An Examination of the Adoption of Agri-Environmental Practices: A Case Study of Alberta

by

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Abstract

Best Management Practices (BMPs) are commonly promoted as a way for agricultural producers to adapt to and mitigate environmental risks on agricultural land. Agri-environmental policies are an integral component towards encouraging producers to adopt these practices, mostly through the use of cost-share environmental stewardship programs. The decision-making process for BMP adoption is influenced by a multifaceted number of factors, and literature has been unable to determine consistent and significant influences on this decision process. In this research, we use a three-paper approach to examine the relationship between policies, programs, and BMP adoption rates using a case study of Alberta, Canada. Our first paper (Chapter 4) provides an in-depth overview of Canadian and Albertan agri-environmental policies where we discuss current policy limitations and compare their effectiveness to other developed nations. We find policies and programs were not properly monitored resulting in an inability to determine if policies met environmental goals. Findings suggest taking influence from other developed nations policies, including introducing performance-based measures and cross-compliance. The second paper in this thesis (Chapter 5) uses a logistic regression to analyse factors that influence Alberta farmers participation in the Environmental Farm Plan (EFP), a voluntary risk-assessment tool. Alberta farmers decision to complete an EFP was influenced by industry standards, conservation training, and gross farm revenue. Although, exposure to extension was not influential in this process. Our last paper (Chapter 6) addresses BMP adoption rates across agri-environmental risk areas. We develop an ESA adoption score and debate which model is the best fit for fractional (proportional) dependent variables, settling on a Linear Probability Model for our analysis. The analysis supports the importance of the EFP, where respondents who had completed an EFP were significantly more likely to adopt practices. We also address the role of endogeneity regarding the use of the EFP as a measurement variable, where we produce split sample models

to find producer decisions differ depending on whether they had or had not completed an EFP. Significantly, producers without an EFP were highly influenced by exposure to extension. Lastly, we find spatial effects for adoption across Municipal Districts, including the possibility of spill over effects. In line with prior literature, we find vast heterogeneity across respondent characteristics.

Preface

This thesis is an original work by Sarah Van Wyngaarden. This research project was completed thanks to funding from Alberta Agriculture and Forestry and the Alberta Land Institute.

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Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background

Agriculture is inherently linked to the environment through the industries dependence on suitable land conditions for the production of agricultural goods. Environmental risks, such as soil erosion, will result in negative externalities for the supply and profitability of these goods, including substantial impacts to individual producers. The adoption of Best Management Practices (BMPs) has been actively encouraged by the agricultural industry to mitigate these environmental risks. BMPs are classified as voluntary management practices that reduce or eliminate environmental risks, while contributing to a farm's sustainability, economic viability, and overall environmental health (AAFRD 2006). Recently, BMPs have also been promoted as a method to mitigate greenhouse gas emissions associated with agriculture, enhance soil sequestration, and provide producers with adaptive management practices (Smith et al. 2007; Smith et al. 2008; Rodriguez et al. 2009). Certain BMPs can reduce emissions indefinitely, while others provide temporary, or short-term reductions, although all BMPs are meant to manage on-farm environmental risks associated with agricultural production (Smith et al. 2008; West & Marland 2002). To date there is no universal list of BMPs, and according to the Intergovernmental Panel on Climate Change (IPCC), adaptive and mitigative practices and their adoption rely 'on climate, edaphic, social setting, and historical patterns of land use and management (Smith et al. 2007).'

Best Management Practices (BMPs) have been labelled under many different pseudonyms including 'Beneficial Management Practices (BMP),' and 'Climate Smart Agriculture (CSA),' with more poignant terms such as 'conservation practices,' 'sustainable agriculture,' and 'climate mitigating technologies.' For simplicity, the remainder of this thesis will mostly address these practices as BMPs and conservation practices interchangeably. Since BMPs are voluntary in nature, agri-environmental policies have been developed to endorse and regulate the uptake and use of BMPs on farms. For example, agricultural emissions tend to originate from non-point sources of pollution, meaning tracing the source of pollution is incredibly difficult (Weersink et al. 1998; Shortle & Dunn 1986). This inability to pinpoint sources of emissions means policies targeting levels of emissions are not always feasible.

Instead, agri-environmental policies tend to follow a non-point pollution form, including, but not limited to, incentive-based policies, subsidies, and taxes, for adopting practices or altering management decisions to mitigate environmental risks and emissions.

Some significant agricultural policies that address environmental risk reduction stem from the European Union (EU) and the United States. The EU moved towards the use of Agri-Environmental Programmes (AEP) to promote environmentally friendly farming through 'less intensive production,' by reducing market surpluses and mitigating extensive damage to the environment (Piorr 2003). Environmentally friendly farming was directly intertwined with the EUs Common Agriculture Policy, and many programmes cover BMPs that vary across EU countries, allowing for greater adoption rates as farmers are paid to reduce negative externalities (Piorr 2003; Baylis et al. 2008). In the United States, their 2002 Farm Bill began to increase funding for conservation programs where they pay farmers for achieving environmental goals; although the methods used to attain these goals are not considered (Baylis et al. 2008). Even with encouragement at the local and government level from agri-environmental policies, BMP adoption is not always well understood, and there are a multitude of factors influencing whether farmers voluntarily adopt BMPs and/or alter their management practices (Prokopy et al. 2019; Pannell et al. 2006; Rodriguez et al. 2009).

With the voluntary nature of these practices, the adoption process is dependent on individual producers and their decision-making process. Through an economic perspective, this includes how the adoption of a practice can affect a producer's utility, profitability, and overall productivity on their operation (Chouinard et al. 2008; Cary & Wilkinson 1997). The decision-making process can also be hindered by economic factors such as high up-take costs, alongside high levels of uncertainty and risk from adoption, especially for farmers with lower income (Koundouri et al. 2006; Pannell et al. 2006). Besides economic influences, research has identified multifaceted aspects that can alter how a producer manages their land. Other significant factors include extension services (Baumgart-Getz et al. 2012; Feather & Amacher 1994), farm characteristics (Prokopy et al. 2008; Prokopy et al. 2019), perceptions and attitudes (Haden et al. 2012; Arbuckle 2013), social networks (Pannell et al. 2006; Baumgart-Getz et al. 2012) and agri-environmental policies (Pannell et al. 2008; Greiner & Gregg 2011). Essentially, producers must weigh the benefits of adoption alongside situational and environmental factors.

With a proper understanding of this process, it is plausible to engage and motivate farmers to alter their land management practices for long-term environmental sustainability.

1.2 Thesis Objectives

The purpose of this thesis is to better understand overarching components that influence agricultural producers' adoption of Best Management Practices (BMP). Adoption is not a linear process and is dependent on a producer's behaviour, specifically a producers decision-making process and factors which influence this process. Researchers have attempted to disentangle how producers make decisions to incentivize adoption. The bulk of the literature has stated that farmers face a multifaceted number of barriers which may deter farmers from adopting. Even though literature has consistently described these barriers, alongside motivators to adoption, there has been little consistency regarding the significance and level of influence for proposed factors.

This thesis will utilize economic theory and econometric approaches to better understand these factors that promote adoption behaviour. Farmers are often described as stewards of the land and are assumed to be intrinsically motivated to ensure environmental risks on their land are mitigated. Nonetheless, farmers are also driven by economic conditions including efficient agricultural production to increase profitability. The intersection between the environment and economic capital results in a complex decision-making process for how a producer chooses to manage their land. This includes how BMPs will affect their management practices and if they are beneficial towards their environmental, economic, and social goals.

This thesis also uses a region-specific approach focusing solely on factors that affect BMP adoption in Alberta, Canada across eight agri-environmental risk areas. Since BMPs vary across geographic location and farm typology, a region-specific approach is advantageous to address local policies and extension services to engage farmers in adoption. In addition to this, farmer's behaviour will differ across regions with past experiences, social networks, among other factors influencing their on-farm management decisions. It is not plausible to generalize adoption decisions on a global scale, especially regarding the differences between developed and developing nations. Even within Canada, provincial regulations, topography, climate, among other factors vary significantly. Thus, this thesis will only address BMPs that are specific to

Alberta, Canada, and its regional conditions. In Alberta, these BMPs are grouped under eight agri-environmental risk areas which are described further in section 2.2. Further, this thesis will attempt to address regional differences across Municipal Districts in Alberta, Canada. Municipal Districts are also known as 'counties' and are identified as local or urban municipal governments, typically run by a council, for rural areas in the province of Alberta (Government of Alberta 2021). When we discuss Municipal regions, or regions, we mean Alberta land-use regions as identified by the Government of Alberta in the 2016 Census of Agriculture for Alberta (AAF 2020); this is shown in Appendix 2A.

1.3 Thesis Structure and Contributions

This thesis is structured through a three-paper approach, where each paper will address different components which are hypothesized to significantly impact BMP adoption. These papers will cohesively narrate a story regarding a producers decision-making process for BMP adoption. We aim to address the following research questions:

1) How does agri-environmental policy influence the decision-making process to adopt?

2) Have economic incentives been effective and have environmental goals been met?

3) What is the role of the Environmental Farm Plan (EFP) in BMP adoption?

4) Are there significant differences in adoption rates and management decisions across agri-environmental risk areas?

5) Are there regional effects to producer preferences for adoption across Municipal Districts in Alberta, Canada?

The first paper, chapter 4, provides a background of agri-environmental policies in Canada and associated environmental stewardship programs. A comparison between global agri-environmental policies and programs is provided to better understand the efficiency of current policies in Canada. We aim to understand how these policies have adapted over time, and to describe the economic tools used to incentivize BMP adoption. The purpose of this chapter is to develop recommendations for future agri-environmental policies in Canada and future environmental stewardship programs in Alberta.

Chapter 5 first provides an extensive history of the Environmental Farm Plan (EFP) in Canada, then the history of the EFP as it pertains to Alberta. This chapter also examines the EFP using an econometric analysis to describe which factors are associated with its uptake amongst farmers in Alberta. We examine the role of extension, as well as industry standards, to determine their influence on EFP completion. The overall goal of this chapter is to provide an overview of limitations and necessary changes for the EFP, provide recommendations for the Alberta EFP programme, and to add to the limited and relatively non-existent literature on the Alberta EFP.

Finally, chapter 6 delves into an analysis of BMP adoption across eight agri-environmental risk areas, addressing current trends and factors associated with adoption. This region-specific approach addresses 39 BMPs that are specific to producers in Alberta, Canada. Additionally, the econometric analysis is at the Municipal District level to address which counties are more, or less, likely to adopt BMPs. Our hypothesis is that there are differences across Municipal Districts and that factors influencing adoption are unique for each risk area. The goal of this chapter is to provide an understanding of which factors influence or deter from the adoption of BMPs across these risk areas. This includes how local policies, extension services, and regional factors influence adoption decisions. This will provide insight into future extension efforts regionally, and to determine which BMPs need to be targeted by future stewardship programs.

Prior to these papers, an overview of Alberta-specific BMPs is described in chapter 2, and a thorough literature review is provided in chapter 3. This literature review provides an overview of prevalent papers, prominent factors associated with adoption, as well as addressing elements that are limited or overlooked in the research. The remainder of this thesis consists of an overview of limitations and a summary of the main conclusions and policy considerations for each paper.

Chapter 2: Best Management Practices in Alberta

The Government of Alberta has shifted their focus towards sustainable agriculture by developing policies, programs, and resources to aid agricultural producers with adaptation measures for improved environmental stewardship; this is described further in chapter 4. Most of these policies and programs rely on producers actively adopting BMPs that are suitable for their current land conditions. Prior to our discussion on BMPs that are specific to Alberta, some context on Alberta's agricultural industry is provided below. This includes past trends and current issues.

2.1 The Agricultural Industry in Alberta

Alberta is one of three provinces located in the prairie region in Canada. According to the first Canadian agricultural census in 1911, Alberta reported 60,559 farms, and 17.4 million acres of farmland. By 2016, the number of farm acres exponentially grew to 50.3 million acres, the second largest total farm area in Canada, meanwhile number of farms declined (Statistics Canada 2017). Compared to other provinces, Alberta holds strong ties to the beef cattle industry. As of 2016, Alberta has the largest cattle herd at 41.6% of the national cattle herd, 59.6% of all feeder cattle, and 42.3% of beef breeding stock[1] (Statistics Canada 2017). Statistically, Alberta dominates the market compared to other provinces regarding the beef cattle industry. This can be seen in Figure 1.1 which compares the total number of cattle, beef cattle, and heifers across provinces.

[1] This includes beef cows and heifers for beef herd replacement.

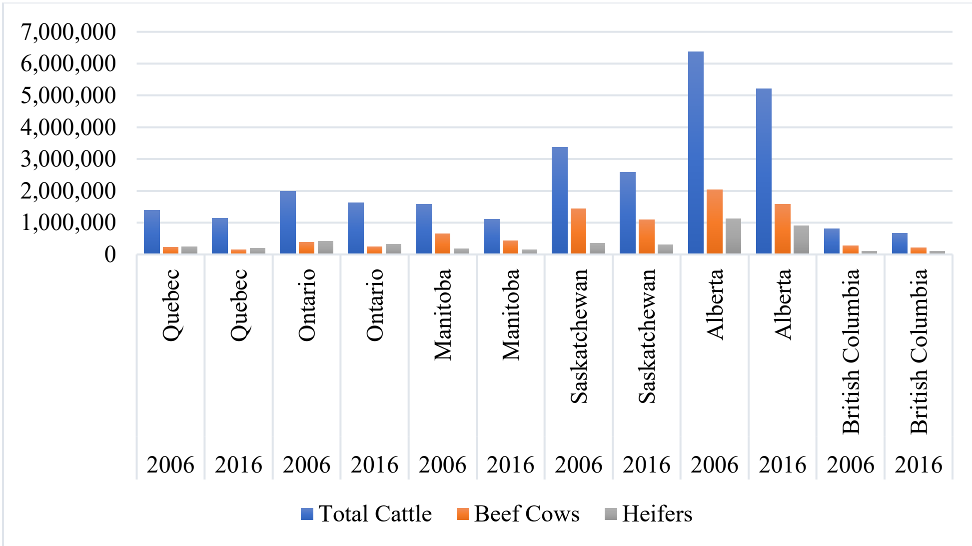

Figure 1.1. Total Cattle in Alberta in 2006 Compared to 2016.
Source: Statistics Canada (2021)

With respect to crop production, the total area of cropland in Alberta increased by 4.8% in 2016 and is the second largest for field crop area in Canada (Statistics Canada 2017). Oilseed and grain type operations equate to roughly a third of all farms in the province, with Canola as the lead field crop by area (Statistics Canada 2017). In July of 2019, Alberta was the lead producer of Barley with 4.8 million tonnes, nearly half (49.8%) of the national total (Government of Alberta 2019). For major crops, Alberta produced 32.2% of all wheat, 21.5% of oats, and 28.8% of canola, based off July 2019 estimates (Government of Alberta 2019). In all, Alberta is a large-scale agricultural producer in both the livestock and crop industries.

2.1.1 Current Issues in Alberta's Agricultural Industry

Concerns over how agricultural production impacts the environment has been raised globally (Jia et al. 2019; Smith et al. 2014). These concerns are often narrowed to negative shocks to environmental risk areas, such as reduced water quality, and the increase in greenhouse gas emissions from agricultural production. Below a general description of agricultural emissions is provided. Following this, a brief overview of the main environmental concerns in Alberta is described and how these concerns relate to the agricultural industry.

Smith et al. (2008) summarize that greenhouse gas emissions (GHG) from agriculture are generally released through microbial decay and soil organic matter and includes to a lesser extent on-farm use of fossil fuels (Government of Canada 2020). Methane (CH_4), is produced when carbon-containing materials decay and are oxygen-deprived (Moiser et al. 1998; Government of Canada 2020). Most methane emissions are from anthropogenic sources, and in Canadian agriculture, the primary source of methane is from enteric fermentation, followed by manure storage sites (Mosier et al. 1998; Government of Canada 2020). Nitrous oxide (N_2O) stems from microbial transformation of nitrogen in soils (as well as manures); this tends to be higher in agricultural soils due to added nitrogen from fertilizer and manure, among other sources (Smith et al. 2008). Farms can also produce indirect emissions where nitrogen run-off is produced outside the farm as N_2O or ammonia gas (Government of Canada 2020). In Alberta, agricultural emissions are significantly higher than other provinces, as shown in figure 1.2. This may correspond to the main sources of N_2O and CH_4 which are from enteric fermentation, manure storage, and ammonia emissions from sources such as beef cattle feedlots (McGinn & Flesch 2018; Government of Canada 2020). With the prominent livestock sector in Alberta, a significant issue is finding a sustainable and economically rational method to mitigate these emissions to improve air quality, land conditions, and combat negative effects from climate change (such as increased weather variability).

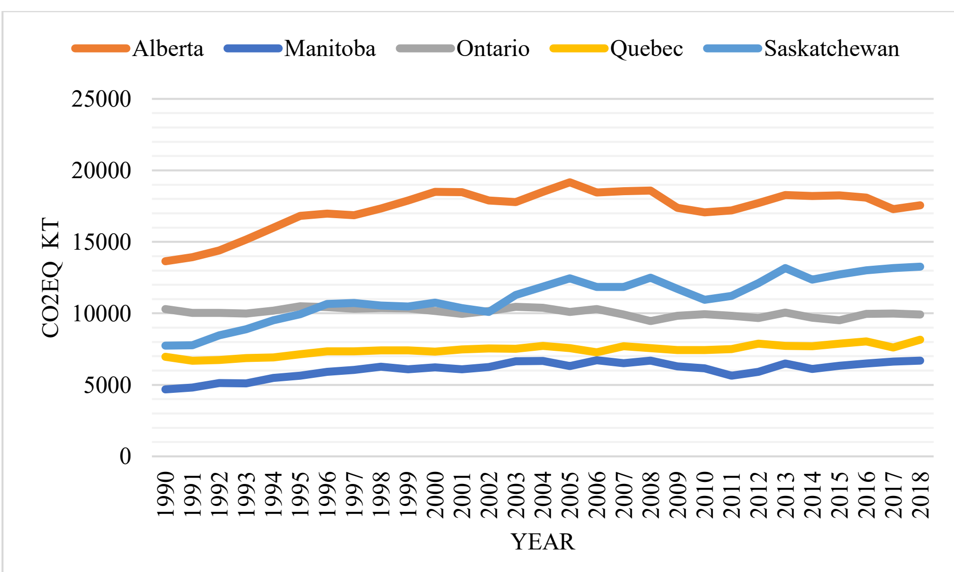

Figure 1.2. Total Agricultural Emissions Across Selected Provinces
Source: Environment and Climate Change Canada (2019).

With respect to environmental risks in Alberta, some of the most significant risks include soil conservation and water quality and/or quantity (AARD 2008). In Canada, land degradation, especially the deterioration of soil quality, has been a large issue for quite some time, and one that could be made worse with more extreme weather events (Dumanski et al. 1986; Smit & Smithers 1992). In Prairie soils, wind erosion is an urgent problem, especially on ground that is summer fallowed, followed by the issue of salinization of dryland agricultural soils (Dumanski et al. 1986).

Climatic variations, especially the extremities of winter in Alberta, have been shown to pose an external risk resulting in excess vulnerability for agricultural lands productivity (Masud et al. 2018; Miller et al. 2010; Olson et al. 2011). For example, during the winter season, cattle bedding sites and grazing management decisions are important to ensure sustainable riparian and water quality. This can include reducing livestock's access to water beds during the winter months to decrease nutrient runoff (Olson et al. 2011). With limited water bodies in general, and the use of irrigation throughout Alberta, water pollution is a significant concern especially from manure and fertilizer runoff (Miller et al. 2010; Kohn et al. 2016). Albertan producers are often expected to adapt to this climatic variability to maximize crop yields and to ensure sufficient waterbody resources for livestock (Masud et al. 2018).

Another significant, but often overlooked environmental risk in Alberta is orphan and inactive oil and gas wells on agricultural land. These wells lead to adverse environmental and human health effects, including leakage of oil into agricultural lands, which can contaminate water and soil resources (Alboiu & Walker 2019; Munene et al. 2019). Unfortunately, farmers are often left to mitigate these risks without support since orphan well sites generally do not have any legally or financially responsible parties that can be held accountable (Government of Alberta 2020).

2.2 The Environmentally Sustainable Agriculture Tracking Survey

The Alberta Agriculture and Forestry Department (AAF) conducts a bi-annual survey called the Environmentally Sustainable Agriculture Tracking Survey (ESATS) that monitors farm-level adoption of environmentally sustainable agriculture (ESA) practices in the province. The results of this survey have been used to improve ESA programming by understanding the levels of adoption of ESA practices (BMPs) by agricultural producers. These results are also used to improve programs to motivate further adoption of environmentally friendly practices (AAF 2018). Since 1997, the survey has measured producer's awareness and adoption of BMPs under agri-environmental risk areas (AAF 2018). Today, there are eight agri-environmental risk areas:

1) Water Quality and Quantity;
2) Wildlife Habitat Conservation;
3) Grazing Management;
4) Manure Management;
5) Agricultural Waste Management;
6) General Practices;
7) Soil Conservation and;
8) Energy and Climate Change.

Each survey report includes an ESA adoption score, which is defined as ''the average percentage of improved environmentally sustainable agriculture practices adopted by producers (AAF 2018)." A total number of eligible practices are determined, and a percentage is calculated for each responding producer after dividing the total adopted practices by the total eligible practices. This is described further in chapter 6.

We were able to obtain individual level respondent data for four surveys over the period 2012-2018. During this time while the questionnaires were slightly updated to align with current environmental conditions and issues, the questions were essentially identical, and we viewed them as reliable to understand temporal dimensions of adoption. Each year, the questionnaires were administered by telephone, with a random and representative sample of roughly 500 agricultural producers in Alberta who had gross farm sales of at least $10,000. Across the years, the survey results are considered to be accurate to within ±4.4 percentage points, 19 times out of 20, of what they would have been had the entire population of Alberta farms been surveyed (AAF 2018). Nonetheless, we recognize the possible existence of non-response bias in these surveys. Agricultural market research firms were hired to collect respondent data, and the pool of producers contacted were only those who had previously agreed to be part of a Canadian agricultural producer panel. Thus, it is plausible the respondents are not as representative of the true population as we would prefer.

The questionnaire was split into different sections and included screening questions, farm characteristics, ESA practice adoption, and individual farmer characteristics. An overview of Esa practices and adoption requirements listed under the 2012-2018 ESAT survey is presented in Appendix 1, table A1. A full description of each ESA practice can be found below starting in section 2.3. The survey was weighted to ensure that the overall sample's regional and gross farm sales reflected the distribution of the most recent corresponding Census of Agriculture. The Census of Agriculture is conducted by Statistics Canada and provides a statistical portrait of Canada's agricultural industry (Statistics Canada 2020). The 2012 survey was weighted to reflect the 2006 Census of Agriculture, both the 2014 and 2016 surveys were weighted using the 2011 Census, and the 2018 survey was weighted to reflect the most recent 2016 Census.

Table 2.1 describes some farm and farmer descriptive statistics for the 2012-2018 ESAT survey. We find between 2012 to 2018, the respondents are relatively comparable for most farm and farmer characteristics. Across the years, most respondents are between the age of 45 to 64, which is comparable to the 2016 Census of Agriculture for Alberta (AAF 2020). Less than a third of respondents have a degree (or diploma) in an agriculturally related area, and less than a third have attended conservation training in the past two years. Most respondents are currently maintaining their land, although almost a third were planning to reduce their operation and almost a quarter were planning to expand. Respondents were split between primarily owning land and equally owning and renting, but across all years only 1% of respondents were primarily renting. The percentage of primarily livestock producers increased to almost half of all respondents for the 2016 and 2018 survey years, where 2012 and 2014 respondents were more likely to be primarily crop producers. The number of respondents who stated they had gross farm revenue greater than $250, 000 also increased over time, but decreased between the 2016 and

2018 survey. Lastly, almost half of respondents reported they had an EFP. This is significantly higher than what was reported in the 2017 Farm Management Survey, which found only 25% of producers in Alberta had an EFP (Statistics Canada 2017). This may speak to a level of non-response bias, where producers who participated in this survey may be more conservation oriented or more likely to participate in environmental programmes

Table 2.1. Mean Descriptive Statistics of Farm and Farmer Characteristics Across the 2012, 2014, 2016 and 2018 ESAT Survey.

	2012 Survey	2014 Survey	2016 Survey	2018 Survey
Farmer Characteristics				
Age: 18 to 44	11%	7%	10%	10%
Age: 45 to 64	54%	59%	49%	51%
Age: 65+	35%	33%	30%	38%
GRF > $250k	35%	40%	47%	42%
Has an EFP	44%	46%	45%	48%
Has an Agricultural-Related Degree	28%	30%	32%	28%
Attended Conservation Training	28%	29%	28%	21%
Farm Characteristics				
Planning to Expand Operation	20%	19%	19%	16%
Planning to Reduce Operation	27%	29%	24%	27%
Planning to Sell Operation	7%	4%	4%	6%
Maintaining the Operation	47%	48%	53%	50%
Primarily Owns Land	47%	44%	39%	42%
Primarily Rents Land	1%	1%	1%	1%
Equally Own and Rent	51%	55%	60%	56%
Primarily a Livestock Producer	35%	31%	43%	49%
Primarily a Crop Producer	45%	54%	31%	36%
Both Livestock and Crop	20%	15%	25%	16%

Source: AAF (2018); Government of Alberta (2016); Government of Alberta (2014); Government of Alberta (2012)

2.3 Categorization of Best Management Practices (BMPs)

This section provides a breakdown of BMPs associated with each agri-environmental risk area in Alberta. All categorizations of BMPs follow what is described in the 2012-2018 ESAT surveys. Some descriptions for practices come directly from the survey reports, where other descriptions are derived from relevant studies and government documents. All practices were identified in the 2012, 2014, 2016 and 2018 ESAT survey.

2.3.1 Water Quality and Quantity

Practices under this risk area are meant to prevent pollutants from entering wells, waterways, lakes, wetlands, or ground water for quality control, and to prevent runoff from irrigated fields for quantity purposes (AAF 2018). Twelve practices are recommended for producers as shown in Table 2.2.

Table 2.2. Water Quality and Quantity ESA Practices.

Practice	Description
Properly seal & maintain active wells	Maintenance of active wells includes shock chlorination, collection of water samples, among others (Government of Alberta 2018).
Avoid draining/filling in natural wetland sloughs	This practice is to retain wetlands in Alberta and to prevent further alteration of local ecosystems. The Pembina institute states wetland losses in Alberta result in an economic loss of $3,650 per hectare annually (Wetlands Alberta 2021).
Maintain 10 metre buffer area from water wells & water bodies when applying pesticides	Pesticides are a common water contaminant from agricultural sources, as well as a significant contaminant for human and livestock consumption (AAFRD 1998). Maintaining buffers reduces the potential for contamination and follows guidelines set by Alberta's Environmental Code of Practice for Pesticides.
Choose wintering sites to avoid manure contamination	Wintering sites are where cattle are fed during winter months and these sites can be a feeding area, a sheltered area and/or a water source (AAFRD et al. 2006). Manure builds up in these areas and measures must be taken to avoid manure contamination of adjacent water bodies.
Maintain buffer areas along edge of natural water bodies	Buffer areas help promote long term sustainability of water bodies and are used to properly maintain livestock and protect wetlands.
Manage livestock access to water bodies that are used as a water source	Water bodies used for livestock range from lakes, wetlands, creeks, and sloughs. Managing livestock access aids with maintaining the health of these areas, including improved water quality, reduced pollutants, among others (AARD 2010).
Control runoff from manure storage	To prevent and reduce contaminants to water bodies from livestock manure.

Apply chemical fertilizer at recommended rate	Recommended to apply fertilizer based on soil or tissue tests as nutrient requirements differ by crops, and the soils' ability to supply nutrients. Producers should follow the 4R nutrient stewardship principles[2].
Control runoff from livestock pens	Includes considering a livestock pens proximity to water ways, the slope of the sight to reduce runoff, and in Alberta's climate, the snow load which will increase site runoff (AAF 2015).
Plug or seal abandoned wells	This BMP includes properly sealing using bentonite or other approved material.
Control runoff from feeding areas	Similar to controlling runoff from livestock pens. The main goal is to reduce contaminants and prevent environmental risks to waterways from livestock feeding.

Source: AAF (2018)

2.3.2 Soil Conservation

Since 1998, Alberta has regulated under the Soil Conservation Act where landholders must take appropriate actions a) to prevent soil loss or deterioration from taking place, or b) if soil loss or deterioration is taking place, to stop the loss or deterioration from continuing (Government of Alberta 2010). Alberta Agriculture and Forestry (AAF) describe these practices under the ESAT survey as management strategies (and practices) that prevent soil erosion or fertility changes because of nutrient depletion. Table 2.3 describes the three practices recommended to producers.

Table 2.3. Soil Conservation ESA Practices.

Practice	Description
Use of Reduced Tillage	According to Agriculture and Agri-Food Canada, no till or reduced tillage aids with moisture conservation, reducing soil erosion, improves soil organic matter, as well as increasing crop yields. Further environmental benefits include improved soil and water quality, biodiversity, and a reduction in greenhouse gas emissions (Government of Canada 2014).
Use of Pulse Crops in Rotation	Research by Agriculture and Agri-Food scientist Dr. Yantai Gan found that compared to summer fallowing, diversifying cropping system with pulse crops results in: i) improved soil use; ii) improved soil nitrogen availability; iii) increased crop production; and iv) helps with mitigating greenhouse gas emissions (Government of Canada 2018).
Use of Winter Cereals in Rotation	Similar to pulse crops in rotation. The main idea is diversifying the cropping system to improve environmental conditions.

Source: AAF (2018)

[2] The 4R Nutrient Stewardship protocol stands for "Right Source, Right Rate, Right Time, Right Place."

2.3.3 Grazing Management

Grazing management practices can reap environmental benefits such as reduced soil erosion, better air and water quality, more biodiversity, and improved wildlife habitats (AAF 2018). Alemu et al. (2017) reported that several studies found grazing impacts forage quality and productivity, animal productivity, soil quality and water cycling, and soil carbon sequestration. The use of grazing is commonly used in the beef cattle industry, especially as part of pasture and rangeland management, where the industry alone contributes 43% of Canadas national agricultural emissions (Alemu et al. 2017). Given the prominence of Alberta's beef cattle industry, the use of management practices under this category could be important in reducing emissions in Alberta. Two main practices were recommended; five other practices were considerations for grazing management (Table 2.4).

Table 2.4. Grazing Management ESA Practices.

Practice	Description
Protect riparian areas from grazing to prevent overuse	Riparian areas are often strips of green vegetation around creeks, wetlands, sloughs, rivers, or lakes (Government of Alberta 2020). These areas are used to prevent runoff in waterways (filter and buffer), trap and store sediments and nutrients, help maintain biodiversity, reduce soil erosion, among other benefits (Hillard & Reedyk 2020). Producers should prevent livestock from over-grazing.
Time grazing to avoid vulnerable times of the year for riparian areas	Similar to the above description, except protecting riparian areas during specific times of the year. Wet soils, especially during the springtime in Alberta, are vulnerable to plugging and compaction (Fitch 2003). Thus, avoiding grazing during high moisture conditions is advised.
Considered Practices[1]	
Manage native rangelands[2]; Time the grazing of native rangelands; Rotate use of pasture; Annually consider or adjust stocking rate to balance livestock forage demand with available forage supply; Move livestock away from riparian areas (with tools such as salt blocks, windbreakers, herding)[2].	

Source: AAF (2018)

Note: [1]These practices were not included as a performance measure under the ESAT surveys.

[2]These practices were not included as additionally considered practices under the 2018 ESAT survey.

2.3.4 Manure Management

Chadwick et al. (2011) explain that manure contains significant traces of nitrogen (N), and since manure is mostly inorganic and water, these factors produce N_2O and CH_4 emissions. Unmanaged accumulation of organic waste can cause harm to both humans and animals through environmental and health concerns (Montes et al. 2013). Montes et al. (2013) explain that leaching from nitrate (NO_3-) and pathogens to ground water, degradation of soil production potential (via build-up of nutrients, salts, and metals), as well as emissions of gases, are all health and environmental risks that can occur from unmanaged organic waste. The purpose of manure management is to preserve and recycle nutrients in livestock production (Montes et al. 2013), and through these actions, reduce emissions of gases through handling, treatment, and storage of manure (Peterson et al. 2013). Table 2.5 provides an overview of the practices included under this risk area.

Table 2.5. Manure Management ESA Practices.

Practice	Description
Avoid applying compost/manure on frozen or snow-covered ground	When applying manure or compost on frozen or snow-covered grounds, once it melts, runoff occurs resulting in contaminants to waterways. Depending on the slope of the land, Alberta guidelines require a setback distance of application from open bodies of water.
Avoid applying close to waterways to minimize increased nutrients runoff	To protect water quality and reduce the risk of contamination.
Avoid storing manure near abandoned/active water wells	This is to reduce the risk of runoff contamination.
Keeping manure records	In Alberta, based off the Agricultural Operations Practices Act (AOPA) manure management standards require confined feeding operations (CFOs), or anyone handling 500 tonnes of manure or more per year, to keep manure records for a minimum of five years (AARD et al. 2013). These records include the application, production, and transfer of manure.
Frequency of application	Manure application rates must be calculated based on nutrient demands. Manure affects soil quality by possibly increasing salinity and soil compaction, with odour affecting air quality (AAF 2008).
Incorporate manure after applying	Reduces emissions, improves nutrient longevity, and promotes mineralization (Government of Manitoba 2007).
Sampling and analyzing the manure for nutrient content	Related to frequency of application and reducing environmental effects.

Manure application based on Phosphorus (P) or Nitrogen (N) & Phosphorus	Apply manure based on crop phosphorous, nitrogen, or both, rates. This is to reduce negative effects on soil quality and water quality from runoff of P and N contaminants.
Applying liquid manure	Liquid manure is not recommended for farms with irrigation growing crops for consumption. However, liquid manure can be beneficial for soil health as it is rich with microorganisms.

Source: AAF (2018)

2.3.5 Wildlife Habitat Conservation

Wildlife habitat conservation preserves natural habitats and wetland ecosystems and the plants and animals that thrive there (AAF 2018). Alberta has completed extensive work in this area working with partners such as Ducks Unlimited Canada and the Alberta North American Waterfowl Management Plan (NAWMP) partnership, as well as having implemented policies such as Alberta's Wetland Policy. The Wetland Policy defines wetlands as: "Land saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic (water loving) vegetation, and various kinds of biological activity that are adapted to a wet environment (Government of Alberta 2020)." Studies such as Pywell et al. (2015) have found that wildlife friendly farming can increase crop yields through enhanced ecosystems. Other studies such as Pywell et al. (2012) focus on biodiversity loss from agricultural intensity and increased food production, finding that integrating conservation methods that are wildlife-friendly can benefit both rare and common species. Table 2.6 shows the three practices included under this risk area.

Table 2.6. Wildlife Habitat Conservation ESA Practices.

Practice	Description
Retain bush or native grassland	These BMPs are meant to retain biodiversity and ensure the conservation of habitats for wildlife on agricultural lands.
Manage grazing to encourage natural rejuvenation of understory in woodlands	
Manage grazing for wildlife habitat	

Source: AAF (2018)

2.3.6 Energy and Climate Change

These practices mainly focus on removing or mitigating emissions on agricultural lands and operations. Table 2.7 provides an overview of the three practices recommended to producers.

Table 2.7. Energy and Climate Change ESA Practices.

Practice	Description
Carbon Credit Trading Participation	Participation involves a producer adopting practices to create carbon offsets to trade in the Alberta carbon market. The purpose is to reduce greenhouse gas emissions, a farm's carbon footprint and to produce extra income (Government of Alberta 2020).
Renewable Power[1]	This includes, but is not limited to, solar energy through the addition of solar panels, wind turbines for wind energy, geothermal energy, biogas from agricultural waste, etc.
Energy Saving Practices	Some examples include separate electricity meters or separate gas meters.

Source: AAF (2018)
[1]This was identified as producers who answered they produce grid-connected electricity.

2.3.7 General Practices and Agricultural Waste Management

General practices are meant to reduce emissions or promote sustainable agriculture, and generally do not fit within other agri-environmental risk areas. The agricultural waste management risk area involves recycling agricultural plastics (baler twine, feed bags, silage wraps and/or bale wraps) and crop protection product containers. Table 2.8 provides an overview of these recommended practices.

Table 2.8. General Practices and Agricultural Waste Management ESA Practices.

General Practices	Description
Precision farming - Variable rate technology: Crop protection products and/or Commercial Fertilizer	Variable rate technology (VRT) allows for fertilizer and other crop protection products to be applied at differing rates across different landscapes and soil types on a producer's land. This aids with the correct level of these products being applied to minimize effects on soil quality and water quality.
Soil sampling fields at least once every three years	This relates to manure application, fertilizer application, and understanding nutrient needs.
Trees for agriculture purposes	This includes planting trees for shelterbelts and/or windbreakers, wildlife habitat, soil conservation, etc.

Agricultural Waste Management	
Recycle agricultural Plastics	Plastic waste poses environmental threats to farmland, with many producers resorting to burning plastics, sending them to landfills, or burying them on-farm (Government of Alberta 2016).
Recycle crop protection product containers[1]	
Properly dispose of veterinary waste[2]	

Source: AAF (2018)
Note: [1]This was not included as a performance measure
[2]This was not included as a performance measure and was only mentioned in the 2012 and 2014 survey years.

Chapter 3: Literature Review

Understanding a producer's decision-making process is imperative for influencing the adoption of Best Management Practices. A considerable amount of the agri-environmental literature has surrounded producer adoption behaviour of BMPs, including perceptions of barriers and motivators to adoption. Both barriers and motivators have been extensively studied with many inconclusive or contrasting findings (Rodriguez et al. 2009; Baumgart-Getz et al. 2012; Prokopy et al. 2019; Pannell et al. 2006). Factors which have been more consistently significant however are often used to aid policymakers towards shaping more effective agri-environmental policies (Pannell 2008; Pannell et al. 2006). Thus, understanding these factors is essential since these policies are also notable components towards a producers decision-making process (Pannell 2008; Greiner & Gregg 2011). Generally, barriers and motivators towards adoption can be separated into three broad groups: 1) economic factors; 2) knowledge and information sources; and 3) farm and farmer characteristics. Below a synopsis of the BMP adoption and agri-environmental literature is provided.

3.1 Developed and Developing Nations

The bulk of the agri-environmental literature has centred on barriers to adoption in developing countries, primarily addressing food security and poverty mitigation (Murage et al. 2015; Lipper 2014; Chandra et al. 2018; Steenwerth 2014), financial barriers and access to markets (Atisa et al. 2014; Pannell et al. 2014) and climatic risks to subsistence farmers livelihoods (Khatri-Chhetri et al. 2017; Arslan et al. 2015; Zougmoré et al. 2016). Producers in developing nations face a different set of challenges in comparison to developed nations, such as affordability and accessibility to external inputs like fertilizers and machinery (Lee 2005). The decision-making process for developing nation producers includes social networks, the political climate, labour intensity, poverty, and management capacity, all of which significantly differ from developed nation producers (Lee 2005; Takahashi et al. 2020; Antle & Diagana 2003). For these reasons, this thesis will forgo using any literature from developing nations, as these producer behaviours are not directly comparable to producer behaviour in developed nations.

3.2 Economic Factors

3.2.1 Economic Barriers

According to the 2011 Farm Environmental Management (FEM) Survey, roughly 55% of Canadian agricultural producers indicated economic barriers as a reason for not implementing BMPs (Statistics Canada 2013). High uptake costs, maintenance costs, financial uncertainty, and perceived risks to profitability are among some of the economic barriers frequently mentioned within the literature (Prokopy et al. 2019; Rodriguez et al. 2009; Liu et al. 2018; Pannell et al. 2006; Roesch-McNally et al. 2017; Nowak 1987). A producer's economic capacity, often described as capital availability or household income, is hypothesized to be a significant indicator for adoption. Kim et al. (2005) find that higher household income influenced positive rates of adoption among beef cattle producers, alluding that capital availability is important to BMP adoption. Baumgart-Getz et al. (2012) found that many researchers hypothesize holding higher household income (on or off-farm) may ease the burden of investing in BMPs. This may relate to these farmers already holding higher levels of economic return and having the ability to bare more risk.

