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ABSTRACT

The Pan-Canadian Framework was implemented in 2016 to help meet emission reduction targets set out by the Paris Agreement. Carbon pricing is at the foundation of this framework, where Alberta has used a carbon-credit market to reduce emissions from large-scale emitters. Agricultural producers voluntarily participate in these markets through agricultural carbon offset protocols; regulated emitters can purchase agricultural carbon credits to meet their emission reduction requirements. The main goal of these agricultural protocols is to reduce on-farm emissions through the adoption of best management practices (BMPs), alongside providing producers with the potential benefit of earning additional revenue by selling carbon credits on the market. While producers have participated in the market for quite some time, the impact of the market on Alberta agricultural producers is unknown. The main objective of this paper is to understand this impact by analyzing two considerations: 1) emission reductions (or removals) from agricultural protocols; and 2) economic benefits to producers from participating in the carbon offset market. After a case study of current agricultural carbon offset protocols, the results suggest producers are mainly participating for the economic benefits stemming from the adoption of BMPs, rather than the potential revenue from selling carbon credits on the market. Results also show protocols have high emission reduction potential, but this analysis was limited due to a lack of publicly available data. The most significant observation is that the majority of protocol emission reductions come from one protocol, the Conservation Cropping Protocol. The remaining agricultural protocols have seen minimal uptake in participation, specifically from livestock producers, which is concerning given the retirement of the Conservation Cropping Protocol on December 31, 2021. The main consideration will be addressing current protocol shortcomings to ensure producers are willing and able to participate in the market.

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EXECUTIVE SUMMARY

This paper provides a framework outlining Alberta's carbon offset market and its relation to agriculture in the province, examining how the environmental policy can help mitigate or reduce on-farm greenhouse gas emissions. This paper estimates both emissions reductions (or removals) to date from agricultural carbon offset protocols and the uptake or farmers' and ranchers' participation in these protocols. In addition, potential barriers and motivations driving participation are discussed.

As a party to the Paris Agreement, Canada is committed to substantial greenhouse gas (GHG) emission reductions by 2030. The Pan-Canadian Framework on Clean Growth and Climate Change (PCF) was implemented in 2016. It required the development of carbon pricing systems across provinces and territories in the form of an explicit price-based system or a cap-and-trade system, which regulates the carbon offset market.

Progress toward emission reductions in Canada's agriculture industry is voluntary for farmers and ranchers, mainly relying on the adoption of best management practices (BMPs). Some provinces have incorporated these BMPs in their carbon pricing systems, where producers adopt BMPs under agricultural carbon offset protocols to accumulate carbon credits. Credits are sold on the market to regulated emitters who have not met their emission reduction requirements. Four of the 19 active protocols are agriculture-based in Alberta and they provide revenue potential to farmers and ranchers in the form of payment for accumulated carbon credits.

Across all protocols in Alberta, the total emissions reduction to date is 70.4 mega tonnes of carbon dioxide equivalent (Mt CO_2eq) in carbon offsets. The protocol driving the largest number of offsets issued is agriculture-based — the Conservation Cropping Protocol, combined with its predecessor, the Tillage System Management Protocol. These protocols account for 23 per cent of the total carbon offset credits issued to date. The three remaining agriculture-based protocols have only produced less than one per cent of issued agriculture-based credits so far. Across the four agriculture-based protocols, 136 projects have been developed, all submitted and managed by aggregators, and encompass a range of farms within each project. Unfortunately, due to data limitations, not all protocols reported the number of farms involved, and it is unknown whether double counting has occurred (if a producer participated in more than one project).

An analysis of the estimated revenue gain for farmers from the sale of carbon credits (considering an average farm in Alberta) reveals that the revenue per acre may not be enough to offset the potential costs required to implement BMPs. While not definitive, this indicates the carbon offset market only offers a small incentive to producers who participate, likely imposing a barrier to participation. Instead, the results suggest the true economic benefits are from the actual implementation of BMPs. For example, a recent study of the Nitrogen Emission Reduction Protocol (NERP) reveals that while

carbon credit revenues provide positive incentives to farmers, the additional forecasted revenues from implementing 4R stewardship[1] alone offers considerably more revenue per acre.

Minimal participation rates outside of the Conservation Cropping Protocol, based on available information, are certainly troubling. With the protocol's retirement on December 31, 2021, agriculture's role in the carbon offset market will likely be limited if producers do not see the value or are unable to participate in the remaining quantification protocols. For example, two livestock-related protocols have low implementation, with a maximum of five farms participating in some projects. This is a major shortfall since these protocols have high emission reduction potential. Further, a number of past protocols were revoked for various reasons, including high complexity, practicality or implementation challenges and other unknown reasons. This constraint limited the type of producer (e.g., dairy, feedlot, etc.) that can participate in the market.

Barriers to adopting BMPs parallel the barriers farmers may face from participating in carbon offset protocols, including risk perceptions, financial barriers and a lack of reliable information regarding potential benefits. Another substantial barrier is the role of additionality when developing and implementing agricultural quantification protocols. Once an action reaches an adoption threshold, it is perceived as the baseline condition and the adoption of a practice is no longer additional in terms of GHG emissions, resulting in protocol retirement. In Alberta, the adoption threshold is classified as a penetration threshold of 40 per cent adoption in a sector. This illustrates a final challenge when developing agricultural protocols; when the adoption rate is above the penetration rate, agriculture's role in the offset market is confined.

While the retirement of the Conservation Cropping Protocol is troubling, the protocol's high participation, including numerous farms adopting reduced or no-tillage practices, is encouraging. Ensuring farmers continue to participate in the market under the remaining protocols will be a challenge. This includes understanding why farmers are currently participating in the market despite low economic benefits from carbon credit sales.

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[1] 4R stewardship is a best management practice (BMP) used to improve fertilizer efficiency to benefit the environment. 4R stands for the right source, at the right rate, right time and right place (Fertilizer Canada n.d.).

INTRODUCTION

Globally, efforts to reduce greenhouse gas (GHG) emissions are an emerging priority across sectors, including the agricultural industry. The Intergovernmental Panel on Climate Change (IPCC) recognized the agricultural industry as a priority sector due to its high emission intensity (Weersink et al. 2005), as well as its emission mitigation potential (Smith et al. 2014). Agriculture accounts for 8.1 per cent of Canada's total GHG emissions, including 29 per cent of national methane (CH_4) emissions and 78 per cent of national nitrous oxide (N_2O) emissions (Government of Canada 2021). The primary drivers of agricultural emissions are fluctuations in livestock population, namely mainly from enteric fermentation, which accounts for 41 per cent of total agricultural emissions, and the application of inorganic fertilizer, accounting for 23 per cent of total agricultural emissions (Government of Canada 2021).

To mitigate emissions from Canadian agricultural production, policies relied on the voluntary adoption of best management practices (BMPs). BMPs are classified as voluntary management practices that reduce or eliminate on-farm environmental risks, including the indefinite or temporary reduction of agricultural emissions. Notably, environmental stewardship programs under the national Canadian Agricultural Policy Frameworks[2] use a cost-share approach to subsidize the adoption of on-farm BMPs to meet environmental and climate goals. In short, BMPs are meant to manage on-farm emissions associated with agricultural production through the adoption or alteration of management practices, including the adoption of new technologies (West and Marland 2002; Smith et al. 2008).

Some provinces have begun to use these BMPs in their carbon pricing systems. In Alberta, where there is an active market for agricultural carbon credits, agricultural producers can voluntarily participate in carbon offset protocols. The main objective is the voluntary reduction of on-farm GHG emissions through sequestration or removal activities. Producers can sell agricultural carbon credits for profit to firms that have not met their emission obligations. However, it is unclear whether carbon pricing systems have been effective in reducing on-farm emissions in Canada due to a limited analysis of emission reductions from projects under agricultural carbon offsets.

