift within the industry, which will likely result in more concern surrounding data uses, ownership, and privacy. As this study has aimed to demonstrate the adoption of technologies and how relationships have changed due to that, there is also a need for research to investigate why some farmers are disengaged from using digital agricultural technologies and what the social implications are for them. This study starts at the most immediate level of those who assist farmers with their use of these technologies – retailers – but more investigation into how data is being used by corporations is a pressing research topic for future inquiry.
6.2 Study Limitations

The main limitation of this study was its limited sample size. While it was simple through online research to find retailers selling precision agriculture products, it was much more difficult to find farmers using precision agriculture technologies as there are no specific producer groups in Ontario for precision agriculture. Furthermore, due the variation in adoption of precision technologies, particularly in the cropping sector, farmers who had some precision tools but did not use data for management decisions would not have been considered for this study. Therefore, it is not entirely inclusive of those perspectives, nor of perspectives of farmers that have decided against adoption of precision agriculture. By focusing on only the top five counties of the highest adoption for precision agriculture, there were also the perspectives of other adoptees that were excluded from this study. In addition, this study only aims to look at precision agriculture from the cropping and dairy sectors, despite that precision agriculture is present in almost all sectors of agriculture, from other forms of livestock production to horticulture. This presents an opportunity for future research to compare the results from this study to the perspectives in other sectors.

Due to the highly evolving nature of PA technologies, this study only presents a snapshot in time of what technologies are available. Additionally, given that this was the first time that the Census of Agriculture collected information on technology adoption, these results cannot be compared over time. Another limitation of relying on the census as a data source is that it did not include all types of PA technologies, such as variable rate technologies or drones. Many respondents mentioned that they see the cropping sector evolving towards autonomous tractors and the precision dairy sector focusing more on ruminations factors and efficient feeding. As more precision technologies continue to be implemented in agriculture, it will be crucial to monitor whether the trends identified through this study continue to prevail or are disrupted by new innovations. This study was intended to explore PA technologies in Ontario and be
generally descriptive in nature, therefore there are important opportunities for future research in this area.

6.3 Recommendations

As this study is one of the first to fully scope the technological landscape in Ontario it has several contributions. It provides a realistic scope of the limited use of PA technologies in this area and that could have potential implications for how these technologies are marketed in the future. For scholars in Science and Technology Studies, one recommendation from this thesis is that a diversity of social relations needs to be explored beyond the farmer-retailer dynamic. Additionally, to collect more data on PA adoption during the 2021 Census of Agriculture, it is recommended that the technology adoption question be reformulated to include more PA technologies and to have a follow up question about the use of data. As observed from this study, even though farmers may own PA equipment, it does not necessarily mean that they are making data-based decisions in a PA management system. Most importantly, the practical contribution of this study is that it draws attention to the need for institutional support for farmers as they continue to adopt more PA technologies.

In terms of recommendations for institutional support for PA technologies, this research finds that developing extension services and training the next generation of agriculturalists to be adept in using PA tools would most likely be the most effective. In the case of extension services, one dairy farmer lamented the absence of an extension service that is able to provide another perspective outside of the retailer:

*Andrew (dairy farmer)*: “Well we can see something is going on…We kind of knew our parlour system just over time, and there are some things and I am not a technician and there is no independent person or company. We have hired independent people to come and trouble shoot when we had problems with our milking parlours but there is no
independent person that I am aware of that will come in that is familiar with all these robotic systems and can give you – just a third party opinion. I am going off my technician from the dealership and if they are not telling me something or they are not aware of something, we are all scratching our head going “why is this happening?”

While past studies noted the domination of the PA market by private corporations (Wolf and Buttel 1996; Wolf 1997; Piesse and Thittle 2010), however more recent studies have noted the role of public institutions in being advocates for open-data, innovations driven by data, and attention to data governance issues (Wolfert et. al 2017). Therefore, there is definitely a role for organization such as OMAFRA to play in providing extension services and assistance in helping farmers to make successful management decisions for profitability and sustainability. As noted from the results, there is less of a role to play in providing incentives for adoption and for increasing environmental regulations based on digital agricultural data at this time.

Secondly, educational institutions need to enhance their role in providing the next generation of farmers, advisors, and technicians with the right training and skills to utilize PA in farm management. Programs in colleges and universities catered to students who hope to have a career in the agricultural industry should focus on developing the interdisciplinary skills from agricultural sciences, environmental sciences, geography, and computer sciences. This study recommends that educational opportunities should be geared towards producing future employees who will be able to be “precision-minded” and able to use PA.