A farmer's risk perceptions and risk attitudes towards conservation practices has been used as a parameter in understanding adoption behaviour (Greiner & Gregg 2011; Liu et al. 2018; Greiner et al. 2009; Ghadim et al. 2005; Ranjan et al. 2019). Ervin & Ervin (1982) develop a risk-aversion index to identify producers' preferences for avoiding risk, finding farmers' who are more risk adverse are hesitant to commit to short-run losses for less certain benefits of conservation practices. They indicate that operators with higher risk-aversion values are expected to adopt fewer practices (Ervin & Ervin 1982). Greiner et al. (2009) find risk perceptions and preferences influence information acquisition in the adoption process and sources of risk are important to adoption decisions. For example, they suggest that perceived threats of environmental regulation can lead graziers to take preventative action resulting in practice adoption. Literature has also shown producers risk perceptions regarding weather variability is also significant towards influencing adoption as this relates to perceived short-term economic losses or reduced productivity (Mase et al. 2017; Haden et al. 2012). On the other hand, Baumgart-Getz et al. (2012) provide an alternative viewpoint for risk perceptions by hypothesizing BMPs have become more common and thus perceived risk of adoption has diminished over time. Through a thorough meta-analysis, they found risk was insignificant with minimal heterogeneity, suggesting risk has diminished over time. Nonetheless, studies continue to include risk as a factor influencing adoption decisions. This is mostly attributed to the argument that vast heterogeneity of technologies and producer characteristics lead to altering risk perceptions and tolerance (Liu et al. 2018; Reimer et al. 2012).

3.2.2 Financial Incentives

Feather & Amacher (1994) explain that financial incentives allow producers to share the burden of risk from adoption and inadvertently becomes a method to overcome adverse perceptions. Given the voluntary nature of BMPs, financial incentives are often cited as a method to promote and encourage adoption (Palm-Forster et al. 2017; Cooper & Keim 1996). Literature has surrounded the use of auctions for conservation contracts (Palm-Forster et al. 2016; Wichmann et al. 2016; Kits et al. 2014), cost-share programming (Paudel et al. 2008; Gillespie et al. 2007) and general incentive payments, such as pay-for-performance and tax credits (Palm-Forster et al. 2017; Cooper 2003), as these are commonly used financial incentives. Wichmann et al. (2016) explain that socially optimum levels of adoption are not likely to occur as producers face net financial costs, thus, to negate this externality, producers must be compensated. As Pannell (2008) states, positive incentives, such as financial incentives, need to be just large enough to prompt adoption. However, Paudel et al. (2008) found that cost-shares are often not equivalent to the true costs of adopting BMPs, and thus increased values of these cost-shares are necessary to promote adoption.

Many researchers have also argued that financial incentives may not be the most efficient way to encourage adoption (Feather & Amacher 1994; Pannell 2008). Feather & Amacher (1994) found improving producers information levels is more cost-effective than financial incentives or direct regulations. Palm-Forster et al. (2016) argue that conservation auctions are a key policy tool, although, they are only cost-effective if they attract enough of a population to submit bids. Without enough producers participating, projects could be funded at too high of a cost per unit of environmental benefit procured (Palm-Forster et al. 2016). Pannell (2008) finds that financial incentives (positive incentives) are only effective when public net benefits are highly positive, and private net benefits are almost zero. Above all, Greiner & Gregg (2011) scrutinize financial incentives affirming that policies do not consider factors influencing adoption, thus failing to both engage the policy audience, and achieve conservation targets.

3.3 Knowledge and Information Sources

3.3.1 Information Sources

Several studies have proposed that access to, and quality of information, influences farmers' adoption decisions (Baumgart-Getz et al. 2012; Feather & Amacher 1994; Ranjan et al. 2019). Farmers gain knowledge about conservation practices through a multitude of networks, all of which have differing levels of insight regarding costs and benefits of BMPs. A lack of access to information, and the quality of information, have been identified as a significant barrier for adoption (Baird et al. 2016; Bjornlund et al. 2009). Extension services are commonly used to disseminate information using a top-down approach between scientific research and government programs, to farmers at an individual level (Boxall 2018; Rollins et al. 2018; Rodriguez et al. 2009). Pannell (2008) defines extension as technology transfer, education, communication, demonstrations, and support for community network.

Recently, there has been a shift in the importance of extension services due to limited funding and reduced promotion of extension, including an increase of inexperienced personnel (Vanclay & Lawrence 1994; Rodriguez et al. 2009). Rodriguez et al. (2009) found that many extension agents are unfamiliar or are not well prepared to inform farmers about sustainable agriculture, especially ill informed for the needs of specific farming situations. This relationship between extension funding and extension personnel has been limited throughout the research however and is a significant gap in the literature. The level of trust in information sources has also been significant towards farmers perceptions for BMP adoption (Arbuckle et al. 2015; Sutherland et al. 2013; Ranjan et al. 2019). Many farmers are less trusting of government actors and prefer to receive information on management decisions from other farmers, conservation agencies, among other trusted sources (Ranjan et al. 2019; Dietz et al. 2007; Arbuckle et al. 2015). Thus, connecting farmers to trusted sources for communicating conservation information may increase adoption rates. Regardless, studies have also shown that extension, promotion, and marketing programs by government personnel and/or the private sector can be positively correlated to adoption decisions (Pannell et al. 2006).

Other studies, such as Pannell et al. (2006), recognize the adoption decision-making process is a social process inadvertently influenced by a farmer's local social network. Neighbours, family, and peer farmers influence producers' norms, beliefs, and preferences for adoption (Rodgriguez et al. 2009; Liu et al. 2018; Baumgart-Getz et al. 2012; Pannell et al. 2006). Even ethnic or cultural divisions within a landholder population can be a barrier to the flow of information and can ultimately negatively affect adoption (Pannell et al. 2006). Although, studies have also determined producer's association and membership to certain organizations (such as conservation organizations and catchment groups) can be positively related to adoption (Pannell et al. 2006; Campbell et al. 2011; Gillespie et al. 2007; Tamini 2011). Studies such as Gillespie et al. (2007) find beef farmers increased contact with Louisiana agricultural organizations[3] reduced unfamiliarity of BMPs and resulted in higher levels of adoption for practices specified for beef producers. However, the literature has not addressed whether these organization and/or catchment groups are preferred because they provide financial aid (or technical support) or because they provide useful information.

Studies have also shown that a farmer's proximity to adopters of BMPs can impact adoption rates (Pannell et al. 2006; Yang & Sharp 2017). Closer proximity to adopters may relate to the observability of a practice, which helps reduce unfamiliarity and risk perceptions for a BMP, such as observing increased yields from adopting reduced tillage (Pannell et al. 2006). This finding has brought into question the role of spatial determinants to adoption, where findings such as Baird et al. (2016) showed that access to regional actors resulted in farmers being more likely to adopt conservation practices than those without access. Spatial effects have only recently been added as a component that may influence BMP adoption, especially the consideration of spillover effects from farmers management decisions and preferences (Yang & Sharp 2017). Yang & Sharp (2017) found spatial spillover effects for dairy farmers in New Zealand and based on information exchange among local farmers, they conclude policies should address the whole community as opposed to individual farmers. Across the literature however, the role of spatial effects is exceptionally limited for both effects of community or neighbourhood relationships and spatial effects of extension personnel (Liu et al. 2018).

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[3] This study identified Louisiana agricultural organizations as Natural Resources Conservation Services and Cooperative Extension Service.

3.3.2 Information from Agri-environmental Policies

As previously stated in section 1.1, agri-environmental policies and programs are used to guide and incentivize producers to alter their land-management decisions towards using more sustainable practices. Pannell (2008) states that policies and programs aim to encourage change through education, awareness raising, technology transfers, research and development, regulations, subsidies, along with other economic instruments. Limited research has been conducted to better understand how or if these policies and programs alter the decision-making process. Further, it is also not well understood if they have specifically influenced farmers to adopt BMPs over time.

Pannell (2008) produced one of the most cohesive research papers on policy mechanisms for encouraging environmentally beneficial land-use change. Pannell does this through an analysis of public and private benefits. Five policy mechanisms were considered, including positive incentives (financial incentives to encourage change), negative incentives (inhibit change), extension, technology development, and no action (informed inaction). When public net benefits are highly positive, the use of positive incentives is the best fit if private benefits are close to zero, or extension if private benefits are slightly positive. When public net benefits are highly negative, negative incentives are the best policy mechanism if private net benefits are slightly positive. Technology development, such as research and development, is only to be used if private costs are similar (or outweigh) public benefits. One of the most significant findings is the use of no action. Pannell (2008) explains this mechanism should only be utilized when private net benefits outweigh public costs, public and private net benefits are negative, private net benefits are high enough to prompt adoption, or when private net costs outweigh public net benefits.

Other studies have attempted to address components that may affect policy support or efficiency with heterogenous results. Greiner & Gregg (2011) question why conservation policies and programs in Australia have been relatively ineffective, hypothesizing that the top-down approach to policies lack the consideration of factors that influence adoption. They find that farmers motivations influence their stated barriers to adopting new (or additional) conservation activities, and that well designed policies can lead to self-developed interest in conservation (Greiner & Gregg 2011). Savage & Ribaudo (2013) state producers may respond to more strict environmental regulations by adopting BMPs, without assistance, to overcome foreseeable barriers from new regulations. Haden et al. (2013) found policies focusing on mitigation practices that offer direct benefits are more likely to be preferred by farmers. Whereas Niles et al. (2013) found farmers who held greater climate risk concerns were more likely to participate in government incentive programs. Regardless, Reimer et al. (2014) argue that top-down approaches to policy implementation have been largely unsuccessful; considering most agri-environmental policies are top-down in nature, this is important to recognize.

Across the agri-environmental policy literature, only a small proportion of research has even considered farmers' preferences for specific policies and programs. Greiner & Gregg (2011) found grazing farmers in Australia rated government regulation as the least effective policy measure, although they agreed regulation is necessary for defining environmental duty of care and setting minimum standards. Reimer & Prokopy (2014) studied the perception of the U.S. Farm Bill Conservation programs, finding that farmers perception of the complexity of the program's application process was a barrier to participation for farmers. Dietz et al. (2007) noted that policies with direct impacts to producers 'lives and pocketbooks,' such as a gasoline tax, were the least supported. Some studies have also addressed farm and farmer characteristics which may influence farmers policy opinions (Conrad et al. 2017; Orazem et al. 1989; Niles et al. 2013). For example, Orazem et al. (1989) found farmers education, farm experience, and operation type can influence policy perceptions. Regardless, limited research has occurred in developing nations addressing preferences or the effectiveness of agri-environmental policies. Even though papers like Pannell (2008) attempt to provide a guideline on how to implement policy mechanisms, they do not consider if farmers are willing to participate or agree with their implementation.

3.4 Farm and Farmer Characteristics

Farm and farmer characteristics are common additions to a BMP adoption analysis across the agri-environmental literature (Baumgart-Getz et al. 2012; Prokopy et al. 2008; Prokopy et al. 2019). The significance of these characteristics towards influencing adoption are often debated, with heterogeneous results across disciplines (Prokopy et al. 2008; Baumgart-Getz et al., 2012).

Although, some studies have found common characteristics that have been negatively associated with adoption over time. Prokopy et al. (2019) found that farming experience, and subsequently farmers age, is negatively associated with BMP adoption after a thorough meta-analysis of the literature. As explained by Baumgart-Getz et al. (2012) and Ervin & Ervin (1982), older farmers have a shorter planning horizon which may reduce their capacity or willingness to adopt. Further, Prokopy et al. (2008) found livestock farmers are significantly less likely to adopt conservation practices compared to crop farmers. Most other characteristics which have been hypothesized to negatively impact adoption have remained inconsistent or insignificant (Prokopy et al. 2019; Pannell et al. 2006; Baumgart-Getz et al. 2012).

On the other hand, studies have also found certain characteristics to be significant towards increasing the likelihood of adoption (Baumgart-Getz et al. 2012; Prokopy et al. 2019; Ranjan et al. 2019). Number of acres farmed, education level, conservation training, environmental attitudes and awareness, and higher income and higher gross farm revenue have been found to be positively associated with adoption and adaptation (Prokopy et al. 2008; Prokopy et al. 2019; Pannell et al. 2006). Baumgart-Getz et al. (2012) however found that education was insignificant after a meta-analysis of 77 studies; although, Prokopy et al. (2008) meta-analysis found education was more likely to be found significant and was never found to have a negative impact on adoption. Conservation training was found to be significant in two meta-analysis studies (Baumgart-Getz et al. 2012; Prokopy et al. 2019); but Prokopy et al. (2019) explain that too few studies have included this factor as an explanatory variable in their analysis for a conclusive finding. Thus, more studies should include conservation training as a factor hypothesized to influence adoption to determine its impact on adoption decisions. Income is often associated with economic capacity or income from farm sales, and studies have often concluded that income, capital, and gross farm revenue are positively associated with adoption (Liu et al. 2018; Prokopy et al. 2019). Nowak (1987) found larger-scale farmers have more flexibility with their decision making as they have greater access to resources allowing them to handle more risk, and subsequently adopt more practices. Farmers environmental and climate attitudes can also positively influence conservation adoption decisions. For example, agricultural producers who believe, or agree, that climate change is predominantly from anthropogenic origins are more likely to support mitigative action and to alter their management practices (Arbuckle et al. 2013; Barnes & Toma 2012). The significance of specific characteristics, however, remains heterogenous across studies, typically depending on region-specific factors (Pannell et al. 2006; Liu et al. 2018; Yang & Sharp 2017).

3.5 Prior Empirical Methods and Theories Behind BMP Adoption

3.5.1 Theoretical Approaches

Studies often employ economic theory and applications to better understand components that influence farmers to adopt BMPs. A common method in the economic literature is the application of the utility theory or expected utility theory (Davey & Furtan 2008; Greiner & Gregg 2011). Economists tend to narrow utility to financial goals, especially the notion of profit maximization, on the theory that farmers are rational decision makers and aim to maximize farm profits (Greiner & Gregg 2011; Lin et al. 1974; Lynne et al. 1988). This has often been criticized in the literature where many state profit maximization is a gross simplification of a more complex decision-making process (Lynne et al. 1988; Greiner & Gregg 2011). Lynne et al. (1988) explains this theory fails to account for attitudinal variables, whereas Greiner & Gregg (2011) state this theory forgoes producers' goals and aspirations, especially in the context of land stewardship. Utility theory beyond profit maximization is less restrictive as it follows the notion that farmers will adopt practices if they improve their perceived utility, which is unique to each producer (Rollins et al. 2018; Greiner & Gregg 2011). Theories from other disciplines have also been used in economic studies. This includes the theory of planned behaviour, now the Reasoned Action Approach (RAA), where an individual's decision to adopt is a function of their intent to adopt (Floress et al. 2018; Reimer et al. 2012). Earlier literature suggested theories of behaviour using positive or negative valences in a farmer's psychological environment (Lynne et al. 1988). This theory has often been incorporated into utility maximization.

3.5.2 Empirical Approaches

Economists tend to employ both parametric and non-parametric approaches dependent on the dataset used. Non-parametric methods across the literature include correlation analysis, mean comparison, cluster analysis, among others (Liu et al. 2018). Common parametric methods include the use of ordinary least squares, dichotomous models (logit, probit, and tobit), bayesian models, along with spatial models and time series applications (Liu et al. 2018; Paudel et al.

2008; Prokopy et al. 2008). Modelling techniques differ across research objectives and chosen variables for analysis, specifically the chosen dependent variable. Examples include Gillespie et al. (2007) who use a multinomial logit analysis to study factors that influence non-adoption of conservation practices; and Davey & Furtan (2008) who employ a probit function to model adoption decisions following the development of a lexicographic utility function. Often economic research tends to utilize a probit or logistic model as they follow a binary dependent variable for whether a producer did or did not adopt a practice (Prokopy et al. 2008). In general, there is a high degree of heterogeneity with respect to methodology for researching conservation practices and their adoption. The empirical method is highly dependent on research objectives and the availability or reliability of data.

Economic studies often use surveys, such as the tailored design method[4] (Paudel et al. 2008), to produce a large enough sample size for further analysis. Surveys often include different economic methods to examine adoption decisions. This can include elements from experimental economics, such as conservation auctions which explore financial incentives for adoption (Boxall et al. 2013; Kits et al. 2014). Another method is the use of stated preference, specifically contingent valuation surveys to elicit willingness-to-pay (WTP) or willingness-to-accept (WTA) values for adopting or dis-adopting specific practices (Hudson & Hite 2003; Cooper & Keim 1996). Many of these surveys are used in conjunction with public or private datasets, such as a study by Cooper (1997) who combined contingent valuation survey data with market data from four watershed regions in the United States. A more recent consideration has been the addition of asking farmers' preferences, such as the use of Best-Worst Scaling (BWS) (Jones et al. 2013; Dumbrell et al. 2016). Further, many papers will use surveys purely to develop behavioural measures, such as observed or self-reported behaviours towards BMP adoption, or the use of Likert scales to understand farmers attitudinal characteristics (Floress et al. 2018; Greiner & Gregg 2011).

[4] The tailored design method includes customizing a survey based on extensive knowledge about a topic, for the individuals who are targeted for the survey, and resources available (Dillman et al. 2014). The method is meant to reduce survey errors including coverage, sampling, nonresponse, and measurement which may deter from the quality of the information collected (Dillman et al. 2014).

Chapter 4: An Overview of Agri-Environmental Policies in Canada and Alberta

Agri-environmental policies can influence Best Management Practice (BMP) adoption decisions if they engage the intended audience and apply policy mechanisms that incentivize change (Pannell 2008; Greiner & Gregg 2011). Research has derived components that can lead to the success of a policy or program, yet limited work has been done to understand whether current (past) policies are (have been) effective in inducing adoption decisions. With respect to Canadian policies and conservation programs, there has been a very limited analysis of whether environmental goals have been met or if these policies have promoted an uptake of BMP adoption (Boxall 2018). The purpose of this chapter is to provide an overview of agri-environmental policies and programs specific to Alberta, Canada. Later in this chapter, a comparison of Canadian and international agri-environmental policies and programs is provided.

4.1 Introduction of Agri-Environmental Policies in Canada

In 2003, the Agricultural Policy Framework (APF) was enacted, resulting in the first *national* agricultural policy framework in Canada (Office of the Auditor General of Canada 2008). These frameworks have continued to be enacted every five years. Thus, all APFs are five-year funding and program agreements among governments at the federal, provincial, and territorial levels. A program common amongst all four APFs to date (2003-2023) are environmental stewardship programs, which aim to reduce many environmental impacts from agriculture. To achieve environmental goals, these frameworks rely on subsidizing the adoption of on-farm beneficial (best) management practices (BMPs); typically, through a cost-share approach. After the completion of the first APF in 2008, the Auditor General of Canada criticized the program for its inability to determine to what extent the environmental stewardship programs reduced or mitigated environmental risks (Office of the Auditor General of Canada 2008). There was a lack of monitoring and reporting on program results, beyond basic outputs, leading to insufficient data needed to determine the efficiency or effectiveness of the APF. Since 2008, three additional APFs have been implemented: Growing Forward (2008-2013), Growing Forward 2 (2013-2018), and the more recent Canadian Agricultural Partnership (2018-2023).

A key component for producers to access support under these environmental stewardship programs, across all the APFs, is the need to have completed an Environmental Farm Plan (EFP). The EFP is a voluntary, whole-farm, self-assessment tool that helps producers identify environmental risks on their farm. The idea is then to have producers develop individual plans to mitigate these risks (ARECA 2020). An EFP holder can then access the remaining components of the environmental stewardship programs, which provide funding to incentivize the adoption of practices suggested in their producer plans. These stewardship programs remained relatively the same for Alberta across frameworks, with all Alberta programs continuing to require an EFP. All information regarding agri-environmental policies are specific to Alberta, Canada after direct consultation with the Environmental Stewardship Branch at Alberta Agriculture and Forestry (AAF). The only exception is the description for the Agricultural Policy Framework in section 4.2, where all information is directly from Boxall (2018) and the Office of the Auditor General of Canada (2008), and is general to producers in Canada, not just Alberta.

4.2 Agricultural Policy Framework (APF)

The 2003-2008 Agricultural Policy Framework held a budget of $5.2 billion and set out to enhance the Canadian agricultural sector's long-term profitability, competitiveness, and sustainability (Office of the Auditor General of Canada 2008). The APF had five distinct chapters: 1) Business Risk Management; 2) Food Safety and Quality; 3) Science and Innovation; 4) Environment; and 5) Renewal. The environment chapter had a budget of $600 million over the five-year period, which primarily focused on sustainable development practices. All programs under this environmental stewardship program are described in Table 4.1. These programs were designed to complement one another, starting with the completion of the Environmental Farm Planning program, as this served as an eligibility requirement for producers to participate in the remaining programs (Boxall 2018).

Table 4.1. Environment Chapter Programs for the 2003-2008 Agricultural Policy Framework.

Program	Description	National Budget
Environmental Farm Planning (EFP)	Voluntary process for farmers to identify environmental risks on their farm and develop plans to mitigate these risks. The EFP was required to receive funding under the NFSP and Greencover Canada programs. Producers were not paid for completing an EFP.	$70 Million
National Farm Stewardship Program (NFSP)	Meant to aid producers in adopting BMPs in the management of land, water, air, and biodiversity.	$176 Million
Greencover Canada Program	Improve grassland-management practices, protect water quality, reduce GHG emissions, and enhance biodiversity and wildlife habitat.	$58 Million
National Water Supply Expansion Program (NWSEP)	Meant to aid farmers with handling drought situations, such as through conducting groundwater studies.	$64 Million
Environmental Technology Assessment for Agriculture	Research-based program to evaluate the performance of innovative technologies of food production. This is meant to improve the long-term economic and environmental performance of agriculture.	$3 Million

Source: Information provided by Office of the Auditor General of Canada (2008) and Boxall (2018).

At the time of this APF, Agriculture and Agri-Food Canada developed environmental targets using six indicators from the National Agri-Environmental Health Analysis and Reporting Program (NAHARP). Despite these targets, indicators were not reported after the completion of the APF in 2008, and the impacts at the farm level remain unknown.

4.3 Growing Forward (2008-2013)

Growing Forward (GF) was the successor to the APF. Originally, GF Stewardship Plans Program was to be implemented in 2008, however, the start date was delayed until September 1st, 2009. To mitigate the delay in the program launch, there was retroactive funding available to successful applicants for eligible expenses incurred back to September 1, 2009. The Stewardship Plans Program was designed for producers to plan for operational improvements that would reduce their environmental impacts. Three programs were developed under the Stewardship Plans Program which are described in Table 4.2 and all descriptions were developed for producers in Alberta, Canada. All stewardship programs were cost-share programs (roughly 50%) where producers would incur some of the costs and the federal and provincial government would incur the rest. Each practice differed with respect to their funding maximums.

Table 4.2. Growing Forward Stewardship Plans Program Alberta, Canada.

Program	Description
Integrated Crop Management (ICM)	The ICM was developed for producers to develop a workplan to maximize crop inputs and for operational improvements to reduce their environmental impacts.
Manure Management	This program focuses on environmental impacts regarding manure storage and handling on producers' operations.
Grazing and Winter-Feeding Management (GWFM)	Meant for producers to develop a workplan to maximize the use of their grassland resources and plan for improvements on their operation to reduce their environmental impact.

Source: Government of Alberta (2020).

For all programs, the eligibility requirement was that a producer must actively be farming land for the production of crops or livestock, be registered with Growing Forward and have a completed EFP. Work plans were accepted for approval until January 31st, 2013, or until all available funds were exhausted.

4.4 Growing Forward 2 (2013-2018)

Following the end of GF in 2013, Growing Forward 2 (GF2) came into effect from 2013 to 2018. Alberta's GF2 implemented a similar on-farm stewardship program, which again used a cost-share system ranging from 30-70% for government funding and applicant contributions. Program funding maximums were up to $50,000 over the program term, with some exceptions. The on-farm stewardship program was split into five categories, which had targeted lists of BMPs and funding maximums found in Table 4.3; all are specific to producers in Alberta, Canada. Unlike prior APFs, GF2 permitted each province and territory to design its own suite of GF2 cost-shared programs to target their own environmental needs and circumstances (Government of Canada 2017).

Table 4.3. Growing Forward 2 On-Farm Stewardship Program Alberta, Canada.

Projects	**Funding Maximum**	**Cost Share**
	Category A: Grazing Management	
Riparian Area Fencing and Management	$10,000 - $50,000	Between 50-70% Government funding
Year Round/Summer Watering Systems		30-50% applicant contribution
Wetland Restoration		
Shelterbelt Establishment		
	Category B: Manure and Livestock Facilities Management	
Livestock Facility Runoff Control	$50,000 maximum for both	50% cost share
Livestock Facility and Permanent Wintering Site Relocation		
	Category C: Crop Input Management	
Improved Pesticide Management	$10,000-$15,000	50% cost share
Improved Nutrient Management		

Category D: Agricultural Waste Management		
Used Oil Storage Agricultural Plastic Waste Management	$2,000-$5,000	Between 50-70% Government funding 30-50% applicant contribution
Category E		
Innovative Stewardship Solutions *Consideration will be given to projects that provide innovative solutions	*Contact program coordinator prior to purchase or construction	

Source: Government of Alberta (2020).

Alberta also developed two additional provincial programs focusing on environmental stewardship funded by the provincial government. The Agricultural Watershed Enhancement (AWE) Program was established by Alberta Agriculture and Rural Development (AARD) and the administers of GF2-AWE. The program's main goal was to increase the adoption of wetland restoration and riparian health BMPs by facilitating the delivery of targeted extension programs focusing on water quality issues. Like AWE, the Watershed Resiliency and Restoration Program (WRRP) was developed by Alberta Environment and Sustainable Resource Development (ESRD). The WRRP was designed to increase the natural capacity of Alberta's watershed to reduce the negative effects from flooding and droughts. The program aimed to accomplish these goals through non-structural mitigation measures, ongoing stewardship, and providing information to producers. It is important to note that this program did not require producers to have an EFP, and was open to watershed groups, municipalities, and industry groups (Boxall 2018).

The second provincial program was the Confined Feeding Operation (CFO) Stewardship Program. The program was designed to aid Alberta livestock farmers and commercial manure applicators with minimizing their impacts on water quality and the environment (Yakimishyn n.d.). AARD describe three key areas associated with the CFO program:

i) Less of an agricultural impact on water quality by reducing risk of agricultural contaminants entering water sources.

ii) Improve business outcomes for livestock producers through more sustainable business decisions to support long-term efficiency and profitability.

iii) Improve market opportunities by helping producers meet current legislated environmental standards (Yakimishyn n.d.).

Individuals and businesses who operate a confined feeding operation in Alberta were eligible to participate, however, like other programs all producers must have completed an EFP. Under the CFO program, cost shares range from 30 to 70% of eligible expenses, with a funding maximum of $100,000 per applicant (certain projects have maximums between $15,000 to $70,000).

Alberta's expenditures on environmental stewardship were roughly $5.3 million annually over the course of the five-year policy. There was also a 50% increase in funding for Alberta under GF2 compared to GF, resulting in a total of $400 million for the duration of GF2. Similar to the APF (2003-2008) and GF (2008-2013), there is no publicly available evaluation on the effectiveness of the program or if any environmental goals were met.

4.5 Canadian Agricultural Partnership (2018-2023)

The current framework, the Canadian Agricultural Partnership (CAP), is a five-year $3 billion joint investment by the federal, provincial, and territorial governments (Government of Canada 2019). In Alberta, the province initiated the Environmental Stewardship and Climate Change (ESCC) producer program. This program is to support Albertan producers in assessing environmental risks on their operation, and to mitigate these risks through implementing BMPs. To be eligible for this program, individuals must be a) an active producer in Alberta who has a current EFP certificate or is working on an EFP and will have a letter of completion prior to the end of the project term; or b) a commercial manure applicator that has completed a manure management training event (or course after January 1st, 2019) (Government of Alberta 2018). The Alberta EFP changed its regulations in 2018, implementing a 10-year renewal requirement, thus any EFPs completed more than 10 years from their application date is invalid. CAP also has a merit-based review process, where projects are reviewed on a merit first-come first-serve, or by a technical review panel. Similar to the GF2's On-Farm Stewardship Program, the ESCC program was split into five funding categories described in Table 4.4.

Table 4.4. Environmental Stewardship and Climate Change (ESCC) Producer Program Funding Alberta, Canada.

Projects	Funding Maximum	Cost Share (%)
Category A: Riparian Management		
Riparian Area Fencing and Management Year-Round/Summer Watering Systems Watercourse Crossings Riparian Management Strategies Wetland and Riparian Assessments	$10,000-$100,000	If approved, some are 30% or 50% - decided after approval. If not, 50% cost share.
Category B: Manure and Livestock Facilities Management		
Engineering investigation/Feasibility assessment Construction (or upgrade) of surface water management system Improved Manure Storage Facilities Relocation of a Livestock Facility and Permanent Wintering Site or CFO Improved Land Application of Manure Manure and Livestock Facilities Management Strategies	$15,000 –$100,000	If approved, some are 30% or 50% - decided after approval. If not, 50% cost share.
Category C: Agricultural Input and Waste Management		
Improved Pesticide Management Improved Nutrient Management Plastic Rollers and Compactors Shelterbelts & Eco-Buffers	$7,000-$100,000	If approved, some are 30% or 50% - decided after approval. If not, 50% cost share.

Agricultural Input and Waste Management Strategies		
	Category D: Innovation	
Innovative Solutions	$100,000, but may be eligible for an additional $100,000	If approved 30% or 50%.
	Category E: Commercial Manure Applicators	
Improved Land Application of Manure Manure Management Strategies	$100,000	If approved, some are 30% or 50% - decided after approval.

Source: Government of Alberta (2021)

Alberta has committed the same level of investment from federal and provincial governments as GF2, resulting in $406 million across the five years. The investment is cost shared 60:40 between the federal and provincial governments (Government of Alberta 2018). Since this policy is still in effect, it is too early to note any final reporting for environmental stewardship programs.

4.6 Criticisms of Canadian Agri-Environmental Policies Over Time: From APF to CAP

The APF (2003-2008) was heavily criticized for the lack of monitoring and reporting. The Auditor General of Canada originally stated the lack of reporting limits the level of understanding for economic and environmental impacts of BMPs adopted through stewardship programs (Office of the Auditor General of Canada 2008; Boxall 2018). This also means the overall efficiency of the policy is unknown, thus necessary changes were unable to occur prior to developing Growing Forward (GF). During the implementation of Growing Forward (GF) in 2008, the Treasury Board Secretariat (TBS) failed to provide guidance on the development for Performance Measurement Strategies (PMS') for all non-grant and contribution programs (stewardship programs) (Government of Canada 2015). However, the Agri-Environmental Services Branch (AESB) did manage to develop PMS' for NAHARP and the National Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS), but these were plagued with weaknesses. These weaknesses included ill defined outcomes, activity and output-based measures as opposed to performance-based measures, and data tracking systems were not sufficiently developed prior to the implementation of GF (Government of Canada 2015; Boxall 2018).

Agriculture and Agri-Food Canada (AAFC) recognized in their 2012 evaluation report on Growing Forward that the successor policy, Growing Forward 2 (GF2), needed to move towards targeted, collaborative, and result-oriented approaches to address environmental challenges. Bilateral agreements were developed to define provincial and territorial programming, alongside reporting commitments such as performance indicators and targets for each program and subprogram (Government of Canada 2017). Priorities included the implementation of BMPs, assessment and consulting services, conservation training, and research and environmental analysis (Government of Canada 2017). Although, since the bilateral agreements included variations of wording or omissions of some indicators, GF2 cost-share programming performance was plagued with a lack of comprehensive, reliable, and empirical data for analysis. Unlike APF and GF, GF2 performance outcome for stewardship programs is unknown or unclear due to reporting errors rather than a complete lack of monitoring. It should be noted AAFC did survey some participants of GF2's stewardship program, where a high percentage stated they had adopted BMPs (Government of Canada 2018). Unfortunately, we are unable to determine how many participants were interviewed in general and how many were Albertan producers. Further, we cannot determine how accurate this information is. No information was able to be found on performance measures which will be implemented for the most recent policy, the Canadian Agricultural Partnership. Essentially, from APF to GF2 there were no notable improvements across each policy framework in the environmental areas.

Aside from issues involving reliable reporting, criticisms of each APF have surrounded the requirement of the Environmental Farm Plan (EFP). Under the original APF, Agriculture and Agri-Food Canada (AAFC) funded the EFP program, however, they were not allowed to possess any information contained in these plans (Office of the Auditor General of Canada 2008). There is a high degree of confidentiality allotted towards the EFP and it is difficult to know if farmers made any improvements to their land. Further, one of the largest constraints from the confidentiality of the program is that AAFC was unable to identify needed improvements to the EFP and programs are unable to be targeted towards common environmental risks identified in producer workbooks. Chapter 5 will provide a complete breakdown of the EFP and its role in agri-environmental policy.

4.7 Funding Trends Across Stewardship Programs for Alberta, Canada

Table 4.5 expands on Table 5 completed by Boxall (2018), where they provide a summary of BMP projects and total expenditures for stewardship programs under APF, GF and GF2; we include values for the Canadian Agricultural Partnership. Since the Canadian Agricultural Partnership is still in effect, total expenditures included are expenditures up until July 2020; this program will end in March of 2023. Further, the number of projects under this framework that are shown in the table are projects that have been approved to date for 2018-2019, 2019-2020, and 2020-2021 fiscal years. All data was privately provided by program delivery agents and our numbers may differ from Boxall (2018); actual numbers may also differ from this data. We adapt total expenditure values from Boxall (2018) by expressing them in 2019 CAD and all values are the lump sum of all projects under each environmental stewardship program.

Table 4.5. BMP Expenditures Per Environmental Stewardship Program for Alberta.

Stewardship Project Category	**No. of Projects**	**Total Expenditure ($2019)**	**Expenditure per project ($2019)**
	Growing Forward 1 (2008-2013)		
Integrated Crop Management	740	$4,086,167	$5,522
Grazing and Winter-Feeding Management	831	$2,928,867	$3,525
Manure Management	216	$5,566,124	$25,769
Total	1,787	$12,581,158	$7,040
	Growing Forward 2 (2013-2018)		
On-Farm Stewardship: Grazing Management	1148	$6,525,173	$5,446
On-Farm Stewardship: Manure Management	44	$946,557	$21,513

On-Farm Stewardship: Crop Input Management	382	$2,967,525	$7,768
On-Farm Stewardship: Ag. Waste Management	246	$661,625	$2,690
Agricultural Watershed Enhancement	96	$1,161,805	$12,102
Confined Feeding Operation	134*	$5,150,636*	$38,438*
Total	2,050	$17,413,321	$8,494
Canadian Agricultural Partnership (2018-July 2020)			
ESCC: Riparian Management	222	$1,811,853	8,162
ESCC: Manure and Livestock Facilities Management	105	$3,802,654	$36,216
ESCC: Agricultural Input and Waste Management	157	$1,524,989	$9,713
ESCC: Innovation	4	$76,888	19,222
ESCC: Commercial Manure Applicators	1	$48,216	$48,216
Total (so far)	489	$7,264,600	$14,856

Source: Data adapted from (Boxall 2018). Note: *Values for CFO have been lost since Boxall (2018) report and these values are taken directly from their Table 5.

GF2 had a higher number of practices adopted overall, as well as higher levels of expenditures. Although it is premature to comment on the expenditure and adoption rates under the Canadian Agricultural Partnership, it seems this policy is on track to producing levels that are comparable to prior policies. Under GF, the highest level of expenditure was for manure management. GF2 made the categorization of BMPs less general, showing that a large portion of expenditure was for CFOs and grazing management (part of the on-farm stewardship program). So far, the Canadian Agricultural Partnership ESCC program has spent the most on manure and livestock management. Across all policies, the focus and highest level of expenditure has been allotted to livestock related BMPs. This may be related to the nature of Alberta's agricultural industry, which is livestock intensive.

4.8 Global Agri-environmental Policies

Canadian agri-environmental policies, alongside stewardship programs, have only recently been implemented compared to other developed nations. Given the lack of monitoring and reporting, little improvements have been made to environmental stewardship programs since 2003. With this, there is no indication whether stewardship programs have reduced environmental risks or if they have benefited producers in the long term. For this reason, it is worthwhile recognizing agri-environmental policies elsewhere to see how other developed nations have regulated conservation programs and if they have been effective in reducing environmental risks from agriculture. For this thesis two policies were chosen for comparison, the European Unions (EU) Common Agricultural Policy and the United States Farm Bills.

4.8.1 The European Union: Common Agriculture Policy

The EU's Common Agricultural Policy was launched in 1962 with the aim to increase agricultural productivity, ensure food and price stability, safeguard farmers livelihoods, alongside a more recent goal to fight climate change and promote sustainable agriculture (Dobbs & Pretty 2008; European Commission 2020). By 2013, income support under the Common Agricultural Policy began to include financial rewards to farmers for taking care of the environment. Farmers in the EU can benefit from "green direct payments" or "greening" for adopting or maintaining practices that meet environmental and climate goals (European Commission 2017). Member states are required to allocate 30% of their direct payment allocation towards these green payments, and farmers receive these payments if they comply with three greening obligations: 1) crop diversification; 2) maintenance of permanent grassland; and/or 3) ecological focus areas[5] (European Commission 2017). After the introduction of the European Green Deal, the Common Agricultural Policy reformed to help farmers meet new objectives identified under this deal. These new measures include farm advisory services and

[5] Under ecological focus areas, the European Commission defines this as "Farmers with arable land exceeding 15 hectares (ha) must ensure that at least 5% of their land is an ecological focus area with a view to safeguarding and improving biodiversity on farms (European Commission 2017)."

eco-schemes. Eco-schemes are new payment schemes for the care of the climate and environment, funded and developed by each member state[6] (European Commission 2021).

Member states can also choose to develop agri-environmental schemes that compensate income loss for farmers who actively display sustainable and environmentally friendly farming (Batáry et al. 2015). The United Kingdom (UK) launched the first agri-environmental scheme entitled The Environmentally Sensitive Areas (ESA) program in 1986 (Dobbs & Pretty 2008). All ESA programs were taxpayer-funded, and administered by government agencies, where producers could enter voluntary management agreements (of up to 10 years) in return for annual payments (Dobbs & Pretty 2008). These agreements came in the form of conditional contracts and a breach in these agreements could lead to financial penalties (Dobbs & Pretty 2008). Among the largest critique of this early program was the lack of accountability farmers were held to after a contract expired. Specifically, an inability to ensure a producer retained any environmental capital produced under the ESA program (Hanley et al. 1999).

More recently, result-based agri-environmental schemes were piloted where farmers are paid for providing environmental improvements (Burton & Schwarz 2013; European Commission 2019). The pilot projects for these schemes were rolled out in 2014-15 in Ireland, Romania, England, and Spain and focused on biodiversity achievements in agriculture. Payments were only made to producers when results of a specific quality or criteria were delivered; this added to the cost-effectiveness of the program (European Commission 2019). Early results, as of 2019, suggest that the costs of result-based payments are similar to management-based measures, although there was evidence that producers benefited from an increased awareness of biodiversity associated with their operations (European Commission 2019).

In all, the Common Agricultural Policy incorporates three pillars: 1) Social Sustainability; 2) Environmental Sustainability; and 3) Economic Sustainability. Figure 4.1 provides a breakdown of goals and measures under the environmental sustainability pillar. For environmental measures, cross-compliance is used to encourage farmers to be more sustainable, where farmers are ineligible to receive farm income support unless they comply with a set of

[6] Actions under Eco-schemes can include strategic plans for climate change mitigation or adaptation, protection of water quality and biodiversity, prevention of soil degradation, as well as actions for sustainable and reduced use of pesticides and enhanced animal welfare (European Commission 2021).

rules (Zimmermann & Britz 2016)[7]. Rural support has three overarching goals according to the European Commission: i) support competitiveness of agriculture; ii) ensure sustainable management of natural resources and climate action; and iii) balanced development of rural economies and communities, including the creation and maintenance of employment (European Commission n.d.). This is supported through the European agricultural fund for rural development (EAFRD); where rural development for innovation, environment, and climate change mitigation and adaptation are promoted.