Recent and relevant literature and research are limited on this topic, resulting in a knowledge gap. Given the voluntary nature of BMPs, the adoption process depends on an agricultural producer's capacity to alter operational management practices. Capacity can be hindered by numerous factors, including economic barriers such as high uptake costs and long-term maintenance costs. Producers are often left to weigh tangible and intangible benefits from participating in carbon offset protocols against possible financial and time constraints. The benefits from participating in these

2 The Canadian Agricultural Policy Frameworks (APFs) are five-year funding and program agreements with the federal, provincial and territorial governments, with the first framework being developed in 2003. These frameworks rely on the adoption of best management practices (BMPs) through environmental stewardship programs, with the goal of mitigating on-farm environmental risks, including agricultural emissions. These programs use a cost-share approach to subsidize the adoption of BMPs, with BMPs varying in their cost-share eligibility (Boxall 2018).

protocols outweighing potential barriers to BMP adoption have yet to be quantified. There is a limited understanding of the market and the economic benefits for agricultural producers.

This paper provides an extensive overview of carbon pricing systems in relation to Alberta's agricultural sector. The main objective is to better understand how the carbon offset market has impacted Alberta agricultural producers through two broad components. The first component is quantifying emission reductions to date from agricultural offset protocols, the main objective of the carbon offset market. This includes relative participation in these protocols, as participation and emission reduction potential are positively correlated. The second component provides an overview of direct benefits from participating in protocols. For this paper, the assumption is that economic benefits drive protocol participation, such as the additional revenue per acre, increasing gross farm revenue. Potential barriers to the uptake of projects under these protocols and future agricultural carbon offset protocols are also addressed. The main outcome is to provide policy-makers with a guideline for possible improvements regarding the carbon offset market as it pertains to the agricultural sector.

The next section provides background information regarding Alberta's carbon offset system. Following this, the two components mentioned above will be outlined for each active agricultural carbon offset protocol, including relevant examples. Then, future protocol considerations are explored, concluding with a summary of the paper's main findings.

BACKGROUND OF ALBERTA'S CARBON OFFSET SYSTEM

Alberta is one of three provinces located in the prairie region and emits 38 per cent of national greenhouse gas (GHG) emissions, the highest of any province or territory (Statistics Canada 2021; ECCC 2021). Unlike other regions, Alberta's emissions steadily inclined, primarily due to its active role in the global fossil fuel market, increasing 61 per cent since 1990 (ECCC 2021). Alberta's agricultural sector emissions increased 29 per cent compared to 1990 levels (ECCC 2021) and have remained relatively stagnant since 2005. A large portion of agricultural emissions stems from Alberta's livestock-intensive agricultural industry, specifically the beef cattle industry, where Alberta holds 41.6 per cent of the national cattle herd (Statistics Canada 2017). This includes 59.6 per cent of national feeder cattle and 42.3 per cent of beef breeding stock.

Alberta was praised for being the first to enact a carbon trading system in North America in 2007 (Goddard 2021). This was regulated through the Specific Gas Emitters Regulation (SGER), where a carbon price was applied to combustion emissions, fugitive emissions and non-combustion waste and wastewater emissions, and the pricing only applied to emitters of more than 100,000 tonnes of carbon dioxide (CO_2) equivalent per year (Dobson et al. 2019; Goddard 2021). Rather than imposing caps on emissions, the program required emitters of more than 100,000 tonnes of carbon dioxide equivalent per year to reduce emissions by 12 per cent below the baseline (Goddard 2021; Childs 2010). According to Goddard (2021), if a firm failed to meet targets, any of the following methods could be used for compliance:

1. Purchase others' or use their own emission performance credits (EPCs) from any facility that reduced more than the required emissions;
2. Purchase emission offsets produced in Alberta using government-approved protocols;
3. Pay into a tech fund at a set rate, C$15/tonne. The fund is largely used for investment in research into technologies that reduce GHG emissions in any sector.

The second option provided a carbon credit market for the agricultural industry. Regulated emitters (emitters of more than 100,000 tonnes) purchase offsets from agricultural producers who voluntarily participate in approved protocols. Individual farms rarely hold large enough volumes of carbon offsets to attract buyers' interest. Thus, aggregator companies group together tonnage created from offset projects (Haugen-Kozyra 2009) and sell to buyers on behalf of producers.

ALBERTA'S CURRENT CARBON OFFSET MARKET: POST-PAN-CANADIAN FRAMEWORK

Under the Paris Agreement, signing parties agreed to combat climate change by reaching global peaking of GHG emissions as soon as possible (United Nations 2015; Government of Canada 2016). Canada signed with the intention of reaching the emission reduction target of 30 per cent below 2005 levels by 2030 (ECCC 2021). On December 9, 2016, Canada implemented the Pan-Canadian Framework on Clean Growth and Climate Change to move towards a low-carbon future. Pricing carbon pollution is the foundation of this framework, where provinces and territories were meant to develop and then implement carbon pricing systems by 2019 (Government of Canada 2016). Systems take a common scope approach, where pricing is based on emissions and is applied to a common set of sources to minimize interprovincial competitiveness impacts (ECCC 2016).

Provinces and territories were free to tailor carbon pricing systems and implement either an explicit price-based system[3] or a cap-and-trade system. Both systems had to meet national stringency standards, also known as the federal benchmark (Statistics Canada 2017). For jurisdictions that chose an explicit price-based system, prices began at $10 per tonne in 2018 and rose $10 per tonne each year to reach $50 per tonne by 2022 (Statistics Canada 2017; ECCC 2020). In 2021, the federal government approved an increase of the carbon price by $15 per tonne, per year, starting in 2023, reaching $170 per tonne of carbon by 2030 (Government of Canada 2021). The choice of a cap-and-trade system required: a) a 2030 emission reduction target equivalent to Canada's 30 per cent reduction target, and b) declining annual caps that correspond

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3 This can be in the form of a carbon tax (i.e., British Columbia) or a carbon levy and performance-based emission system (i.e., Alberta) (Government of Canada 2017).

to projected reductions from carbon pricing that year in a price-based system (ECCC 2021). If a system did not meet the federal benchmark, a federal backstop carbon pollution pricing system was implemented to meet the benchmark requirements.[4] According to the Government of Canada (2022), only British Columbia, the Northwest Territories, Quebec and Newfoundland and Labrador have systems that do not require the federal backstop, either in part or in full. All other provinces and territories partially or fully apply the federal backstop (Government of Canada 2022).

Previously, Alberta had a hybrid system, using both a carbon levy and a revitalized output-based pricing system. The provincial government repealed the carbon levy in the spring of 2019, resulting in the carbon levy component of the federal backstop being introduced to cover emission sources not covered by the output-based pricing system. The output-based pricing system, which covers the carbon offset market, meets national stringency standards. The current output-based pricing system, and thus the carbon offset system, operate under the Technology Innovation and Emission Reduction (TIER) regulation, which applies to approximately 60 per cent of Alberta's emissions (Government of Alberta 2021c). All emission offset projects must meet requirements under the TIER regulation, the Standard for Greenhouse Gas Emission Offset Project Developers and a relevant Alberta-approved quantification protocol. If companies regulated under the carbon offset system fail to meet emission reduction targets, operators can consider the following options:

1. Increase efficiency, for example by cogeneration;
2. Pay a set provincial carbon price into a fund called the Technology Innovation and Emissions Reductions (TIER) fund;
3. Purchase offsets from facilities that have exceeded their reduction requirements; or
4. Pay for emissions reductions in the other half of Alberta's emission total, the non-regulated part of Alberta's economy, which includes agriculture (Alberta Government 2021c).