### 6.4 Concluding Remarks

As Carolan (2016) states “technologies veil practices, oughts, and politics”. This thesis research has attempted to lift the veil of PA technologies to understand how they are being used, who is benefitting from them, and how political-economic factors have
impacted their adoption in the cropping and dairy sectors in Ontario. Through understanding the technological landscape of PA and characterizing its' impacts on the relationships of particular actors in the agriculture industry, this research has found that PA has profound effects on the relationship between farmers and retailers. In order for PA to truly be able to realize the benefits of profitability, sustainability, and a more transparent food system, there needs to be consideration given to how the way the social relations are changing due to PA might impact power relations in the agricultural industry and change the roles and responsibilities of farmers and retailers.
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APPENDIX

Figure 5: Percentage of Farmers using Computers for Farm Management
Figure 6: Percentage of Farmers using Smartphones for Farm Management
Figure 7: Number of Farmers using Automated Steering in Ontario
Interview Protocol – Retailer Interviews

1. Retail Business Name:
2. Position:
3. Number of years working here:
4. What precision agricultural products do you sell here?
   a. How long have you retailed these products?
   b. Do you sell an online data management platform/decision support system?
5. What are the most commonly purchased products?
6. How does your retail operation differentiate itself compared to competitors who might offer similar products?
7. What are some of the benefits of these technologies that you stress to potential customers?
8. Could you describe the average type of customer who is looking for Precision Agriculture technologies? (i.e. young, educated, large farm, etc?)
9. Do potential customers often come with a pre-conceived interest in purchasing a product with Precision Agriculture capabilities?
   a. If someone is simply looking to buy a new tractor, for example, do you try to promote PA capabilities?
10. What training is offered to farmers who purchase this technology?
11. Do farmers ever come back and report challenges that they have had using the technology?
12. Do you, as the retailer, assist in making farm management decisions from the data, or how do you help farmers interpret the data?
13. In your opinion, do most customers utilize the full capabilities of precision agricultural products?
   a. Why? What can be done to change that?
14. What role do you perceive the government having to promote new agricultural technologies?
15. Do farmers ever mention to you concerns over data privacy or data ownership?
16. How much of your sales is generated from precision agricultural products?
   a. Could you estimate the value of annual sales in PA products?
17. In your opinion, do you think these technologies will become more common in the future?
   a. What role do you see yourself as the retailer being for farmers with regard to new precision agriculture technologies?
18. Is there anything else that you would like to share that would be useful to my study?
19. Can you help me connect with farmers?
Interview Protocol – Farmer Interviews

1. Age:
2. Gender:
3. Location of farm:
4. Acres Owned:
5. Acres Farmed:
6. Crops grown:
7. # of Cows milked:
8. Years farming:
9. What technology is used in your farm management practices?
10. How long have you been using this technology?
11. Could you describe why you started using this technology?
12. How much did this technology cost to implement?
13. What new skills did you have to learn to use these tools?
   a. Could you expand on what your experience was with learning these skills?
   b. Did you have to reach out to others, if so, who?
14. Is the technology well suited to your informational needs as a farmer?
   a. If you could make suggestions to the technology developer, what would you change about the precision agricultural tool that you use?
15. Have you formed any new business or social relationships as you have adopted these technologies?
16. How has this technology changed your farming operation? (Probe for how it has changed decision making)
17. Who did you purchase this technology from?
   a. Why did you choose this retailer over others?
18. Are you still in contact with your technology retailer?
19. Does someone help you to manage your farm data?
   a. If so, who?
   b. What do they charge for their services?
c. How often do you communicate with them? Do they come out to the farm?
d. Does the person who helps manage your farm data help you to make farm management decisions?
   i. If so, how?
e. How would you describe your relationship with this person who helps you manage your farm data?

20. What role do you perceive the government having to promote new agricultural technologies?

21. Do you ever have any concerns over data privacy or data ownership?

22. Generally, there has been a lot of hype around precision agriculture technologies and the promise of these technologies to increase sustainability, profits, yields, and increase traceability and transparency in the food system. What are your thoughts on the way these technologies have been promoted?

23. In the agricultural supply chain, there are many different actors, such as input retailers, farmers, processors, equipment dealers, technology retailer, consumers. In your opinion, who do you think has benefitted the most from the introduction of precision agriculture technologies and what were those benefits?

24. In your opinion, do you think these types of technologies will become more common in the future?
   a. Do you personally know many other farmers using these technologies?

25. Is there anything else that you would like to share that you think might be useful to my study?