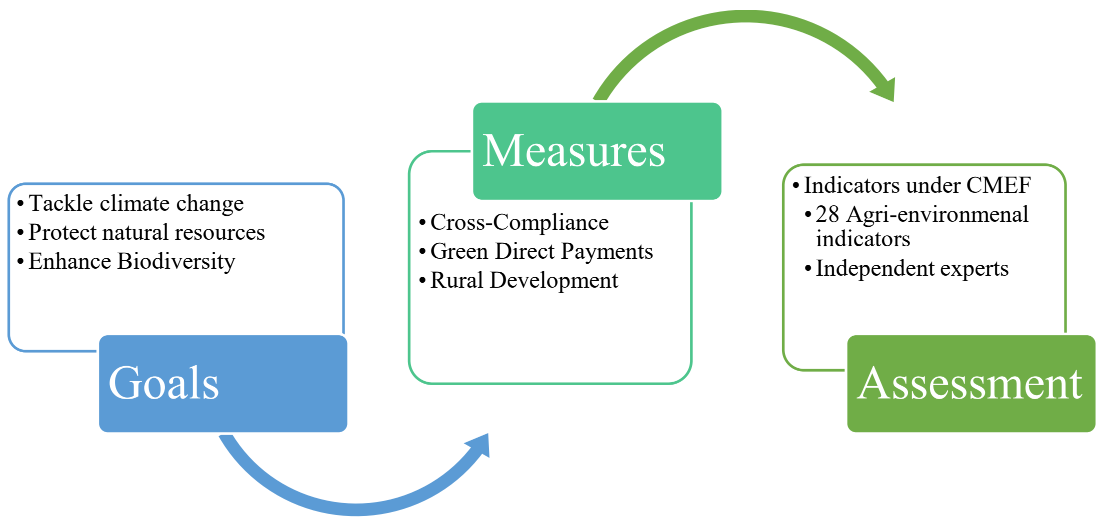

Figure 4.1. European Union Common Agriculture Policy Goals, Measures, and Assessments. Source: European Commission (2020).

The European Commission developed the common monitoring and evaluation framework (CMEF) to assess the performance of the Common Agricultural Policy and improve its efficiency (European Commission 2017). Several indicators were developed, including output indicators, result indicators, impact indicators, and context indicators[8]. Impact and result based indicators include indicators for emissions, water quality, soil erosion, renewable energy, and results for land under greening. CMEF also uses output indicators to monitor greening payments, including monitoring environmental focus areas or areas under cross-compliance. Above all, the

[7] If farmers do not comply and violate EU law on environmental, public, and animal health, animal welfare or land management, EU support payments will be reduced, alongside the possibility of other penalties (European Commission n.d.).

[8] The European Commission defines each indicator as the following: 1) output indicators are 'activities directly realised by interventions'; 2) result indicators are 'direct and immediate effect of interventions'; 3) impact indictors are 'outcome of intervention beyond immediate effects'; and 4) context indicators are 'general contextual trends' (European Commission 2017).

CMEF provides extensive indicators to monitor the efficiency of the Common Agricultural Policy and its programs for future policy improvements.

4.8.2 The United States: 2018 Farm Bill

The United States operates agricultural and food policies under Farm Bills, which are renewed roughly every five years; the latest being the 2018 Farm Bill (2018-2023). Environmental policies are included under the conservation title, where the Conservation Reserve Program (CRP) is among the oldest program (originally enacted in 1985) (Reimer & Prokopy 2014). The CRP uses rental payments to engage farmers to voluntarily sign contracts to remove sensitive land from agricultural production (Reimer & Prokopy 2014). These contracts vary by the number of years in force and include criteria specific to individual farmers. In 1996, CRP underwent a transformation under the Federal Agricultural Improvement Reform (FAIR), where several programs and regulations were introduced (USDA 2019; Reimer & Prokopy 2014). This included an Environmental Quality Incentives Program (EQIP) which was a $1.3 billion USD investment over seven years, and was used to provide technical, educational, cost-share assistance and incentive payments for producers who implement practices to protect soil and water resources (USDA 2019).

Under the 2018 Farm Bill, the main conservation programs are categorized into working lands, land retirement, and easement programs (McMinimy 2019). Most programs are delivered through the Natural Resource Conservation Service (NRCS), with some being delivered by the Farm Services Agency (FSA); both are agencies within the U.S. Department of Agriculture (Reimer & Prokopy 2014). Table 4.6 provides an overview of the main conservation programs provided under the 2018 Farm Bill. Over time, the number of federal conservation programs has been reduced, with the most significant reduction being 23 programs in the 2008 Farm Bill to 13 programs under the 2014 Farm Bill (Reimer 2015).

Table 4.6. Conservation Programs Under the 2018 Farm Bill.

Working Lands Programs	
Environmental Quality Incentives Program (EQIP)	• Delivers technical and financial assistance to producers to implement practices for water quality and quantity, soil health, and wildlife habitat improvement. • Programs are voluntary, NRCS provides one-on-one assistance to plan and implement improvements (conservation practices) while maintaining agricultural productivity (Reimer et al. 2013) • 2018 Farm Bill introduced EQIP incentive contracts which offer annual payments to cover operation, maintenance costs and foregone income for introducing incentive practices (conservation practices) (USDA n.d.).
Conservation Stewardship Programs (CSP)	• Provides financial and technical assistance to maintain and improve existing conservation systems and to adopt new conservation activities as a whole-farm approach (Stubbs 2019). • Plans are tailored to a producer's operation, where problems are identified on their land and assistance is provided to mitigate risks. • Contracts are for five years, with an ability to compete for renewal if participants have met the terms in their original contract (USDA n.d.).
Land Retirement and Easement Programs	
Conservation Reserve Program (CRP)	• Provides annual rental payments to farmers for replacing crops on environmentally sensitive and highly erodible land with long-term resource-conserving plantings (Stubbs 2019). • Under the 2018 Farm Bill, 2 million acres must be grassland contracts, and 8.6 million is for the continuation of existing contracts. • Payments have also expanded to include annual rental payments, cost-share payments, and incentive payments (USDA 2019).
Agricultural Conservation Easement Program (ACEP)	• Provides technical and financial assistance through easements (Stubbs 2019). • Easements include: 1) agricultural land easements that limit non-agricultural usage on productive farm or grasslands and 2) wetland reserve easements that protect and restore wetlands.
Other Conservation Programs	
Regional Conservation Partnership Program (RCPP)	• Promotes relations between NRCS conservation activities with partners who can provide value-added contributions (USDA 2019). • Producers and partners enter into producer contracts and additional agreements to carry out conservation activities (USDA 2019).

Note: Categorization for programs under the 2018 Farm Bill came from the USDA (USDA 2019).

The conservation programs link environmental conservation with agricultural productivity and the working lands programs are notable for the close linkage between environmental protection and agricultural production (Reimer 2015). Land retirement programs directly address soil erosion, surface runoff or water pollutants, and habitat conservation for wildlife, with the added benefit of addressing supply control and farm income support (Reimer 2015). Further, the 2018 Farm Bill did not add new conservation programs, but to address prior inefficiencies, programs were given specific levels of funding or required number of acres for resource or interest-specific environmental issues (Stubbs 2019). This increased the flexibility agencies held to allocate funding to resource-specific needs.

4.9 Comparing Canadian and International Policies

The Canadian Agricultural Policy Frameworks were developed much more recently compared to those implemented in the European Union and the United States. Current frameworks are activity-based rather than performance-based, and payments are typically provided as part of a cost-share program. Producers are not held to contractual obligations and performance of environmental stewardship is not monitored or factored into cost-share funding. Further, in each framework there has been a lack of monitoring and reporting to determine program efficiency. In the case of provincial monitoring, this has also been limited. Provincial stewardship programs differ resulting in significant difficulties for comparing outcomes across provincial programs and on a national scale. Even within Alberta, there was no evidence of long-term monitoring for producers who participated in the cost-share programs and adopted management practices. There has also been limited work to understand if the cost-shares are enough to reduce the financial barriers (or burden) that may stem from implementing practices. Without sufficient information or data regarding stewardship programs performance over time, there is no causal evidence suggesting these programs have made a positive environmental or economic impact on agricultural land.

Unlike Canadian policy frameworks, the European Union (EU) and the United States (U.S.) have grown to actively link producer support programs to environmental conservation and agricultural productivity by using cross-compliance and payment schemes. The use of cross-compliance allows for developing performance standards that are tied to payments and can be used to target sensitive environmental areas. Although, as described by Rude & Weersink

(2018), both the U.S. and the EU differ in how they motivate compliance under these schemes. The U.S. relies more on penalties rather than extensive monitoring to motivate compliance. For example, under the Conservation Stewardship Programs (CSP) competing for contract renewals is only possible if participants met all the terms in their initial contract. Instead, the EU relies more heavily on monitoring than on penalties (Rude & Weersink 2018). This is shown in Figure 4.1 highlighting measurement and assessment indicators. Regardless, both the Common Agricultural Policy and the Farm Bills continue to evolve through extensive monitoring and reporting which has allowed for improved program efficiency, to ensure cost-effectiveness, and to meet environmental goals.

Canadian (federal and provincial) policies and programs are lagging compared to other developed nations. Based on EU and U.S. policies, it is imperative federal and provincial governments consider the use of cross-compliance to ensure environmental risk mitigation is occurring and that producers continue to implement BMPs long-term. If producers are obligated to meet minimum standards of environmental care, while being compensated for their stewardship, this may motivate BMP adoption over time. Rude & Weersink (2018) suggests for cross-compliance to be effective in Canada, the size of the incentive will have to be adequate for participation, with a fixed direct payment among the most beneficial when controlled by the regulatory agency facilitating the targets. Further, as Boxall (2018) recommended, performance-based measures should be used as opposed to activity-based. For example, this could mirror the EUs result-based schemes which were found to be effective and increased producer knowledge, or the U.S. Farm Bills use of incentive contracts as seen in EQIP and CRP. Lastly, for the next framework, monitoring and consistent reporting needs to occur to examine the effectiveness of stewardship programs. An outstanding example of this has been shown in the EU through a multitude of indicators including output indicators, result indicators, impact indicators, and context indicators (as shown in figure 4.1). These indicators should be decided upon prior to the next APFs implementation and should remain consistent across provinces and territories so a national scale comparison can occur.

Chapter 5: An Analysis of Alberta's Environmental Farm Plan

The previous chapter provided an overview of agri-environmental policies and environmental stewardship programs specific to Canada and Alberta. The Environmental Farm Plan (EFP) forms an integral component of agri-environmental policy at the federal and provincial government levels as it is a requirement for producers to participate in almost all cost-share programs. The issue is that not all producers in Alberta have obtained an EFP or even want to obtain one, meaning willing adopters of BMPs are unable to obtain funding support from these sources. This chapter will explore producer participation in the EFP program, as well as provide an overview of what the EFP program entails. The main purpose of this chapter is to better understand determinants that influence or hinder producers in Alberta from obtaining an EFP.

5.1 A Brief History of the Environmental Farm Plan

The EFP originally began as a pilot project in 1993 across seven Municipal Districts in Ontario and was funded by the Land Management Assistance Program[9] (Government of Ontario 2020). Prior to the pilot program, the Ontario Farm Environmental Coalition (OFEC) showed concern over farmers addressing key environmental issues associated with agricultural production. This concern then lead to the creation of the pilot project (Robinson 2006b). By 1995, the EFP was launched in Ontario following a six-stage sequence (Robinson 2006b) outlined in figure 5.1.

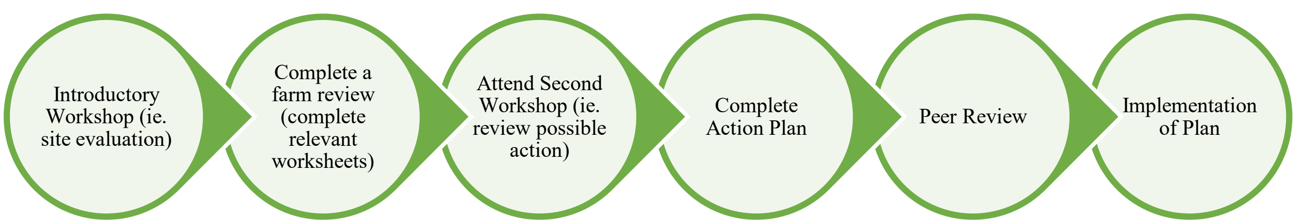

Figure 5.1. The six-stage sequence for the completion of the early Environment Farm Plan. Source: Robinson (2006b)

[9] The Land Management Assistance Program was part of Agriculture and Agri-Food Canada's (AAFC) Green Plan (Government of Ontario 2020).

Robinson (2006b) explains that the peer review stage was meant to meet Agriculture and Agri-Food Canada's (AAFC) funding requirements by monitoring the quality of the individuals EFP. Workshops were meant to encourage farmers to complete workbooks, which listed ways to mitigate environmental risks on their operation (Robinson 2006b). The workbooks included a four-point scale for farmers to evaluate their operations and any environmental risks on their farm. A rating of 4 indicated a 'best' condition, or as Robinson wrote "conditions that protect the environment or have least potential for environmental damage." A rating of 1 was poor, or "conditions have the highest potential to impact the environment (Robinson 2006b)." This rating process was completely self-regulated and was up to the producer to decide the scale of environmental risks on their land. Originally, Ontario farmers were eligible for up to $1500 per farm business to address environmental issues identified, with an added incentive of $1000 for the 12 best individual plans (Robinson 2006a,b). From the beginning, the EFP was a voluntary measure aiming to encourage farmers to identify environmental risks on their farm, and to develop plans to mitigate these risks. As Boxall et al. (2013) stated, the EFP focuses on education and moral suasion by appealing to the notions of "stewardship."

After the launch of the EFP in Ontario, other provinces began to adopt the EFP, with all provinces having implemented the EFP around the start of the first APF (2003-2008). As mentioned in Chapter 4, this plan formed an integral part of the first national policy framework and served as an eligibility criterion for accessing environmental stewardship program funding. Like the environmental stewardship programs, the provinces differed in their delivery of the EFPs. The main differences are the original time of implementation, as well as delivery methods, which may result in the differing rates of EFP completion. Table 5.1 includes the percentage of farms who hold an EFP in each province from the 2011 Farm Environmental Management Survey (FEMS) and the 2017 Farm Management Survey (FMS). Numbers in bold represent the provinces with the highest and lowest percentage of completed EFPs.

Table 5.1. The Number of Farms by Province Holding an Environmental Farm Plan.

Province	FEMS 2011 Completed EFPs (%)	FMS 2017 Completed EFPs (%)
British Columbia	**21**	28
Alberta	23	**25**
Saskatchewan	26	28
Manitoba	28	28
Ontario	38	46
Québec	**72**	**81**
New Brunswick	53*	63
Nova Scotia	53*	74
P.E.I.	53*	66
Total	35	40

Source: Statistics Canada (2013) and Statistics Canada (2019).
*For these provinces, the percentage of holding an EFP were combined for the 2011 Farm Environmental Management Survey.

From the 2011 FEMS to the 2016 FMS, increase in uptake varied by province, with a minimal increase in EFP completion in western Canada. Québec continued to have the highest percentage of farms with an EFP, which may be attributed towards Québec's cross-compliance measures, where some farm financial support programs are linked to environmental standard compliance and holding an EFP (Gouvernement du Québec 2020). New Brunswick (NB), Nova Scotia (NS), and P.E.I, also have high percentages of EFP participation. Both NS and P.E.I. require producers to renew their EFP every 5 years, whereas NB suggests it should be updated every 5 years. These eastern provinces have the least number of farms (Statistics Canada 2017), which may correspond to higher EFP uptake. A trend is that eastern provinces tend to have more farms holding an EFP, whereas the western provinces have a lower uptake. One reason may simply be the later implementation of the EFP in the west, as opposed to its origins and faster implementation in the east.

Since each policy framework involved negotiations between the federal and provincial governments, each province adapted the EFP to fit their own regional and agronomic situations (Boxall 2018). The Alberta EFP is currently run by a private provider called the Agricultural Research and Extension Council of Alberta (ARECA). To promote the EFP, extension services are offered to Alberta producers regarding information on the program and process. This includes workshops at the Municipal District level operated by EFP technicians, who are individuals educated on the EFP process and benefits. EFP technicians range from county or municipal employees to members of local agricultural research groups. It is not clear what level of experience each technician has with the EFP process however, or their level of education, which complicates the ability to determine the accuracy and usefulness of the information producers receive about the EFP. Regardless, producers have the option to attend workshops run by ARECA, where they can receive proper information about the EFP and can receive aid regarding the completion of their workbooks.

Workbooks for the EFP are offered either in a paper format, or online, dependent on producers' preferences. The EFP workbook is similar to what was described by Robinson (2006b) where a four-point scale is used to assess environmental risks on their land across a multitude of risk categories. Unlike the original scale however, in Alberta it is reversed where a rating of '1' indicates 'low environmental risk' and '4' indicates 'high environmental risk' on their land. Farmers who identify a risk rating of either '3' or '4' must develop action items that can mitigate these risks on their farm. Actions items can be actual actions (this usually involves moving down to a rating of '1' or '2' in a short time frame), mitigating factors (such as having a fuel tank down slope from a water source), or a monitoring plan. These action plans are then reviewed by technicians to determine if they are feasible and of good quality prior to a producer receiving a certificate of completion for the EFP. If the technician believes a producers' action plan is not feasible or of poor quality, producers are asked to reconsider their plans until deemed reasonable. Regardless, throughout the workbook producers are encouraged to think about solutions to negate environmental risks on their land given the reality of their current production practices. Although, it should be noted that once producers receive a certificate of completion and obtain an EFP, there is no monitoring for producer plans and action items. Thus, it is very plausible producers only complete a few, or do not complete any of these action items to reduce on-farm environmental risks.

One of the most overlooked problems with the current EFP (across each province) is that farmers may not be assessing their whole farm for environmental risks. Smithers & Furman (2003) found 55% of farmers said they did not apply the application to their whole farm, rather, just to the part they see as being managed. Robinson (2006b) also commented on this issue, saying that farmers may overlook certain environmental aspects if they do not believe they are of importance. These points were raised more than a decade ago, yet we are unable to find any records showing that this has been discussed or addressed by those who deliver the program. Given the voluntary nature and reliance on farmer self-reporting, this may be one of the most complex issues under the EFP. Another issue arises from the link between the policy frameworks and the EFP. Many farmers may participate in the EFP program purely to be eligible for cost-shares under environmental stewardship programs. If this is a farmer's only motive to complete an EFP, then it is possible the farmer will not address all environmental risks, assess the whole farm, and may be disengaged from possible mitigation options suggested under their workbook.

Even with extension efforts, a significant proportion of Alberta producers are not completing an EFP. Alberta has the lowest number of farms with a completed EFP at 25%, only increasing 2% between 2011 and 2016 (Table 5.1). With the new 2018 regulations requiring producers to renew their EFP every 10 years, it is plausible that less than 25% of farmers still hold a formal and completed EFP. The other issue with this number is that researchers are unable to access data regarding the EFP and its completion. As mentioned in chapter 4, the EFP is highly confidential, and this confidentiality exists to protect farmers and reduce the risk of their private information being shared (Office of the Auditor General of Canada 2008). Given this reality, one cannot ascertain if the 25% completion rate involves most of the land area under agricultural production, and this relates back to the notion that producers may not complete the EFP using a whole-farm approach. Even spatially, researchers are unaware of the regions where producers are prone to non-participation in the EFP programme. Both points may indicate that the 25% completion rate is much lower than stated in the 2017 Farm Management Survey and that a significant proportion of producers in Alberta are ineligible for stewardship programs under the APFs. Thus, many producers are not eligible to receive funding from cost-share programs that are meant to encourage the adoption of Best Management Practices.

5.2 Literature on the EFP

The EFP originally drew praise for its bottom-up approach, where farmers could take a leading role in addressing environmental concerns on their operations (Smithers & Furman 2003). The EFP connects farmers to program managers and extension personnel, providing opportunities for each stakeholder to communicate and learn from one another (Robinson 2006a,b; Boxall 2018). However, there is a limited pool of producers benefitting from the EFP due to poor rates of completion, especially in western provinces. Unfortunately, there is little relevant and recent research exploring factors that motivate farmers to complete the EFP process. Furthermore, most of the literature has concentrated on the province of Ontario (Robinson 2006a; Smithers & Furman 2003; Summers et al. 2008), with a few focusing on the province of Nova Scotia (Atari et al. 2009; Yiridoe et al. 2010). Even with the limited research on the EFP so far, similar points have been raised across the literature.

Most studies address the inadequate monitoring and assessment of the EFP to date (FitzGibbon et al. 2004; Smith et al. 2020; Atari et al. 2009; Robinson 2006a; Morrisson & FitzGibbon 2014). FitzGibbon et al. (2004) state a major downfall of the EFP is the current inability to measure impacts of the program on the environment, where there is no indication the EFP has improved environmental conditions over time. They also argue without this burden of proof, a lack of public support may occur resulting in diminished funding or reduced rates of participation. Atari et al. (2009) also comment that the lack of monitoring may compromise the credibility of the programme and its relation to environmental stewardship. Although, it should be noted that Plummer et al. (2008) found the Ontario EFP program made an impact across several agri-environmental risk areas after conducting potential impact models. Regardless, many suggest the confidentiality of the program does not allow for an efficient monitoring system to be developed. However, confidentiality was also identified as an important component towards improving rates of participation, with many noting the confidentiality has led to the current 'success' of the program (Smith & Furman 2003; Morrison & FitzGibbon 2014).

Many studies have also identified the need for confidentiality given the persistence of privacy concerns where many producers fear negative consequences for identifying certain environmental risks (Atari et al. 2009; Smithers & Furman 2003). This has led to the requirement of strict confidentially surrounding producer responses and has resulted in minimal publicly available information for researchers to better understand what motivates farmers to complete an EFP (Boxall 2018). Even with the promise of confidentiality, many producers are still concerned they may face fines or other consequences. For example, Smithers & Furman (2003) found that many farmers are willing to forego financial incentives to protect the confidentiality of their farms, where 12% of Ontario farmers skipped the peer review section, which at the time was necessary to be eligible for financing (Smithers & Furman 2003). These concerns also relate back to the issue of farmers not assessing the whole farm; where farmers may be spatially selective in their evaluations and management plans to protect their operations privacy (Smithers & Furman 2003).

Aside from the points raised above, some studies have pointed to additional concerns and benefits of the program. One concern is the heightened regulations which may detract from the voluntary nature of the EFP (Morrison & FitzGibbon 2014; Yiridoe et al. 2010; FitzGibbon et al. 2004). For example, Atari et al. (2009) found 62% of farmers participated in the Nova Scotia EFP program to improve compliance with government environmental regulations. Morrison & FitzGibbon (2014) express the government, agricultural organizations and other food groups have increased their own interests by using the EFP program, causing a shift away from its original farmer-led (bottom-up) approach. A prevalent yet overlook example of this shift is the requirement of having an EFP to access cost-share funding under environmental stewardship programs. On the other hand, others see the benefit of increasing regulations with respect to the EFP. Morrison & FitzGibbon (2014) point out regulation is not a substitution for stewardship, yet it can aid and reinforce stewardship actions. The EFP also has the potential to be used as a cross-compliance tool, where environmental risk reduction is linked to support schemes (Atari et al. 2009). For example, in Alberta the possibility of using the EFP to meet industry standards for sustainable sourcing has been discussed (Alberta EFP 2020); this will be addressed further in section 5.3.

Moreover, many studies have also argued incentives to participate, especially the economic incentives, may not be enough to motivate participation in the EFP program. Compared to other nations, financial support for the EFP is limited (Robinso 2006a). Producers are not paid to complete an EFP, yet through the notion of stewardship, they are expected to invest resources into reducing on-farm environmental risks. Even with economic incentives available, Morrison & FitzGibbon (2014) illustrate available funds are often limited given their first come first serve nature (ie. provincial environmental stewardship programs). However, studies have shown farmers are willing to invest their own time and resources to implement their action plans. As Smith et al. (2020) find, farmers make significant financial and time investments when choosing to complete agri-environmental projects outlined in their EFP workbook. Through a 2010 survey of Ontario farmers, they found farmers spend an average of 163 hours and $69,600 CAD to implement EFP project plans. Thus, it seems some farmers see the value (private benefits) to participating in the EFP.

Lastly, the literature on farm and farmer characteristics and their influence on EFP participation has been exceptionally limited. Atari et al. (2009) found that higher gross farm revenue, more land area, and being a livestock farmer were all significant towards having an EFP for famers in Nova Scotia. Specialized knowledge and training from EPF information sessions and workshops, as well as farm demonstrations of stewardship practices, were also highly significant to participants in the Nova Scotian (NS) EFP program. However, adoption rates of the EFP in Nova Scotia are significantly higher, and with a smaller producer population, these findings are not directly comparable to western provinces. With this, the Nova Scotian EFP program differs from the Alberta EFP. The NS EFP is less self-regulated as farmers receive on-farm consultations, where technicians point out areas of environmental risks and provide personalized recommendations during their visit; Alberta EFP does not provide this service. Smithers & Furman (2003) found that positive perceptions of the program, farmers' environmental motivations, and farm-specific environmental conditions (such as soil quality) were associated with completing an EFP for Ontario farmers. Many farmers also chose to participate given its bottom-up approach, preferring this to government regulation (Smithers & Furman 2003; Robinson 2006b).

To summarize, since producer responses to the EFP are private, there is a strict lack of public information and data to have a clear picture of how successful the EFP has been. There is no insight into the long-term results from producer plans, mainly if producers mitigate identified environmental risks on their land through implementing BMPs. With this, there is also no determination as to whether producers use a whole-farm approach, or if they identify only a portion of their land due to privacy concerns. This inability to obtain information has resulted in limited research on the EFP and minimal findings regarding components that influence a producers decision-making process to complete an EFP. This is especially true for the province of Alberta, where research and information has been virtually non-existent (Boxall 2018).

5.3 Outlook for the EFP

The possibility of using the EFP to meet industry standards for sustainable sourcing has been in motion for some time (Alberta EFP 2020). Recently, several commodity groups began to require (or support) the completion of the EFP to meet market demands, as large agri-food businesses begin to primarily purchase products from sustainably sourced operations. For example, food giant McCain's, the largest manufacturer of frozen potatoes who sell to over 160 countries, will only purchase produce from farmers who have completed an EFP (Alberta EFP 2020). This made Potato Growers of Alberta adapt to market demands, and as of 2010, the completion of the EFP is required for membership in that association[10]. Many industries, whether federal or provincial, have begun to develop their own programs to ensure environmental stewardship meets sustainable sourcing standards; this includes some programs requiring the completion of the EFP. Some of these programs are explained below.

In 2014, Egg Farmers of Alberta developed the Producer Environmental Egg Program (PEEP) as part of a sustainable strategy. PEEP is a voluntary provincial program aimed to help Alberta egg farmers identify environmental impacts on their farm and to implement BMPs (EFA 2021). This program was derived from the EFP, and with help from Alberta EFP, the program mirrors the EFP risk scale, and uses a multitude of priority risk areas taken directly from the EFP workbook (Alberta EFP 2016). PEEP was developed for corporations to market their products as fresh, high-quality local food, and to signal that it was produced in an environmentally responsible manner (EFA 2021). Although it is voluntary, 100% of Alberta egg farmers have participated according to the Egg Farmers of Alberta (EFA) website (EFA 2021). It should be noted the EFP is not required, rather it is a recommended tool to egg producers.

Recently, Dairy Farmers of Canadas' proAction plan incorporated the requirement of having a completed EFP as part of the new environment module; this module must be completed

[10] All potato growers who grow five or more acres of potatoes in Alberta or are greenhouse nuclear growers who grow plantlets and sell mini tubers, must register with Potato Growers of Alberta for licensing annually (PGA 2018).

by September 1st, 2021 (Dairy Farmers of Canada 2020). Knowledge about the environmental module has existed as early as 2017 according to proAction's 2017-2018 progress report. Thus, it is plausible many Canadian dairy farmers completed an EFP prior to 2021 to overcome this new regulation (Dairy Farmers of Canada 2019). This module was developed to match the increased interest in environmental sustainability from industry stakeholders and consumers regarding dairy products. Under proAction, trained independent professionals audit each farm in person once every two years, with 5% being randomly selected for full validation each alternative year, to ensure the farmers adhere to proAction requirements (Dairy Farmers of Canada 2020). Beginning September of 2021, the completion of the EFP will be part of this auditing process.

There are also discussions surrounding the requirement of an EFP for producers who participate in the Verified Beef Program Plus (VBP+). VBP+ is meant for certified beef cattle operations to prove to retailers and consumers that their operation meets standards for food safety, animal care, and environmental stewardship (Canadian Cattlemen's Association 2021). In the VBP+ producer manual, under their environmental stewardship section, the EFP is promoted as an 'excellent base for land and water stewardship.' Additionally, under VBP+ auditors will monitor producers who self-identify they have an EFP, specifically auditing practices undertaken in the last 1 to 3 years (CCA & BCRC 2018; VBP+ 2017). According to the VBP+ website, many certified operators have completed an EFP as part of the VBP+ audit process (Canadian Cattlemen's Association 2021).

The use of the EFP to meet industry standards has a multitude of pros and cons for Alberta producers; these are summarized below.

<u>Cons</u>

i. This may limit market access for producers who are not willing to complete an EFP, whether for privacy concerns, lack of information about the EFP, or other reasons.
ii. Having the EFP as a requirement removes the voluntary nature of the EFP programme.
iii. The quality of workbooks and producer plans may suffer as producers may forego important environmental risks if they are only completing the EFP for market access and no other motivation.

iv. This may force producers to exit the market if they are not willing to comply.

Pros

i. This presents an opportunity to increase the rate of EFP completion in Alberta.
ii. Producers may be more willing to adopt BMPs for identified environmental risks on their land to meet sustainable sourcing standards.
iii. Producers may benefit from increased knowledge and awareness of environmental risks and sustainable production.
iv. The more producers who have an EFP, the larger the pool of eligible producers for cost-share stewardship programs under APFs.

5.4 Examination of the Adoption of the Environmental Farm Plan in Alberta: Methodological Approach

To understand a producer's decision-making process regarding environmental stewardship and BMP adoption, we develop a flow chart of possible decisions presented in figure 5.2. This figure illustrates seven pathways, alongside possible components, that can affect the decision-making process from the farm (farmer) level to BMP adoption.

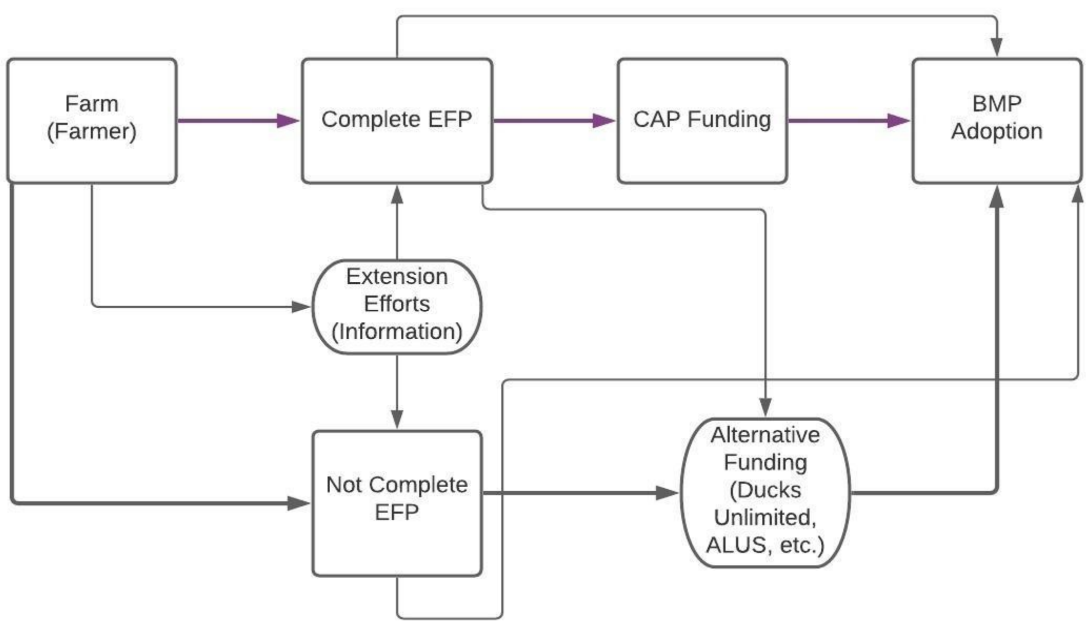

Figure 5.2. Various pathways an Alberta farmer can take to adopt BMPs.

Pathway 1: When an EFP is completed:

The farmer can decide on their own to participate and complete an EFP. From here, the farmer can apply to receive Alberta Government funding under the current APF to participate in the environmental stewardship cost-share program. If approved, the farmer can then adopt one or more BMPs with the aid of provincial government funding.

Pathway 2: Producer accesses extension services to facilitate EFP completion:

The farmer's decision-making process includes extension services, which provides information and knowledge about the EFP program. This information influences their perception of the program in a positive way, enticing them to participate in the EFP program. Once the farmer has completed their EFP, they follow the same process as the first pathway and access funding for BMP adoption through the provincial government. They can also follow options 3) and 4) stated below.

Pathway 3: Extension coupled with EFP completion and self-financing of BMP adoption:

The farmer completes an EFP with extension efforts, but the farmer decides not to apply for government funding under ESCC through CAP. Instead, this individual decides to finance the project themselves, as they are motivated to reduce environmental risks on their operation.

Pathway 4: Extension coupled with EFP completion and access of non-government funding to adopt BMPs:

The farmer completes an EFP with extension efforts, but instead of applying for government funding, they either seek out or are targeted by external sources of funding to implement BMPs on their operation. These external sources through the period of analysis consist largely of programs offered by Ducks Unlimited Canada (DUC) or Alternative Land Use Services (ALUS). These typically target farms with specific environmental characteristics (DUC) or operate at a local scale where external funding has been secured by a Municipal government.

Pathway 5: EFP is NOT completed but producer accesses non-government funding to assist with BMP adoption:

A farmer does not receive any extension services and decides an EFP is not something they want to participate in on their own merit. This decision may stem from a lack of awareness of the EFP, privacy concerns, or they are unaware of the benefits of holding an EFP. They would not be eligible for CAP funding; thus, they choose to seek out alternative funding sources to adopt BMPs on their operation.

Pathway 6: EFP is NOT completed but producer has received extension services and seeks out non-government funding:

A farmer receives education and information from extension services about the EFP, however, they still choose not to participate. This may be due to poor extension effort, a strong negative opinion towards the EFP from the farmer (such as confidentiality concerns), or an overall lack of interest/time in completing a workbook. These producers can still be conservation oriented and since they are not eligible for CAP funding, they seek out alternative funding sources to adopt BMPs.

Pathway 7: Extension effort but the EFP is NOT completed and producer self-funds projects:

A farmer receives education and information from extension services about the EFP but chooses not to participate. Rather than seeking out non-government funding, the farmer decides to self-fund the adoption of BMPs on their land.

Farmers with and without an EFP do not necessarily apply or receive funding, nor are they obligated to adopt BMPs on their operation. However, as we will discuss in Chapter 6, we know farmers are adopting BMPs with and without an EFP. The purpose of figure 5.2 is to outline possible pathways a producer can take when they want to implement adaptive and mitigative environmental strategies on their land. Many farmers do not apply for CAP funding under the ESCC program, and some who apply will have their applications rejected. In fact, in 2011 only four in ten farmers who had an EFP received financial support to implement BMPs included in their EFP workbook (Statistics Canada 2013). Therefore, alternative funding is often used, especially since private organizations like Ducks Unlimited Canada offer more than just a cost-share program. Usually, they also provide technical assistance by providing expertise and resources throughout the adoption process.

Further, literature has shown information sources are significant towards disseminating environmental information and motivating farmers towards participating in the EFP process (Smith et al. 2020; Robinson 2006b; Atari et al. 2009). This is an important aspect as new policies and legislation are often perceived by farmers as an increase in workload or a reduction of income (Willock & Deary 1999). Thus, farmers who lack awareness, knowledge of benefits, and the structure of the EFP are less likely to be willing to participate. Given the low participation rates in the prairie provinces, it is plausible extension efforts are not reaching their full potential.

5.5 An Econometric Model of EFP Participation

To explore factors that influence EFP participation, we develop a binary dependent variable (0,1) representing whether a producer has completed an EFP (1) or not (0). With a binary dependent variable, three common models are considered, the Linear Probability Model (LPM), a Probit model, and a Logistic (Logit) model. However, numerous studies point out that when using Ordinary Least Squares (OLS), there is nothing to ensure that $0 \leq X_i\hat{\beta} \leq 1$ at all observations. A more thorough explanation of the LPM can be found in section 6.4. Due to the limitations of the LPM, we do not pursue this model further. Further, Hill et al. (2011) explain the probit model is numerically complicated since it is based on the normal distribution. A logistic regression is often a frequent alternative to the probit, though the models only really differ in their S-shaped curve's which are used to constrain probabilities into a [0,1] interval (Hill et al. 2011). Prior literature on the EFP to date has seemingly chose to use a logistic regression as a best fit model (Atari et al. 2009; Yiridoe et al. 2010). Given the complexity of the probit model (Hill et al. 2011) and to remain consistent with the current (yet limited) literature, we decide to use a logit model to perform our analysis.

In our binary choice model, a producer derives utility from each alternative. Farmers derive some form of utility by choosing to complete an EFP or not, shown as $U(X) = (E_Y, E_N)$; where U is utility, E_Y is completing an EFP, and E_N is not completing an EFP. Economic theory assumes that rational agents seek to maximize their utility, choosing the option that they perceive makes them better off. For example, a farmer will complete an EFP if the expected utility of completing an EFP is greater than choosing not to ($E[U(E_Y)] > E[U(E_N)]$. In economic theory, utility maximization is often narrowed to financial goals for farmers, especially the notion of profit maximization (Greiner & Gregg 2011; Lin et al. 1974). Although, Greiner & Gregg (2011) explain literature has expanded this narrow assumption to show that utility includes an individual's aspirations, such as additional conservation action (obtaining an EFP), which can be rational and consistent with economic theory. More information on the utility theory can be found in section 6.3.

With a binary dependent variable, an observed choice $A_{fi} = 1$ implies choosing to obtain an EFP for farmer f, evaluating choice i, where choice represents choosing to complete an EFP or not. Whereas $A_{fi} = 0$ implies a farmer choosing not to obtain an EFP. Discrete choice models are bounded by the random utility theory where we do not assume a producer's real level of utility. For the EFP we find a farmer, f, random utility U, for alternative i, is assumed to be:

(1) $U_{fi} = V_{fi} + \varepsilon_{fi}$

where U_{fi} represent utility, V_{fi} is the systematic component (including developing a functional form and included variables), and ε_{fi} is the random component. Our model of choice is a logistic regression, where ε_{fi} is a standardized Type 1 Extreme Value Distribution[11]. V_{fi} uses a linear-in-parameters functional form, with the utility function described in (2):

(2) $U_{fi} = (\beta' X_f + \alpha' X_j) + \varepsilon_{fi}$

$where\ A_{fi} = 1\ if\ U_{fi} > 0,\ \ and\ A_{fi} = 0\ otherwise.$

U_{fi} represents utility for farmer, *f*, and A_{fi} represents the decision to complete an EFP. If U_{fi} is positive, the farmer is better off by completing an EFP and $A_{fi} = 1$, while $A_{fi} = 0$ if utility is lost by completing an EFP. X_f is a vector of producer and farm operation characteristics meant to control for the social, cultural, personal, and agronomic factors affecting adoption, while β' represents parameters relating X_f to U_{fi}. X_j contains observable characteristics relating to

[11] A standardized Type 1 Extreme Value Distribution has probability density function $PDF = f(x) = \exp(-x)\exp[-\exp(-x)]$, and cumulative density function $CDF = F(x) = \exp[-\exp(-x)]$, with variance $\frac{\pi^2}{6}$.

local industry regulations and standards, as well as extension practices of the EFP technicians and/or extension efforts by municipal governments that are meant to affect adoption decisions and/or agri-environmental information, and α' is a vector of associated coefficients.