The fourth option specifically supports the market for carbon offsets for agricultural producers in Alberta. As of April, 2021, there were 19 active protocols, four of which were highlighted for the agricultural industry, according to the Alberta government (2021a). These protocols include: 1) Conservation Cropping (previously the Tillage System Management Protocol); 2) Nitrous Oxide Emissions Reduction; 3) Reducing Greenhouse Gas Emissions from Fed Cattle; and 4) Selection for Low Residual Feed Intake Markers in Beef Cattle. It is important to note that other protocols may be relevant to agricultural producers, and producers can choose to develop projects under alternative protocols (e.g., Wind-Powered Electricity Generation Protocol (Government of Alberta 2021a)). As of December 2021, 136 projects were developed across all four protocols, as shown in Table 1.

4 The federal backstop is made up of a regulatory charge on fuel (fuel charge) and a regulatory trading system for large industries (output-based pricing system). The backstop can be in part or in full for a province or territory (Government of Canada 2022).

Table 1. The Number of Projects Under Agricultural Quantification Protocols.

Protocol	Active Projects	Inactive Projects	Closed Projects	Total Developed Projects[1]
Conservation Cropping & Tillage System Management	17	58	47	122
Agricultural Nitrous Oxide Emission Reductions	9	0	1	10
Reducing Greenhouse Gas Emissions from Fed Cattle Protocol	2	0	1	3
Selection for Low Residual Feed Intake Markers in Beef Cattle Protocol	1	0	0	1
Total	**29**	**58**	**49**	**136**

[1] Projects are classified as: active — currently collecting carbon credits; inactive — carbon credits are no longer being collected, existing credits are pending retirement (waiting to be sold on the market) or retired through market sale; and closed — credits are no longer being collected and all credits are retired. Some closed projects include credits that were revoked or removed, therefore ineligible for market sale.

[2] Caution must be used when examining this table as the true number of projects may differ.

Source: Alberta Carbon Registries, "Alberta Emissions Offset Registry Listing," 2021, https://alberta.csaregistries.ca/GHGR_Listing/AEOR_Listing.aspx.

The Conservation Cropping and Tillage System Management protocols have been the most popular, accounting for roughly 90 per cent of projects with 122 projects in total; this is in line with Goddard's (2021) findings. Lesser project development represented in the table through other protocols may reflect late implementation compared to the Tillage System Management Protocol. The number of projects, however, does not correspond to the level of participation (number of farms), nor does it reflect the level of emission reductions (in carbon dioxide equivalent).

THE CARBON OFFSET SYSTEM AND ITS IMPACT ON ALBERTA'S AGRICULTURAL INDUSTRY

To better understand how carbon offsets have impacted agricultural producers in Alberta, this section focuses on two broad components which are applied to each agricultural carbon offset protocol. These components were developed based on the limited literature available reviewing Canadian agricultural carbon offsets (Weersink et al. 2005; Goddard 2021), as well as literature examining the adoption of best management practices (BMPs). Since agricultural offset protocols rely on BMP adoption, viable factors impacting adoption will likely impact protocol participation. The two components are described more in detail below.

Current On-farm Emission Reductions from Agricultural Carbon Offset Protocols, Including the Relative Participation Under a Protocol

The carbon offset market is meant as a tool for producers to improve long-term sustainability and to reduce their farms' emission intensity, while potentially providing a source of extra income. This includes the ability to mitigate on-farm emissions through the adoption or alteration of management practices. These protocols rely on adopting BMPs, which have variable effects on the rate of emission reduction, the type of greenhouse gas mitigated and the longevity of emission reductions (Smith et al. 2008). BMPs are among the most effective methods to mitigate agricultural production emissions (Snyder et al. 2009; Asgedom and Kebreab 2011; Yanni et al. 2021), but limited research explores BMPs' effectiveness in accumulating carbon credits from emission reductions under carbon offset protocols.

For this paper, the number of farms that participated in carbon offset projects is used as an indicator for the relative rate of participation under agricultural carbon offset protocols. Producers must actively apply to participate in these protocols to procure carbon credits. In theory, increased participation by farms under these protocols would result in increased emission reduction potential.

The Benefits Procured by Agricultural Producers from Participating in Carbon Offset Protocols

Economic incentives, such as financial incentives, are commonly cited as a method to encourage agricultural producers to adopt sustainable practices (Pannell 2008; Lamba et al. 2009; Palm-Forster et al. 2017; Liu et al. 2018). The foundational incentive to participate in the carbon offset market is the ability to earn extra income from selling carbon offsets — farmers spend time and money to produce a product — a carbon credit — to sell in this market. The question is whether these incentives are large enough to entice management changes, especially since producers face an array of costs when adopting practices under offset protocols. For example, many practices may have high upfront costs, long-term maintenance costs (such as annual soil testing) or extensive time requirements, presenting barriers to participation (Pannell et al. 2006; Prokopy et al. 2019). Regarding the protocols themselves, some may have high transaction costs (e.g., the cost of verifying and retiring registered offsets) as a barrier to participation. To offset barriers, farmers often require compensation. BMPs provide economic benefits when adopted (Weersink et al. 2005; Manley et al. 2005); however, the true economic benefit from selling carbon credits on the market is unclear.

This section first explores the most used protocol, the Tillage System Management Protocol, and its successor, the Conservation Cropping Protocol. Next, the remaining active protocols are discussed to investigate their effectiveness.

CONSERVATION CROPPING PROTOCOL

Conservation Cropping, the successor to the Tillage System Management Protocol, has numerous on-farm benefits, including a reduction in soil degradation (reducing loss of nutrients, increasing water storage capacity) and a reduction of GHG emissions, primarily from carbon sequestration in agricultural soils (Davey and Furtan 2008; Awada et al. 2014; Awada et al. 2016). Under the original Tillage System Management Protocol, producers could earn carbon offsets by increasing soil carbon levels through shifting segments of their land from full tillage to reduced tillage or no-tillage (Government of Alberta 2011). The current Conservation Cropping Protocol, introduced in 2012, includes the flexibility to quantify additional emission reductions in the Dry Prairie ecozone by decreasing summer fallow on farmland (Alberta Environment and Water 2012).

The Conservation Cropping Protocol identified three activities to quantify GHG emission reductions:

1. New carbon stored annually in agricultural soils;
2. Lower nitrous oxide emissions from soils under no-till management; and,
3. Associated emission reductions from reduced fossil fuel use from fewer passes per farm field (Alberta Environment and Water 2012).

The recently retired protocol used a performance standard baseline "to quantify annual emission reductions based on annual, incremental increases in soil carbon adjusted (discounted) for 2006 sector level adoption" (Alberta Government 2021b). Thus, as more producers adopt conservation cropping (no-tillage), the potential for new carbon sequestration is reduced, resulting in a decline in carbon offset opportunities. The Conservation Cropping Protocol was the most attractive in terms of participation (Goddard 2021). The Alberta government estimates that 600,000 to 700,000 tonnes of carbon went through the protocol each year, with adoption at over a third of all seeded acres in Alberta (Government of Alberta 2021b). Based on the Environmentally Sustainable Agricultural Tracking (ESAT) survey, administered bi-annually by the Alberta Agriculture and Forestry (AAF) department, the adoption of reduced tillage on farms in Alberta increased from 39 per cent in 2012 to 51 per cent by 2018 (Alberta Agriculture and Forestry 2018). Unfortunately, it is difficult to directly attribute the increase in adoption to the protocol itself.