Our general logit model holds latent variable A^*_{fi} which is unobserved, what we do observe is a binary variable denoted in (3).

(3) $A_{fi} = \{^{1\ if\ A^*_{fi}>0}_{0\ if\ A^*_{fi}\leq 0}$

Under a logit model, the cumulative density function can be shown in (4).

(4) $F(x) = \Lambda(x) = \dfrac{1}{1+e^{-x}}$

Where the mean is zero, variance is $\frac{\pi^2}{3}$, and the density is $f(x) = \Lambda(x)[1-\Lambda(x)]$. A logit model explores the probability of a producer having an EFP, where the probability that a producer has an EFP ($A_{fi} = 1$) is shown in (5). The probability a producer does not have an EFP ($A_{fi} = 0$) is shown in (6) (Hill et al. 2011).

(5)P= $\frac{1}{1+e^{-(\beta_1+\ \beta_{2x})}} = \frac{\exp\,(\beta_1+\ \beta_{2x})}{1+\exp(\beta_1+\ \beta_{2x})}$

(6)$1-P = \frac{1}{1+\exp(\beta_1+\ \beta_{2x})}$

If we rewrite this probability in terms of utility, we can show:

(7) $P_{fi} = p(V_{fiE_Y} + \varepsilon_{fiE_Y} > V_{fiE_N} + \varepsilon_{fiE_N}\ \forall\ N \neq A)$

= p($\varepsilon_{fiE_N} < \varepsilon_{fiE_Y} + V_{fiE_Y} - V_{fiE_N} \forall\ N \neq A)$

Where an increase in V_{fiE_Y} also means an increase in P_{fiE_Y}, or an increase in utility is attributed to an increase in choosing to complete an EFP.

After consulting prior literature on the EFP, and consulting with staff at Alberta Agriculture and Forestry and ARECA, we developed variables to be considered in X_f and X_j. We hypothesize that a producer decides to complete an EFP based on the function shown in (8):

(8) $EFP\ Completion = f(X_f + X_j)$

$where\ X_f = f(Farm\ Characteristics, Farmer\ Characteristics), and$

$X_j = f(Exposure\ to\ Extension, Industry\ Standards)$

We expand our functions identified for both X_f and X_j showing variables that we hypothesize influence EFP completion; these are further explained below.

Factors under X_f :

(9)

$$Farm\ Characteristics = f(Current\ State\ of\ Farm\ Operation, Land\ Ownership, Type\ of\ Operation)$$

$$Farmer\ Characteristics = f(Age, Gross\ Farm\ Revenue, Agricultural\ Degree, Conservation\ Training)$$

Spatial Effects = Municipal Districts[12]

As stated previously, X_f is a vector of farm and producer characteristics that influence EFP completion. Farm characteristics such as landownership (compared to renting land), being a livestock or crop farmer, and succession plans have been found as significant factors that influence a producers decision-making process (Gillespie et al. 2007; Kim et al. 2005; Prokopy et al. 2019). Farmer characteristics are often heterogeneous across the literature, and only age and higher gross farm revenue have been found as significant in both the BMP adoption literature and the limited EFP literature (Baumgart-Getz et al. 2012; Prokopy et al. 2008; Smithers & Furman 2003; Atari et al. 2009). Having an agricultural degree is also included as a farmer characteristic. Although the significance of this feature has fluctuated across the literature (Baumgart-Getz et al. 2012; Prokopy et al. 2008); we hypothesize that having a degree would increase a producer's awareness of environmental risks and mitigation tactics, which may correspond to a producer being more likely to voluntarily complete an EFP. Conservation training has also been shown to influence adoption through increased awareness and education

[12] This is identified as a dummy variable indicating which county a producer's farm is located. Even though we can observe where the farm is located, we are not able to fully observe regional factors which may influence a farmers decision-making process towards completing an EFP.

(Prokopy et al. 2019; Atari et al. 2009) and is hypothesized to increase a farmer's likelihood of completing an EFP.

Lastly, we include spatial effects which are identified as Municipal Districts in Alberta. We develop a dummy variable that represents whether a producer's farm is located in a specific Municipal District. These districts will differ in their agronomic conditions, producer characteristics, social networks, information exchange, as well as level of extension which are not always observable. These differences will influence a producers' decision-making process, making them more or less likely to complete an EFP compared to a producer in another district. Thus, this variable is included to capture these differences which we hypothesis will influence EFP participation.

Factors under X_j :

(10a) $Exposure\ to\ Extension = f(Extension\ Funding, Number\ of\ EFP\ Extension\ Agents)$

X_j is a vector of observable characteristics which includes exposure to extension (shown in equation (10a)) and industry standards. Exposure to extension is hypothesized as a function of how much funding is allocated to extension services, and how many EFP extension agents are assigned to a specific Municipal District. Prokopy et al. (2015) found that extension performance and impact has suffered from diminished budgets, resulting in less experienced personnel. Thus, the hypothesis is that higher levels of funding should correspond to more EFP technicians, and this should positively impact EFP completion. Further, Atari et al. (2009) found specialized knowledge and training from EFP workshops significantly influenced EFP participation, thus, exposure to extension should have a positive impact on EFP completion. Our variable is a proxy for extension as we are unable to determine whether a respondent has had any contact or received any services from an EFP technician or other extension personnel. Thus, it is labelled exposure to extension, as higher extension expenditure and more EFP technicians should result in a higher likelihood of being exposed to extension services.

Based on section 5.3, we assume that industry standards will significantly alter a producer's willingness to participate in the EFP programme. As previously described, certain commodity groups have begun to either require an EFP or are promoting the EFP to meet sustainable sourcing standards, retain market access and remain competitive in international markets. We hypothesize producers who are members of commodity organizations that require or promote an EFP are more likely to complete an EFP. We include Potato Growers of Alberta, Egg Farmers of Alberta (PEEP), Beef producers (VBP+) and Dairy Farmers of Canada (proAction plan) for the purpose of this analysis as shown in figure 5.3. These industries or commodity groups were described in section 5.3 and our function is shown in equation 10b.

$$(10b)\ Industry\ Standards = f(Potato\ Growers\ of\ Alberta, Egg\ Farmers\ of\ Alberta\ (PEEP), VBP+, proAction\ Plan)$$

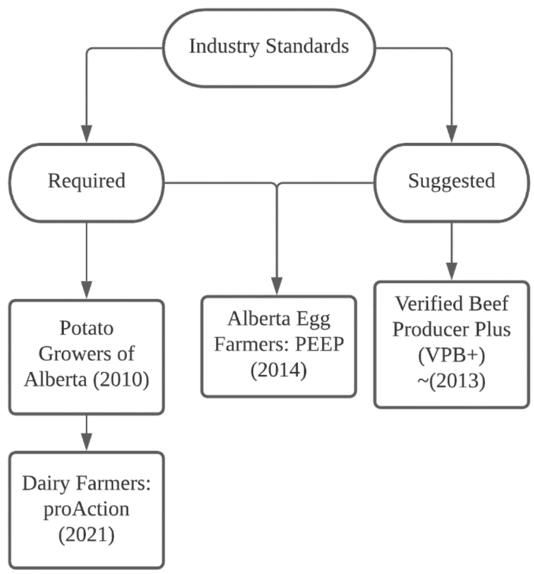

Figure 5.3. A flow chart describing industry standards for the Environmental Farm Plan for various commodity organizations in Alberta.

The EFP literature has addressed concerns over the increase of regulations and industry influences (Morrison & FitzGibbon 2014; Yiridoe et al. 2010); however, most studies have failed to account for industry standards as an explanatory variable. Thus, the influence of industry standards on a producers' decision-making process regarding EFP participation has not been appropriately examined. This is most likely attributed to a large portion of the literature being published prior to the development of programs that require or promote the EFP and the discussion surrounding sustainable sourcing. Further, a good portion of the literature has not used economic theory to examine factors influencing EFP participation. We hypothesize that industry standards should positively influence EFP participation, especially for producers who want to remain competitive.

5.6 The Environmentally Sustainable Agriculture Tracking Survey Dataset

The primary source of data comes from the 2012, 2014, 2016 and 2018 Environmentally Sustainable Agriculture Tracking (ESAT) surveys. As stated in Section 2.2, the ESAT survey is a bi-annual survey sponsored by the Agriculture and Forestry branch of the Government of Alberta, that monitors farm-level adoption of environmentally sustainable agriculture (ESA) practices (Government of Alberta 2018). The survey asked whether a responding producer in Alberta has completed the EFP, which we used to develop our dependent variable A_{fi}. To develop variables under X_f (farm and farmer characteristics), we gather these from the ESAT survey which asked each responding farmer their age, their succession plans, whether they owned or rented land, as well as their gross farm revenue. The ESAT survey also elicited whether an individual had attended a degree or diploma program in an agriculturally related academic area which is represented by a dummy variable labelled degree. Further, a conservation training dummy variable was developed from a survey question that asked respondents if they had attended any environmental agriculture training sessions within the last two years. We recognize that producers may consider an EFP workshop as a conservation training session. Unfortunately, given the nature of the surveys, we are unable to verify what type of conservation training session a producer had attended or if a producer had attended an EFP workshop.

To obtain data under X_j that would align with our function for exposure to extension, this required reaching out to two different sources given the limited publicly available data for Alberta. Extension funding is related to the notion that higher levels of government expenditure for conservation extension efforts should result in more informed farmers and subsequently a higher rate of EFP completion. In the Alberta context, we hypothesize that Municipal Districts who receive more funding for extension will have higher rates of producers completing an EFP, as higher rates of funding should correspond to more local EFP technicians. We received expenditure information from Alberta Agriculture and Forestry's (AAF) environmental stewardship branch for the Agricultural Service Board Grant Program (ASBGP) for 2010, 2011 to 2013, 2014 to 2016 and 2017 to 2019. One objective of the ASBGP is to support the delivery of environmental extension programming, including increasing awareness, understanding, and implementation of environmental agricultural practices and programs (AAF 2016). We also hypothesized Municipal Districts with more EFP technicians within a closer proximity should have higher EFP completion rates. To find data for this, we reached out to ARECA, asking for the number of EFP technicians per Municipal District. We obtained this information for 2012, 2014, 2016 and 2018. All data was provided either at a Municipal District level or on a provincial scale. A third source of data used to develop variables under our industry standards function involved data from the 2011 and 2016 Census of Agriculture for Alberta for the numbers of potato producers, egg producers, beef producers and dairy farmers at the Municipal District level.

5.7 Empirical Models of EFP Participation

All variables included in our logistic regression are explained further in Table 5.2. All variables under farm and farmer characteristics are binary and $\partial_2 County_i$ is included as a dummy variable for spatial effects on EFP completion. Our variables representing exposure to extension are all interaction terms indicating how the effect of extension expenditure on EFP participation depends on the number of EFP technicians in a district (county). Conservation expenditure is lagged as the process of funding being received by a Municipal District for conservation extension, and the time between actual extension outreach, is not simultaneous. Regarding the number of technicians, there is a lag between information and education provided by local technicians and the uptake of this knowledge by the farmer. Unfortunately, we could not obtain data for number of technicians prior to 2012; thus, we do not have an interaction variable for the year 2012. We summarize the extension variables in figure 5.4. Further, we chose to make gross farm revenue (GFR) binary (for producers who make above and below $250,000) as this was mean response for survey respondents.

Table 5.2. Descriptions of Variables Used to Examine Participation for the Environmental Farm Plan in Alberta.

Variables	Description
Dependent Variable	
EFP ($\boldsymbol{A}^*$)	Whether or not a farmer has completed the EFP process; binary [0,1].
Independent Variables	
Farmer Characteristics	
$\boldsymbol{\beta_2 Age_{18-44}}$	Farmers between the age of 18 to 44.
$\boldsymbol{\beta_3 Age_{45-64}}$	Farmers between the age of 45 to 64.
$\boldsymbol{\beta_4 GFR250}$	Farmers whose gross farm revenue (GFR) is greater than $250,000.
$\boldsymbol{\beta_5 Degree}$	Farmers who have a degree or diploma in an agricultural related area.
$\boldsymbol{\beta_6 Training}$	Farmers who have attended an environmental agriculture training session within the last two years.
Farm Characteristics	
$\boldsymbol{\beta_7 Expand}$	Farmers who stated they are expanding their farm operation.
$\boldsymbol{\beta_8 Reduce}$	Farmers who stated they are reducing their operation.
$\boldsymbol{\beta_9 Sell}$	Farmers who stated they are planning to sell their farm.
$\boldsymbol{\beta_{10} Livestock}$	Farmers who are primarily livestock producers. This was identified as farmers who responded their GFR came from primarily livestock production.
$\boldsymbol{\beta_{11} Equal}$	Farmers who are an equal mix of livestock and crop producers based off their GFR.
$\boldsymbol{\beta_{12} Own}$	Farmers who responded they primarily own their land.
$\boldsymbol{\beta_{13} Both}$	Farmers who equally rent and own land.
Exposure to Extension	
Extension Funding * # EFP Technicians	
2014: $\boldsymbol{\beta_{14} F_{2011to2013} * Tech_{2014}}$ 2016: $\boldsymbol{\beta_{15} F_{2014to2016} * Tech_{2016}}$ 2018: $\boldsymbol{\beta_{16} F_{2017to2019} * Tech_{2018}}$	Each variable indicates the total amount of expenditure under the ASBGP per Municipal District, per year, interacting with the total number of EFP technicians working in and/or for a Municipal District in a given year. EFP technician was simplified to a binary variable, indicating 1=county has EFP technician, 0=no technician. Funding was left as total expenditure divided by the number of farms in a Municipal District and is continuous.
Industry Standards	
$\boldsymbol{\beta_{17} Potato}$	Total number of potato producers per Municipal District; 2011 and 2016 census. This is for Municipal Districts with major or minor packers and/or farm gate producers in Alberta only. Districts that were not indicated as major producers by Alberta Potato producers were coded as having 0 farms.
$\boldsymbol{\beta_{18} Egg}$	Total number of farms who are table egg producers; 2011 and 2016 census years.
$\boldsymbol{\beta_{19} Beef}$	Total number of farms who are primarily beef cow producers; 2011 and 2016 census years.
$\boldsymbol{\beta_{20} Dairy}$	Total number of farms who are primarily dairy producers; only the 2016 census year.
Indicator Variables	
$\boldsymbol{\partial_1 Year_i}$	This indicator is a dummy variable for each year of the ESAT survey (2012, 2014, 2016, 2018).
$\boldsymbol{\partial_2 County_i}$	This is a dummy variable to represent Municipal Districts (counties) in Alberta.

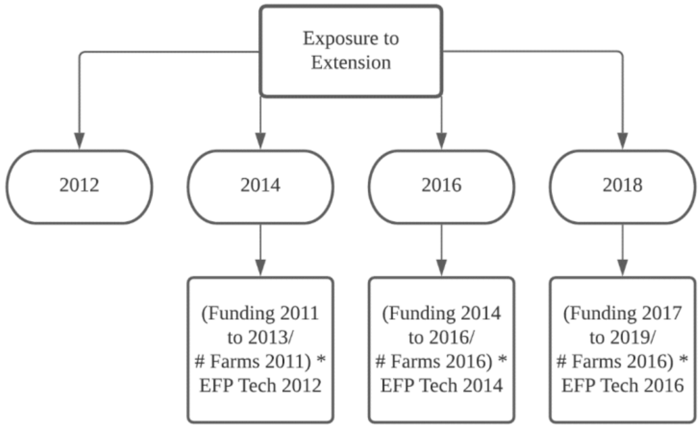

Figure 5.4. The development of interaction variables as a proxy for exposure to extension.

A model to understand the influence of farm and farmer characteristics (X_f) on EFP completion is first developed. Given that a significant proportion of research examining the EFP has centred on these characteristics, we find it is relevant to begin with this initial model, described in (11), prior to adding variables corresponding with exposure to extension or industry standards. This model includes all years of the ESAT survey.

$$(11)\ E(EFP|x) = G(\beta_1 + \partial_1 Year_{2014} + \partial_1 Year_{2016} + \partial_1 Year_{2018} + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 GFR250 + \beta_5 Degree + \beta_6 Training + \beta_7 Expand + \beta_8 Reduce + \beta_9 Sell + \beta_{10} Livestock + \beta_{11} Equal + \beta_{12} Own + \beta_{13} Both + \partial_2 County_i$$

With the addition of exposure to extension and industry standards (X_j), due to the nature of these variables, we develop four models to represent each survey year individually; these are shown in (12) to (15).

<u>Year: 2012</u>

$$(12)\ E(EFP|x) = G(\beta_1 + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 GFR250 + \beta_5 Degree + \beta_6 Training + \beta_7 Expand + \beta_8 Reduce + \beta_9 Sell + \beta_{10} Livestock + \beta_{11} Equal + \beta_{12} Own + \beta_{13} Both + \beta_{17} PotatoFarmer_{2011} + \beta_{19} Beef_{2011} + \partial_2 County_i$$

Year: 2014

(13) $E(EFP|x) = G(\beta_1 + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 GFR250 + \beta_5 Degree + \beta_6 Training + \beta_7 Expand + \beta_8 Reduce + \beta_9 Sell + \beta_{10} Livestock + \beta_{11} Equal + \beta_{12} Own + \beta_{13} Both + \beta_{14} F_{2011to2013} * Tech_{2012} + \beta_{17} PotatoFarmer_{2011} + \beta_{18} Eggfarm_{2011} + \beta_{19} Beef_{2011} + \partial_2 County_i$

Year: 2016

(14) $E(EFP|x) = G(\beta_1 + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 GFR250 + \beta_5 Degree + \beta_6 Training + \beta_7 Expand + \beta_8 Reduce + \beta_9 Sell + \beta_{10} Livestock + \beta_{11} Equal + \beta_{12} Own + \beta_{13} Both + \beta_{15} F_{2014to2016} * Tech_{2014} + \beta_{17} PotatoFarmer_{2016} + \beta_{18} Eggfarm_{2016} + \beta_{19} Beef_{2016} + \partial_2 County_i$

Year: 2018

(15) $E(EFP|x) = G(\beta_1 + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 GFR250 + \beta_5 Degree + \beta_6 Training + \beta_7 Expand + \beta_8 Reduce + \beta_9 Sell + \beta_{10} Livestock + \beta_{11} Equal + \beta_{12} Own + \beta_{13} Both + \beta_{16} F_{2017to2019} * Tech_{2016} + \beta_{17} PotatoFarmer_{2016} + \beta_{18} Eggfarm_{2016} + \beta_{19} Beef_{2016} + \beta_{20} Dairy_{2016} + \partial_2 County_i$

Our 2012 model (12) does not incorporate exposure to extension due to a lack of available data. Further, this model does not include PEEP as an industry standard since this program did not begin until 2014, after the 2012 survey was administered. Our 2018 model (15) includes proAction, represented as $\beta_{20} Dairy_{2016}$, as we assume the introduction of the environment chapter, and the requirement of the EFP, may have been a motivating factor as early as 2017. As Greiner et al. (2009) found, producers will often adapt in anticipation of new environmental regulations. In the case of this thesis, it is hypothesized farmers may have completed the EFP prior to the implementation of the environmental module under proAction to overcome the anticipation of new regulations. Some of the variables are weighted, which was described in section 2.2, to ensure that the overall sample's regional and gross farm sales reflect the distribution of the Census of Agriculture statistics. With respect to the goodness of fit of our models, we follow post estimation techniques as described in Chapter 6. All models were run through STATA 16.0, a common econometric modelling software. We produce results showing the coefficients under a general logistic regression as well as calculated marginal effects.

Marginal effects tell us how the probability of participation is altered when an independent variable changes, and these results are easier to interpret.

5.8 Results

5.8.1 Descriptive Statistics

Comparing producers with and without an EFP:

We begin this section by focusing on the comparison between Alberta producers who have and have not completed an EFP. This is used to determine if there are significant farm or farmer characteristic differences between the two groups. Table 5.3 provides an overview of mean responses for farm and farmer characteristics for respondents with and without an EFP for each corresponding year of the ESAT survey (2012-2018). We find respondents who have an EFP are more likely to have an agriculturally related degree or diploma, attend conservation training, and have higher gross farm revenue on average. These producers also are more likely to be expanding their operation and are slightly less likely to primarily own land compared to those without an EFP. An interesting result is the contrast between livestock and crop producers. Originally, in 2012 and 2014 those with an EFP were more likely to be crop producers, but by 2016 and 2018 there was a higher percentage of livestock producers with an EFP. This may reflect the nature of industry standards or may be associated with the increase in livestock producers in these surveys. Respondents without an EFP are slightly more likely to be planning to reduce their operation. No other characteristics differed between those with and without an EFP. All together, we find there are characteristic differences between producers who have obtained an EFP compared to those who have not.

Table 5.3. Characteristics of Alberta Producers with and without an Environmental Farm Plan Across ESAT Surveys.

	Has an Environmental Farm Plan				Does Not Have an Environmental Farm Plan			
	2012	2014	2016	2018	2012	2014	2016	2018
Age 18 to 44	11%	6%	13%	11%	11%	9%	8%	10%
Age 45 to 64	62%	65%	65%	55%	51%	56%	58%	48%
Has a Degree	36%	37%	41%	39%	23%	24%	25%	20%
Attended Conservation Training	44%	38%	38%	29%	16%	21%	16%	15%
Planning to expand operation	27%	30%	24%	22%	15%	10%	16%	11%
Planning to reduce operation	17%	24%	19%	22%	34%	31%	27%	33%
Planning to sell operation	1%	4%	2%	5%	1%	5%	5%	7%
Primarily a livestock producer	27%	28%	42%	45%	40%	32%	43%	52%
Primarily a crop producer	49%	56%	33%	41%	43%	54%	31%	31%
Equally a crop and livestock producer	24%	16%	25%	14%	17%	13%	26%	17%
Gross farm revenue (GFR) > $250k	53%	57%	60%	61%	23%	25%	37%	25%
Primarily Owns Land	40%	36%	32%	38%	53%	51%	43%	46%
Primarily Rents Land	0%	2%	0%	0%	2%	0%	2%	3%
Equally Rent and Owns	59%	63%	68%	62%	45%	49%	55%	52%
Obs. (N)	202	191	193	207	262	224	240	227

Table 5.4 shows the average extension expenditure in a Municipal District for producers with and without an EFP and the average expenditure for all respondents. This table also shows the average number of EFP technicians in a district for all respondents and those with and without an EFP.

Table 5.4. Mean Extension Expenditure and EFP Technicians for Producers with and without an Environmental Farm Plan (EFP).

Year	Mean Respondent	Mean (With EFP)	Mean (Without EFP)
	Extension Expenditure from ASBGP		
2010	$27,157	$28,665	$25,897
2011 to 2013	$89,888	$94,315	$86,204
2014 to 2016	$28,688	$30,011	$27,586
2017 to 2019	$25,873	$27,394	$24,606
	Number of EFP Technicians		
2012	~1	~1	~1
2014	~1	~1	~1
2016	~2	~2	~2
2018	~2	~2	~2

Source: Environmental Stewardship Branch at Alberta Agriculture and Forestry (2020).

We find no significant differences between farmers with and without an EFP regarding the number of EFP technicians in a Municipal District. Although, farmers who have completed an EFP were more likely to live in a Municipal District which had slightly higher levels of extension expenditure. However, the level of expenditure does not seem to be significantly more than those without an EFP.

Environmental Farm Plan completion descriptive statistics:

The second half of this section will discuss EFP completion in general rather than comparing producers with and without an EFP. Table 5.5 provides an overview of mean EFP completion per Municipal District in Alberta biannually from the year 2010 to 2018. Note, this information does not come from the ESAT survey and was provided by ARECA. Due to confidentiality limitations, we only provide mean results for EFP completion and do not identify individual Municipal Districts.

Table 5.5. Mean Number of Completed EFPs Across Alberta Municipal Districts from 2010 to 2018.

Year	Mean	Min	Max	Alberta Total
2010	2	0	17	105
2012	2	0	22	125
2014	~5	0	17	317
2016	4	0	14	277
2018	~7	0	29	465

Source: ARECA (2020)

We find that there are Municipal Districts who had no producers complete an EFP on an annual basis, as shown by the minimum value equal to zero. There are also Municipal Districts who had significantly higher levels of EFP completion as shown by the maximum values. The most important finding is the upward trend in EFP completion over time, aside from the 2014 to 2016 decline. This decline from 2014 to 2016 may be attributed to the significant reduction of extension expenditure, as shown in Table 5.4, per Municipal District. However, this expenditure did not increase for the 2018 year. This increase in EFP completion between 2016 to 2018 may be attributed to the new Alberta EFP regulations (beginning in 2018) where producers must renew their EFPs every 10 years, where it is plausible a proportion of this increase is producers renewing their EFPs. Regardless, it is noteworthy to recognize that EFP completion has significantly increased from 2010 with 105 EFPs completed, to 2018 with 465 EFPs completed in these fiscal years. This upward trend has also increased at the Municipal District level, where in 2010, an average of 2 producers in a Municipal District completed an EFP, to 2018, where roughly 7 producers in a Municipal District are likely to complete an EFP in a fiscal year.

Municipal District Statistics:

In Appendix 2A, a map identifying Alberta Land-use Regions is included, showing which Municipal Districts are located under each of the seven regions. Land-use regions were developed by the Government of Alberta and are based on major watersheds, with boundaries aligned to fit with existing municipal boundaries and natural regions (Government of Alberta 2017). Table 5.6A provides an overview of mean region-specific characteristics in Alberta. The South Saskatchewan region has the highest percentage of farmers with gross farm revenue greater than $250,000, the highest percentage of farmers who have a degree or diploma in an agriculturally related area, as well as the highest percentage of producers who primarily own land. The Red Deer region has the highest percentage of producers who have an EFP, the most farms per Municipal District, and the highest level of extension funding over time. The Northern Saskatchewan region is tied with the Red Deer region with the highest percentage of completed EFPs, the Lower Peace region had the highest percentage of producers who had attended conservation training in the past two years, and Lower Athabasca had the most livestock producers.

Table 5.6B provides an overview of the mean number of farms in Alberta who identify as potato, egg, beef and/or dairy producers. Some Municipal Districts had no egg, potato, or dairy farmers, although this varied as shown by the standard deviation. Every Municipal District had a minimum of 13 beef producers, which is not surprising given Alberta's beef cattle industry. However, there are Municipal Districts who had significantly more egg, potato, beef, or dairy producers. These districts should correspond to higher levels of EFP completion as these producers are impacted by current industry standards. To further explore the relationship between EFP completion and industry standards, we develop Table A2 found in Appendix 2B. For this section, we summarize this information in Table 5.7. We find that, on average, out of the five top Municipal Districts with egg, potato, beef, or dairy producers, most of these regions had producers who were more likely to complete an EFP. Although, overall, the relationship between EFP completion and industry standards was relatively heterogeneous.

Table 5.6A. Descriptive Statistics for Alberta Land-Use Regions Based on the 2012-2018 ESAT Surveys.

Region	Age (Mean)	GFR > $250,000 (%)	Degree (%)	Attended Conservation Training (%)	Total Extension Funding ($)	Own Land (%)	EFP (%)	No. of Farms 2016	Livestock Farmer	Obs. (N)
Lower Athabasca	55 to 64	33%	20%	33%	$98,333	43%	32%	578	50%	40
Lower Peace	45 to 54	43%	24%	39%	$21, 599	37%	42%	446	22%	54
North Saskatchewan	55 to 64	33%	27%	24%	$152,027	42%	51%	740	39%	575
Red Deer	55 to 64	40%	28%	27%	$238,726	44%	51%	1028	48%	188
South Saskatchewan	55 to 64	51%	39%	27%	$230,952	45%	39%	733	34%	465
Upper Athabasca	55 to 64	33%	22%	21%	$117,189	43%	52%	658	46%	216
Upper Peace	55 to 64	47%	28%	29%	$149,000	43%	45%	567	31%	244

Source: AAF (2020); AAF (2018); Government of Alberta (2016); Government of Alberta (2014); Government of Alberta (2012).

Table 5.6B. Mean Number of Egg, Potato, Beef, and Dairy Farms per Municipal District (2016 Census of Agriculture for Alberta)[13].

	2016 Alberta Census of Agriculture (Mean)	Std. Dev.	Min	Max	Obs. (N)
Number of Egg Farms per Municipal Region	19	12	0	46	1745
Number of Potato Farms per Municipal Region	4	8	0	63	1745
Number of Beef Farms per Municipal Region	211	118	13	529	1745
Number of Dairy Farms per Municipal Region	9	15	0	60	1745

Source: (AAF 2020)

Table 5.7. Municipal Districts with the Most Egg, Potato, Beef and Dairy Farms and Their Mean EFP Completion.

Commodity Group	Municipal Districts with the Most Farmers per Commodity Group (Mean EFP Completion (%))
Egg Farmers	1. Mackenzie (29%) 2. Lethbridge (55%) 3. Mountain View (52%) 4. Rocky View (60%) 5. Red Deer (59%)
Potato Farmers	1.Taber (63%) 2. Red Deer (59%) 3. Forty Mile (53%) 4. Parkland (21%) 5. Sturgeon (42%)
Beef Farmers	1. Mountain View (52%) 2. Red Deer (59%) 3. Ponoka (33%) 4. Clear Water (45%) 5. Cypress (39%)
Dairy Farmers	1. Lethbridge (55%) 2. Lacombe (47%) 3. Ponoka (33%) 4. Leduc (41%) 5. Red Deer (59%)

Source: AAF (2020).

[13] The number of farms shown in Table 5.6B did not differ significantly from the 2011 Alberta Census of Agriculture.

To further explore possible spatial determinants of EFP participation, we develop figures 5.5 to 5.7 which provide a basic mapping of EFP completion[14], extension expenditure, and the number of EFP technicians across Municipal Districts. Figure 5.5 maps the spatial relationship between Municipal Districts and the mean percentage of EFP completion for farmers in that district. We find that EFP completion is relatively higher in the southern region of Alberta, with the lowest number of EFP completion in the central and far north regions. In figure 5.6, it seems extension expenditure is also higher in the southern regions, which may correspond to the higher rate of EFP completion. Finally, in figure 5.7 we map the spatial relationship between Municipal Districts and the number of EFP technicians, where the number of technicians is relatively heterogeneous across counties.

[14] All mapping is done with 72-74% confidence and does not represent all Municipal Districts in Alberta. Only Municipal Districts included as a subsample in the 2012-2018 ESAT surveys were included.

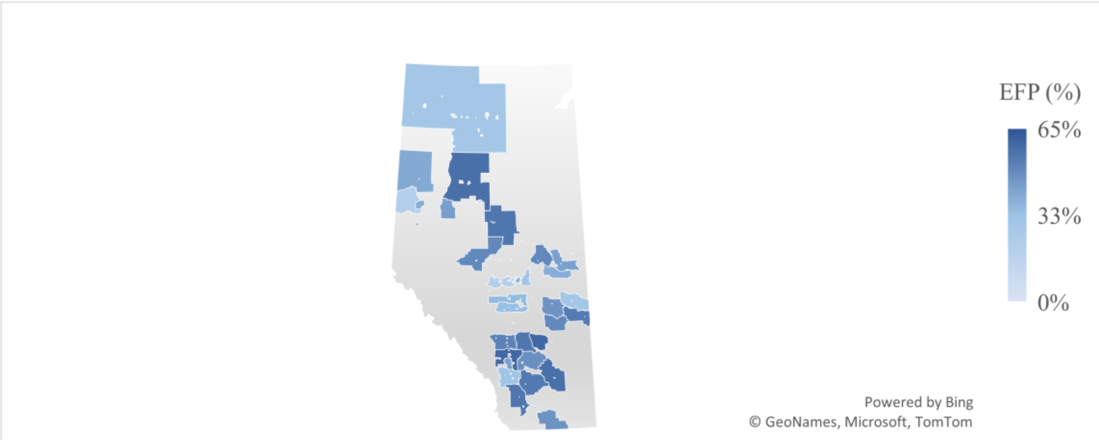

Figure 5.5. Farmers who have completed an EFP across Municipal Districts (%).

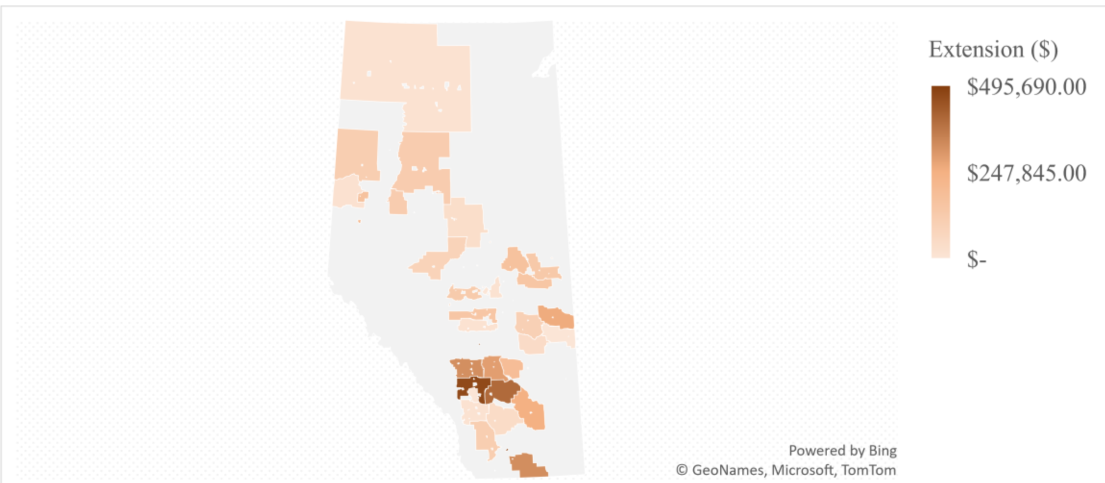

Figure 5.6. Extension Expenditure per Municipal District (2010-2019).

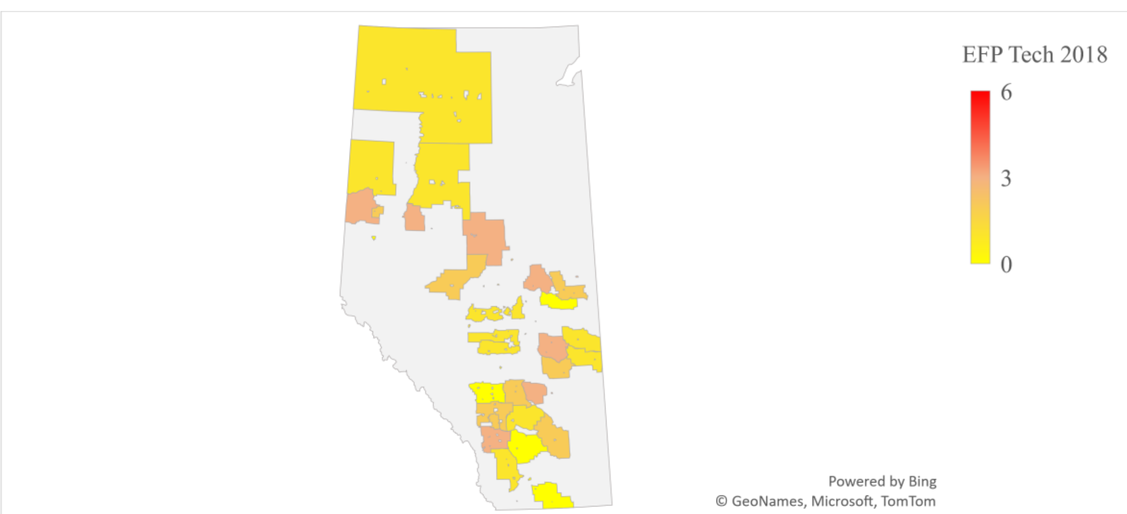

Figure 5.7. Number of EFP Technicians in a Municipal District (2018).

Lastly, tables 5.8 and 5.9 compare five Municipal Districts with the highest percentage of EFP completion and five Municipal Districts with the lowest percentage of EFP completion, respectively. These tables also include mean total extension expenditure from 2010 to 2019 and the number of EFP technicians for these Municipal Districts (as of 2018). A good proportion of the Municipal Districts with the highest percentage of EFP completion are in Southern Alberta (Red Deer and South Saskatchewan regions). These Southern Municipal Districts have some of the largest farms in acres, as well as farms with the highest gross farm revenue, higher total farm capital as of 2016, including the highest values for livestock capital (AAF 2020; Statistics Canada 2017). This may indicate livestock intensive, larger, and higher revenue farms are more likely to complete an EFP. This again may correspond to industry standards. Some of these districts also have more EFP technicians compared to the average Municipal District in Alberta, as well as higher levels of total extension expenditure.

Table 5.8. Five Municipal Districts with the Highest Percentage of EFP Completion.

Municipal District	Municipal Region	No. of Farms in 2016[1]	Mean EFP Completion (%)	Mean Total Expenditure ($)	No. of Technicians in 2018	N
1. Greenview	Upper Peace	534	65%	$117,333	4	26
2. Taber	South Saskatchewan	633	63%	$0	0	40
3. Yellowhead	Upper Athabasca	611	62%	$86,600	2	26
4[2]. Fairview	Upper Peace	202	60%	$142,933	3	15
4. Rocky View	South Saskatchewan	1,135	60%	$468,250	3	30
4. Starland	Red Deer	309	60%	$189,600	0	10
5. Red Deer	Red Deer	1,460	59%	$495,690	3	37

Source: AAF (2020); ARECA (2020); AAF (2020). [1]This information was provided by the 2016 Census of Agriculture for Alberta. [2]These Municipal Districts were tied and had the same mean EFP completion.

Municipal Districts who held the lowest percentage of completed EFPs were located in either Northern Alberta (Lower/Upper Athabasca, Upper Peace) or in the Central region (North Saskatchewan). Northern Alberta is more crop-dependent and has less producers who are livestock intensive compared to southern regions (AAF 2020). Further, there are less farms in these regions, lower average farm capital, and lower gross farm receipts compared to the south. These factors may attribute to the lower completion rates for the EFP. Total extension expenditure in this region was also lower, although it seems most of these regions had access to an EFP technician, except in Lower Peace. With respect to the central region (North Saskatchewan), this region is comparable to the south, but still has lower gross farm receipts compared to South Saskatchewan and less total acres compared to the southern region overall. However, total extension expenditure and access to EFP technicians is comparable to the south. These results are surprising since the North Saskatchewan region as a whole has the highest rate of EFP completion (tied with Red Deer) which shows a contrast between Municipal Districts within the North Saskatchewan region.

Table 5.9. Five Municipal Districts with the Lowest Percentage of EFP Completion.

Municipal District	Municipal Region	No. of Farms in 2016[1]	Mean EFP Completion (%)	Mean Total Expenditure ($)	No. of Technicians in 2018	N
1. Saddle Hills	Upper Peace	381	20	17,500	3	15
2. Beaver	North Saskatchewan	631	21	146,930	2	24
2. Parkland	North Saskatchewan	679	21	125,085	3	24
4. Athabasca	Upper Athabasca	650	28	111,002	1	18
5[2]. Lac La Biche	Lower Athabasca	238	29	98,333	1	7
5. Mackenzie	Lower Peace	610	29	15,000	0	21
5. Wainwright	North Saskatchewan	535	29	259,125	1	14

Source: AAF (2020); ARECA (2020); AAF (2020). [1]This information was provided by the 2016 Census of Agriculture for Alberta. [2]These Municipal Districts were tied and had the same mean EFP completion.