Emission Reductions Under the Conservation Cropping Protocol

The remainder of this section discusses quantifiable impacts on the agricultural industry from the Conservation Cropping Protocol. This includes examining the first component of our analysis, addressing the level of emission reduction (or sequestration) achieved so far from participating in the Conservation Cropping and Tillage System Management protocols. Table 2 provides a summary of emission reductions in tonnes of carbon dioxide equivalent (tCO_2e[5]) for projects under each protocol across vintage years (the year the carbon emission reduction project generated carbon offset credits) from 2002 to 2020. All information is sourced from the Alberta Emission Offset Registry; however, the results may not reflect the true level of emission reductions.

5 This measurement employs Global global Warming warming Potential potential (GWPs) for greenhouse gases and are is applied to calculate the carbon dioxide equivalent in tonnes (tCO_2e). Using this method simplifies the calculation of all agricultural emissions and is the standard unit of measurement used across regulations (Government of Alberta 2021c).

Table 2. Emission Reductions from the Tillage System Management and Conservation Cropping Protocols Across Vintage Years (2002 to 2020)

Protocol	Time Period	Active Offsets[6] *(tCO_2e)*	Pending Retirement *(tCO_2e)*	Retired Offsets[1] *(tCO_2e)*	Total Emissions *(tCO_2e)*
Tillage System Management	2002	1,793	221,635	593,020	816,448
	2003	2,110	243,137	644,280	889,527
	2004	2,194	266,165	680,738	949,097
	2005	2,564	278,773	719,141	1,000,478
	2006	2,754	308,971	742,489	1,054,214
	2007	3,113	327,474	758,536	1,089,123
	2008	13	366,103	780,515	1,146,631
	2009	0	427,487	718,854	1,146,341
	2010	0	476,394	567,858	1,044,252
	2011	0	538,713	489,129	1,027,842
Total		**14,541**	**3,454,852**	**6,694,560**	**10,163,953**
Conservation Cropping	2012	0	586,441	0	586,441
	2013	0	570,165	75,000	645,165
	2014	444	653,723	0	654,167
	2015	91,745	647,827	0	739,572
	2016	8,594	730,994	0	739,588
	2017	77,818	648,782	0	726,600
	2018	125,083	590,064	0	715,147
	2019	553,116	159,858	0	712,974
	2020	602,635	0	31	602,666
Total		**1,459,435**	**4,587,854**	**75,031**	**6,122,320**
Complete Total		**1,473,976**	**8,042,706**	**6,769,591**	**16,286,273**

1 This includes offsets retired for compliance purposes.

Source: Alberta Carbon Registries, "Alberta Emissions Offset Registry Listing," 2021, https://alberta.csaregistries.ca/GHGR_Listing/AEOR_Listing.aspx.

Total emission reductions across all protocols are estimated to be around 70,359,301 tCO_2e. This means both the Tillage System Management and Conservation Cropping protocols make up roughly a quarter (23 per cent) of all emission reductions (or removals) from carbon offset protocols. Further, 6,769,591 tCO_2e were retired, with 8,042,706 tCO_2e pending retirement (waiting to be sold on the market). This suggests the protocols have resulted in a significant level of carbon credits in the carbon offset market.

6 Emission offsets with an active status are offsets that have not been purchased or sold on the market (as of December 1, 2021). Once sold, they are marked as retired. All information on active offsets comes from the Alberta Carbon Registries directly and may vary from the emission offset project developer reports.

Another component to consider is the level of emission reduction per project, per farm. Thorough inspection of verification and project reports indicated some projects did not accurately report the number of farms that participated; this was especially true for reports under the earlier Tillage System Management Protocol where the number of farms went unreported on average. With this limitation in mind, to gain a relative understanding of participation rates, Table 3 outlines a sample of projects under the Conservation Cropping Protocol where information on the number of farms that participated was available. Further, only projects with a one-year period are included for simplicity. All information was sourced from verification reports and project reports provided by Alberta's Emission Offset Registry (Alberta Carbon Registries 2021).

Table 3. Participation Across Select Conservation Cropping Projects

Project	Time Period	Number of Farms	Total Project *(tCO_2e)*	per Farm	Status	Project Developer (Aggregator)
Carbon Credit Solutions Inc. Tillage Project #14	Jan. 1st, 2012 – Dec. 31st, 2012	204	49,552	243	Inactive	Radicle Group Inc.
Carbon Reduction Offset Project Series 18	Jan. 1st, 2013 – Dec. 31st, 2013	115	11,455	100	Inactive	Radicle Group Inc.
Conservation Cropping Pool 15	Jan. 1st, 2014 – Dec. 31st, 2014	236	71,908	305	Inactive	Trimble Canada Corporation
Conservation Cropping Pool 19	Jan. 1st, 2016 – Dec. 31st, 2016	427	113,562	266	Inactive	Trimble Canada Corporation
Conservation Cropping Pool 21	Jan. 1st, 2017 – Dec. 31st, 2017	336	83,284	248	Inactive	Trimble Canada Corporation
Conservation Cropping Pool 27	Jan. 1st, 2020 – Dec. 31st, 2020	398	100,413	252	Inactive	Trimble Canada Corporation
Conservation Cropping Pool 28	Jan. 1st, 2020 – Dec. 31st, 2020	333	117,357	352	Inactive	Trimble Canada Corporation
Average		**293**	**78,219**	**252**		

Source: Alberta Carbon Registries, "Alberta Emissions Offset Registry Listing," 2021, https://alberta.csaregistries.ca/GHGR_Listing/AEOR_Listing.aspx.

In terms of emission abatements, on average, a project with a one-year verification period, that reported the number of farms participating, resulted in a reduction of 78,219 tCO_2e, or 0.1 per cent of all carbon credits procured to date. Per farm, the average emission reduction was 252 tCO_2e. In terms of participation, the number of farms that participated in a project ranged from 115 to 427 for a one-year verification period. The 2016 Census of Agriculture for Alberta identified a total of 40,638 farms in Alberta (Alberta Agriculture and Forestry 2020). With an average of 293 farms participating, 0.7 per cent of all Alberta farms participated in a project with a one-year verification period under the Conservation Cropping Protocol. If we consider the 17 active projects in 2021 and the 58 inactive projects, the participation rate with an average of 293 farms per project would result in 54 per cent of farms in Alberta participating in this protocol. This estimate must be used with caution, however. Information limitations, such as whether farms participated in more than one project, resulting in double counting, cannot be confirmed. Regardless, it is clear farmers voluntarily participated in these projects by altering management practices through reduced or no-tillage adoption.

Economic Benefits from Conservation Cropping

The remaining question is why producers chose to alter management practices to participate in projects under the Conservation Cropping and Tillage System Management protocols. The assumption is that producers undertook these projects due to economic benefits. To examine the potential economic benefits from participating in the Conservation Cropping Protocol, two examples are provided. The first example explores the potential additional revenue per acre from selling carbon credits on the market. The second example addresses the impact of additional revenue on a farmer's annual gross farm receipts (as a proxy for gross farm revenue).

Example 1: Additional Revenue Per Acre

To calculate the relative tonnes of carbon dioxide equivalent reduction per acre, the province was split into two regions: the Parkland area (black chernozem soils) and the Dry Zone (brown chernozem soils) (Goddard 2021). This split is based on a reserve discount factor (sequestered carbon reserve) for each zone, which is applied to sequestered carbon from reduced or no-tillage practices to account for a known rate of reversal (re-release of carbon into the atmosphere) (Government of Alberta 2012b). Figure 1 explores additional income from selling carbon offsets for three farmers with differing crop acres; this example is displayed for both regions. All numbers used for this calculation are taken from Government of Alberta (2021b), with the following assumptions:

1. The offset sale price is set at $30/tonne;
2. The farm/aggregator price split is 2/3 (farmer) and 1/3 (aggregator); in this example, farmers earn approximately $20/tonne;
3. Parkland tonnes of carbon /acre = 0.113, Dry Prairie tonnes of carbon/acre = 0.057. Note: Irrigated areas in the Dry Prairie Zone harvest carbon at the Parkland rate;
4. The average farm size remains at 1,168 acres.