5.8.2 Farm and Farmer Characteristic Model

Our first econometric model shown in Table 5.10A corresponds to equation (11) which only explores farm and farmer characteristics (X_f) and their impact on a farmer's decision to complete an EFP. The variance inflation factor (VIF) was found to be 1.81 indicating a low level of correlation amongst the independent variables, suggesting we do not have a presence of multicollinearity. To examine the validity of the model, a test for model specification was run called the link test. The link test is to show that there should be no additional independent variables that explain EFP completion, except by chance. Our results for this test indicate our variables are meaningful towards influencing EFP completion, although, we have a specification error. This means there are other variables we have not captured in this model which may be significant towards influencing EFP completion.

Table 5.10A. Logistic and Marginal Effect Coefficients for Farm and Farmer Characteristics Influence on Environmental Farm Plan Participation.

	Model 1: Logit Coefficients (SE)	Model 1: Marginal Effects (SE)
Year: 2014	0.212	0.041
	(0.185)	(0.035)
Year: 2016	-0.054	-0.010
	(0.195)	(0.038)
Year: 2018	0.177	0.034
	(0.196)	(0.038)
Farmer Characteristics		
Age: 18 to 44	-0.128	-0.024
	(0.270)	(0.052)
Age: 45 to 64	0.155	0.03
	(0.170)	(0.033)
Has a degree	0.582***	0.112***
	(0.161)	(0.031)
Attended conservation training	0.977***	0.189***
	(0.162)	(0.03)
GFR>$250k	1.070***	0.207***
	(0.161)	(0.029)
Farm Characteristics		
Planning to expand	0.361*	0.07*
	(0.202)	(0.039)
Planning to reduce	-0.255	-0.049
	(0.178)	(0.034)
Planning to sell	0.025	0.005
	(0.314)	(0.061)
Primarily livestock	-0.049	-0.009
	(0.166)	(0.032)
Both crop and livestock	0.222	0 .043
	(0.197)	(0.038)
Primarily Own land	-0.027	-0.005
	(0.696)	(0.134)
Both rent and own land	0.250	0.048
	(0.698)	(0.135)
Constant	-0.884	-
	(0.793)	
N	1442	1442
AIC	1781.66	-
BIC	2214.11	-

Note: Significance levels are ***p<0.01, **p<0.05, *p<0.1

We find that producers who have a degree, have attended conservation training, and have gross farm revenue greater than $250,000 are significantly more likely to complete an EFP. Further, producers who are planning to expand their operation are also more likely to complete an EFP. From these results, there are no characteristics that significantly deter a producer from completing an EFP, but since the model is missing relevant predictors, we cannot speak more on the significance of these variables.

Table 5.10B provides our results for Municipal Districts of significance in our model. Surprisingly, for this model we find no Municipal Districts where producers are significantly more likely to complete an EFP. However, 14 districts were significantly *less* likely to complete an EFP. Six of these Municipal Districts are in the Northern Saskatchewan region, where farms in this region are likely to have lower gross farm revenue and are more likely to primarily be a livestock producer. However, this region had the highest level of EFP completion. These results suggest a presence of vast heterogeneity within land-use regions.

Table 5.10B. Statistically Significant (p<0.10) Alberta Municipal Districts Where Producers are More (or Less) Likely to Complete an Environmental Farm Plan.

Municipal District(s) with positive significance	Municipal District(s) with negative significance
No counties of significance	Beaver, Big Lakes, Birch Hills, Clear Hills, Cypress, Lac La Biche, Mackenzie, Minburn, Mountain View, Parkland, St. Paul, Thorhild, Two Hills, Warner

5.8.3 Model Results Based on Individual ESAT Survey Years

The results for our individual survey year models correspond to equations (12) to (15) and include variables representing both X_f and X_j. Table 5.11 provides an overview of our post estimation tests that explore the goodness of fit of our models. These tests were completed to ensure we included meaningful predictors across yearly models, and that the models are properly specified. For both our 2016 and 2018 models, our variable indicating producers who both owned and rented land was dropped due to high multicollinearity across these years. Only the 2016 model does not pass the link test indicating there are omitted relevant variables we did not account for. We cannot comment on what possible variables have been omitted; however, it seems there was some additional factor in this year that influenced EFP completion. However, the link test does determine we have chosen meaningful predictors. For the 2012, 2014, and 2018 econometric models, these are all determined to be properly specified and hold meaningful predictors.

Table 5.11. Post Estimation Results for the 2012, 2014, 2016 and 2018 Models Showing Model Goodness-of-Fit.

	Log pseudo-likelihood	VIF	Link test _hat	Link test _hatsq	AIC	BIC	Obs. (N)
2012 Model	-197.77	3.41	✔	✔	533.55	813.79	429
2014 Model	-171.23	4.14	✔	✔	476.46	739.02	372
2016 Model	-146.15	1.26	✔		412.30	627.31	266
2018 Model	-127.37	1.32	✔	✔	368.75	571.70	260

* ✔ signifies the model passed the conditions imposed by the link test.

Table 5.12A represents model estimates (general logistic coefficients) based on individual survey year data, which now includes extension effort and industry standards as measures which are hypothesized to influence EFP completion. Table A3 provides marginal effects for model estimates based on individual survey years and can be found in Appendix 2C. For simplicity, all results will be discussed by each category rather than by individual model.

Table 5.12A. Coefficients Associated with Individual Year Models for EFP Completion Among Alberta Farmers in the ESAT Data.

	Model 2 Year 2012 (SE)	Model 3 Year 2014 (SE)	Model 4 Year 2016 (SE)	Model 5 Year 2018 (SE)
Farmer Characteristics				
Age: 18 to 44	-0.465 (0.662)	-1.020 (0.796)	0.882 (0.687)	0.020 (0.643)
Age: 45 to 64	-0.175 (0.338)	0.199 (0.398)	0.213 (0.430)	0.068 (0.413)
Has a degree	0.712** (0.357)	0.848** (0.371)	0.670* (0.388)	0.811* (0.461)
Attended conservation training	1.527*** (0.354)	0.939** (0.370)	1.102*** (0.381)	1.809*** (0.518)
GFR>$250k	1.121*** (0.346)	1.891*** (0.455)	1.742*** (0.449)	1.673*** (0.435)
Farm Characteristics				
Planning to expand	0.564 (0.387)	0.598 (0.568)	-1.010** (0.487)	0.490 (0.498)
Planning to reduce	-0.815** (0.408)	0.082 (0.400)	-0.216 (0.466)	0.408 (0.499)
Planning to sell	0.948* (0.563)	-1.061 (0.795)	-0.725 (1.088)	-0.641 (0.961)
Primarily livestock	-0.467 (0.345)	0.265 (0.417)	0.084 (0.432)	-0.058 (0.465)
Both crop and livestock	0.379 (0.448)	0.654 (0.546)	-0.238 (0.429)	-0.455 (0.531)
Primarily own land	0.800 (1.048)	4.129*** (1.488)	-0.271 (0.358)	0.513 (0.410)
Both rent and own land	1.378 (1.021)	-3.363** (1.436)		
Exposure to Extension				
2011 to 2013 Funding*2012 EFP Technicians		-0.061** (0.028)		
2014 to 2016 Funding*2014 EFP Technicians			0.035 (0.023)	
2017 to 2019 Funding*2016 EFP Technicians				-0.052 (0.035)

Industry Standards				
Main Potato Farmers (2011 Census)	-0.078 (0.052)	0.035 (0.029)		
Main Potato Farmers (2016 Census)			0.010 (0.022)	0.034 (0.026)
Egg Farmer (2011 Census)		0.136** (0.069)		
Egg Farmer (2016 Census)			-0.083** (0.034)	0.022 (0.049)
Beef Producer (2011 Census)	-0.001 (0.003)	0.011 (0.010)		
Beef Producer (2016 Census)			0.003 (0.007)	-0.029* (0.017)
Dairy Farmer (2016 Census)				0.375* (0.210)
Constant	-0.949 (1.767)			5.776 (5.107)
N	429	372	266	260
AIC	533.55	476.46	412.30	368.75
BIC	813.79	739.02	627.31	571.70

Note: Significance levels are ***p<0.01, **p<0.05, *p<0.1

The results indicate that age is statistically insignificant across all models for producers aged 18 to 44 and aged 45 to 64. This is contrary to prior agri-environmental literature, which has shown age is significant towards a producer's management decisions (Baumgart-Getz et al. 2012; Prokopy et al. 2008). Having a degree or diploma in an agriculturally related area is statistically significant at the 5% level in 2012 and 2014, and 10% level in 2016 and 2018. This indicates that producers with a degree are more likely to complete an EFP compared to those without one. Producers who attended conservation training were also significantly more likely to complete an EFP at the 1% level across all models. This is consistent with the significance of conservation training found in Prokopy et al. (2019) and Baumgart-Getz (2012) meta-analysis, as well as Atari et al. (2009) who found EFP training improved EFP completion rates. After calculating marginal effects, we find producers who attended conservation training in 2012, 2014, 2016, and 2018 were 24%, 15%, 20% and 30% more likely to complete an EFP. Lastly, gross farm revenue of over $250,000 also significantly influenced EFP completion across all models, also at the 1% level. Marginal effects show producers in 2012-2018 were 18%, 30%, 31%, and 28% more likely to complete an EFP if they had higher gross farm revenue. This is consistent with the current EFP literature (Smithers & Furnman 2003; Atari et al. 2009; Yiridoe et al. 2010).

Regarding exposure to extension, these results were unanticipated as we found exposure was only statistically significant in the 2014 model. This indicates that in 2012, 2016 and 2018, the level of extension expenditures influence on EFP completion does not depend on the number of EFP technicians (extension agents). This contrasts with prior literature which has shown extension is a commonly used vehicle that is important and significantly influences a producer's management decisions (Pannell et al. 2006; Feather & Amacher 1994). In 2014 however, exposure to extension was found to negatively impact the decision to complete an EFP. This goes against the prior hypothesis that exposure to extension should improve the rate of EFP participation.

For industry standards, we find vast heterogeneity across each individual year. Surprisingly, being a main potato producer in Alberta was found to be statistically insignificant across all models. Even though this industry requires an EFP, it is plausible that most potato producers already completed an EFP prior to each survey since this regulation was introduced in 2010. Thus, this could explain its insignificance. Egg producers were more likely to complete an EFP in the 2014 model but were less likely to complete an EFP in 2016. Prior to 2014, the industry was moving towards sustainable standards, but PEEP was not yet implemented. Thus, producers who answered the 2014 survey may have completed an EFP to meet these standards, whereas 2016 and 2018 respondents may have decided to forego completing an EFP in favour of PEEP. VBP+ was only significant in 2018 where beef producers were less likely to complete an EFP. Possibly, since this industry does not require an EFP, producers may opt out of its completion if VBP+ alone provides the necessary private benefits and allows for continued market access. The 2018 model was also the only model to include proAction as a measure of industry standards, where we found dairy farmers in Alberta are more likely to complete an EFP at the 10% level. Average marginal effects show a unit increase of being a dairy farmer results in a 6% increase in the probability a producer will complete an EFP. This suggests that dairy farmers may have completed an EFP in anticipation of the new regulatory standards provided by proAction's environment module. This is consistent with Greiner et al. (2009) who found producers often adapt prior to new environmental regulations being implemented. This is also consistent with Atari et al. (2009) who found farmers completed an EFP to improve their compliance with environmental regulations. In all, the effects of industry standards seem to be heterogeneous across years, which may relate to program implementation and altering requirements.

The econometric results also indicate that farm characteristics are quite heterogeneous across each individual survey year. In 2012, the average marginal effects show a one unit increase of a producer deciding to reduce their operation reduces the probability of completing an EFP by 13%. Planning to sell increases the probability of completing an EFP by 15%. Possibly, obtaining an EFP would allow for a producer to mitigate environmental risks prior to selling, which may improve the market value, especially for agricultural land. Only in the 2016 model planning to expand their farm results in a reduced probability of completing an EFP by 18%. Across all models, being primarily a livestock farmer or an equal mix, was statistically insignificant; this is contrary to findings by Atari et al. (2009) who found being a livestock farmer was significant to EFP completion. This is also a surprising result given the current industry standards which primarily impact livestock producers. In both the 2014 and 2016 model's, producers who primarily owned land were more likely to complete an EFP. It is plausible producers who own their land are more concerned with environmental risks as they bare more risk if they are not mitigated. However, we find conflicting results with producers who own and rent land equally, where in 2014 these producers were less likely to complete an EFP.

Table 5.12B provides the results for our spatial indicators for Municipal Districts across our yearly models. In 2012 there were no districts of statistical significance where producers were less likely to complete an EFP. Instead, five Municipal Districts had producers who were significantly more likely to complete an EFP, and these producers were less likely to primarily own land. In 2014, three of the seven Municipal Districts which were more likely to complete an EFP are in the Southern Saskatchewan region. All seven of these districts contained primarily livestock producers, and five of the seven Municipal Districts had producers with higher gross farm revenue on average. Further, for our 2014 model, 22 Municipal Districts had producers who were significantly less likely to complete an EFP. Nine of these districts are in the Northern Saskatchewan region, with five located in the South Saskatchewan region; all other Municipal Districts of significance were heterogeneous. Across all 22 Municipal Districts, there were no statistically significant characteristics that could be used to hypothesize why producers in these districts were less likely to complete an EFP. In 2016, producers in two of the three Municipal Districts who are more likely to complete an EFP are in the Northern Saskatchewan region. All three Municipal Districts had respondents with lower gross farm revenue and both Barrhead and Parkland producers were more likely to be planning to reduce their operations. Finally, in 2018 only two Municipal Districts held producers who were more likely to complete an EFP, but there were seven Municipal Districts who had producers that were significantly less likely to complete an EFP. Four of these regions are found in Northern Saskatchewan. Again, this is surprising given the high percentage of EFP completion for some Municipal Districts in this region. This again indicates a high degree of heterogeneity across Municipal Districts, even within the same land-use region.

Table 5.12B. Statistically Significant (p<0.10) Alberta Municipal Districts with Producers Who are More (or Less) Likely to Complete an Environmental Farm Plan.

	Municipal Districts (+) Significance	Municipal Districts (-) Significance
2012		Big Lakes, Camrose, Cypress, Mackenzie, Mountain View
2014	Big Lakes, Newell, Northern Sunrise, Smoky Lake, Smoky River, Warner, Wheatland	Barrhead, Birch Hills, Bonnyville, Clear Hills, Foothills, Forty Mile, Lacombe, Lamont, Leduc, Mountain View, Northern Lights, Peace, Pincher Creek, Provost, Strathcona, Sturgeon, Taber, Two Hills, Vermilion, Wainwright, Wetaskiwin, Willow Creek
2016	Barrhead, Parkland, Sturgeon	
2018	Clearwater, Lac Ste. Anne	Lacombe, Leduc, Lethbridge, Mackenzie, Parkland, Two Hills, Wetaskiwin

5.9 Discussion

This chapter provides insights into components that influence an Albertan farmer's decision to complete an Environmental Farm Plan (EFP). With limited prior literature on the EFP and, to our knowledge, no known literature on the Alberta EFP, these results can aid with the future implementation of the Alberta EFP programme. Our findings showed the significance of having a degree, attending conservation training, and higher gross farm revenue, which align with prior literature (Prokopy et al. 2019; Baumgart-Getz et al. 2012; Atari et al. 2009; Yiridoe et al. 2010). Having a degree and attending conservation training both provide an added layer of awareness and knowledge regarding environmental risks (Atari et al. 2009; Robinson 2006) and these farmers may be more intrinsically motivated to mitigate risks by completing an EFP. Higher gross farm revenue may relate to the idea that these farmers can bare more financial risk and have a higher threshold to adopt BMPs to mitigate environmental risks on their land (Baumgart-Getz et al. 2012; Kim et al. 2005).

Extension services are among the most common methods to convey agri-environmental information to farmers (Pannell 2008; Rollins et al. 2019; Rodriguez et al. 2009). The addition of exposure to extension was meant to understand this relationship in the context of the EFP, adding both the element of extension expenditure and the Alberta EFP programmes EFP technicians. To our surprise, exposure to extension was largely statistically insignificant. This indicates that the effect of extension on EFP completion does not depend on the number of EFP technicians in a Municipal District. Possibly, this may allude to a disconnect between EFP technicians and Alberta producers, where the level of information is not satisfactory and does not convey the benefits of the EFP program. Of course, it could also be the variables we used to examine exposure to extension, and they may not be the correct way to examine extension impacts for Alberta producers and the EFP program.

This analysis is also among the first (to our knowledge) to include industry standards (sustainable sourcing measures) as an explanatory variable that may influence EFP participation. The results show these standards do impact EFP completion and are dependent on the year of which these programs are implemented. This corresponds to the suggestion that producer's membership or association with certain organizations (industries) can alter management decisions (Pannell et al. 2006; Gillespie et al. 2007). This may also represent a gateway to implement cross-compliance measures to help reinforce stewardship actions (Morrison & FitzGibbon 2014; Atari et al. 2009).

Lastly, this analysis included a spatial component where we developed dummy variables to identify rural Municipal Districts in Alberta. These were included to capture unidentified factors at the Municipal District level that may influence EFP completion (ie. social networks). Across our yearly models, the impact of Municipal Districts on EFP completion was relatively heterogeneous. Due to this heterogeneity, and lack of further information, we are unable to speculate on the various regional characteristics which may influence rates of EFP completion.

Chapter 6: Exploring Alberta Farmers' Best Management Practice Adoption

6.1 Introduction

Conservation practices, or Best Management Practices (BMPs), are key components to developing long term sustainable agriculture. The voluntary nature of adoption has resulted in heterogeneous levels of uptake for these practices and technologies, and adoption is dependent on factors that influence a producer's management decisions (Gillespie et al. 2007; Greiner et al. 2009; Pannell 2003; Lamba et al. 2009). This has led researchers to inquire and hypothesize what components are important in altering land management decisions that result in farmers actively adopting practices to reduce environmental risks.

The previous chapters described agri-environmental policies and associated environmental stewardship programs. In Canada, these programs mainly focused on agricultural producers' voluntary adoption of BMPs to meet environmental goals under each policy framework. However, as previously stated, there is no indication regarding adoption rates, or overall environmental impacts since these programs were not subject to proper evaluation. In Alberta, the use of the Environmentally Sustainable Agriculture Tracking (ESAT) survey has shown that Alberta producers are adopting practices (AAF 2018). Albeit, some risk areas exhibit limited adoption rates, or their adoption rates have become stagnant over time. Out of the eight agri-environmental risk areas[15], both soil conservation and energy and climate change held the lowest rates of adoption from 2012 to 2018. Further, water quality and/or quantity, wildlife habitat management, manure management, and grazing management are risk areas that have held relatively similar adoption rates over time. Even though these adoption trends have not been statistically different for quite some time, there has been little effort made to better understand why Canadian producers are choosing to adopt, or not adopt, BMPs.

Research, as well as information on adoption rates and trends are limited across Canada. MacKay et al. (2010) explain that adoption information in Canada "…is often not synthesized in a way that can provide information on overall BMP adoption across the country, and therefore is challenging for policy makers to make use of it." Regulations, incentives, and local conditions all vary across provinces, providing the inability to cohesively explore adoption trends across

[15] The list of agri-environmental risk areas, and associated BMPs, can be found in section 2.3.1 to section 2.3.7.

Canada. Even within an individual province, there is limited information on adoption rates, and studies at provincial levels in western Canada are rare. With the ESAT survey, Alberta is fortunate to have a monitoring system in place to identify adoption trends. This chapter aims to utilize this survey and its results to explore various factors that motivate, or hinder, the adoption of BMPs in the Alberta context. Unlike other studies, we address BMP adoption across eight agri-environmental risk areas (stated in section 2.3) and include spatial relationships for adoption at a Municipal District level. Further, we explore the significance of the Environmental Farm Plan (EFP) across these risk areas.

6.2 Literature Review: Canadian Adoption of Best Management Practices

Literature on the adoption of agri-environmental practices in Canada has been limited, with a large proportion of studies focusing on soil conservation (Smit & Smithers 1992; Stonehouse 1995; Fraser 2004; Wandel & Smithers 2000). For example, Smit & Smithers (1992) examine the adoption of 11 soil conservation practices through measuring farm-level conservation effort and barriers to adoption (such as economic pressures). Further, most of this literature involved analysing adoption behaviour for conservation tillage (Wandel & Smithers 2000; Davey & Furtan 2008; Gray et al. 1996). Gray et al. (1996) explore economic indicators for adopting reduced tillage in central Saskatchewan, whereas Wandel & Smithers (2000) examine the low rates of adoption for conservation tillage in southwestern Ontario. Gray et al. (1996) found producers' decision to adopt reduced tillage depended on machinery and investment costs, as well as the profitability of increased yields. Wandel & Smithers (2000) found farmers were positively influenced by extension efforts and field demonstrations, with farmers also adopting for economic reasons such as cost savings. Another study by Warriner & Moul (1992) found social networks were highly influential on the adoption of tillage practices in southwestern Ontario.

The analysis of adoption in other risk areas in Canada are much less common. Practices affecting water quality represent the second most studied risk area (Yang et al. 2007; Jeffrey et al. 2014; Hassanzadeh et al. 2019; Rousseau et al. 2013). This is likely due to Canada's concentration of freshwater lakes, the use of intensive irrigation in the western provinces, and the strong link between past stewardship programs and water quality BMPs. A portion of this literature has concentrated on evaluating environmental and economic performance of BMPs, including studies in the Watershed Evaluation of Beneficial Management Practices[16] project (Rousseau et al. 2013; Stewart 2017; Yang et al. 2007). For example, Yang et al. (2007) develops an integrated economic-hydrologic modelling framework, including an on-farm economic model, farmer adoption behavioural model, and nonmarket valuation models, to improve the design of water conservation programs. Studies such as Hassanzadeh et al. (2019) suggest plausible frameworks to understand and incorporate stakeholders' viewpoints into water quality modelling in the Qu'Appelle River Basin, Saskatchewan. This included identifying BMPs stakeholders found the most effective, outlining producers preferred policies, and observing the environmental impact of these BMPs.

Most other Canadian research centres on the scientific background and proposed environmental impacts of specific BMPs, such as the level of soil sequestration, as opposed to exploring factors that influence their adoption. For example, Asgedom & Kebreab (2011) explore BMPs from cropping systems and grazing management, and their relation to reducing, removing and/or avoiding greenhouse gas emissions. Smith et al. (2010) use a DNDC-Management Factor Tool to generate soil, climate, and agricultural management model input data to estimate emissions for 462 eco districts across Canada; these results can be used to understand altered emission rates from management changes. Rasouli et al. (2014) study how adopting BMPs in agriculture can be effective for reducing nitrogen losses from agroecosystems in Ontario and Quebec. Even though understanding the environmental and economic implications of BMPs is important, producers must adopt these practices and see their benefits to consider altering their management practices. Thus, understanding determinants to adoption is also critical.

Highly referenced Canadian papers tend to centre on the province of Ontario, with others highlighting the neighbouring province of Québec (Smit & Smithers 1992; Filson et al. 2009; Traoré et al. 1998; Lamba et al. 2009). With respect to the province of Alberta, research has been especially limited regarding major drivers and barriers to BMP adoption. This can mostly be attributed to the grouping of prairie provinces as opposed to individual provincial inquiries. For

[16] The Watershed Evaluation of Beneficial Management Practices (BMPs) or WEBs was a partnership between Agriculture and Agri-Food Canada (AAFC) and Ducks Unlimited Canada and involved an extensive study of BMPs across Canada (Stewart, 2017).

example, Davey & Furtan (2008) studied factors that affected adoption decisions for conservation tillage in the Prairie region. Using a dummy variable to identify each of the three prairie provinces, they found Alberta farmers were less likely to adopt conservation tillage technologies compared to producers in Saskatchewan and Manitoba. Other factors such as gender, age, higher gross farm revenue, and soil type all influenced adoption, as well as larger farms being more likely to adopt (Davey & Furtan 2008).

Bjornlund et al. (2009) surveyed irrigators in two different Alberta irrigation districts (Taber and Raymond) to analyse how differences in production and personal characteristics correspond to adoption decisions. They found farmers in Taber had higher rates of adoption but suggest adoption may become stagnant in the long run; for Raymond, less efficient irrigation technology was adopted due to larger farm sizes, which may correspond to added financial risk. Baird et al. (2016) examined sources of information, advice networks, and spatial links for information in Southern Alberta watersheds and their effect on the uptake of water quality BMPs. Using geo visualization to explore the link between advisors, BMPs, and water quality, they found the quality of information and advice, specifically from government advisors, was significant to increasing adoption. Remarkably, Baird et al. (2016) found local actors, such as neighbours and family, did not play a significant role in influencing adoption decisions. A more recent study completed by Rollins et al. (2018) evaluated the implementation of BMPs to enhance and/or protect biodiversity in Alberta and examined the possible impact of extension activities. They found participants were more likely to adopt practices that had lower adoption costs, higher levels of trialability, and those that were more compatible with their operations. Higher cost practices were more likely to be adopted when private environmental benefits were observable. Further, Rollins et al. (2018) showed that extension services were successful in promoting a variety of BMPs to producers in Alberta.

In general, research regarding factors that influence the adoption of BMPs have been minimal for Canada, and particularly sparse in the province of Alberta. A significant proportion of research has been narrowly focused on specific BMPs and environmental risk areas, leaving a large gap for needed research. Thus, this chapter contributes to this gap by exploring factors that influence the adoption of BMPs across eight agri-environmental risk areas for producers in Alberta, Canada.

6.3 Methodology

6.3.1 Dependent Variable Development

This chapter uses the 2012-2018 ESAT survey data as described in Chapter 2, section 2.2. All supplementary data for this chapter is described in Chapter 5, section 5.6. This chapter first explores determinants influencing the level of adoption across agri-environment risk areas specific to Alberta. To facilitate this, seven of the agri-environmental risk areas were developed into dependent variables by generating an 'ESA Adoption Score' that can be seen below in (1), where ESA stands for environmentally sustainable agriculture. We group the general practices and agricultural waste management risk areas together for simplicity, this provides us with seven risk areas instead of the original eight. The ESA score has similarities to the score developed by MacKay et al. (2010) who developed a BMP Adoption Index calculated using data from the Canadian Farm Environmental Management Survey (FEMS). Their work was influenced by Andreoli and Tellarini (2000). Generally, studies have used some measure of BMP adoption for their dependent variable (Vercammen 2011), although most forego the issue surrounding farmers who are not eligible to adopt certain practices. The score used in this present analysis is:

$$(1)\ \ ESA\ Score_{jf} = \frac{Number\ of\ Practices\ Adopted_{jf}}{Number\ of\ Practices\ Eligible_{jf}}$$

where j represents the risk area for farmer f. To identify a farmer's eligibility for adopting a specific BMP, we examined each producer's reported operational characteristics to see if a BMP was feasible for their land or operation. To illustrate this process, Figure 6.1 provides a flow chart showing the eligibility requirements under the soil conservation risk area.

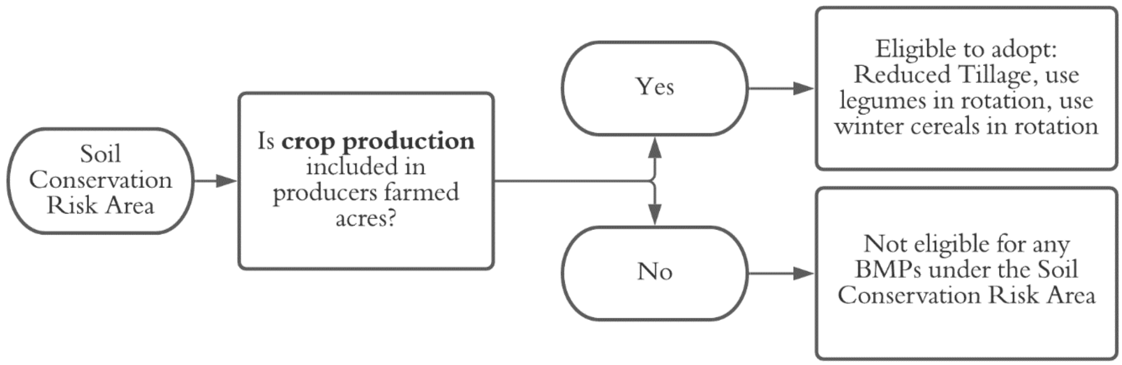

Figure 6.1. An example of how farmers were determined to be eligible for adopting soil conservation practices.

Figure 6.2 depicts the calculation of the ESA score for a producer who is eligible to adopt all practices under the soil conservation risk area yet does not adopt all practices they are eligible for.

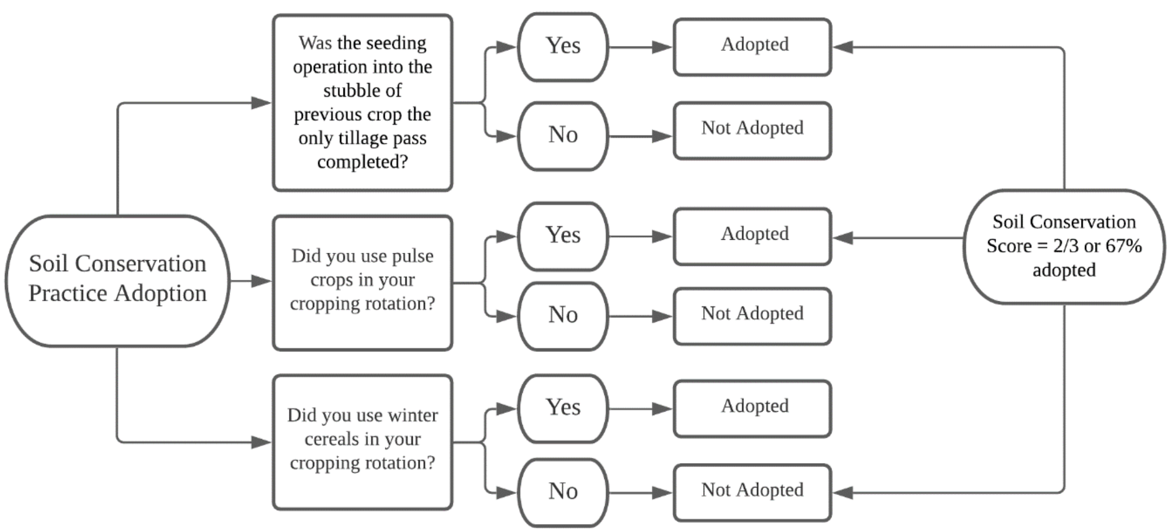

Figure 6.2. A visual representation of a producer adopting soil conservation practices and their ESA Score from adopted practices.

This visual representation can also be presentation in equation (2):

$$(2)\ ESA\ Adoption\ Score_{Soil1} = \frac{Number\ of\ Practices\ Adopted_{Soil1}}{Number\ of\ Practices\ Eligible_{Soil1}} \approx 67\%$$

Here *j* represent the soil conservation risk area for farmer *f,* who we numerically label as respondent 1 for this example. Each farmer in the survey data may not be eligible for all ESA practices based on certain characteristics of their farming operation. As shown in Figure 6.1, producers who did not have crop production on their farm were not eligible for any practices under the soil conservation risk area. To obtain a more accurate and reliable adoption rate, the ESA Adoption Score was adjusted to account for this eligibility across all risk areas[17]. Eligibility was deduced in each ESAT survey through examining screening questions that determined characteristics of each producers' farming operation. Risk areas and farm characteristic eligibility is summarized in Table 6.1. BMPs that were not addressed had 100% eligibility across all producers or had no eligibility requirements in the screening process. Producers who were determined to not be eligible for certain practices were never asked if they had adopted them, instead, these questions were not seen by the respondents using a skip pattern employed by interviewers during the telephone survey (AAF 2018).

Table 6.1. A Summary of Eligibility Requirements for Each BMP Under all Agri-Environmental Risk Areas Used in the 2012-2018 Alberta ESAT surveys.

Practice	Eligible Characteristics
Water Quality and/or Quantity	
Maintain buffer areas along edge of natural water bodies	Producer has natural streams, rivers, wetlands and/or sloughs on their farm.
Apply chemical fertilizer at recommended rate	Had commercial fertilizer applied on their land.
Control runoff from manure storage	Stored solid, liquid or compost manure on their farm.
Control runoff from livestock pens	Producer had any of the following: beef or dairy cattle, broiler or layer chickens, turkeys, sheep or lamb, horses, or any other livestock.
Control runoff from feeding areas	Producer had any of the following: beef or dairy cattle, broiler or layer chickens, turkeys, sheep or lamb, horses, or any other livestock.

[17] For the Energy and Climate Change risk area, we only identify that renewable energy was adopted if a respondent indicated 'Yes' under producing grid-connected energy. We did not include the individual renewable energy adoption (i.e., has a wind turbine) as part of the ESA Adoption Score.

Maintain a 10m buffer area from water bodies when applying pesticides	Producer has natural streams, rivers, wetlands and/or sloughs on their farm.
Maintain a 10m buffer area from water wells when applying pesticides	Has active wells on their farm.
Manage livestock access to water bodies that are used as a water source	Producer grazes livestock on their land and there are natural streams, rivers, wetlands and/or sloughs on their farm.
Choose wintering site to avoid manure contamination	Producer grazes livestock on their land and there are natural streams, rivers, wetlands and/or sloughs on their farm.
Grazing Management	
Protect riparian areas from grazing to prevent overuse	Producer grazes livestock on their farm.
Time grazing to avoid vulnerable times of the year for riparian areas	Producer grazes livestock on their farm.
Wildlife Habitat Conservation	
Manage grazing for wildlife habitat	Producer grazes livestock on their farm.
Manage grazing to encourage natural rejuvenation of understory in woodlands	Producer grazes livestock on their farm.
Manure Management	
Avoid storing manure near water wells	Stored solid or liquid manure and/or compost and has active wells on their land.
Keeping manure records	Producer manages (receives or produces) more than 500 tonnes of manure per year.
All other practices	Applied liquid or solid manure and/or compost on their farm.
Energy and Climate Change	
All practices	All producers are eligible.

General Practices & Agricultural Waste Management	
Precision farming – VRT	Producer applied commercial fertilizers or crop protection products (herbicide, insecticide, fungicides).
Soil sampling fields at least once every three years	If producer has crop production, forages or hay, or improved land used for pasture or grazing.
Soil Conservation	
All practices	Producer indicated they have crop production on their farm.

Source: AAF (2018).

Eligibility was completed for all seven agri-environmental risk areas to obtain fractional (proportional) dependent variables. An overall ESA adoption score was also developed where the number of practices a farmer was eligible to adopt was considered across all agri-environmental risk areas. Equation (3) shows our overall ESA Adoption Score, which is equal to the sum of all risk areas, j, for farmer, f, subject to eligibility E_{jf}.

(3) $ESA\ Score_{overall f} = \sum_{n=1}^{39} ESA\ Score_{jf} + \varepsilon_{jf} \sim$ s.t. E_{jf}

In total there are 39 ESA practices, however, a farmer could obtain an ESA adoption score of 100% if a farmer adopts all practices they were eligible for. Table 6.2 provides summary statistics for eligibility and adoption scores for each agri-environmental risk area and for the overall ESA Score.

Table 6.2. Mean Eligibility and Adoption Scores for Alberta Producers for Practices across Agri-Environmental Risk Areas Used in the 2012-2018 ESAT surveys.

Risk Area (Number of practices)	Mean No. of Practices Eligible (SD)	Mean Adoption (SD)	ESA Adoption Score			No. of Producers
			Mean (SD)	Min	Max	
Soil Conservation (3)	2.35 (1.17)	0.80 (0.82)	0.27 (0.28)	0	1	1,442
Water Quality and/or Quantity (12)	6.42 (2.98)	5.08 (2.76)	0.77 (0.24)	0	1	1,760
Wildlife Habitat Conservation (3)	2.09 (0.93)	1.52 (1.05)	0.71 (0.39)	0	1	1,772
Grazing Management (2)	1.15 (0.96)	1.31 (0.78)	0.68 (0.40)	0	1	1,079
Manure Management (11)	3.2 (3.24)	3.79 (1.98)	0.69 (0.25)	0	1	1,028
Energy and Climate Change (3)	2.83 (0.39)	0.42 (0.62)	0.15 (0.22)	0	1	1,784
General Practices (4)	3.19 (1.08)	1.46 (1.1)	0.43 (0.31)	0	1	1,784
Overall (39)	22 (7.07)	12 (5.9)	0.53 (0.15)	0	1	1,774

The mean eligibility for sampled producers was 22 practices, with a mean adoption of 12 practices. The overall mean ESA adoption score was around 53% for all seven risk areas. Among all ESAT survey participants, the highest mean ESA adoption scores were calculated for the water quality and/or quantity and wildlife habitat conservation risk areas. This was closely followed by manure management and grazing management. Across all ESAT years, the lowest mean ESA adoption scores were present under the energy and climate change and soil conservation risk areas. This is noteworthy since energy and climate change practices have 100% eligibility across each year. Across all sampled respondents, for each year of the ESAT survey, there were producers who had ESA adoption scores equal to 0 (0%) indicating they did not adopt any practices that they were eligible to adopt. There are also producers who were avid adopters with an adoption score equal to 1 (100%). Table 6.3 was developed to show the frequency of extreme values for each agri-environmental risk area for the entire sample population.

Table 6.3. A Frequency Table Showing Extreme Value Observations Across 2012-2018 ESAT Surveys.

Risk Area	No. Extreme Values of Zero (%)	No. Extreme Values of One (%)	No. of Producers in Sample (N)
Soil Conservation	609 (42.95%)	39 (2.75%)	1,418
Water Quality and/or Quantity	42 (2.44%)	605 (35.11%)	1,723
Wildlife Habitat Conservation	289 (16.67%)	1,009 (58.19%)	1,734
Grazing Management	210 (19.92%)	599 (56.83)	1,054
Manure Management	30 (2.99%)	231 (23.03%)	1,003
Energy and Climate Change	1,124 (64.38%)	15 (0.86%)	1,746
General Practices	380 (21.76%)	47 (2.69%)	1,746
Overall	8 (0.46%)	1 (0.06%)	1,736

6.3.2 Theoretical Model of Best Management Practice Adoption

To examine a farmer's decision-making process for adopting BMPs, a utility framework is developed similar to the one described in section 5.5. Adoption is dependent on the farmer f evaluating practice p under risk area j. We draw influence from Rollins et al. (2018) where the utility associated with adoption can be shown as U_{fpj} and the adoption decision can be shown as A_{fpj}, subject to practice eligibility. If U_{fpj} is positive, under rational behaviour $A_{fpj} = 1$ where a farmer decides to adopt the practice, while $A_{fpj} = 0$ if utility is lost through adoption. Our utility function is shown in (4).

(4) $U_{fpj} = (\beta' X_f + \alpha' X_k) + \varepsilon_{fpj}$

Where $A_{fpj} = 1$ if $U_{fpj} > 0$ and $A_{fpj} = 0$ otherwise.

X_f is a vector of producer and farm operation characteristics, including Municipal District indicators, and X_k represents a vector of unobserved factors such as the level of extension and knowledge about a practice. Further, ε_{fpj} is an error term or random component, and β', α' are estimated coefficients. Under neoclassical economic theory, rational farmers will aim to maximize their utility by adopting all practices where $U_{fpj} > 0$.

Under the *income paradigm* the assumption is producers aim to maximize profits and thus they will adopt practices that increase their net returns (Upadhyay et al. 2003). This is consistent with neoclassical economics, but it does not recognize farmer heterogeneity (Nowak 1987). Upadhyay et al. (2003) explain that this theory fails to explain why profitable technologies or practices are not adopted. Instead, the *utility paradigm* explains that producers make adoption decisions based on utility maximization, rather than just profit maximization, and this paradigm includes alternative motivating factors aside from profit. In addition to utility maximization, as explained by Greiner & Gregg (2011), if utility includes an individual's aspirations, such as additional conservation action, this can be rational and consistent with economic theory. Here, a farmer who strives to be a good steward of the land may adopt more conservation practices as this will increase their utility.

6.3.3 Independent Variables

Expanding on the prior section, this section describes the development of all explanatory (independent) variables that are hypothesized to affect ESA adoption scores. Rather than specifying each risk area individually, this section will provide a general overview of the ESA adoption score shown in (5).