Figure 1. Example 1: Carbon Offset Income from Participating in Conservation Cropping

	Farmer 1	Farmer 2	Farmer 3
Region	**Parkland**	**Parkland**	**Parkland**
Farm Size	500 acres	1,200 acres	2,000 acres
Tonnes (t) of carbon	500 x 0.113/t = 56.5t	1,200 x 0.113/t = 135.6t	2,000 x 0.113/t = 226t
(C$) per tonne for farmer	56.5t x $20/t = $1,130	135.6t x $20/t = $2,712	226t x $20/t = $4,520
(C$) per acre	*$2.26/acre*	*$2.26/acre*	*$2.26/acre*

	Dry Zone	**Dry Zone**	**Dry Zone**
Farm Size	500 acres	1,200 acres	2,000 acres
Tonnes (t) of carbon	500 x 0.057/t = 28.5t	1,200 x 0.057/t = 68.4t	2,000 x 0.057/t = 114t
(C$) per tonne for farmer	28.5t x $20/t = $570	68.4t x $20/t = $1,368	114t x $20/t = $2,280
(C$) per acre	*$1.14/acre*	*$1.14/acre*	*$1.14/acre*

Source: Government of Alberta (2021b).

The income per acre is the same across farms in Figure 1, regardless of farm size. Differences in earnings stem from the number of acres a producer delegates to reduced or no-tillage practices, the zone the farm is in and the carbon price. Between regions, farmers located in the Parkland area earn more compared to farmers located in the Dry Zone. For example, at a carbon price of $30 per tonne, if a producer allocates 100 acres to reduced or no-tillage, a producer in the Parkland area would earn $226, whereas a Dry Zone producer would earn $114, a difference of $112. While it is not a large difference, it may deter Dry Zone producers' participation, especially if income procured does not offset the cost of adopting reduced tillage or potential market transactional costs. This statement does not hold for farms with irrigated land in the Dry Zone, however, as they harvest carbon at the Parkland rate.

Example 2: Economic Impacts to Annual Gross Farm Receipts

To represent the average Parkland area and Dry Zone farm, two Alberta land-use regions[7] were selected based on the 2016 Census of Agriculture. The Red Deer land-use region represents the average Parkland area farmer, whereas the South Saskatchewan region represents the average Dry Zone farmer. Based on the Census of Agriculture, the following assumptions were made:

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7 Alberta land-use regions were developed by the government of Alberta, are based on major watersheds, and boundaries are aligned to fit existing municipal boundaries and natural regions (AAF 2020).

Red Deer Region

1) The average cropland is 721 acres per farm; they entirely use reduced or no-tillage methods and are therefore eligible for the carbon offset protocol.

2) The average gross farm receipt is $373,000 per farm.

South Saskatchewan Region

3) The average cropland is 983 acres per farm; they entirely use reduced or no-tillage methods and are therefore eligible for the carbon offset protocol.

4) The average gross farm receipt is $858,000 per farm.

Table 4 outlines the additional revenue and effect on gross farm receipts under a carbon price of $30 per tonne of carbon dioxide equivalent for each region.

Table 4. Impacts on Gross Farm Receipts from Additional Carbon Credit Revenue.

	Red Deer Region	South Saskatchewan Region
Additional Revenue:		
$30 per tonne	$2.26 per acre x 721 acres = $1,629	$1.14 per acre x 983 acres = $1,121
Gross Farm Receipts:		
$30 per tonne	$373,000 + $1,629 = $374,629	$858,000 + $1,121 = $859,121
Increase in Gross Farm Receipts	0.43 per cent	0.13 per cent

Although the amount of additional revenue required to incentivize participation varies on an individual basis, at face value, the revenue from market sales is small compared to average gross farm receipts. On average, annual revenue from selling on the market is less than one per cent of the average annual gross farm receipts. The main consideration is whether this revenue offsets associated implementation costs. Adopting no-tillage costs an additional $3 to $6 per acre compared to conventional tillage (Epplin et al. 2005). Based on this cost, additional revenue does not offset the added operational costs at a lower carbon price.

While the Conservation Cropping Protocol was still active, the carbon price remained below $50 per tonne. At this price, it likely did not provide adequate compensation to motivate changes in management practices. Although, from Table 1, farmers were participating in projects under these protocols. Farmers potentially adopted this practice due to long-term private benefits that stem from reduced or no-tillage adoption. This includes a reduction in fuel costs per acre (Epplin et al. 2005) and increased crop yields related to an improved soil environment (Busari et al. 2015), supporting possible farm profit growth. These benefits are not tangible monetary payments, but the adoption of reduced or no-tillage over time might suggest farmers have directly observed or are informed on the benefits of adopting this practice.

REMAINING AGRICULTURAL CARBON OFFSET PROTOCOLS

The Conservation Cropping Protocol was retired December 31, 2021 and no longer generates emission offsets. With the end of the protocol, it is imperative to understand whether producers are engaged and participating in other agricultural carbon offset protocols. Current emission reductions, relative protocol participation and potential economic benefits from participation are discussed in this section for each remaining protocol. Due to data and information limitations, the analysis of emission reductions, participation and economic benefits is constrained for some protocols. This section focuses on the three remaining active agricultural quantification protocols:

1. Agricultural Nitrous Oxide Emission Reductions (NERP);
2. Reducing Greenhouse Gas Emissions from Fed Cattle;
3. Selection for Low Residual Feed Intake Markers in Beef Cattle.

As previously stated, the main sources of agricultural emissions in Canada are from enteric fermentation (41 per cent) and the application of inorganic fertilizer (23 per cent) (Government of Canada 2021). NERP can aid on-farm emission reductions associated with inorganic fertilizer application and is an opportunity for crop producers. The other remaining protocols provide opportunities for livestock producers to reduce enteric fermentation, as well as general emissions stemming from the fluctuations in livestock populations. All three protocols provide favourable circumstances toward mitigating emissions from primary sources; thus, higher rates of participation may correspond to increased reductions of agricultural GHG emissions.

Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions

The Agricultural Nitrous Oxide Emission Reductions Protocol (NERP) is based on integrating a set of BMPs known as a Comprehensive 4R[8] Nitrogen Stewardship Plan, or 4R plan (Government of Alberta 2015). The 4R plan results in applied nitrogen[9] being used at a more effective rate to grow crops, resulting in reduced nitrous oxide (N_2O) emissions associated with nitrogen fertilizer application. Under the protocol, 4R plans are developed under three levels — basic, intermediate and advanced.[10] The protocol accounts for all direct and indirect nitrous oxide emissions per crop unit per crop type, meaning all emissions are "corrected for each predominant soil type, topography, and climate" (Government of Alberta 2015). All N_2O emissions are quantified using Canada's Tier II methodology and emission reductions from the 4Rs are based on reduction

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8 The 4Rs stand for the right source, at the right rate, the right time and right place (Government of Alberta 2015).

9 According to the government of Alberta, this includes nitrogen sources and fuel used in association with the management of synthetic fertilizer, manure fertilizer, biological fixation and crop residues (Government of Alberta 2015).

10 The basic level refers to the management zone of a whole field of a crop type, intermediate refers to each subfield of a crop type and the advanced level refers to the delineation of each slope and aspect on the digital map of a field of a crop grown (Government of Alberta 2015).

modifiers. One of the main requirements is that the entire farm enterprise follows 4R management; other requirements can be found in the report titled "Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions. Version 2.0."