(5) $MaxU_{Esascorefj} = f(X_f, X_k)$

Where $X_f = f(Farm\ Characteristics, Farmer\ Characteristics, Spatial\ Effects)$,

$X_k = f(Exposure\ to\ Extension, Knowledge)$

Like Chapter 5 section 5.5, our functions under X_f for farm and farmer characteristic remains the same and the development of these variables remain the same as those shown in Table 5.2. Farmer characteristics shown to be important in prior BMP adoption literature include a farmers age and education level, higher gross farm revenue, and whether they attended a conservation training session (Prokopy et al. 2019; Knowler & Bradshaw 2007; Baumgart-Getz et al. 2012; Wu & Babcock 1998). Conservation training is not often added as an explanatory variable towards adoption (Prokopy et al. 2019), but it has been found to be positive and significant towards influencing adoption in the meta-analysis by Baumgart-Getz et al. (2012). Farm characteristics include succession plans such as plans to expand or reduce their operation, owning or equally owning and renting their land and farm type (livestock, crop, equal mix). Lastly, spatial effects are included to capture unobserved characteristics specific to a Municipal District, such as social network influences or agronomic conditions. This again is presented as a dummy variable as described in section 5.5.

X_k is expanded in (6) to show functions for exposure to extension, which is defined by extension expenditure in a Municipal District, as well as a proxy for conservation knowledge defined as 'knowledge'.

(6) $X_k = [Exposure\ to\ Extension = (\frac{Extension\ Expenditure}{Number\ of\ Farms}), Knowledge = Has\ an\ EFP]$

Knowledge is measured by examining whether a producer had completed an EFP or not. As described in Chapter 5, the EFP allows farmers to voluntarily assess environmental risks on their land, as well as develop individualized plans to reduce and mitigate these risks. This includes the producer altering their on-farm management, usually through the implementation of BMPs. The completion of the EFP should increase a farmer's awareness of their on-farm risks, and these producers may be more likely to adopt practices across risk areas.

Exposure to extension is also included as a factor in X_k. Here, exposure to extension is equivalent to the level of extension expenditure per farm in a Municipal District. Studies such as Rollins et al. (2018) found extension could be a significant influence on adoption of BMPs in Alberta, Canada, thus we hypothesize exposure to extension should be a positive influence on adoption. There are 69 Municipal Districts included in our dataset, and the average number of farms per district was calculated from the 2016 Census of Agriculture for Alberta (Statistics Canada 2020). Figure 6.3 provides an overview of the development of our proxy for exposure to extension, where we provide an example at the Municipal District level for Red Deer County.

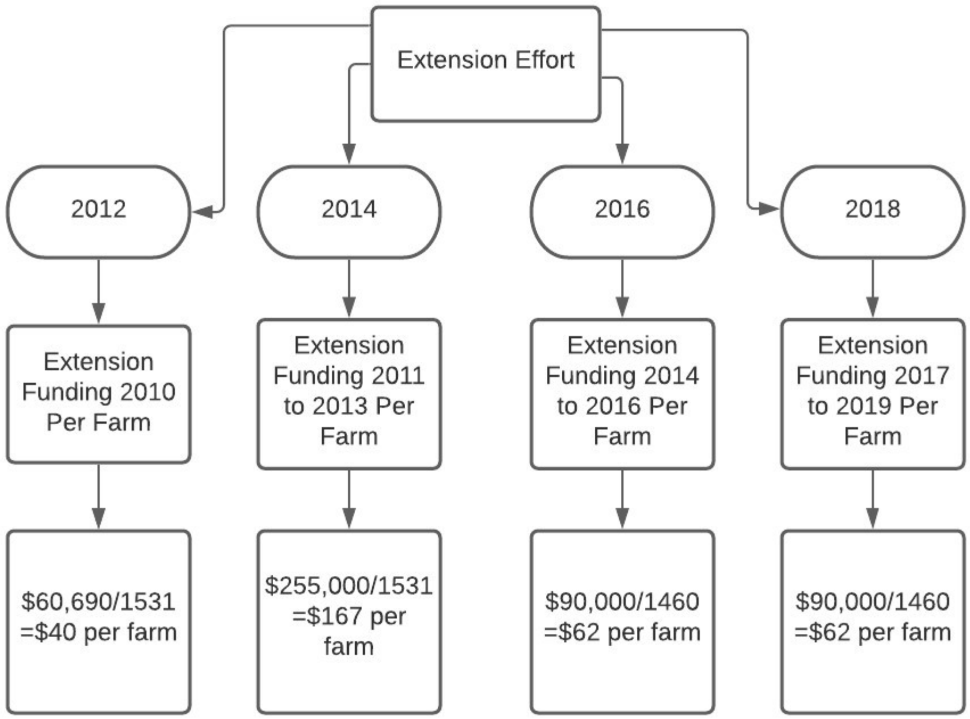

Figure 6.3. The development of a proxy variable measuring exposure to extension for BMP Adoption. The final quantitative numbers provide an example for Red Deer County across the four Alberta ESAT survey periods.

6.4 Econometric Models

The modelling approach employs a fractional (proportional) dependent variable that guides the choice of econometric modelling techniques. Further, our dataset is pooled with cross sections of farmers (f) who are not the same individuals over time; this also guides the development of the econometric model. Our dependent variable is bounded between 0 and 1 and due to the eligibility requirements for certain practices, some values lie on the boundaries, also known as extreme values. Extreme values for this binary variable (i.e., 0, 1) occur when a producer decides to adopt no practices they are eligible for ($Esa\ Score_{jf}$= 0), or all practices they are eligible for ($Esa\ Score_{jf}$= 1). Extreme values are present across all risk areas in the ESAT data as shown in Table 6.3. Respondents who were not eligible for any practices under a risk area did not obtain an ESA adoption score for this specific risk area. For example, as shown in figure 6.1, producers who do not have crop production on their operation are ineligible for all three practices under the soil conservation risk area. These producers would not be given a score under the soil conservation risk area.

Table 6.4 provides an overview of econometric models that were considered for the examination of the influence of our explanatory variables on adoption decisions. Most of these were not found to be a good fit due to the specification of our dependent variable. A more thorough description of why these models were not chosen can be found in Appendix 3A. For analysis and testing of all models, we use STATA 16, a common analytical software used by economists.

Table 6.4. Econometric Models Considered for the Analysis of BMP Adoption.

Econometric Model	Reasoning
Beta Distribution	This approach was suggested by Mullahy (1990) for fractional distributions of a dependent variable. Papke & Woolridge (1996) and Buis (2010) explain that this model is difficult to justify if there are extreme values of 0 and 1 and works best if bounded. We find a large proportion of extreme values under certain risk areas; this indicates that a Beta Distribution would not be a good fit.
Zero Inflated Beta	This can be used when there is a presence of extreme values (0 or 1) and can be used for bounded proportions. However, this model is best used if we believe that the decisions for these extreme values are governed by a different process than the other proportions (Buis 2010). We are unable to make this assumption, especially since these values are mostly present due to eligibility and a farmer's decision-making process regarding adoption; thus, this model is not a good fit.
Tobit Model	Long (1997) suggest using a two-limit tobit model where the proportion is a censored continuous variable (no information above or below extreme values of 1 or 0). However, Long (1997) describes that this approach is only feasible if there is not an excessive amount of censoring. Some ESA scores have large proportions of extreme values; thus, we would have an excessive amount of censoring. Again, this model is not a good fit for our dependent variable.
Count Model	Count variables are meant to measure how many times something has happened, in our case, how many times a practice was adopted (Long & Freese 2006). However, our aim is not simply to measure how many BMPs are adopted. With the added eligibility requirement, we are interested in scores rather than the number of BMPs adopted overall. Since not every producer is eligible for each BMP, and with a goal of understanding the proportion of eligible BMPs adopted under each risk area, this model is not considered a good fit.

Given that many of the modelling approaches described in Table 6.4 were not a good fit for our data, we explored two models that show promise for examining the adoption scores. These models are the fractional logistic regression, and the Linear Probability Model.

Fractional Logistic Regression[18]

Woolridge & Papke (1996) explored econometric approaches for fractional response variables and were one of the first to identify a fractional logit regression using Generalized Linear Models (GLM). The GLM approach is defined in (7) where *g(.)* is a link function and *F* is a member of the exponential family (StataCorp LP 2013). In STATA, the GLM model defaults to the use of Maximum Likelihood Estimation, which implies choosing an asymptotically efficient[19] estimator for a parameter or set of parameters (Greene 2012). The basic GLM function is provided in (7), representing a GLM model of y with covariates x.

(7) $g\{E(y)\} = \boldsymbol{x\beta}, \qquad y \sim F$

Papke & Woolridge (1996) explain that our exponential family (F) should be Bernoulli (8), with logit link (g(.)).

(8) $P(x = 1) = \alpha; Prob(x = 0) = 1 - \alpha$

Here $0 \leq \alpha \leq 1$ is the success probability, α is constant and alternative trials are independent (Greene 2012). We use a Binomial (family) distribution (9) to represent x success in n trials as this is a better fit for the data provided under the ESAT surveys.

(9) $Prob(X = x) = \binom{n}{x} \alpha^x (1 - \alpha)^{n-x}, \ x = 0,1, \dots \dots ., n$

Using the logit link (g()) we develop (10).

(10) $g\{E(y)\} = \boldsymbol{x\beta}, \qquad y \sim Binomial$

Of which the functional form of $(x_j{}'\beta)$ or logit is (11).

[18] It is important to note that regular logistic commands in STATA do not account for fractional response variables and will automatically transform the dependent variable into a binary format (Woolridge & Papke 1996).
[19] Greene (2012) defines asymptotic efficiency as "…consistent, asymptotically normally distributed, and has an asymptotic covariance matrix that is not larger than the asymptotic covariance matrix of any other consistent, asymptotically normally distributed estimator."

(11) $\exp(x'\beta) / \{1 + exp(x'\beta)\}$

Woolridge & Papke (1996) also suggest the use of robust standard errors. Maximum likelihood estimation typically incorporates the assumption that our error term is independent and identically distributed (i.i.d.) across respondents with a mean of zero and variance σ^2 (Greene 2012). To relax this assumption, we can include the use of robust standard errors. In addition, if heteroskedasticity is present, then robust standard errors are more reliable (Greene 2012). This model has been used and referenced across the economic literature for addressing fractional response variables (Papke & Wooldridge 2008; Reinhart & Rogoff 2011) and has been shown to be reliable and valid for fractional behavioural responses.

<u>The Linear Probability Model</u>

The simplicity of employing a Linear Probability Model (LPM) is often cited as a reason for its common use. The basis of this model stems from the basic linear regression approach (12) as described by Greene (2012):

(12) $(\boldsymbol{x}, \boldsymbol{\beta}) = \boldsymbol{x}'\boldsymbol{\beta}$

where β is a set of parameters that reflects the impact of changes in x on the probability of influencing y, the chosen dependent variable. Greene (2012) shows that the regression model (13) can be constructed through the following:

(13) $Since, [y|\boldsymbol{x}] = 0[1 - (\boldsymbol{x}, \boldsymbol{\beta})] + 1[(\boldsymbol{x}, \boldsymbol{\beta})] = F(\boldsymbol{x}, \boldsymbol{\beta})$

$the\ regression\ model\ is: y = E[y|\boldsymbol{x}] + y = E[y|\boldsymbol{x}] = \boldsymbol{x}'\boldsymbol{\beta} + \varepsilon$

Although, it is important to recognize the many criticisms of the LPM approach. For example, Papke & Wooldridge (1996) claim that the drawbacks of the linear model for analyzing fractional data is comparable to those for binary data. The LPM is modelled under an Ordinary Least Squares (OLS) regression, and OLS regressions are not guaranteed to lie in the unit interval (Greene 2012; Papke & Wooldridge 1996) meaning that predicted values of y may not lie between [0,1]. Instead, predicted values can be $0 \lesseqgtr y \lesseqgtr 1$ which is implausible given our fractional dependent variable. Further complications are the belief that the model leads to biased and inconsistent OLS parameter estimates, which takes away any advantages of holding a simple interpretation (Greene 2012; Long & Freese 2006). Literature has cited that the LPM has three distinct problems: the variance of the error term is not constant, the error term is not normally distributed, and there are no restriction which mandate the prediction to fall between 0 and 1 (Zhao et al. 2001).

With every criticism for the LPM however, there is research showing that the LPM can be feasible. Lewis & Linzer (2005) find that fitting the LPM with White's or Efron robust standard errors aid reliability of the model. Further, a general rule of thumb is that for probabilities between 0.2 to 0.8 the log odds under a logistic function produce an almost linear function of the probability (Long 1997). Thus, values in this range could show that a LPM is just as efficient as a logistic regression. Accounting for all the arguments described above, we estimate both the LPM and the fractional logistic regression. To make a distinct conclusion regarding the suitability of the econometric models, we rely on comparing and testing for goodness of fit.

For simplicity, our basic logistic regression equation is shown in (14) and Table 6.5 provides a summary for each measurement variable included in the model.

(14) $E(Esa\ Adoption\ Score|\ \boldsymbol{x}) = G\Big(\beta_1 + \partial_1 Year_i + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 Degree + \beta_5 Training + \beta_6 Expand + \beta_7 Reduce + \beta_8 Sell + \beta_9 Livestock + \beta_{10} Equal + \beta_{11} GFR250 + \beta_{12} Own + \beta_{13} Rent + \beta_{14} EFP + \beta_{15} \frac{Funding2011to2013}{Numberoffarms2011} + \beta_{16} \frac{Funding2014to2016}{Numberoffarms2016} + \beta_{17} \frac{Funding2014to2016}{Numberoffarms2016} + \partial_2 County_i\Big) + \varepsilon_i$

Table 6.5. A Summary of all Measurement Variables Included in the Analysis for ESA Adoption Scores for the Alberta ESAT Survey from 2012-2018.

Variables	Description
Dependent Variable	
ESA Adoption Score ($\boldsymbol{A}^{*}$)	Proportion of adopted practices compared to practices a farmer is eligible for; same across each risk area, bounded between 0 and 1.
Independent Variables	
Farmer Characteristics	
$\boldsymbol{\beta_2 Age_{1844}}$	Farmers between the age of 18 to 44.
$\boldsymbol{\beta_3 Age_{4564}}$	Farmers between the age of 45 to 64.
$\boldsymbol{\beta_4 GFR250}$	Farmers whose gross farm revenue (GFR) is greater than $250,000.
$\boldsymbol{\beta_5 Degree}$	Farmers who have a degree or diploma in an agricultural related area.
$\boldsymbol{\beta_6 Training}$	Farmers who have attended an environmental agriculture training session within the last two years.
Farm Characteristics	
$\boldsymbol{\beta_7 Expand}$	Farmers who stated they are expanding their farm operation.
$\boldsymbol{\beta_8 Reduce}$	Farmers who stated they are reducing their operation.
$\boldsymbol{\beta_9 Sell}$	Farmers who stated they are planning to sell their farm.
$\boldsymbol{\beta_{10} Livestock}$	Farmers who are primarily livestock producers. This was identified as farmers who responded their GFR came from primarily livestock production.
$\boldsymbol{\beta_{11} Equal}$	Farmers who are an equal mix of livestock and crop producers based off their GFR.
$\boldsymbol{\beta_{12} Own}$	Farmers who responded they primarily own their land.
$\boldsymbol{\beta_{13} Both}$	Farmers who equally rent and own land.
Knowledge	
$\boldsymbol{\beta_{14} EFP}$	This is a binary variable which represents whether a farmer has an EFP, where EFP=1 if yes, and EFP=0 if no.
Exposure to Extension	
$\boldsymbol{\beta_{15} \frac{Funding2011to2013}{Numberoffarms2011}}$ $\boldsymbol{\beta_{16} \frac{Funding2014to2016}{Numberoffarms2016}}$ $\boldsymbol{\beta_{17} \frac{Funding2017to2019}{Numberoffarms2016}}$	Each variable indicates the total amount of expenditure under the Agricultural Service Board Grant Program per farm in a Municipal District. Expenditure was left as a continuous variable, and number of farms is also continuous. Information on number of farms was provided by the Alberta Census of Agriculture 2011 and 2016.
Indicator Variables	
$\boldsymbol{\partial_1 Year_i}$	This indicator is for each year of the ESAT survey (2012, 2014, 2016, 2018).
$\boldsymbol{\partial_2 County_i}$	This is an indicator variable to represent Municipal Districts (counties) in Alberta.

6.5 Endogeneity

The assumption imposed under each model is that our explanatory variables are exogenous. However, endogeneity can arise from several plausible sources in the data. A common reason is omitted variables, where a variable observed, or unobserved, is not included in our model but is related to a variable included in our model. We hypothesize that our variable representing the completion of an EFP could be endogenous. We explored in Chapter 5 factors associated with EFP uptake, some of which are statistically significant. Thus, it is imperative to address and identify if there is true endogeneity of the EFP stemming from omitted variables. Omission of this variable, whose coefficient is nonzero, leads to a bias known as omitted variable bias (Hill et al. 2011). The result of this bias, and subsequent endogeneity is the inability to make causal claims affecting the reliability of our model for future policy considerations.

To test for endogeneity, we rely on the Durbin-Wu-Hausman (DWH) test; also known as the augmented regression test. This test includes the residuals of the suspected endogenous right-hand side variable as a function of all exogenous variables, in a regression of our original model (Davidson & MacKinnon 1993). With respect to the LPM model, we can also use a general Hausman test to decide whether we should implement Instrumental Variables (IVs). The null hypothesis under the DWH test is that our variable is exogenous; however, if the residual is statistically significant, we reject the null and the variable is endogenous. If we find that our EFP variable is endogenous after this test, Greene (2012) explains there are two methods to account for this: 1) a more detailed "structural specification"; or 2) use of instrumental variables (IV), where a model would be inefficient, but consistent.

Often, instrumental variables are the preferred method, and this involves instrumental variables (IV) estimation using two-stage least squares (2SLS) (Greene 2012; Angrist & Imbens 1995). Use of instruments includes the assumption that there is an additional set of variables, Z, that have two properties, 1) exogeneity $(z_t, x_t) = 0$, IVs are uncorrelated with the error; and 2) relevance $cov(z_t, x_t) \neq 0$, these variables are correlated with the endogenous variable, X (Greene 2012). This approach is viable for the LPM as it is a linear model and uses OLS; however, for our fractional logistic regression we use a GLM approach, which is non-linear. In this case, Terza et al. (2008) identify the use of IV with two-stage residual inclusion (2SRI) is the most consistent model when non-linear. However, a working paper by Wooldridge (2011) suggests using a fractional probit with an endogenous explanatory variable given its underlying normality. Further, Wooldridge (2015) identifies that if the endogenous variable is binary, of which the EFP variable is, the IV estimator is generally consistent even if the probit model is misspecified.

Unfortunately, testing the EFP to discover if it is truly endogenous proved to be a challenge. The four models shown in Chapter 5, section 5.6 in table 5.12A, represent models for each year of the ESAT survey and over each year, differing variables are hypothesized to influence EFP completion. However, the models proposed in this chapter are not annual and are the total outcomes from all survey respondents for each ESAT survey year (2012-2018). The Durbin-Wu-Hausman test (augmented regression test) relies on the notion that residuals of all endogenous right-hand side variables, as a function of all exogenous variables, are included in a regression of our original model, and if the residuals are significant then the EFP is found to be endogenous. We cannot simply impose yearly model residuals into our current model; thus, this test was unable to be performed properly.

Secondly, without being able to use the Durbin-Wu-Hausman test, we were left with the option of assuming the EFP is endogenous and using an instrumental variables (IV) estimation using two-stage least squares (2SLS). These instrumental variables must meet the two moment conditions of exogeneity and relevance. Again, we run into the challenge of choosing instrumental variables from yearly survey models, as these variables must be relevant to each year of the survey and influence EFP participation over time. With this in mind, no exogenous variables under industry standards or exposure to extension are able to be used as their significance varies across years. Thus, we are again unable to test or correct for the possible endogeneity of the EFP with these proposed methods.

To overcome these challenges and to correct for assumed endogeneity, we instead propose splitting our dataset. This would mean running our models for ESA adoption scores for each agri-environmental risk area for producers who have an EFP only, then running these models for producers who do not have an EFP. Here, we forego knowledge as a function under our vector X_k and the EFP is no longer included as a measurement variable. Now, the only function under X_k is exposure to extension. This would ensure we correct for any assumed presence of endogeneity and would rule out omitted variable bias if the EFP is truly endogenous.

Our models for each risk area now become (15) for producers with an EFP and (16) for those without.

(15) $E(Esa\ Adoption\ Score|\ \boldsymbol{x}) = G\Big(\beta_1 + \partial_1 Year_i + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 Degree + \beta_5 Training + \beta_6 Expand + \beta_7 Reduce + \beta_8 Sell + \beta_9 Livestock + \beta_{10} Equal + \beta_{11} GFR250 + \beta_{12} Own + \beta_{13} Rent + \beta_{15} \frac{Funding2011to2013}{Numberoffarms2011} + \beta_{16} \frac{Funding2014to2016}{Numberoffarms2016} + \beta_{17} \frac{Funding2017to2019}{Numberoffarms2016} + \partial_2 County_i\Big) + \varepsilon_i \quad \sim \quad \text{if } EFP = 1$

(16) $E(Esa\ Adoption\ Score|\ \boldsymbol{x}) = G\Big(\beta_1 + \partial_1 Year_i + \beta_2 Age1844 + \beta_3 Age4564 + \beta_4 Degree + \beta_5 Training + \beta_6 Expand + \beta_7 Reduce + \beta_8 Sell + \beta_9 Livestock + \beta_{10} Equal + \beta_{11} GFR250 + \beta_{12} Own + \beta_{13} Rent + \beta_{15} \frac{Funding2011to2013}{Numberoffarms2011} + \beta_{16} \frac{Funding2014to2016}{Numberoffarms2016} + \beta_{17} \frac{Funding2017to2019}{Numberoffarms2016} + \partial_2 County_i\Big) + \varepsilon_i \quad \sim \quad \text{if } EFP = 0$

For this thesis, we will still show our results for our models first described in (14) as it is imperative to understand the role of the EFP regarding adoption decisions. Although, we do recognize the limitation of possible endogeneity that stems from the EFP included as a measurement variable, especially after our findings in Chapter 5. After, we will present our results for our models described in (15) and (16) to highlight any differences in adoption decisions for Alberta producers with and without an EFP. This will also aid researchers and policymakers to better understand the role of the EFP in BMP adoption.

6.6 Postestimation: Goodness of Fit

To determine which model (fractional logistic or LPM) is the best fit, we explored a multitude of tests including the likelihood ratio (LR) test, F test, and the Wald test. However, given our use of robust standard errors, STATA is unable to accurately compute these tests and we forgo their use. Further, due to our use of probability weights we are limited in what post estimation analysis techniques we can use. Additional methods to determine which model is of best fit includes comparing general statistics including r-squared values, log likelihood values, and more importantly the Akaike information criterion (AIC) and Bayesian information criterion

(BIC)[20] . As Verbeek (2004) explains, models with a lower AIC and BIC are preferred, and the use of this criteria is often restricted to cases where alternative models are not nested, such as our case. Further, since we compare a fractional logit which does not produce an r-squared, we rely further on the AIC and BIC for comparison.

Another option to test a model's goodness of fit is a model specification link test for single-equation models provided in STATA 16.0. The main purpose of this test is to determine if a regression or regression-like equation is properly specified, meaning we should find no additional independent variables that are statistically significant, unless by chance (STATA n.d.). This post estimation technique stems from Pregibon (1979) who based the idea from Tukey (1949). The specification of the link test can be shown in (17).

(17) $Our\ Model$: $y = (\boldsymbol{X}\beta)$

$Let\ us\ identify\ \hat{\beta}\ as\ the\ parameter\ estimates$; $the\ linktest\ calculates$:

$\_hat = \boldsymbol{X\hat{\beta}}$; $\_hatsq = \_hat^2$

The test indicates that if the variable of squared prediction is statistically significant (_hatsq), then our model is not specified correctly[21].

Lastly, we include a test for multicollinearity known as the variance inflation factor (VIF). Multicollinearity occurs when an independent variable is highly correlated with one or more independent variables in our regression. As explained by Craney & Surles (2002), the issue with collinearity between one or more variables is that the associated parameter estimates become meaningless as a measure of explanatory power. As described by Craney & Surles (2002) and Stine (1995), for $p-1$ independent variables VIF (18) is equal to:

(18) $VIF_i = \frac{1}{r_i^2}$

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[20] The AIC can be shown as $AIC = log\frac{1}{N}\sum^{N}_{i=1} e_i^2 + \frac{2K}{N}$ where $\sum^{N}_{i=1} e_i^2$ is the trade off between goodness of fit, and the simplicity of the model, as measured by K parameters. BIC can be shown as $BIC = log\frac{1}{N}\sum^{N}_{i=1} e_i^2 + \frac{K}{N}\log N$ (Veerbeek 2004).

[21] Another option brought forward by Woolridge & Papke (1996) is the use of Ramsey's RESET test to uncover nonlinearities in the functional form. As cautioned by Woolridge (2010), the RESET test should only be used as a test for misspecification between the relationship of y and x and nothing more. This test can also only be used under the LPM in STATA due to the weighted nature of our GLM model which results in our reliance on the link test for both models.

Where r_i^2 can be interpreted as the r^2 statistic, or more formally as the coefficient of determination through fitting a regression model for the i^{th} independent variable on other p-2 independent variables (Craney & Surles 2002; Stine 1995). Studies such as Chatterjee & Price (1991) suggest 10 to be a "large" enough VIF to suggest multicollinearity, although more recent studies suggest values over 5 and 10 may indicate a presence of multicollinearity (Craney & Surles 2002).

Table A4 shows the results of all post-estimation tests conducted for our models identified in equation (14); this table can be found in Appendix 3B. After reviewing the results, the LPM was found to be the best fit model for all agri-environmental risk areas, including the overall ESA adoption score model. Based on these results, we only use the LPM to test if our models in equation (15) and (16) are properly specified. These results are shown in Table A5, also in Appendix 3B.

6.7 Results

6.7.1 Descriptive Statistics

Given the connection between the EFP and government funding for BMP adoption (as described in Chapters 4 and 5), we develop table 6.6 which explores the difference in adoption decisions between producers who have, and do not have an EFP. We find across all agri-environmental risk areas that there is a higher rate of BMP adoption when a producer holds an EFP, except for the wildlife and habitat conservation risk area. One of the largest differences exists under the soil conservation risk area where non-EFP holders have an 11% lower adoption score. For adoption across all risk areas, we find a 6% difference in adoption rates between producers who have and do not have an EFP. This indicates that farmers without an EFP are adopting BMPs, but to a lesser extent. These results relate back to our flow chart (figure 5.2) in section 5.4 where we show there are alternative pathways for adopting BMPs beyond those of obtaining an EFP. For example, this may indicate producers are accessing other sources of funding for adopting BMPs. This also may suggest that stewardship programs are not focusing their funding appropriately towards environmental risk areas with lower rates of BMP adoption. Regardless, it is important to recognize there is a lower adoption rate for those without an EFP.

Table 6.6. The Adoption of BMPs Across Each Agri-Environmental Risk Area for Farmers with and without an EFP for the 2012-2018 Alberta ESAT Survey.

	Soil Cons.	**Water Quality/Quantity**	**Grazing Mgmt.**	**Wildlife & Habitat Cons.**	**Manure Mgmt.**	**Energy**	**General**	**Overall ESA Score**
Number of Total Practices	3	12	2	3	11	3	4	39
				Eligibility (Mean)				
All Producers	2.35	6.42	1.15	2.09	3.21	2.83	3.19	22
With an EFP	*2.56*	6.54	1.11	2.04	3.38	2.89	3.48	22.79
Without an EFP	2.21	6.33	1.19	2.13	3.06	2.78	2.98	21.41
				Adopted (Mean)				
All Producers	0.70	6.62	1.32	2.03	3.88	0.35	1.64	16.980
With an EFP	0.96	5.41	1.41	1.49	4.29	0.53	1.68	13.65
Without an EFP	0.64	4.83	1.24	1.54	3.41	0.33	1.28	11.54
				ESA Score (Mean)				
All Producers	24%	78%	69%	72%	70%	12%	47%	58%
With an EFP	33%	82%	73%	71%	73%	18%	47%	58%
Without an EFP	22%	73%	65%	71%	66%	12%	40%	52%

Source: AAF (2018); Government of Alberta (2016); Government of Alberta (2014); Government of Alberta (2012).

Figure 6.4 provides a visual overview of mean ESA adoption scores for each risk area across individual ESAT survey years. Both soil conservation and water quality and quantity risk areas have slightly increased mean adoption scores over time. All other risks areas have fluctuated in their adoption scores, although not to a significant degree. Across all risk areas however, it seems that adoption trends have remained relatively stagnant over time. Even though two different government environmental stewardship programs were operating during these surveys (GF and GF2), it seems program managers were not successful in targeting risk areas with lower adoption rates.

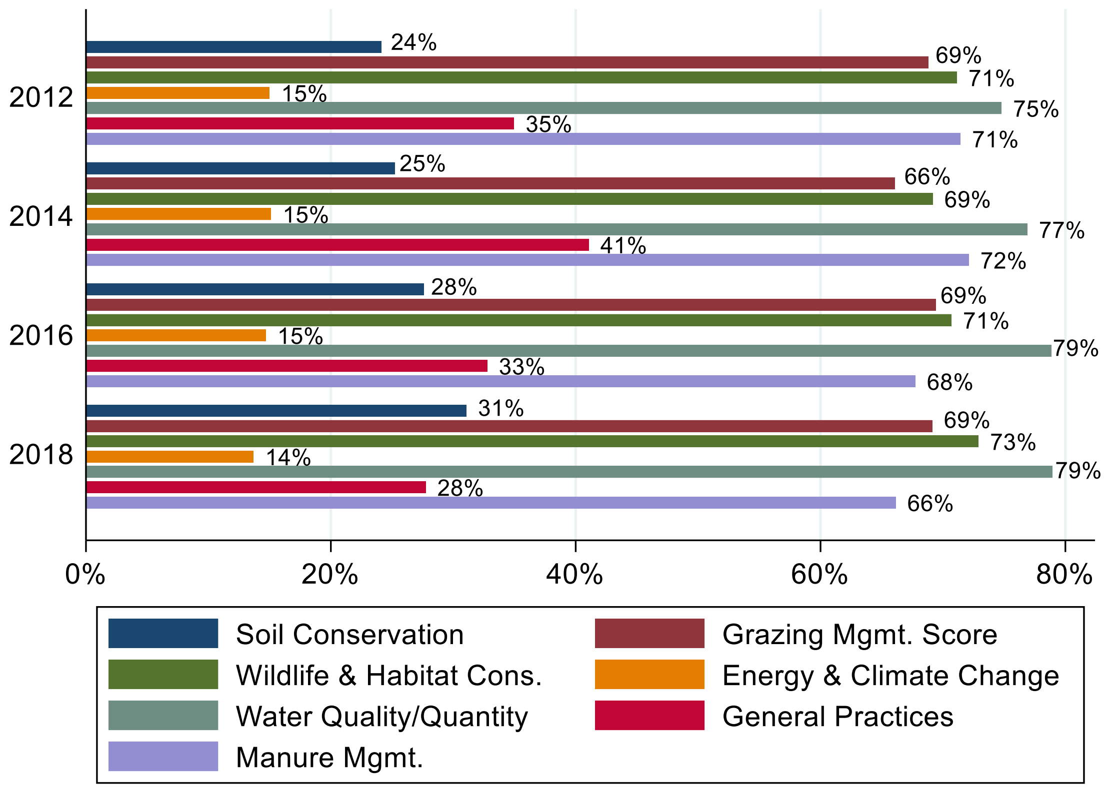

Figure 6.4. Overall ESA Adoption Scores Across Each ESAT Survey (2012-2018)

6.7.2 Regional Characteristics Descriptive Statistics

Table 6.7 shows the top 10 Municipal Districts with the highest ESA Adoption Scores across each risk area, as well as the overall ESA Adoption Score, for all survey years. For Soil Conservation, out of the 10 Municipal Districts, half reside in the South Saskatchewan region. Since producers are more likely to own land in this region and are less likely to be primarily livestock producers, they may be more invested in soil quality on their land. Water Quality and Quantity was more heterogeneous, with 3 of the top 10 Municipal Districts located in North Saskatchewan and 3 in South Saskatchewan. Grazing Management was most prominent in North Saskatchewan with 4 of the top 10 districts being in this area, the rest were heterogeneous across Municipal Districts. Under the wildlife and habitat management risk area, 5 of the Municipal Districts are in the North Saskatchewan region, although none of the top 10 Municipal Districts were located in the South Saskatchewan region. Manure Management and General Practices risk areas were highly heterogeneous across all regions. Compared to the other risk areas, 5 of the top 10 Municipal Districts for the energy and climate change risk area are in the Upper Peace region. This may correspond with higher gross farm revenue in this area compared to most other regions. For our overall ESA Score, 4 of the top 10 Municipal Districts are in the North Saskatchewan region, 3 are in the South Saskatchewan region, 2 in Red Deer, and 1 in Lower Peace; no districts were located in Upper Peace, Upper Athabasca or Lower Athabasca. In general, a good proportion of Municipal Districts who have higher ESA adoption scores were in the North Saskatchewan region, and this may correspond to the high level of EFP completion in this region.

Table 6.8 provides an overview of the 10 Municipal Districts with the lowest ESA Adoption Scores across each risk area, and for the overall ESA Adoption Score, for all years. Under the Soil Conservation risk area, 4 out of 10 Municipal Districts with the lowest soil score were in the North Saskatchewan region, with 3 in Upper Athabasca; no regions were located in the South Saskatchewan region. This may relate to the low levels of conservation training in these regions. For the Water Quality and Quantity risk area, the Upper Peace region had 4 out of 10 Municipal Districts with the lowest water score, with the rest being heterogeneous. However, none of these districts were in the South Saskatchewan region. This may correspond to a higher prevalence of irrigation and drought in southern Alberta, where producers may actively adopt water practices to overcome these challenges. Municipal Districts with the lowest scores under the Wildlife and Habitat Management risk area were primarily located in the southern Alberta region, with half located in the South Saskatchewan region, and 3 were in the Red Deer region. Municipal Districts with the lowest Manure Management scores were primarily located in eastern Alberta, with 3 located in the Upper Peace region and 3 in the Upper Athabasca region. Half of the lowest scores under the Energy and Climate Change risk area were in the North Saskatchewan region, with the rest being relatively heterogeneous. The lowest Grazing Management scores, as well as General Practices scores were heterogeneous across regions. Finally, with respect to the lowest overall ESA Scores, 4 of the 10 Municipal Districts were in the Upper Peace region, with the rest being heterogeneous across regions.

Table 6.7. Alberta Municipal Districts with the 10 Highest ESA Scores Across Risk Areas for the 2012-2018 Surveys.

	Soil Cons.	Water Quality & Quantity	Grazing Mgmt.	Wildlife & Habitat Cons.	Manure Mgmt.	Energy and Climate Change	General Practices	Overall ESA Adoption Score
1.	Cypress	Northern Sunrise	Northern Sunrise	Northern Sunrise	Lesser Slave River	Wheatland	Northern Sunrise	Northern Sunrise
2.	Forty Mile	Strathcona	Provost	Thorhild	Edmonton	Birch Hills	Provost	Willow Creek
3.	Vulcan	Paintearth	Vulcan	St. Paul	Wainwright	Fairview	Kneehill	Provost
4.	Provost	Pincher Creek	Forty Mile	Stettler	Lac La Biche	Kneehill	Fairview	Vulcan
5.	Mackenzie	Calgary	Willow Creek	Flagstaff	Kneehill	Warner	Lethbridge	Stettler
6.	Spirit River	Kneehill	Greenview	Wainwright	Stettler	Spirit River	Mackenzie	Flagstaff
7.	Pincher Creek	St. Paul	Edmonton	Paintearth	Starland	Smoky River	Sturgeon	Pincher Creek
8.	Clear Hills	Grande Prairie	Peace	Fairview	Mackenzie	Wainwright	Warner	St. Paul
9.	Wainwright	Parkland	Minburn	Clearwater	Vulcan	Clear Hills	Special Areas	Kneehill
10.	Wheatland	Lethbridge	Brazeau	Greenview	Greenview	Cypress	Beaver	Strathcona

Table 6.8. Alberta Municipal Districts with the 10 Lowest ESA Adoption Scores Across Risk Areas for the 2012-2018 Surveys.

	Soil Cons.	Water Quality & Quantity	Grazing Mgmt.	Wildlife & Habitat Cons.	Manure Mgmt.	Energy and Climate Change	General	Overall ESA Adoption Score
1.	Clearwater	Lesser Slave River	Birch Hills	Lethbridge	Big Lakes	Special Areas	Woodlands	Saddle Hills
2.	Edmonton	Peace	Lesser Slave River	Calgary	Smoky River	Thorhild	Greenview	Smoky Lake
3.	Parkland	Clear Hills	Special Areas	Taber	Birch Hills	Parkland	Athabasca	Lesser Slave River
4.	Lesser Slave River	Northern Lights	Saddle Hills	Kneehill	Ponoka	Athabasca	Special Areas	Birch Hills
5.	Special Areas	Smoky River	Wainwright	Warner	Smoky Lake	Smoky Lake	Foothills	Taber
6.	Yellowhead	Special Areas	Fairview	Special Areas	Westlock	Leduc	Clearwater	Smoky River
7.	Lac La Biche	Birch Hills	Calgary	Lesser Slave River	Bonnyville	Edmonton	Yellowhead	Edmonton
8.	Lacombe	Brazeau	Camrose	Newell	Peace	Yellowhead	Edmonton	Calgary
9.	Athabasca	Starland	Taber	Saddle Hills	Athabasca	Cardston	Bonnyville	Fairview
10.	Smoky Lake	Lac La Biche	Lamont	Starland	Cypress	Lacombe	Lacombe	Northern Lights

6.7.3 Agri-Environmental Risk Areas Model Results

Table 6.9A shows the results for the LPM across each risk area, with table 6.9B showing an overview of statistically significant Municipal Districts under each model. The results from our fractional logistic model are found in table A6 which can be found in Appendix 3C. While we choose the LPM for this thesis, the results from the fractional logistic were found to be comparable to the results under the LPM. For simplicity, econometric results will be described across measurement variable categories rather than across environmental risk areas separately.

For the LPM specification, we find the impact of farmer characteristics on BMP adoption to be relatively heterogeneous across risk areas for some measurement variables. Farmers between the ages of 18 to 44 are 4.7% more likely to adopt practices under the water quality and quantity risk area but were 5.4% less likely to adopt under the energy and climate change risk area. For farmers between 45 to 64 years of age, like younger producers, they are 3.3% more likely to adopt under the water quality and quantity risk area and were 6.1% less likely to adopt under the energy and climate change risk area. However, we do find farmers in this age group were 3.5% less likely to adopt under general practices. Using age as a measurement variable has been common in the literature, although as previously stated, with inconclusive results (Prokopy et al. 2019; Baumgart-Getz et al. 2012; Prokopy et al. 2008). These results show that age is relatively insignificant towards adoption and that regardless of age, producers are not likely to adopt practices under the energy and climate change risk area.

Producers who have a degree or diploma in an agriculturally related area were more likely to adopt water quality and quantity practices, as well as wildlife and habitat conservation practices. Having a degree was also highly significant for a farmers overall ESA adoption score, where farmers with a degree were 3.6% more likely to adopt practices overall. Previous literature has shown that a farmer's education plays a significant role in the adoption process (Greiner et al. 2009; Gillespie et al. 2007) and it is possible producers who have a degree are more aware of these practices and the benefits of conserving water quality and wildlife habitats.

Having gross farm revenue (GFR) over $250,000 was significant for adoption under energy and climate change, general practices, and highly significant under soil conservation, where higher GRF resulted in producers being 12% more likely to adopt soil conservation practices. Higher gross farm revenue was also highly significant in the overall ESA adoption score model, where farmers with higher gross farm revenue were 3.6% more likely to adopt practices. Producers with higher gross farm revenue are often described as being able bare more financial risk from adoption and have a better capacity to adopt practices with high uptake costs or long-term maintenance costs (Baumgart-Getz et al. 2012; Kim et al. 2005). Thus, it makes sense producers with higher gross farm revenue would be more likely to adopt practices under energy and climate change for example, as practices such as generation of renewable energy require higher levels of capital input.