As of December 2021, almost all projects under NERP were active (start dates range from 2015 to 2022). Information on the number of farms participating or the amount of emission reductions to date is not publicly available (Alberta's Emission Offset Registry 2021). Publicly available information is limited to the estimated reductions in annual tonnes of carbon dioxide equivalent (tCO_2e), which range across the nine active projects starting at 38,500 per year to 200,000 per year. Thus, it is not feasible to comment on the effectiveness of the protocol in regard to emission reductions based on current projects, or the nature of farmer participation.

Instead, this paper provides an analysis for potential economic benefits associated with NERP, alongside estimated emission reduction potential, using examples provided by Thomassin (2013) and The Prasino Group (2014). Table 5 draws from the calculations completed by Thomassin (2013), providing an overview of possible economic benefits associated with participating in this protocol, across soil types for canola crops and assumes the cropping area is 1,000 hectares (2471.05 acres). It is important to note this example is a gross simplification; see Thomassin (2013) or The Prasino Group (2014) for a more thorough explanation. Table 5 is based on a preliminary study conducted prior to the latest update of the protocol in 2015. All proposed revenue from carbon credits, for this example, works under the assumption that producers receive two-thirds of the carbon price value (one-third goes to the aggregator) and producers choose a basic level of 4R stewardship. Calculations are shown for a carbon price of $30 per, a carbon price of $50 per, the 2022 carbon price, and also for $170 per, the expected carbon price for 2030, to highlight the difference in economic benefits as the carbon price increases. Thomassin (2013) estimates the following emission reductions for canola crops across 1,000 hectares under basic 4R stewardship:

- Dark Brown Soil Zone = 173 tCO_2e per 1,000 hectares
- Brown Soil Zone = 259 tCO_2e per 1,000 hectares
- Black Soil Zone = 404 tCO_2e per 1,000 hectares

These estimates are used to calculate additional revenue from carbon credits for all carbon prices. For reference, all calculations for Table 5 can be found in the Appendix.

Table 5. Additional Revenue from NERP for Canola Crops Across Soil Type.

Carbon Price of $30 per Tonne (1,000 hectares of Canola)			
	Dark Brown Soil Zone	**Brown Soil Zone**	**Black Soil Zone**
Additional Cost Per Acre from Implementing 4R Stewardship	$11.54	$11.54	$11.54
Additional Revenue from Cropping Per Acre from 4R Stewardship	$117.00	$117.00	$117.00
Additional Revenue from Carbon Credits	**$1.40**	**$2.10**	**$3.27**
Net Revenue Per Acre	**$106.86**	**$107.56**	**$108.73**
Carbon Price of $50.00 per Tonne (1,000 hectares of Canola)			
Additional Cost Per Acre from Implementing 4R Stewardship	$11.54	$11.54	$11.54
Additional Revenue from Cropping Per Acre from 4R Stewardship	$117.00	$117.00	$117.00
Additional Revenue from Carbon Credits Per Acre	**$2.33**	**$3.49**	**$5.45**
Net Revenue Per Acre	**$107.79**	**$108.95**	**$110.91**
Carbon Price of $170 per Tonne (1,000 hectares of Canola)			
Additional Cost Per Acre from Implementing 4R Stewardship	$11.54	$11.54	$11.54
Additional Revenue from Cropping Per Acre from 4R Stewardship	$117.00	$117.00	$117.00
Additional Revenue from Carbon Credits Per Acre	**$7.93**	**$11.88**	**$18.53**
Net Revenue Per Acre	**$113.39**	**$117.34**	**$123.99**

Source: Thomassin (2013) and The Prasino Group (2014).

Based on Table 5, there is additional net revenue from participating in the NERP protocol. This additional revenue is mainly from management changes, such as improved crop yields from altering nitrogen fertilizer inputs, as opposed to selling offsets in the carbon credit market. As the carbon price increases, however, selling offsets on the carbon credit market improves in monetary value for a producer. Based on this example, producers with an average of 1,000 hectares (~2471.05 acres) allocated for canola crops, and with a carbon price of $30 per tonne, would earn the following (annually) based on soil zone, per acre:

- Dark Brown Soil Zone = 2,471.05 acres x $1.40/acre = $3,459.47
- Brown Soil Zone = 2,471.05 acres x $2.10/acre = $5,189.21
- Black Soil Zone = 2,471.05 acres x $3.27/acre = $8,080.33

With a carbon price of $170 per tonne, producers in each soil zone, per acre, could instead annually earn:

- Dark Brown Soil Zone = 2,471.05 acres x $7.93 = 19,595.43
- Brown Soil Zone = 2,471.05 acres x $11.88 = $29,356.07
- Black Soil Zone = 2,471.05 acres x $18.53 = $45,788.56

The increase in the carbon price from $30 per tonne to $170 per tonne increases annual earnings in the Dark Brown Soil Zone by $16,135.96, the Brown Soil Zone by $24,166.86 and the Black Soil Zone by $37,708.23.

The question of whether this additional revenue is large enough to incentivize participation in this protocol still stands. Since soil zones overlap in more than one Alberta land-use region, it is not plausible to address the impact additional revenue may have on annual gross farm receipts. Instead, this example provides an opportunity to address whether selling in the market offsets adoption costs. Based on Table 5, the average cost from implementing basic 4R stewardship on 2,471.05 acres of canola crops is $28,515.92. Additional revenue from carbon credits at a carbon price of $30 per tonne, as well as $50 per tonne, does not offset added costs. Although, at a carbon price of $170 per tonne, the Brown Soil Zone and the Black Soil Zone both generate enough additional revenue from selling carbon credits to offset the cost of implementing basic 4R stewardship; the exception is the Dark Brown Soil Zone. This does not account for the implementation of intermediate or advanced 4R stewardship plans, which likely have higher uptake costs and possibly higher transaction costs. The largest benefit to producers is in adopting 4R stewardship practices, which may increase revenue by $117 per acre across soil zones. Again, this suggests that long-run private benefits from management changes possibly drives BMP adoption under agricultural protocols, and future gains from an increasing carbon price are more of an added benefit to adoption.

Quantification Protocol for Reducing Greenhouse Gas Emissions from Fed Cattle

This protocol reduces indirect and direct greenhouse gas emissions associated with the digestion of feed materials in the rumen (enteric emissions), as well as emissions from manure storage and handling (Government of Alberta 2016). Projects under this protocol begin with a baseline period (approximately two years) where farmers continue diet and feeding strategies already in place. After this period, farmers implement feed BMPs, such as reducing the number of days beef cattle are on finishing diets or decreasing the feed-to-gain ratio during finishing stages (Government of Alberta 2016). The protocol has four projects — one closed and another has a recent offset start date of April 25, 2021. The remaining two projects (one active and one inactive) are discussed to quantify emission reductions from the protocols. Table 6 breaks down the emission offsets. All information comes from verification and project reports available on the Alberta Emission Offset Registry website (Alberta Carbon Registries 2021).

Table 6. Emission Reductions from the Quantification Protocol for Reducing GHG Emissions from Fed Cattle

Project	Time Period	Estimated Annual Emission Reduction or Sequestration *(tco_2e)*	Total Project *(tco_2e)*	Number of Farms	Active Offsets[11] *(tco_2e)*	Retired Offsets *(tco_2e)*	Project Developer (Aggregator)
Reducing GHG Emissions from Fed Cattle Aggregation Project (Inactive)	January 1st, 2012 – December 31st, 2015	10,000	45,126	4	0	45,126*	Trimble Canada Corporation (Agri-Trend)
	January 1st, 2016 – December 31st, 2016		10,589	3	76	10,513*	
	January 1st, 2017 – December 31st, 2017		3,833	1	0	3,833*	
	January 1st, 2018 – December 31st, 2018		3,598	1	3,598	0	
	January 1st, 2019 – December 31st, 2019		4,109	1	4,109	0	
Project Total			**67,255**	**1-41**	**7,783**	**59,472***	
Reducing GHG Emissions from Fed Cattle Aggregation Project Pool 3 (Active)	January 1st, 2016 – December 31st, 2017	100,000	12,892	2	0	12, 892*	Trimble Canada Corporation (Agri-Trend)
	January 1st, 2018 – December 31st, 2018		16,134	5	16,134	0	
	January 1st, 2019 – December 31st, 2019		16,948	4	16,948	0	
Project Total			**45,974**	**2-52**	**33,082**	**12,892***	
PROTOCOL TOTAL			**113,229**	**9 (in total)**	**40,865**	**72,364**	

*Indicates offsets pending retirement.

1 The number of farms under the Reducing GHG Emissions from Fed Cattle Aggregation Project varied across years as three of the four original farms closed between 2016 and 2017. Only four farms participated in total.

2 The farms that participated varied across years.

Source: Alberta Carbon Registries, "Alberta Emissions Offset Registry Listing," 2021, https://alberta.csaregistries.ca/GHGR_Listing/AEOR_Listing.aspx.

11 Emission offsets with an active status are offsets that have not been purchased or sold on the market (as of December 1, 2021). Once sold, they are marked as retired. All information on active offsets comes from the Alberta Carbon Registries directly and may vary from the emission offset project developer reports.

The two projects under the protocol have reduced emissions by 113,229 tco_2e, accounting for 0.16 per cent of all carbon offset emissions. Approximately 40,865 tco_2e are still active and ready to be sold on the market, with 72,364 tco_2e retired (or pending retirement). In terms of participation, nine farms (feedlots) participated across the two projects that have reported emission reductions. The most recent project, which began in April 2021 (not shown in Table 6), reported five farms are participating. According to the Alberta Cattle Feeders' Association (ACFA) website, approximately 153 feedlots are registered in Alberta. Based on this registry, nine per cent of all feedlots in Alberta have participated in projects under these protocols.

A notable finding is the emission reduction potential for a one-year verification period. Under the first project, one farm accounted for 4,109 tco_2e emission reductions in 2019. Under the second project (project pool 3), the average emission reduction across five farms in 2018 was 3,227 tco_2e per farm. Both examples show high emission reduction potential per farm compared to the Conservation Cropping Protocol (252 tco_2e per farm). This likely reflects the type of greenhouse gas mitigated, namely the reduction of methane emissions. Methane has higher global warming potential, estimated to be 25 per cent greater than carbon dioxide over a 100-year period (Government of Alberta 2022), which reflects greater reductions in tonnes of carbon dioxide equivalent.

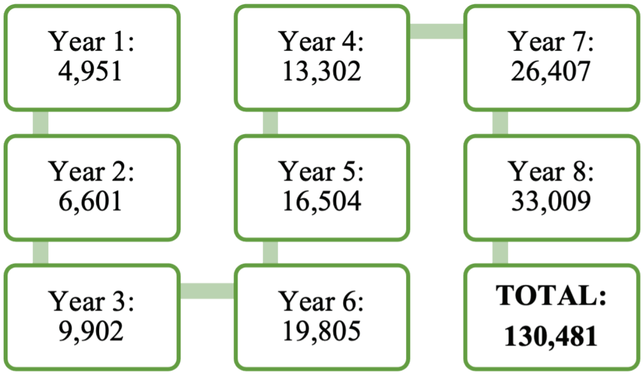
Unfortunately, due to insufficient information, economic benefits were not examined. Regardless, it is important to recognize feedlot producers' participation in this protocol, indicating producers see benefits in adopting these practices.

Quantification Protocol for Selection for Low Residual Feed Intake Markers in Beef Cattle

The Quantification Protocol for Selection for Low Residual Feed Intake in Beef Cattle (L-RFI) generates carbon offsets through beef breeding selection for increased feed efficiency. There is one project under this protocol. The emission offset project developer, Grow Safe Systems Ltd. (GrowSafe), developed technology to quantify individual cattle feed efficiency per unit of weight gained. This supports farmers selectively breeding stock with higher feed efficiency, resulting in offspring with similar feed efficiency traits (Government of Alberta 2012a). This results in a reduction of direct and indirect greenhouse gas emissions from beef cattle associated with enteric fermentation, manure storage and handling (Government of Alberta 2012a).

The one active project had an offset start date of January 1, 2017 and is projected to end December 31, 2024 (Viresco Solutions 2017). While reports on emission offsets are not yet available (based on information from Alberta Carbon Registries), the project plan submitted to the government of Alberta provided yearly estimated emission reductions in across the eight-year program. The estimated emission reductions for the project, entitled "Selection for Feed Efficiency to Reduce Environmental Impact of Beef Cattle in Alberta," are shown in Figure 3.

Figure 3. Emission Reductions (tco_2e) Across the Eight-Year Program Under the Quantification Protocol for Selection for Low Residual Feed Intake (L-RFI) in Beef Cattle



Source: Viresco Solutions (2017).

The level of emission reduction (in tonnes of carbon dioxide equivalent) is expected to increase yearly as the feed efficiency of cattle improves and the cattle population grows. Based on the most recent project proposal, there are four test sites: Benchmark Angus, Thorlakson Feedyards, Olds College and the University of Alberta. The project appears to be at a pilot stage. Therefore, the real emission reduction values, and if farmers would find value in protocol participation, cannot yet be determined. Additionally, there is no information available to quantify possible economic benefits.

DISCUSSION

This paper examined the impact of current agricultural offset protocols by reviewing two considerations: 1) agricultural emission reductions (or removals) and participation rates; and 2) economic benefits (observed or unobserved). Essentially, the results show agricultural producers in Alberta participate in agricultural carbon offset protocols to widely varying degrees. The Conservation Cropping (and prior Tillage System Management) Protocol had a high degree of participation, alongside significant emission reductions across projects, despite minimal economic benefits from carbon credit sales. Impacts of the remaining protocols were less clear due to data and information limitations.

The Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions (NERP) presented high economic benefits from adopting 4R stewardship principles, whereas the economic benefits from selling on the market were minimal at a lower carbon price. These results suggest producers are participating for the economic benefits stemming from the adoption of BMPs, rather than the potential revenue from selling carbon credits on the market. However, it was shown that at a higher carbon price ($170 per tonne), in two regions, the sale of carbon credits offsets implementation costs. While this may not drive participation, it may provide added benefits that influence farmers' management decisions. The Quantification Protocol for Reducing Greenhouse Gas

Emissions from Fed Cattle showed high emission reduction potential across farms and projects, as did the Quantification Protocol for Selection for Low Residual Feed Intake Markers in Beef Cattle, but the rates of participation were minimal. This low participation rate is likely attributed to the relatively recent implementation of projects under the protocols, including one of these protocols being in an assumed pilot stage. Regardless, the most concerning aspect is the limited participation outside of the Conservation Cropping Protocol, based on available information. With the protocol's retirement on December 31, 2021, agricultural producers' participation in the market is limited, unless they are able and willing to participate in the remaining protocols.

An overlooked issue with the current market is the inadequate participation from livestock producers, a severe shortfall given Alberta's livestock-intensive industry. Livestock producers are less likely to adopt BMPs as a whole (Prokopy et al. 2008), which may influence willingness to participate in carbon offset protocols. Another factor is the sheer complexity of the current livestock-related protocols, which is likely a barrier for the average agricultural producer. Two of the agricultural protocols are targeted for livestock producers, but they target a specific type of livestock farmer, particularly feedlots and large-scale (industrial) cow-calf producers with verified beef cattle. Thus, these protocols are not accessible to all livestock producers in Alberta, such as dairy farmers or poultry farms. This results in unrealized greenhouse gas emission reductions and reduces the pool of eligible livestock producers for livestock-related protocols.