Producers who had attended conservation training were significantly more likely (at the 1% level) to adopt practices across all risk areas, except for practices under the wildlife and habitat conservation risk area. Further, producers who had attended conservation training were 5.4% more likely to adopt practices overall as shown in the overall ESA adoption score model. As previously stated, studies have found conservation training can significantly influence BMP adoption (Prokopy et al. 2019; Baumgart-Getz et al. 2012), although too few studies have included this variable in their analysis for a conclusive finding (Prokopy et al. 2019). These results show that conservation training is highly significant towards influencing an Albertan farmers' decision-making process regarding BMP adoption.

Exposure to extension was statistically insignificant across all risk areas except one, as well insignificant for our overall ESA adoption score model. The exception was our model for habitat and wildlife conservation. This is surprising as prior literature has found extension plays an important role in adoption decisions (Pannell et al. 2006; Rollins et al. 2018; Gillespie et al. 2007). In 2016, extension expenditure per farm resulted in producers being 19.6% less likely to adopt practices associated with wildlife and habitat management. This is also surprising as we would hypothesize exposure to extension should aid in the adoption process. Contrary to this result, we found extension funding per farm in 2018 resulted in producers being 20.8% more likely to adopt practices under the wildlife and habitat conservation risk area. Although this model was determined to be properly specified, it may be plausible there are external factors driving these results. For example, the implementation or ending of conservation programs at the time producers responded to these surveys may have impacted our proxy for exposure to extension. It is also important to note that wildlife and habitat management was the only risk area not influenced by conservation training and was the only one influenced by exposure to extension. This may suggest there is a lack of awareness regarding wildlife and habitat conservation and that extension services, as well as stewardship programs, need to address this. These results may also stem from the way we measure exposure to extension, which may not have been the correct method to measure the nature of extension. In all, it seems extension funding is less important than primarily hypothesized towards adoption.

Knowledge was assumed to be a function of whether a producer has or has not completed an Environmental Farm Plan (EFP). We find producers who have an EFP are significantly more likely to adopt BMPs across all risk areas except for general practices and wildlife and habitat management. Having an EFP was also statistically significant in our overall ESA adoption score model, where producers who have an EFP are 3.6% more likely to adopt practices. As stated previously, the EFP helps producers develop their own plans to mitigate environmental risks on their farm, usually through adopting BMPs. These plans may correspond to the higher likelihood of adoption as producers have more knowledge and awareness of BMPs and the benefits that stem from their adoption.

The impacts of farm characteristics on adoption were also highly heterogeneous across each risk area. Producers planning to expand their operation were 3.7% more likely to adopt practices under the energy and climate change risk area; while planning to reduce their operation resulted in a producer being 3.2% less likely to adopt these practices. Possibly, practices identified under this risk may be easier to incorporate when already in the planning stage or building process, and given the high up-front costs of these practices, this would not maximize a producer's utility if they were reducing their operation. Producers planning to sell their operation were 8.7% less likely to adopt under the habitat and wildlife conservation risk area. Most likely these producers may not be as invested in the land and/or surrounding wildlife. This can also be related to the notion that farmers planning to sell are generally older, and older farmers often have shorter planning horizons which may explain why these BMPs were less likely to be adopted (Ervin & Ervin 1982; Baumgart-Getz et al. 2012). Farmers who were primarily livestock producers were 12.8% less likely to adopt soil conservation practices, 7.1% less likely to adopt energy and climate change practices, and 11.4% less likely to adopt general practices. However, unsurprisingly, they were 10.9% more likely to adopt grazing management practices.

Surprisingly however, in our overall ESA adoption score model, we find livestock producers are 4.6% more likely to adopt BMPs overall. Some of our results align with Prokopy et al. (2008) who found that livestock farmers were generally less likely to adopt conservation practices. However, we note that our overall ESA adoption score model contrast this. Producers who were an equal mix of crop and livestock production were also less likely to adopt soil conservation practices and general practices and were more likely to adopt grazing management practices. We also find producers who are an equal mix are 5.3% more likely to adopt BMPs overall (compared to crop farmers) based on our overall ESA adoption score model. We find there was no significant difference in adoption for producers who primarily owned, or equally owned and rented their land.

For statistically significant Municipal Districts, shown below in table 6.9B, we find no districts were significance for the water quality and quantity risk area, as well as the manure management risk area. We also find minimal significance under the grazing management risk area and the energy and climate change risk area. For these risk areas it seems spatial effects are not significant towards adoption decisions. For soil conservation, there were no Municipal Districts that were less likely to adopt practices, but we found two districts located in North Saskatchewan and 1 in the Red Deer region who were more likely to adopt; this may correspond to higher rates of EFP completion in these regions. Wildlife and Habitat Conservation had a significant number of Municipal Districts who were more likely to adopt. Out of 29, 10 are in the North Saskatchewan region, 7 are in the South Saskatchewan region, and 5 are in the Red Deer region. All these regions have higher levels of extension expenditure, with Red Deer and North Saskatchewan having the highest percentage of producers who have completed an EFP. It is important to note however, these are the three largest land-use regions with the most districts. There are 16 Municipal Districts that were less likely to adopt wildlife and habitat conservation practices. Out of 16, 5 were in South Saskatchewan and 5 were in Upper Athabasca. With respect to South Saskatchewan, Municipal Districts who are spatially connected tend to influence one another. For example, Cypress, Newell, and Vulcan are significantly more likely to adopt wildlife practices and these districts all borders one another. This connection was also seen in the North Saskatchewan region and may indicate spillover effects. Lastly, for general practices, 11 out of 23 Municipal Districts which are more likely to adopt are in North Saskatchewan, whereas out of seven that were less likely to adopt, four are in the South Saskatchewan region.

Table 6.9A. Linear Probability Model Results for Each Agri-Environmental Risk Area and Overall ESA Adoption Score.

	Soil Conservation (SE)	Water Quality & Quantity (SE)	Grazing Management (SE)	Habitat & Wildlife Conservation (SE)	Manure Management (SE)	Energy & Climate Change (SE)	General Practices (SE)	Overall ESA Adoption Score (SE)
Year: 2014	-0.021	0.034*	0.002	-0.013	0.017	-0.004	0.048**	0.029**
	(0.019)	(0.020)	(0.043)	(0.030)	(0.025)	(0.015)	(0.021)	(0.012)
Year: 2016	0.012	0.026	0.032	0.007	-0.022	-0.014	-0.023	0.025**
	(0.021)	(0.020)	(0.039)	(0.031)	(0.024)	(0.018)	(0.019)	(0.012)
Year: 2018	0.052**	0.013	0.033	0.003	-0.040*	-0.009	-0.062***	0.006
	(0.022)	(0.021)	(0.041)	(0.032)	(0.024)	(0.016)	(0.020)	(0.013)
Farmer Characteristics								
Age 18 to 44	0.033	0.047*	0.047	-0.058	0.051	-0.054**	-0.019	0.017
	(0.031)	(0.027)	(0.055)	(0.047)	(0.033)	(0.023)	(0.031)	(0.017)
Age 45 to 64	0.025	0.033*	-0.022	-0.020	0.006	-0.061***	-0.035**	
	(0.019)	(0.018)	(0.036)	(0.027)	(0.021)	(0.015)	(0.018)	(0.011)
Has a Degree	0.021	0.066***	-0.002	0.047*	0.011	0.015	0.016	0.036***
	(0.019)	(0.016)	(0.032)	(0.026)	(0.020)	(0.014)	(0.018)	(0.011)
Attended Conservation Training	0.059***	0.058***	0.096***	0.039	0.061***	0.041***	0.093***	0.054***
	(0.019)	(0.015)	(0.035)	(0.026)	(0.019)	(0.015)	(0.017)	(0.010)
GFR > $250k	0.123***	0.024	-0.051	-0.031	0.024	0.069***	0.032*	0.036***
	(0.019)	(0.016)	(0.035)	(0.027)	(0.021)	(0.016)	(0.017)	(0.010)
Farm Characteristics								
Planning to Expand Operation	0.037	0.001	0.024	-0.030	-0.022	0.037**	0.015	0.016
	(0.023)	(0.019)	(0.038)	(0.033)	(0.023)	(0.019)	(0.020)	(0.012)
Planning to Reduce Operation	-0.011	-0.006	-0.022	-0.000	-0.017	-0.032**	-0.029	-0.006
	(0.019)	(0.019)	(0.039)	(0.030)	(0.024)	(0.014)	(0.019)	(0.011)
Planning to Sell Operation	0.0002	-0.026	-0.081	-0.087*	0.010	0.029	-0.023	-0.023
	(0.042)	(0.035)	(0.075)	(0.052)	(0.042)	(0.036)	(0.032)	(0.022)
Livestock Producer	0.128***	-0.007	0.109***	0.006	-0.027	-0.071***	-0.114***	0.046***
	(0.018)	(0.017)	(0.039)	(0.029)	(0.026)	(0.014)	(0.018)	(0.011)

Both Livestock and Crop	-0.043**	-0.010	0.117***	0.037	-0.001	-0.010	-0.034*	0.053***
	(0.021)	(0.021)	(0.042)	(0.033)	(0.028)	(0.019)	(0.020)	(0.013)
Primarily Owns Land	-0.105	0.064	-0.027	-0.103	0.016	0.034	0.063	0.047
	(0.076)	(0.081)	(0.198)	(0.106)	(0.137)	(0.048)	(0.070)	(0.052)
Both Rents and Owns Land	-0.096	0.057	-0.005	-0.072	0.015	0.018	0.094	0.052
	(0.075)	(0.082)	(0.199)	(0.106)	(0.138)	(0.047)	(0.070)	(0.052)
Knowledge								
Has an EFP	0.047***	0.044***	0.085***	0.005	0.039**	0.030**	0.021	0.036***
	(0.017)	(0.015)	(0.030)	(0.023)	(0.019)	(0.013)	(0.016)	(0.010)
Exposure to Extension								
Extension $ per Farm 2014	-0.003		0.003		0.001	0.001	-0.001	
	(0.002)		(0.003)		(0.001)	(0.001)	(0.001)	(0.001)
Extension $ per Farm 2016	0.053	0.013	0.035	-0.196*	-0.021	0.080	-0.078	-0.005
	(0.096)	(0.075)	(0.211)	(0.104)	(0.160)	(0.069)	(0.053)	(0.047)
Extension $ per Farm 2018	-0.044	-0.015	-0.052	0.208*	0.018	-0.087	0.089	0.005
	(0.105)	(0.079)	(0.225)	(0.110)	(0.168)	(0.073)	(0.056)	(0.050)
Constant	0.106	0.737***	1.091	0.111	0.743	0.393*	-0.148	0.410**
	(0.378)	(0.262)	(0.750)	(0.361)	(0.532)	(0.235)	(0.168)	(0.172)
Obs. (N)	1169	1428	1019	1433	950	1443	1443	1438
AIC	-67.93	-6.44	1053.96	1234.99	36.64	-560.80	41.56	-1435.41
BIC	347.31	430.47	1467.79	1672.19	434.87	-123.02	484.62	-997.92

Significance levels are ***p<0.01, **p<0.05, *p<0.1

Table 6.9B. Statistically Significant (p<0.10) Alberta Municipal Districts Across Agri-Environmental Risk Areas.

Risk Area	Municipal Districts (+) Significance	Municipal Districts (-) Significance
Soil Conservation	Kneehill, Minburn, Sturgeon	None
Water Quality and Quantity	No Significance	
Grazing Management	Minburn, Northern Sunrise	None
Wildlife and Habitat Management	Beaver, Bonnyville, Clear Hills, Cypress, Edmonton, Fairview, Flagstaff, Foothills, Forty Mile, Greenview, Lamont, Leduc, Lesser Slave River, Mackenzie, Mountain View, Newell, Northern Lights, Paintearth, Parkland, Pincher Creek, Ponoka, Smoky Lake, St. Paul, Stettler, Strathcona, Thorhild, Vulcan, Willow Creek, Special Area 2	Athabasca, Barrhead, Big Lakes, Birch Hills, Camrose, Cardston, Kneehill, Lacombe, Lethbridge, Rocky View, Saddle Hills, Spirit River, Warner, Westlock, Wheatland, Woodlands
Manure Management	No Significance	
Energy and Climate Change	Wheatland	Brazeau, Edmonton, Lac Ste. Anne, Two Hills
General Practices	Beaver, Brazeau, Calgary, Cypress, Edmonton, Flagstaff, Forty Mile, Lac Ste. Anne, Lamont, Leduc, Mackenzie, Newell, Northern Lights, Parkland, Pincher Creek, Ponoka, Provost, Sturgeon, Taber, Thorhild, Vermilion River, Vulcan, Willow Creek	Big Lakes, Cardston, Lacombe, Lethbridge, Warner, Wheatland, Woodlands
Overall ESA Score	No Significance	

6.7.4 Split Sample Results: Producers with and without an Environmental Farm Plan

As stated previously in section 6.5, we decide to run models with a split sample for producers who have an EFP, and for those without an EFP, to correct for assumed endogeneity. Table 6.10A provides our results for our split sample for producers who have an EFP and table 6.11A represents our results for our sample of producers without an EFP. Rather than discussing each of these models separately, we will instead compare results for our measurement variables across each risk area. Later we will discuss Municipal Districts of significance in tables 6.10B and 6.11B for our sample of producers who do and do not have an EFP, respectively.

We find the impact of farmer characteristics remains similar across sample populations, especially the significance of conservation training and higher gross farm revenue across risk areas. Conservation training was significant across almost all risk areas for producers who had an EFP, except under the wildlife and habitat conservation and energy and climate change risk areas. These results were similar for producers without an EFP, except conservation training was found to be significant under the energy and climate change risk areas and insignificant for grazing management. Regardless, these results again highlight the prominence of conservation training towards adopting BMPs across agri-environmental risk areas (Baumgart-Getz et al. 2012; Prokopy et al. 2019). Having gross farm revenue greater than $250,000 was significant across most risk areas for producers who had an EFP, except under grazing management, general practices and wildlife and habitat conservation risk areas. These results are similar to our combined sample model shown in table 6.9A, aside from the lack of significance under general practices. For producers without an EFP, higher gross farm revenue was only significant for soil conservation, energy and climate change and general practices risk areas. However, for both samples higher gross farm revenue was highly significant at the 1% level for the overall ESA adoption score models. This indicates that higher gross farm revenue is an important component to adoption decisions which is cohesive with prior literature (Kim et al. 2005; Liu et al. 2018). The impact of age and having a degree on producer BMP adoption decisions was mostly insignificant which is relatively cohesive with prior literature (Ervin & Ervin 1982; Prokopy et al. 2008; Baumgart-Getz et al. 2012).

Amongst the most significant results from our split sample models are the impacts from our proxy variables for exposure to extension. We find heterogeneous results, where signs and the level of significance differ not only across sample populations, but between agri-environmental risk areas. For producers with an EFP, we find exposure to extension is mostly insignificant and our results reflect table 6.9A. For producers without an EFP however, we find a stark contrast in the level of significance for exposure to extension. We find exposure to extension in 2016 was negatively associated with BMP adoption under the water quality and quantity and general practice risk areas, yet in 2018, exposure to extension was positively associated with BMP adoption for these risk areas. These results may reflect the decrease in extension expenditure in 2016, or this may reflect policy changes such as the implementation of Alberta's Wetland Policy in 2015, where extension may not have been as important towards BMP adoption at this time. On the other hand, we find exposure to extension in 2016 was positively associated with BMP adoption for the soil conservation, wildlife and habitat management and energy and climate change risks areas, but in 2018 exposure to extension was negatively associated with BMP adoption for these risk areas. These results reflect some on-going changes that we have not accounted for in our models, possibly something that is not directly observable at this time. Something to note is that exposure to extension did not influence livestock intensive risk areas, namely grazing management, and manure management. This may be reflective of livestock producers which we will discuss below.

The impact of farm characteristics was heterogeneous across risk areas and sample models. In general, succession planning, as well as land ownership status, was mostly insignificant with few exceptions. Although, we find farm typology significantly impacted BMP adoption decisions. For producers with an EFP, being a livestock producer is negatively associated with BMP adoption under the soil conservation, energy and climate change, and general practice risk areas, but is positively associated for water quality and quantity practices. Most likely, livestock producers with an EFP are more aware of the benefits of reducing risks to water sources on their land, especially the impacts to livestock populations. For risk areas livestock farmers are less likely to adopt under, this may reflect a producer's workbook, where these producers may not have identified environmental risks in these areas. For producers without an EFP, being a livestock farmer was negatively associated with BMP adoption under the soil conservation, water quality and quantity, energy and climate change, and general practices risk areas. This may be reflective of a lack of knowledge about environmental risks on their land. Only under grazing management was being a livestock producer positive and significant. Here, a livestock producer without an EFP may implement these BMPs for the benefit of their operation economically, rather than for conservation action. Nevertheless, for producers with and without an EFP, under the overall ESA adoption score model we find being primarily a livestock producer is highly significant and positively associated with BMP adoption.

Table 6.10A. Results for Each Agri-Environmental Risk Area for Producers Who Have an EFP.

	Soil Conservation (SE)	Water Quality & Quantity (SE)	Grazing Management (SE)	Habitat & Wildlife Conservation (SE)	Manure Management (SE)	Energy & Climate Change (SE)	General Practices (SE)	Overall ESA Adoption Score (SE)
Year: 2014	0.003	0.037	-0.029	-0.031	-0.048	-0.040	0.054*	0.021
	(0.033)	(0.028)	(0.054)	(0.045)	(0.033)	(0.025)	(0.032)	(0.017)
Year: 2016	0.028	0.032	0.053	0.051	-0.031	-0.029	-0.011	0.032*
	(0.037)	(0.028)	(0.053)	(0.048)	(0.032)	(0.031)	(0.034)	(0.018)
Year: 2018	0.119***	0.023	0.113*	0.033	-0.069*	-0.059**	-0.068**	0.016
	(0.038)	(0.028)	(0.058)	(0.047)	(0.035)	(0.028)	(0.034)	(0.018)
Farmer Characteristics								
Age 18 to 44	0.033	0.032	0.013	-0.049	0.002	-0.084*	-0.024	-0.010
	(0.053)	(0.039)	(0.082)	(0.077)	(0.041)	(0.045)	(0.054)	(0.027)
Age 45 to 64	0.026	-0.003	-0.079	-0.034	-0.036	-0.109***	-0.044	-0.024
	(0.035)	(0.027)	(0.052)	(0.045)	(0.031)	(0.029)	(0.030)	(0.016)
Has a Degree	0.015	0.068***	0.001	0.072**	0.034	0.003	0.014	0.040***
	(0.028)	(0.022)	(0.040)	(0.035)	(0.028)	(0.020)	(0.025)	(0.014)
Attended Conservation	0.052*	0.044**	0.105***	0.036	0.047*	0.035	0.079***	0.051***
Training	(0.028)	(0.021)	(0.038)	(0.037)	(0.024)	(0.021)	(0.023)	(0.014)
GFR > $250k	0.082***	0.049**	-0.050	0.008	0.059**	0.076***	0.041	0.043***
	(0.028)	(0.023)	(0.047)	(0.037)	(0.030)	(0.023)	(0.026)	(0.014)
Farm Characteristics								
Planning to Expand	0.071**	0.007	0.058	-0.012	-0.003	0.029	0.031	0.025*
Operation	(0.033)	(0.024)	(0.049)	(0.045)	(0.029)	(0.027)	(0.026)	(0.015)
Planning to Reduce	-0.020	-0.012	-0.010	0.051	-0.012	-0.055**	-0.030	-0.014
Operation	(0.036)	(0.029)	(0.056)	(0.045)	(0.037)	(0.027)	(0.032)	-0.014
Planning to Sell Operation	-0.028	0.016	-0.242**	-0.019	-0.015	0.021	0.020	-0.034
	(0.058)	(0.051)	(0.114)	(0.090)	(0.082)	(0.075)	(0.054)	(0.029)
Livestock Producer	-0.131***	0.059**	0.080	-0.005	-0.015	-0.111***	-0.052*	0.056***
	(0.031)	(0.024)	(0.056)	(0.040)	(0.035)	(0.026)	(0.029)	(0.015)
Both Livestock and Crop	-0.074**	0.072***	0.074	0.035	-0.010	-0.061**	-0.021	0.053***
	(0.035)	(0.027)	(0.063)	(0.049)	(0.038)	(0.030)	(0.031)	(0.018)
Primarily Owns Land	-0.038	-0.055	0.187	0.026	-0.323**	0.019	0.256**	0.012
	(0.150)	(0.067)	(0.233)	(0.133)	(0.126)	(0.109)	(0.122)	(0.080)

Both Rents and Owns Land	-0.027	-0.063	0.172	0.040	-0.322**	-0.015	0.224*	0.009
	(0.150)	(0.066)	(0.241)	(0.134)	(0.125)	(0.106)	(0.121)	(0.080)
Exposure to Extension								
Extension $ per Farm 2014	-0.004	-0.002**	0.001	-0.001	0.001	0.001	-0.002	-0.002
	(0.003)	(0.001)	(0.005)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Extension $ per Farm 2016	-0.024	0.008	0.013	-0.356***	-0.085	0.034	-0.087	-0.049
	(0.121)	(0.074)	(0.238)	(0.070)	(0.171)	(0.083)	(0.058)	(0.055)
Extension $ per Farm 2018	0.039	-0.002	-0.024	0.380***	0.089	-0.040	0.102	0.058
	(0.137)	(0.077)	(0.259)	(0.073)	(0.180)	(0.087)	(0.063)	(0.058)
Constant	-0.148	0.640***	0.904	-0.587***	0.790	0.415	-0.389*	0.196
	(0.536)	(0.221)	(0.801)	(0.219)	(0.511)	(0.296)	(0.204)	(0.202)
Obs. (N)	554	643	444	639	432	646	646	645
AIC	105.76	-89.36	385.98	574.05	-49.67	-124.85	44.32	-720.47
BIC	455.45	272.40	689.07	939.76	239.19	237.29	406.45	-358.47

Significance levels are ***p<0.01, **p<0.05, *p<0.1

Table 6.1A. Results for Each Agri-Environmental Risk Area for Producers Who Do Not Have an EFP.

	Soil Conservation (SE)	Water Quality & Quantity (SE)	Grazing Management (SE)	Habitat & Wildlife Conservation (SE)	Manure Management (SE)	Energy & Climate Change (SE)	General Practices (SE)	Overall ESA Adoption Score (SE)
Year: 2014	-0.042* (0.025)	0.041 (0.027)	0.050 (0.063)	0.022 (0.040)	0.041 (0.035)	0.013 (0.018)	0.036 (0.028)	0.036** (0.016)
Year: 2016	0.002 (0.025)	0.036 (0.027)	0.035 (0.055)	-0.015 (0.042)	-0.031 (0.035)	-0.003 (0.022)	-0.039 (0.025)	0.024 (0.017)
Year: 2018	0.020 (0.026)	0.019 (0.031)	0.028 (0.055)	-0.009 (0.042)	-0.025 (0.035)	0.019 (0.018)	-0.062** (0.025)	0.011 (0.019)
<u>Farmer Characteristics</u>								
Age 18 to 44	0.016 (0.036)	0.046 (0.040)	0.051 (0.082)	-0.061 (0.058)	0.069 (0.051)	-0.044* (0.024)	-0.029 (0.037)	0.030 (0.023)
Age 45 to 64	0.022 (0.022)	0.051** (0.025)	0.036 (0.050)	-0.005 (0.033)	0.021 (0.028)	-0.033** (0.015)	-0.037 (0.023)	0.011 (0.014)
Has a Degree	0.009 (0.026)	0.069*** (0.025)	-0.011 (0.052)	0.014 (0.037)	-0.010 (0.032)	0.030 (0.019)	0.023 (0.027)	0.033** (0.016)
Attended Conservation Training	0.053** (0.025)	0.084*** (0.025)	0.045 (0.058)	0.030 (0.036)	0.082*** (0.030)	0.043** (0.020)	0.112*** (0.028)	0.053*** (0.016)
GFR > $250k	0.162*** (0.026)	0.016 (0.025)	-0.014 (0.059)	-0.062 (0.040)	-0.008 (0.032)	0.072*** (0.023)	0.043* (0.025)	0.043*** (0.016)
<u>Farm Characteristics</u>								
Planning to Expand Operation	0.019 (0.029)	-0.016 (0.033)	0.073 (0.063)	-0.049 (0.051)	0.001 (0.039)	0.039 (0.024)	0.001 (0.034)	0.009 (0.022)
Planning to Reduce Operation	0.002 (0.025)	-0.026 (0.026)	0.000 (0.053)	-0.034 (0.038)	-0.021 (0.031)	-0.015 (0.016)	-0.031 (0.024)	-0.007 (0.015)
Planning to Sell Operation	0.018 (0.050)	-0.041 (0.047)	0.020 (0.089)	-0.128* (0.069)	0.023 (0.050)	0.025 (0.040)	-0.057 (0.040)	-0.018 (0.030)
Livestock Producer	-0.120*** (0.022)	-0.058** (0.025)	0.143*** (0.055)	-0.004 (0.038)	-0.050 (0.038)	-0.041** (0.016)	-0.158*** (0.024)	0.035** (0.016)
Both Livestock and Crop	-0.018 (0.027)	-0.068** (0.029)	0.164*** (0.060)	0.038 (0.047)	-0.015 (0.042)	0.016 (0.023)	-0.055* (0.029)	0.048** (0.019)
Primarily Owns Land	-0.125 (0.079)	0.087 (0.099)	-0.095 (0.210)	-0.176 (0.145)	0.165 (0.137)	0.002 (0.051)	-0.003 (0.091)	0.053 (0.064)

Both Rents and Owns Land	-0.128	0.086	-0.032	-0.132	0.170	-0.005	0.056	0.064
	(0.079)	(0.099)	(0.210)	(0.144)	(0.137)	(0.051)	(0.091)	(0.064)
Exposure to Extension								
Extension $ per Farm 2014	-0.003	0.002	0.004	-0.000	0.001	0.000	-0.001	0.001*
	(0.003)	(0.001)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Extension $ per Farm 2016	0.339***	-0.163***	-0.117	0.227**	-0.038	0.217***	-0.127**	-0.011
	(0.082)	(0.060)	(0.177)	(0.089)	(0.067)	(0.028)	(0.057)	(0.033)
Extension $ per Farm 2018	-0.344***	0.164**	0.107	-0.235**	0.033	-0.229***	0.138**	0.006
	(0.094)	(0.064)	(0.193)	(0.097)	(0.073)	(0.031)	(0.059)	(0.035)
Constant	1.026***	0.351	0.570	1.537***	0.661**	0.772***	-0.194	0.533***
	(0.383)	(0.218)	(0.749)	(0.359)	(0.277)	(0.117)	(0.142)	(0.119)
Obs. (N)	615	785	575	794	518	797	797	793
AIC	-138.82	97.57	674.61	679.36	99.81	-430.96	43.56	-705.31
BIC	219.33	475.49	1018.60	1062.88	422.81	-51.81	422.71	-321.89

Significance levels are ***p<0.01, **p<0.05, *p<0.1

To examine Municipal Districts of significance for our split sample models, we choose to begin by discussing producers who have an EFP, and then we will discuss our models for those without an EFP. For producers with an EFP, we find minimal or no Municipal Districts of significance under the soil conservation, water quality and quantity, grazing management, manure management, and energy and climate change risk areas. Wildlife and habitat conservation had 40 Municipal Districts with farmers who were more likely to adopt BMPs, with 16 located in the North Saskatchewan region. This may correspond to the high uptake of EFP completion in this region. We also find 17 Municipal Districts where producers are less likely to adopt wildlife and habitat BMPs, where 5 districts are in the Upper Athabasca region, the rest being heterogenous. This may correspond to the low levels of conservation training and agricultural degrees in this region. For general practices, we find 25 Municipal Districts with farmers who are more likely to adopt BMPs under this risk area, 12 being in North Saskatchewan and 8 in South Saskatchewan. All other risk areas had heterogeneous or insignificant results.

For our models representing the sample of producers who do not have an EFP, we find a high degree of significance for Municipal Districts across risk areas. The exception is manure management, grazing management and our overall ESA adoption score models, where minimal significance was found. We also find regions of significance are highly heterogeneous across risks area. Some exceptions to this include 5 out of 10 Municipal Districts who are less likely to adopt general practices are located in the South Saskatchewan region and 16 out of 39 Municipal Districts who are less likely to adopt under energy and climate change are in North Saskatchewan. Nevertheless, for producers who do not have an EFP, it seems spatially there is a high degree of heterogeneity across Alberta Municipal Districts. Although, we did notice some degree of spillover effects between Municipal Districts. For example, for producers without an EFP, under the water quality and quantity risk area, we found 5 districts who were more likely to adopt these BMPs bordered one another. This was found for multiple districts of significance. These results may suggest producers without an EFP make adoption decisions based on social networks or extension services given the nature of the spillover effects, whereas those with an EFP may be more inclined to adopt based on their action plans from their workbook.

Table 6.10B. Statistically Significant (p<0.10) Alberta Municipal Districts for Split Sample Models for Producers Who Have an Environmental Farm Plan.

Risk Area	Municipal Districts (+) Significance	Municipal Districts (-) Significance
Soil Conservation	Kneehill, Minburn, Rocky View, Wainwright	Special Area 2.
Water Quality and Quantity	Two Hills	None
Grazing Management	Minburn, Northern Sunrise, Rocky View	None
Wildlife and Habitat Management	Beaver, Bonnyville, Brazeau, Calgary, Clear Hills, Clearwater, Cypress, Edmonton, Fairview, Flagstaff, Foothills, Forty Mile, Grande Prairie, Greenview, Lac Ste. Anne, Lamont, Leduc, Lesser Slave River, Mackenzie, Mountain View, Newell, Paintearth, Parkland, Peace, Pincher Creek, Ponoka, Provost, Smoky Lake, St. Paul, Starland, Stettler, Strathcona, Taber, Thorhild, Two Hills, Vermilion, Vulcan, Wainwright, Willow Creek, Special Area 2.	Athabasca, Barrhead, Big Lakes, Birch Hills, Camrose, Cardston, Kneehill, Lac La Biche, Lacombe, Lethbridge, Northern Sunrise, Saddle Hills, Spirit River, Warner, Westlock, Wheatland, Woodlands
Manure Management	None	Northern Sunrise, Sturgeon
Energy and Climate Change	Wheatland	None
General Practices	Beaver, Brazeau, Calgary, Cypress, Edmonton, Flagstaff, Foothills, Forty Mile, Lac Ste. Anne, Lamont, Newell, Northern Lights, Paintearth, Parkland, Ponoka, Provost, St. Paul, Stettler, Strathcona, Sturgeon, Taber, Thorhild, Vermilion, Vulcan, Willow Creek	Athabasca, Big Lakes, Cardston, Lac La Biche, Lacombe, Lethbridge, Northern Sunrise, Warner, Wheatland, Woodlands
Overall ESA Score	Grande Prairie, St. Paul, Two Hills, Vulcan	Northern Sunrise

Table 6.11B Statistically Significant (p<0.10) Alberta Municipal Districts for Split Sample Models for Producers Who Do Not Have an Environmental Farm Plan.

Risk Area	Municipal Districts (+) Significance	Municipal Districts (-) Significance
Soil Conservation	Athabasca, Barrhead, Birch Hills, Camrose, Lacombe, Saddle Hills, Spirit River, Sturgeon, Woodlands	Beaver, Bonnyville, Calgary, Clear Hills, Clearwater, Cypress, Edmonton, Fairview, Flagstaff, Foothills, Forty Miles, Grande Prairie, Greenview, Lamont, Leduc, Lesser Slave, Makenzie, Mountain View, Newell, Northern Lights, Paintearth, Parkland, Peace, Pincher Creek, Ponoka, Smoky Lake, Smoky River, St. Paul, Starland, Stettler, Strathcona, Taber, Thorhild, Vulcan, Willow Creek, Special Area 2.
Water Quality and Quantity	Beaver, Calgary, Clear Hills, Cypress, Fairview, Flagstaff, Foothills, Forty Mile, Grande Prairie, Lamont, Leduc, Lesser Slave River, Mackenzie, Newell, Paintearth, Parkland, Peace, Pincher Creek, Smoky Lake, Stettler, Strathcona, Thorhild, Willow Creek	Athabasca, Barrhead, Birch Hills, Camrose, Lacombe, Saddle Hills, Spirit River, Westlock, Woodlands
Grazing Management	Northern Sunrise	Rocky View, Sturgeon
Wildlife and Habitat Management	Athabasca, Barrhead, Birch Hills, Camrose, Lacombe, Saddle Hills, Spirit River, Westlock, Woodlands	Beaver, Bonnyville, Calgary, Clear Hills, Cypress, Edmonton, Flagstaff, Foothills, Forty Mile, Grande Prairie, Greenview, Lamont, Lesser Slave River, Mackenzie, Newell, Northern Lights, Paintearth, Parkland, Peace, Pincher Creek, Ponoka, Provost, Rocky View, Smoky Lake, Smoky River, St. Paul, Starland, Stettler, Strathcona, Thorhild, Vermilion, Willow Creek
Manure Management	None	None
Energy and Climate Change	Athabasca, Barrhead, Big Lakes, Birch Hills, Camrose, Cardston, Lac La Biche, Lacombe, Lethbridge, Minburn, Saddle Hills, Spirit River, Warner, Westlock, Woodlands	Beaver, Bonnyville, Brazeau, Calgary, Clear Hills, Cypress, Edmonton, Fairview, Flagstaff, Foothills, Forty Mile, Grande Prairie, Greenview, Lac Ste. Anne, Lamont, Leduc, Lesser Slave River, Mackenzie, Mountain View, Newell, Paintearth, Parkland, Peace, Pincher Creek, Ponoka, Provost, Smoky Lake, Smoky River, St. Paul, Starland, Stettler, Strathcona, Taber, Thorhild, Two Hills, Vermilion, Vulcan, Wetaskiwin, Willow Creek

General Practices	Beaver, Bonnyville, Brazeau, Calgary, Clear Hills, Cypress, Edmonton, Fairview, Flagstaff, Foothills, Forty Mile, Grande Prairie, Lac Ste. Anne, Lamont, Leduc, Lesser Slave River, Mackenzie, Newell, Northern Lights, Paintearth, Parkland, Peace, Pincher Creek, Ponoka, Provost, Smoky Lake, Stettler, Strathcona, Taber, Thorhild, Vermilion, Vulcan, Wetaskiwin, Willow Creek	Big Lakes, Birch Hills, Camrose, Cardston, Lacombe, Lethbridge, Saddle Hills, Spirit River, Warner, Wheatland, Woodlands
Overall ESA Score	Northern Sunrise	Brazeau, Calgary, Edmonton, Northern Lights, Rocky View, Two Hills, Vermilion

6.8 Discussion

This chapter explores components that influence an Albertan farmer's decision to adopt BMPs. The analysis suggests that farmers who have attended conservation training, have higher gross farm revenue, and who have completed an EFP are more likely to adopt BMPs across most risk areas. This is also the case once we split our samples, finding producers who have and do not have an EFP are more likely to adopt BMPs if they have attended conservation training and have higher gross farm revenue. Few studies have added conservation training as an explanatory variable (Prokopy et al. 2019), and these finding add to the literature showing in the Alberta context, conservation training significantly improves the rate of BMP adoption across agri-environmental risk areas. Further, these findings highlight the importance of the EFP. With low EFP completion rates in Alberta, these results demonstrate the importance of improving rates of EFP participation, as this may correspond to improved levels of BMP adoption.

We find for our overall sample that exposure to extension, shown as regional extension expenditure per farm, is statistically insignificant towards the adoption decision. However, exposure to extension is highly significant for our sample of producers who do not have an EFP. Possibly, these producers are more likely to be influenced by extension personnel as they do not benefit from individualized action plans provided by the EFP workbook. Our findings for exposure to extension suggests that the quality of information from extension personnel may be more important for the decision-making process than expenditure dollars for extension (Feather & Amacher 1994; Baumgart-Getz et al. 2012). We also find exposure to extension is not always a positive impact for BMP adoption as shown by our results for our sample of producers without an EFP. Unfortunately, even after consulting with Alberta Agriculture and Forestry, we were unable to find any policy, economic, climatic, or other factors that may explain these results. Although, we do note that the way we measure exposure to extension may be incorrect. The rest of the analysis was consistent with prior research where all other farm and farmer characteristics were heterogeneous across agri-environmental risk areas (Prokopy et al. 2019; Prokopy et al. 2008; Baumgart-Getz et al. 2012).

A spatial component was also added using dummy variables to identify Municipal Districts in Alberta. The findings for our overall sample show that certain Municipal Districts with higher

EFP completion, gross farm revenue, with producers who primarily own land, are more likely to adoption BMPs across risk areas. Even spatially, it seems the completion of the EFP is a significant indicator towards adoption, again showing the need to improve EFP completion rates. Some agri-environmental risk areas had no regions which were significantly more or less likely to adopt BMPs; this was also found in our split sample models. Some of our findings are in line with Bjornlund et al. (2009) who found spatial differences between Municipal Districts who were within a close proximity. Although, some of our findings counteract this as we do find spillover effects between Municipal Districts across our split sample models and pooled models. In general, these spatial results suggest using targeted programs and extension efforts for specific environmental risk areas for Municipal Districts (and/or Municipal Regions) who are less likely to adopt BMPs. Our results suggest targeting areas with lower rates of EFP completion, lower rates of conservation training, and those with lower gross farm revenue. For risk areas which had no regions of significance, this leaves room for a more general approach where it may be more important to ensure producers are aware of these practices and their public and/or private benefits. Lastly, with the presence of spillover effects, it may be useful to provide extension and conservation training that includes farmers from nearby Municipal Districts as this may influence a natural uptake of BMP adoption. This may relate to the influence of a farmer's social network or the observability of a practice (Kuehne et al. 2017; Pannell et al. 2006).

Conclusions

This thesis was presented as a three-paper approach to outline the relationship between agri-environmental policies, conservation stewardship programs, and the adoption of Best Management Practices (BMPs). In Chapter 4 we concluded that each national agricultural policy framework was plagued with a lack of monitoring and reporting, resulting in no real information regarding the efficiency of each policy or if environmental or economic goals were met. The inability to determine inefficiencies between policies meant no meaningful improvements were made. For stewardship programs, there was no indication as to whether the cost-share funding resulted in BMPs being adopted or if any adopted BMPs were continued long-term. These programs remained similar across each policy framework, again with little improvement. We recommend to policymakers that future policy frameworks, and associated environmental stewardship programs, should be extensively monitored to allow for cohesive reporting across provinces. The results of this monitoring will allow for necessary changes to improve producer participation and to determine whether cost-share dollars are enough to reduce the financial burden and/or risk from adoption. We also recommend that policymakers consider developing performance indicators and performance-based measures for future policy frameworks as these have been effective in both the European Union's Common Agricultural Policy and the U.S.' Farm Bills. This could come in the form of cross-compliance measures as this will engage producers to continue using BMPs long-term as there would be consequences for non-compliance. Further, this would link payments to conservation action which could be monitored over time.

Chapter 5 provided a thorough analysis of the Environmental Farm Plan (EFP). The first half of the chapter discussed in detail the history of the EFP, especially the requirement of completing an EFP to participate in environmental stewardship programs. This requirement was shown to reduce the pool of eligible producers that can participate in stewardship programs that are meant to encourage BMP adoption. This chapter also discussed the outlook of the EFP, primarily how commodity groups are beginning to incorporate the EFP as a measure to meet sustainable sourcing standards. We suggest this possibility can be beneficial since it should increase producer EFP completion rates, increase the pool of producers eligible to participate in stewardship programs, and increase rates of BMP adoption. Although, we caution that these new standards may also reduce market access or remove producers from the market altogether. The cost and benefits of commodity groups requiring an EFP should be weighted going forward. This overview led to the second half of the chapter where a logistic regression was developed to determine statistically significant factors that influence a producers' decisions to complete an EFP. Similar to prior literature, we found heterogeneous results for farm and farmer characteristics (Prokopy et al. 2019; Pannell et al. 2006; Baumgart-Getz et al. 2012); although our results showed the importance of conservation training (Prokopy et al. 2019; Atari et al. 2009).

Amongst the most significant results from chapter 5 surrounded the influence of industry standards. We found industry standards impact EFP completion, and this impact depended on the year of which commodity group programs were implemented. This is also a significant finding since prior literature has failed to account for industry standards as an explanatory variable. These findings suggest that more commodity groups should actively encourage the completion of the EFP to improve rates of adoption amongst Albertan farmers. This also could relate back to our suggestion for cross-compliance measures, where the completion of the EFP could be used as a form of cross-compliance to meet environmental goals. Another noteworthy finding was the insignificance of exposure to extension as we had hypothesized extension would significantly impact a producer's management decisions (Rollins et al. 2018; Atari et al. 2009). This may represent a disconnect between EFP technicians and Alberta producers. Namely, there is a needed improvement regarding EFP technicians outreach efforts and the way in which they relay information about the EFP. This should involve ensuring EFP technicians are well education on environmental risk management in agriculture to mitigate improper information being provided to producers (Rodriguez et al. 2009; Vanclay & Lawrence 1994).

After a spatial analysis, the results suggest vast heterogeneity of EFP completion across each Municipal District. These results suggest extension and information about the EFP do not necessarily need to be tailored towards a specific Municipal District. Rather, it is imperative to better inform producers about the EFP, such as through commodity groups or extension workshops. This can also be connected towards the significance of conservation training and EFP completion in our models. Workshops for the EFP are already available for producers, and we recommend increasing the number and frequency of workshops across Municipal Districts.

Lastly, this chapter addressed current issues with the EFP, as identified by prior literature. This includes farmers not assessing the whole farm when completing their workbooks and the lack of monitoring that has occurred for the EFP program over time. Currently, there is no ability to determine the extent of environmental risk reduction that has occurred from producers adopting or implementing actions identified in their workbooks. Going forward, Alberta EFP program managers should address the issues that were summarized in this chapter, as these problems have been consistently pointed out across the literature to no avail. We also recommend linking cost-share funding to commonly identified agri-environmental risk areas across producer workbooks. This may aid with the cost-effectiveness of the program by targeting specific environmental issues, resulting in an increase in environmental risk mitigation.

Finally, chapter 6 addressed BMP adoption in Alberta, specifically focusing on components that alter a producer's decision to adopt BMPs across agri-environmental risk areas. An ESA Adoption Score was developed for each risk area producing a proportional dependent variable for analysis. A Linear Probability Model was determined to be the best fit, and models were run for all agri-environmental risk areas and for an overall ESA adoption score. The analysis showed that adoption across risk areas has remained stagnant over time, with risk areas such as soil conservation and energy and climate change having low rates of adoption. The results from our models again highlight the importance of conservation training (Baumgart-Getz et al. 2012; Prokopy et al. 2019), this time showing its significance towards BMP adoption across almost all risk areas.

Perhaps, the most important result was the impact having completed an EFP has on adoption decisions. Our analysis showed producers who had an EFP were significantly more likely to adopt BMPs across risk areas. This result may also be the answer as to why adoption has been stagnant over time. Since the EFP is a requirement to access funding under each policy framework, with a minimal increase in EFP completion, many producers have been unable to access funding to adopt BMPs. Thus, stagnant adoption may be correlated to stagnant EFP completion. This is an important finding for policymakers and going forward two pathways should be considered: 1) increase efforts to improve EFP completion rates to possibly improve the rate of BMP adoption; or 2) weigh the cost and benefits of removing the EFP as an eligibility requirement under environmental stewardship programs to allow equal access to all agricultural producers. Policymakers should note that the EFP is highly influential towards BMP adoption and provides producers with individual plans to reduce environmental risks on their farm. Thus, we recommend working towards improving EFP completion rates and improving extension efforts through EFP technicians. Spatially, a Municipal Districts EFP completion rate was an indicator that a district has more avid BMP adopters. These results provide even more of a reason to increase EFP completion rates, especially through targeting Municipal Districts with lower rates of EFP completion or with lower rates of BMP adoption.

Chapter 6 also addressed the possible endogeneity of the EFP where we split our models into a sample of producers who have an EFP and a sample for producers who do not have an EFP. We find conservation training, farm typology, and higher gross farm revenue are significant factors that persuade BMP adoption decisions. All other farm and farmer characteristics were heterogeneous or insignificant. We also found for producers without an EFP, exposure to extension was highly significant towards the adoption process across risk areas, but not for the overall ESA adoption score. As previously stated, these producers likely rely on extension personnel for information on BMPs as they do not have individualized plans which are offered in an EFP workbook. Unfortunately, even after consulting with personnel at Alberta Agriculture and Forestry (AAF), we were unable to determine other factors which may have influenced the significance of exposure to extension for producers without an EFP. Lastly, we find vast heterogeneity for spatial effects for producers without an EFP. Although, we did find a presence of spillover effects between Municipal Districts. We recommend conducting conservation training in collaboration with other Municipal Districts to improve BMP adoption and to ensure producers receive the same information about BMPs. This also ties into the quality of information where producers must see the benefit of adopting BMPs on their land (Feather & Amacher 1994; Baird et al. 2016; Rodriguez et al. 2009).

Overall, this chapter showed that the decision-making process differs across agri-environmental risk areas. For example, producer decisions for practices under the wildlife habitat conservation risk area varied greatly. Unlike other risk areas, having an EFP or attending conservation training was statistically insignificant. Instead, this risk area was influenced by exposure to extension, which was identified as extension expenditure per farm. These results are important as they show environmental stewardship programs are not "one size fits all" as factors that impact adopt vary across risk areas. To overcome this, future programs should individually target risk areas with lower rates of adoption and should use incentives, as well as extension services, that are tailored to fit the needs of practices under each risk area.

The findings reported in this thesis are relevant for researchers, agricultural organizations, and policymakers. Through comparing Canadian (and Albertan) policies and programs to well developed international policies and programs, we offer possible solutions to overcome current shortcomings and to improve efficiency and policy effectiveness going forward. Our analysis of the EFP is one of the first for the Alberta EFP and contributes to the sparse literature regarding factors that influence EFP completion. With the addition of industry standards, this fills a gap in the literature by including this as a measurement variable in our analysis. The findings in this thesis can help Alberta EFP program managers going forward as they continue to revise and expand the Alberta EFP programme. This is especially important given the fact that only 25% of farmers in Alberta have an EFP (as of 2017).

This thesis also provides a thorough overview of BMP adoption in Alberta across agri-environmental risk areas. Literature in Canada, especially in Alberta, regarding BMP adoption has been limited. This thesis aids policymakers with the ability to pinpoint which risk areas are lagging in their adoption rates and which factors help motivate their adoption. Given our findings, policymakers and agricultural organizations may have an increased interest in agri-environmental policies and how they relate to the adoption of BMPs, as well as the importance of mitigating environmental risks on agricultural land. This may motivate commodity groups to promote the completion of the EFP or to develop their own plans to ensure environmental risks are mitigated. Consequently, the present research widens the scope of the analysis and application of agri-environmental policies, programs, and subsequently, the adoption of BMPs, to other provinces and territories in Canada, possibly at the Municipal District level.

Limitations and Guidelines for Future Research

The largest barrier to our analysis was data limitations. In Chapter 4, we described the inability to find publicly available information for each national policy framework and Alberta's environmental stewardship programs. This was mostly due to a lack of monitoring and reporting on behalf of each policy and program. In the Alberta context, some data was lost through transitionary periods that did not allow us to correctly analyse the total monetary number provided to farmers under each stewardship program (such as the Confined Feeding Operations program). If future policies and programs develop performance measures and have available information, we recommend future research explores this information to better understand whether the policies or programs have met environmental goals and if they have prompted BMP adoption.

In Chapter 5, we were limited in our analysis of the EFP due to its confidentiality, resulting in limited information being available, none of which was public. Information provided in producer workbooks were not available for us to view, meaning we were unable to determine which risk areas were commonly identified. Further, since these workbooks are not monitored, we do not know if producers implement any action plans identified in their workbooks. Future research should be done to identify commonly addressed environmental risks and to identify the long-term success of producer plans, or if producers adopt any BMPs identified in their plans. With this, information on industry standards and their programs rates of completion were not available publicly. We were forced to use a proxy for each industry standard identified. Our measurement variable for exposure to extension was also limited as we were unable to access the level of expenditure for EFP technicians. With this, our variable for the number of EFP technicians per Municipal District was prone to error as some were identified to work in multiple locations (with some technicians not having an identified location) which resulted in them being left out of the analysis.

We developed a basic spatial analysis using dummy variables to identify rural Municipal Districts in Alberta. Future researchers should consider exploring spatial analysis to a higher degree, such as exploring the use of ArcGIS software to account for more regional characteristics. This includes accounting for agronomic variables and topography, such as soil quality, and its relation to BMP adoption. This could follow the work of Baird et al. (2016) who provided a geospatial social-ecological systems analysis for Alberta watersheds. Future research could explore geospatial factors which affect all agri-environmental risk areas identified in this thesis and compare across Municipal Districts or Municipal Land-Use Regions. This could aid with targeted extension programs and could allow for a cost-effective approach to motivate BMP adoption by removing excess financial aid to regions who already actively adopt certain BMPs.

Lastly, we were unable to determine if the EFP was endogenous in our agri-environmental models shown in Chapter 6. This was first due to limitations with the software but was also attributed to an inability to find instrumental variables due to data limitations in our Chapter 5 models. We encourage future researchers to explore the endogeneity of the EFP on BMP adoption decisions, provided they are granted access to data. We also encourage the Federal and Provincial government, as well as Alberta EFP program managers, to provide more thorough data to researchers going forward as this will benefit future policies and programs, as well as outreach efforts.

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Appendix 1

A complete list of ESA practices, questions provided to respondents, and adoption requirements under the 2012, 2014, 2016 ad 2018 ESAT Surveys.

Table A1. ESA Practices as Described Across the 2012, 2014, 2016 and 2018 ESAT Surveys.

ESA Category	ESA Practice	Question	Adoption
Soil Conservation			
	Use reduced tillage	Please indicate which of the following best describes how you seeded the majority of your crop acres in [previous year].	The seeding operation into the stubble of previous crop was the only tillage pass completed
	Use legumes in rotation	Did you use pulse crops in your cropping rotation in [previous year]?	Yes
	Use winter cereals in rotation	Did you use winter cereals in your cropping rotation in [previous year]?	Yes
Water Quality/Quantity			
	Maintain buffer areas along edge of natural water bodies	Did you maintain buffer areas of grass and/or trees along the edge of rivers, streams, sloughs, wetlands, or ditches?	Yes
	Avoid draining or filling in natural wetlands/sloughs	Did you drain or fill in natural wetlands or sloughs?	No
	Apply chemical fertilizer at recommended rate	Did you apply commercial fertilizer based on the results of a soil or tissue test?	Yes
	Control runoff from manure storage	Did you control runoff from all, some, or none of your Manure Storage?	All or some
	Control runoff from livestock pens	Did you control runoff from all, some, or none of your livestock pens?	All or some

	Control runoff from feeding areas	Did you control runoff from all, some, or none of your Overwintering In-field Feeding Areas?	All or some
	Plug or seal abandoned wells	Total # of inactive, abandoned, or unused wells (>0)	Total # of inactive, abandoned, or unused wells that are properly sealed or plugged (>0)
	Properly seal and maintain active wells	Total # of active wells (>0)	Total # of inactive, abandoned, or unused active wells that are properly maintained (>0)
	Maintain a 10m buffer area from water bodies when applying pesticides	In [previous year], did you maintain at least a 10m buffer area from water bodies when applying crop protection products?	Yes
	Maintain a 10m buffer area from water wells when applying pesticides	In [previous year], did you maintain at least a 10m buffer area from water wells when applying crop protection products?	Yes
	Manage livestock access to water bodies that are used as a water source	In [previous year], did you manage or control livestock access to water bodies that are used as a water source?	Yes
	Choose wintering site to avoid manure contamination	Did you locate all, some or none of your winter feeding and bedding sites to prevent runoff from manure entering natural water bodies?	All or some
Grazing Management			
	Protect riparian areas from grazing to prevent overuse	Which of the following do you typically do on your farm? Avoid or minimize grazing in riparian and/or bush areas in the late summer or autumn	Yes

	Time grazing to avoid vulnerable times of the year for riparian areas	Which of the following do you typically do on your farm? Time the grazing of riparian areas to avoid grazing during spring and early summer	Yes
Wildlife Habitat Conservation			
	Retain bush or native grassland	Do you retain woodlands, bush, or native grassland?	Yes
	Manage grazing for wildlife habitat	In [previous year], did you manage your livestock grazing to provide habitat for wildlife?	Yes
	Manage grazing to encourage natural rejuvenation of understory in woodlands	In [previous year], did you manage grazing to encourage natural growth of understory in woodlands? Understory may include small trees, shrubs, forbes and grasses.	Yes
Manure Management			
	Avoid applying manure or compost on frozen or snow-covered ground	Do you typically apply manure on frozen or snow-covered ground? **And** Do you typically apply compost on frozen or snow-covered ground?	No
	Avoid storing manure near water wells	Did you store manure within 100m of: Active water wells? **AND** Did you store manure within 100M of Abandoned water wells?	No
	Frequency of application	On the fields that you have manure applied, how frequently do these fields typically receive manure?	Once every two years, three years or less
	Incorporate manure after applying	Do you typically incorporate Solid manure with 24 hours, 48 hours or greater than 48 hours?	Within 24 or 48 hours

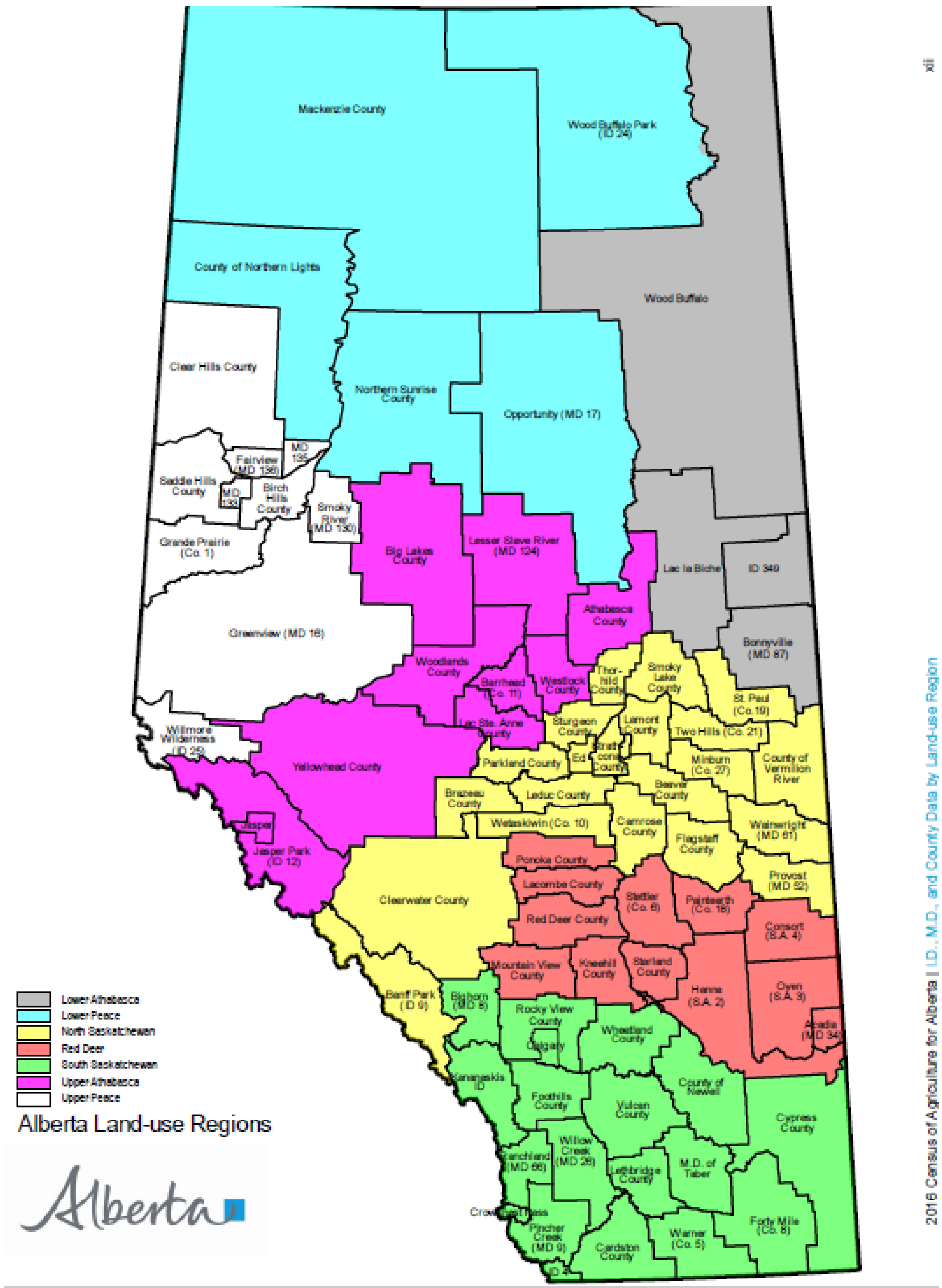
	Applying liquid manure	Thinking about liquid manure, do you typically…?	Broadcast with incorporation within 24 or 48 hours after application
	Avoid applying close to waterways to minimize increased nutrient runoff	Do you typically take into account any of the following factors when applying either solid or liquid manure? Distance between manure applications and waterways – that is low lying paths where surface water collects and flows, slope of land, application method	Yes, to any item
	Sampling and analyzing the manure for nutrient content	Do you typically apply manure – either solid or liquid, based on a soil or tissue test, manure nutrient test or book values?	Yes, to soil or tissue test OR manure nutrient test OR book values
	Manure application based on P or N&P	Are your manure application rates typically based on crop nitrogen requirements, crop phosphorus or neither?	Crop nitrogen or phosphorus requirements
	Keeping manure records	Do you typically keep records detailing the amount and field location of where the manure is spread for all, some, or none of your fields?	All or some
Agricultural Waste Management			
	Recycle Plastics	Please indicate if you did each of the following on your farm in 2017. Recycle plastics such as baler twine, feed bags, silage wraps and/or bale wraps.	Yes
Energy and Climate Change			
	Energy saving practices	Other than the main utility meter that shows the total electricity usage for your entire property, do you have any submeters – that is, extra	Yes

	Renewable power	Do you produce grid-connected electricity using any of the following Renewable Energy methods? Solar panels, not counting for water pumping or electric fencing, wind turbine generator on a tower, biogas generator using farm waste. **OR** Do you produce heat from any of the following Renewable Energy methods? Solar thermal water heating, solar thermal air heating incorporated into farm building walls, wood combustion (whole, pellets, chips), combustion of any other biomass (straw bales, straw pellets, grain)	Yes, to either
	Participate in carbon credit trading	Are you currently participating in the Alberta Carbon offset market?	Yes
General Practices			
	Precision farming – VRT	Last year, did you utilize variable rate technology in the application of commercial fertilizer? **AND** Last year, did you utilize variable rate technology in the application of crop protection products such as herbicides, insecticides, and fungicides?	Yes
	Environmental Farm Plan**	Have you completed the Environmental Farm Plan process?	Yes
	Soil sampling fields at least once every three years	Do you typically soil sample your fields yearly, at least once every three years or less than once every three years?	Yearly OR at least once every 3 years
Trees for agricultural purposes	Have you planted trees on your farm in the past 2 years for agriculture purposes (shelterbelts/windbreaks, wildlife habitat, soil conservation, odour control, etc.)?	Yes	

Source: AAF (2018); Government of Alberta (2016); Government of Alberta (2014); Government of Alberta (2012). Note: *The Environmental Farm Plan was not included as a practice for our analysis.

Appendix 2A

A Map of Alberta Land-use Regions and Municipal Districts in Each Region.



Appendix 2B

The relationship between industry standards for potato, egg, beef, and dairy farmers and their percentage of EFP completion across Municipal Districts.

Table A2. Industry Standards and Municipal Districts EFP Completion Based on the 2016 Census of Agriculture for Alberta.

Municipal Region	No. of Egg Farms	No. of Potato Farms	No. of Beef Farms	No. of Dairy Farms	Completed an EFP (%)
Athabasca	16	0	189	3	28%
Barrhead	23	0	209	17	57%
Beaver	14	5	167	4	21%
Big Lakes	7	0	95	0	36%
Birch Hills	4	2	24	0	39%
Bonnyville	16	0	239	1	33%
Brazeau	11	0	134	1	42%
Calgary	2	0	28	0	43%
Camrose	25	0	200	7	43%
Cardston	21	3	217	3	48%
Clear Hills	9	0	72	2	40%
Clearwater	23	0	421	9	45%
Cypress	13	0	385	1	39%
Edmonton	3	5	19	1	40%
Fairview	1	0	23	0	60%
Flagstaff	7	2	133	4	46%
Foothills	35	0	346	2	31%
Forty Mile	16	17	106	2	53%
Grande Prairie	35	0	209	0	48%
Greenview	19	0	153	1	65%
Kneehill	14	4	154	2	56%
Lac La Biche	8	0	88	0	29%
Lac Ste. Anne	26	0	297	2	59%
Lacombe	20	10	310	49	47%
Lamont	9	0	137	1	44%
Leduc	30	3	254	38	41%
Lesser Slave River	6	0	48	0	56%
Lethbridge	42	12	218	60	55%
Mackenzie	46	4	56	1	29%
Minburn	8	0	127	1	33%
Mountain View	42	0	529	22	52%

Newell	12	9	299	4	57%
Northern Lights	8	0	50	0	50%
Northern Sunrise	4	0	25	2	57%
Paintearth	12	0	172	0	50%
Parkland	33	16	208	9	21%
Peace	5	0	27	0	36%
Pincher Creek	16	0.	247	1	36%
Ponoka	23	2	459	48	33%
Provost	5	0	156	0	54%
Red Deer	38	17	480	36	59%
Rocky View	40	12	329	2	60%
Saddle Hills	12	0	73	0	20%
Smoky Lake	7	0	133	1	50%
Smoky River	4	0	16	0	43%
Special Area 2	1	0	260	0	45%
Special Area 3	1	0	120	0	80%
Special Area 4	5	0	139	0	40%
Spirit River	11	0	13	0	40%
St. Paul	10	1	249	2	43%
Starland	19	1	70	2	60%
Stettler	19	5	307	4	50%
Strathcona	20	7	115	5	30%
Sturgeon	15	13	128	5	42%
Taber	12	27	177	6	63%
Thorhild	14	0	95	1	29%
Two Hills	12	2	140	0	39%
Vermilion	12	3	362	0	41%
Vulcan	18	0	126	2	55%
Wainwright	21	0	182	0	29%
Warner	20	5	112	0	47%
Westlock	20	5	215	8	47%
Wetaskiwin	21	9	302	23	35%
Wheatland	24	11	186	1	48%
Willow Creek	21	2	378	9	56%
Woodlands	19	0	90	1	50%
Yellowhead	6	0	185	5	62%
Mean	19	4	213	9	45%

Sources: AAF (2020), 2012, 2014, 2016 and 2018 ESAT Survey provided by AAF.

Appendix 2C

Calculated marginal effects for yearly survey models estimating factors that influence EFP completion.

Table A3. Marginal Effects for Model Estimates Based on Individual Survey Year Data.

	Model 2 Year 2012	Model 3 Year 2014	Model 4 Year 2016	Model 5 Year 2018
Farmer Characteristics				
Age: 18 to 44	-0.074	-0.163	0.156	0.003
	(0.104)	(0.127)	(0.119)	(0.108)
Age: 45 to 64	-0.028	0.032	0.038	0.011
	(0.053)	(0.064)	(0.076)	(0.069)
Has a degree	0 .113**	0.136**	0.119*	0.136*
	(0.055)	(0.056)	(0.067)	(0.075)
Attended conservation training	0.242***	0.151**	0.195***	0.302***
	(0 .049)	(0.057)	(0.064)	(0.081)
GFR>$250k	0.178***	0.304***	0.309***	0.280***
	(0.051)	(0.062)	(0.068)	(0.065)
Farm Characteristics				
Planning to expand	0.09	0.10	-0.179**	0.082
	(0.061)	(0.10)	(0.083)	(0.083)
Planning to reduce	-0.13**	0.013	-0.038	0.068
	(0.063)	(0.064)	(0.083)	(0.083)
Planning to sell	0.150*	-0.170	-0.128	-0.107
	(0.088)	(0.126)	(0.192)	(0.160)
Primarily livestock	-0.074	0.043	0.015	-0.010
	(0.055)	(0.067)	(0.076)	(0.078)
Both crop and livestock	0.060	0.105	-0.042	-0.076
	(0.071)	(0.089)	(0.076)	(0.089)
Primarily own land	0.127	-0.663***	-0.048	0.086
	(0.168)	(0.223)	(0.064)	(0.067)
Both rent and own land	0.219	-0.540**		
	(0.165)	(0.218)		

Exposure to Extension				
2011 to 2013 Funding*2012 EFP Technicians		-0.010**		
		(0.004)		
2014 to 2016 Funding*2014 EFP Technicians			0.006	
			(0.004)	
2017 to 2019 Funding*2016 EFP Technicians				-0.009
				(0.006)
Industry Standards				
Main Potato Farmers (2011 Census)	-0.012	0.005		
	(0.008)	(0.005)		
Main Potato Farmers (2016 Census)			0.002	0.006
			(0.004)	(0.004)
Egg Farmer (2011 Census)		0.022**		
		(0.011)		
Egg Farmer (2016 Census)			-0.015**	0.004
			(0.006)	(0.008)
Beef Producer (2011 Census)	-0.000	0.002		
	(0.000)	(0.002)		
Beef Producer (2016 Census)			0.001	-0.004*
			(0.001)	(0.003)
Dairy Farm (2016 Census)				0.063*
				(0.035)
N	429	372	266	260

Significance levels are ***p<0.01, **p<0.05, *p<0.1

Appendix 3A
A further explanation of econometric models in Chapter 6 section 6.3.4.

As shown in Table 6.4 in Chapter 6, there are four models which were plausible for a fractional (proportional) dependent variable but were found to not be a good fit. Below provides a further analysis as to why these models are not a good fit.

Beta Distribution

The Beta distribution is commonly known to be flexible for modelling proportions (Ferrari et al. 2004). Often, y is assumed to distributed as:

$$f(y) = \frac{1}{B(p,q)} y^{p-1}(1-y)^{q-1}$$

where $0 \leq y \leq 1$ and $B(p,q)$ is the beta function (Kieschnick & McCullough 2003). Instead of using the linear function, Kieschnick & McCullough suggest using a logit function based on evidence from Cox (1996) who tested multiple link functions for continuous proportional data. Although, Gray & Alava (2018) point out the drawback to the standard beta regression model is that distributional misspecifications can lead to inconsistent parameter estimates. This is because the beta model assumes a distribution for the dependent variable that is conditional on covariates (Gray & Alava 2018). Further, Ospina & Ferrari (2012) explain that the beta distribution does not provide a good description of the data if there are extreme values as it does not allow a positive probability for any point in the interval [0,1]. In short, it is not a good model of choice if extreme values are present.

Zero (or One) Inflated Beta

Given the limitations of the beta distribution, often researchers will implore a zero inflated beta or one inflated beta regression to account for extreme values when using proportional dependent variables (Ospina & Ferrari 2012). The zero inflated beta model allows zeros and nonzero values, whereas a one-inflated beta model separates variables influencing one and non-one values (Williams 2019). There is also an option to produce a zero-one inflated beta distribution, where values of 0 or 1 are analysed as a separate process. Only a zero-one inflated beta distribution would be plausible for our dataset given the level of extreme values that are present. Buis (2010) states the reason this analysis is separate is we assume the proportions of 0 or 1 are qualitatively different and generated through a different process compared to the other proportions. This logic is not applicable for our dataset as the values of 0 and 1 are not formed from a different process, thus this model is not a good fit.

Tobit Model

Researchers have attempted to apply a censored normal model, also known as a Tobit model, for proportional data (Kieschick & McCullough 2003). As Kieschick & McCullough (2003) describe, the Tobit is often assumed to be,

$$y_i^* = x_i'\beta + \mu_i, \qquad i = 1,2,\dots,n$$

and

$$y_i = \begin{cases} 0, & y_i^* \leq 0 \\ y_i, & 0 < y_i^* < 1 \\ 1, & y_i^* \geq 1 \end{cases}$$

Here μ_i is assumed to be i.i.d. Generally, the Tobit model is used to censor data that goes outside the [0,1] bounds. Our dependent variable does not hold any values outside this interval; thus, it would be an inappropriate model of choice. Further, Kieschick & McCullough (2003) state when the dependent variable is bound between [0,1] the Tobit is observationally equivalent to the normal regression model and holds all criticism of the Linear normal regression model. Further, as described in Table 6.4, Long (1997) describes that this approach is only feasible if there is not an excessive amount of censoring. As shown in Table 6.3, our dependent variables would require an excessive amount of censoring making the Tobit model not a good fit for our dataset.

Count Model

Count models are often used for behavioural variables involving counts of events and is a quantitative measure. Generally, the Poisson regression model is the starting point for count data which can be shown as follows:

$$Prob(Y = y_i|\boldsymbol{x}_i) = \frac{e^{-y_i}\lambda_i^{y_i}}{y_i!}, \qquad y_i = 0,1,2, \ldots.$$

Here, y_i is drawn from a Poisson population with parameter λ_i, which is related to the regressors $\boldsymbol{x}_i$. As Greene (2012) states, λ_i is often the loglinear model. The Poisson model is often criticised for its assumption that the variance of y_i is equal to its mean; often this can lead researchers to use the negative binomial model which relaxes Poisson assumptions. The main reason this model is not a good is because we are not counting how many BMPs have been adopted, rather we are interested in the proportion of BMPs adopted given eligibility requirements.

Appendix 3B

Table A4 provides an overview of post estimation results for our LPM and fractional logistic model. Comparing AIC and BIC values across all risk area models we find the Linear Probability Model (LPM) to be a better fit as these values are lower compared to the fractional logit. Our Variance Inflation Factor (VIF) is lower in our fraction logit for our grazing management, wildlife and habitat management, manure management, energy and climate change, and general practices model. Although, this test is to determine if there is a presence of multicollinearity and all VIF scores across models are below the 5 to 10 threshold indicating little presence of multicollinearity. With respect to our test for model specification, the link test, we find only our manure management model is properly specified under the fractional logistic regression. The remainder of our fractional logistic models are not properly specified, but all models have meaningful predictors. Under our LPM, our grazing management model, wildlife and habitat management model, manure management model, and general practices model are properly specified and have meaningful predictors. The rest of the LPMs are not properly specified but hold meaningful predictors. Most likely, this misspecification is occurring due to omitted variables at the Municipal District level, such as identifiers for soil type, typology, among others. Following all the plausible post estimation tests, we identify the LPM as the best fit model for all risk areas.

Table 4A. Post Estimation Results for the LPM and Fractional Logistic Models.

	AIC	**BIC**	R^2	**Log Likelihood**	**Mean VIF**	**Link test: _hat**	**Link test: _hatsq**
Soil Conservation							
LPM	-67.93	347.31	0.31		3.20	✔	
Fractional Logit	970.67	1390.97		-402.34	3.20	✔	
Water Quality & Quantity							
LPM	-6.44	430.47	0.12		3.47	✔	
Fractional Logit	1337.64	1779.82		-584.82	3.47	✔	
Grazing Management							
LPM	1053.96	1467.79	0.11		4.57	✔	✔
Fractional Logit	1258.84	1667.75		-546.42	1.46	✔	
Wildlife & Habitat Management							
LPM	1234.99	1672.19	0.12		3.48	✔	✔
Fractional Logit	1579.80	2022.27		-705.9	1.43	✔	
Manure Management							
LPM	36.64	434.87	0.13		4.88	✔	✔
Fractional Logit	1045.42	1443.65		-440.71	1.54	✔	✔
Energy & Climate Change							
LPM	-560.80	-123.02	0.18		3.51	✔	
Fractional Logit	844.57	992.25		-394.28	1.44	✔	
General Practices							
LPM	41.56	484.62	0.20		3.50	✔	✔
Fractional Logit	1454.93	1897.98		-643.46	1.44	✔	

<u>Overall ESA Adoption Score</u>						
LPM	-1435.41	-997.92	0.20		3.50	✓
Fractional Logit	1481.20	1923.96		-656.60	3.50	✓

* ✓ signifies the model passed the conditions imposed by the link test.

Table A5 provides our post estimation results for our models described in equation (15) and (16) for our split dataset. We find our models for producers who have an EFP are properly specified, except for our water quality and quantity, grazing management and overall ESA adoption score models. Our models representing producers who do not have an EFP were only properly specified for grazing management, wildlife and habitat conservation, and manure management. The rest of our models have meaningful predictors as indicated by the linktest (_hat) results, although the models are not properly specified. Again, like our post estimation results in Table A4, it is likely this misspecification is occurring at the Municipal District level.

Table A5. Post Estimation Results for Agri-Environmental Risk Area Models for Producers with and without an Environmental Farm Plan (EFP).

	AIC	BIC	R^2	Mean VIF	Link test: _hat	Link test: _hatsq
Soil Conservation						
EFP	105.76	-138.82	0.34		✓	✓
Without EFP	455.45	219.33	0.37		✓	
Water Quality & Quantity						
EFP	-89.36	272.40	0.17		✓	
Without EFP	97.57	475.49	0.17		✓	
Grazing Management						
EFP	385.98	689.07	0.25		✓	
Without EFP	674.61	1018.60	0.15		✓	✓
Wildlife & Habitat Management						
EFP	574.05	939.76	0.23		✓	✓
Without EFP	679.36	1062.88	0.18		✓	✓
Manure Management						
EFP	-49.67	239.19	0.23		✓	✓
Without EFP	99.81	422.81	0.17		✓	✓
Energy & Climate Change						
EFP	-124.85	-430.96	0.29		✓	✓
Without EFP	237.29	-51.81	0.19		✓	
General Practices						
EFP	44.32	43.56	0.21		✓	✓
Without EFP	406.45	422.71	0.27		✓	
Overall ESA Adoption Score						
EFP	-720.47	-705.31	0.26		✓	
Without EFP	-358.47	-321.89	0.22		✓	

* ✓ signifies the model passed the conditions imposed by the link test.

Table A6. Fractional Logistic Results for Each Agri-Environmental Risk Area and Overall ESA Adoption Score

	Soil Conservation (SE)	Water Quality & Quantity (SE)	Grazing Management (SE)	Habitat & Wildlife Conservation (SE)	Manure Management (SE)	Energy & Climate Change (SE)	General Practices (SE)	Overall ESA Score (SE)
Year: 2012	-0.085	0.195*	0.017	-0.069	0.081	-0.051	0.217**	0.118**
	(0.125)	(0.107)	(0.207)	(0.155)	(0.120)	(0.140)	(0.093)	(0.047)
Year: 2014	0.116	0.155	0.181	0.040	-0.103	-0.154	-0.110	0.102**
	(0.133)	(0.104)	(0.191)	(0.160)	(0.111)	(0.166)	(0.092)	(0.050)
Year: 2016	0.355***	0.073	0.168	0.016	-0.189*	-0.107	-0.319***	0.024
	(0.133)	(0.109)	(0.194)	(0.161)	(0.109)	(0.157)	(0.101)	(0.052)
Farmer Characteristics								
Age 18 to 44	0.241	0.256	0.251	-0.298	0.249	-0.535***	-0.089	0.073
	(0.191)	(0.157)	(0.290)	(0.230)	(0.159)	(0.201)	(0.141)	(0.069)
Age 44 to 64	0.184	0.178*	-0.125	-0.104	0.030	-0.608***	-0.169**	0.001
	(0.127)	(0.093)	(0.176)	(0.142)	(0.095)	(0.138)	(0.084)	(0.043)
Has a degree	0.126	0.402***	-0.003	0.249*	0.054	0.172	0.080	0.148***
	(0.110)	(0.097)	(0.161)	(0.137)	(0.096)	(0.119)	(0.082)	(0.042)
Attended conservation	(0.110)	0.357***	0.523***	0.213	0.300***	0.353***	0.424***	0.222***
training	(0.115)	(0.094)	(0.190)	(0.137)	(0.092)	(0.123)	(0.077)	(0.042)
GFR > $250k	0.693***	0.134	-0.269	-0.157	0.118	0.602***	0.155*	0.146***
	(0.111)	(0.092)	(0.171)	(0.136)	(0.098)	(0.138)	(0.080)	(0.040)
Farm Characteristics								
Planning to expand operation	0.187	0.016	0.154	-0.155	-0.103	0.266*	0.065	0.069
	(0.125)	(0.110)	(0.193)	(0.162)	(0.106)	(0.141)	(0.091)	(0.049)
Planning to reduce operation	-0.145	-0.029	-0.100	-0.001	-0.077	-0.369**	-0.144	-0.026
	(0.136)	(0.101)	(0.188)	(0.156)	(0.105)	(0.157)	(0.092)	(0.045)
Planning to sell operation	-0.019	-0.149	-0.410	-0.426*	0.049	0.239	-0.111	-0.095
	(0.287)	(0.174)	(0.342)	(0.246)	(0.191)	(0.308)	(0.158)	(0.085)
Livestock producer	-0.881***	-0.040	0.533***	0.025	-0.133	-0.742***	-0.542***	0.189***
	(0.127)	(0.092)	(0.178)	(0.143)	(0.122)	(0.146)	(0.086)	(0.044)

Both livestock and crop	-0.222*	-0.059	0.570***	0.191	-0.005	-0.054	-0.146	0.216***
	(0.124)	(0.110)	(0.198)	(0.172)	(0.130)	(0.150)	(0.090)	(0.052)
Primarily owns land	-0.593	0.310	-0.123	-0.532	0.064	0.252	0.340	0.190
	(0.402)	(0.354)	(0.869)	(0.571)	(0.563)	(0.521)	(0.386)	(0.205)
Both rents and owns Land	-0.540	0.275	-0.013	-0.379	0.060	0.101	0.493	0.211
	(0.397)	(0.357)	(0.873)	(0.570)	(0.566)	(0.513)	(0.386)	(0.205)
Knowledge								
Has an EFP	0.314***	0.250***	0.444***	0.026	0.190**	0.285**	0.099	0.146***
	(0.106)	(0.086)	(0.152)	(0.121)	(0.087)	(0.121)	(0.076)	(0.038)
Exposure to Extension								
Extension $ per Farm 2014	-0.023**	0.0002	0.012	0.0002	0.004	0.156***	-0.005	0.0005
	(0.011)	(0.006)	(0.013)	(0.011)	(0.007)	(0.010)	(0.004)	(0.003)
Extension $ per Farm 2016	0.527	0.102	0.067	-0.962*	-0.104	5.035***	-0.385	-0.020
	(0.507)	(0.445)	(0.911)	(0.504)	(0.745)	(0.442)	(0.279)	(0.187)
Extension $ per Farm 2018	-0.463	-0.114	-0.141	1.027*	0.089	-5.847***	0.436	0.018
	(0.547)	(0.468)	(0.969)	(0.547)	(0.782)	(0.534)	(0.291)	(0.199)
Constant	-2.157	1.218	2.428	-2.142	1.092	-3.121***		-0.362
	(1.885)	(1.488)	(3.190)	(1.948)	(2.454)	(0.889)		(0.680)
Obs. (N)	1169	1428	1019	1433	950		1443	1438
AIC	970.67	1337.64	1258.84	1579.80	1045.42		1454.93	1481.20
BIC	1390.97	1779.82	1667.75	2022.27	1443.65		1897.98	1923.96

Significance levels are ***p<0.01, **p<0.05, *p<0.1