Overall, the conversation highlights the following: 1) how to incentivize producers to participate in carbon offset protocols, and 2) ensuring accessible protocols and equal opportunities for livestock and crop producers. Accurate and reliable information must be ensured to better examine the efficiency of these protocols. Without access to data and information, the true nature of these protocols will remain unknown, including understanding why producers choose to participate in the market.

CONSIDERATIONS FOR AGRICULTURAL PROTOCOLS

The purpose of this section is to develop a framework of considerations for future agricultural quantification protocols based on the findings from the previous sections. The fundamental goal of this framework is to ensure that protocols attract farmers to participate in projects associated with the offset market and that projects benefit farmers and procure environmental benefits. To summarize, protocols should meet two objectives: 1) agricultural emission reductions or removals, and 2) private benefits (e.g., tangible benefits such as financial payments) to a producer. It is important to note that not all barriers are considered below. For example, the extensive verification and documentation may hinder participation for select farms (Weersink et al. 2005), but without more information, that claim cannot be confirmed. Instead, considerations mentioned stem from an extensive literature review.

One challenge is developing protocols that are practical for agricultural producers. In the protocols outlined earlier, only certain farms are eligible to participate: farmers growing certain crops, feedlots and producers with certified beef cattle. While a variety of producers can participate, a pool of producers who are ineligible to sell carbon offsets on the market exist. To date, there are four withdrawn or stopped protocols according to Government of Alberta (2021a):

1. **Forages:** This protocol would reward farmers for converting cropped land into perennial forages. This practice can result in improved yields, better soil quality and enhanced carbon sequestration, among other benefits (Entz et al. 2002; Martens et al. 2015). The development of a protocol was stopped, but the reason why is unclear.
2. **Wetlands**: Wetlands are owned by the Crown in Alberta by virtue of the *Water Act* and *Public Lands Act*. Thus, activities did not qualify as an offset due to the legal obligation to perform this practice. This meant that farmers were not adopting the practice of conserving wetlands; rather, they were required by law to protect and preserve wetlands on their land already.
3. **Quantification Protocol for Reducing the Age at Harvest of Beef Cattle:** This protocol meant to reduce emissions associated with raising beef cattle by reducing the number of days required for feeder calves from birth to harvest (Government of Alberta 2011). Government of Alberta (2021a) states that due to market conditions influencing feed schedules, feed availability and other factors, the protocol faced numerous practical challenges related to uptake, resulting in the protocol being withdrawn.
4. **Quantification Protocol for Emission Reductions from Dairy Cattle:** This protocol would reward farmers for efficient milk production and reducing methane and nitrous oxide emissions from production. While the protocol was trialed on 50 dairy farms in Alberta, the protocol had a layer of complexity resulting in challenges towards becoming fully operational, and the protocol was withdrawn.

Two of the above protocols were withdrawn due to practical challenges and protocol complexity, resulting in the discontinuation of possible projects meant to mitigate on-farm emissions. This also resulted in eligible producers (e.g., dairy farmers) no longer being able to participate in the offset market. It will be imperative to better understand practices (e.g., best management practices) that are feasible for most farm operations, including a farmer's capacity and willingness to adopt practices.

It is not unreasonable to assume that barriers to BMP adoption are similar to barriers that hinder participation in the offset market. Notable barriers to BMP adoption include risk perceptions, financial barriers and a lack of reliable information (Pannell et al. 2006; Liu et al. 2018; Prokopy et al. 2019). Altering a producer's operations management can present numerous perceived risks to farm profitability and productivity, deterring participation in these protocols (Greiner et al. 2009; Greiner and Gregg 2011; Liu et al. 2018). There are no guarantees producers will directly benefit from adopting conservation practices under a protocol, and many of these benefits are not always directly observable (e.g., improved soil quality) (Pannell et al. 2006). This will likely present a point of contention for risk-averse producers. To mitigate these risk perceptions, producers will likely need to be compensated to motivate participation and be able to quantify the benefits from altering their management practices, such as through observability (e.g., seeing increased yields on a neighbouring farm) or through improved information (e.g., training workshops).

Financial barriers, stemming from high uptake costs, long-term maintenance costs, carbon offset transaction costs or other added costs from adopting a practice, can hinder protocol participation. According to the 2011 Farm Environmental Management (FEM) survey, roughly 55 per cent of Canadian agricultural producers indicated economic barriers as a reason for not implementing BMPs (Statistics Canada 2013). Financial incentives are cited as a method to overcome these barriers, allowing producers to share the burden of risk (Feather and Amacher 1994; Palm-Forester et al. 2017). In terms of the carbon offset market, these findings correspond to economic benefits. Participation in these protocols requires agricultural producers to make voluntary management changes, some of which add to operational costs short (or long) term. As shown in Table 5, participating in NERP requires additional costs per acre from implementing 4R stewardship, and current costs outweigh the additional revenue from selling offsets on the market. Instead, implementing 4R stewardship relays the largest benefits towards additional revenue per acre, outweighing the implementation costs. However, it is not clear whether this additional revenue is instantaneous (e.g., within a year of implementing) or if this revenue increases over time. Thus, producers with less capacity to incur high uptake costs may not have the ability to implement 4R stewardship without some form of support.

Assuming other agricultural protocols have high uptake costs, one option is linking these protocols to environmental stewardship programs under federal agricultural policy frameworks, as these stewardship programs use a cost-share approach to subsidize the adoption of on-farm BMPs. Another consideration is improving a producer's knowledge regarding other economic benefits from adopting practices. For example, some benefits include additional profits from improved soil quality resulting in improved crop productivity, or a reduction in fuel costs per acre from improved production efficiency. Improving producers' information levels can be more cost effective than financial incentives or direct regulation (Feather and Amacher 1994; Pannell 2008), where access to, and quality of, information can influence adoption decisions (Baumgart-Getz et al. 2012; Ranjan et al. 2019). Ensuring producers are aware of the additional benefits of participating in these protocols can naturally entice participation, with a main goal of bridging the knowledge gap.

A final consideration is the role of additionality when developing a carbon offset (quantification) protocol. Additionality is the notion that an action to achieve greenhouse gas emission reductions (or removals) is beyond business as usual (Alberta Environment and Parks 2018). In simpler terms, the project must determine a baseline scenario where any emission reductions above are considered additional (Climate Smart Group 2017). In terms of agricultural protocols, this includes the ability to demonstrate that emission reductions or removals are additional to what would occur if the practice were not adopted. Alberta Environment and Parks (2018) developed the Technical Guidance for the Assessment of Additionality, which added the use of a penetration rate. The penetration rate is defined as "…the rate at which a new activity, technology, or practice has been adopted by a given sector." A higher rate of adoption is associated with being considered common practice or business as usual. For Alberta, this penetration rate has been defined as surpassing a threshold of 40 per cent uptake in a given sector (Alberta Environment and Parks 2018). This threshold may limit possible protocol development. According to the ESAT survey, across 40 BMPs specific to Alberta agricultural producers, the average adoption rate was 53 per cent (AAF 2018). Based on this information, more than half of agricultural BMPs are above the threshold, resulting in a business-as-usual status. While it is outside the scope of this paper to provide insight into this issue, it is a meaningful consideration.

CONCLUDING REMARKS

Alberta's carbon offset market was developed early on to combat excess emissions from large-scale greenhouse gas emitters and later adapted to meet regulations under the Pan-Canadian Framework. Allowing emitters to purchase emission reductions provided a market for agricultural carbon offsets. This market preceded development of agricultural quantification protocols, supporting producers voluntarily adopting best management practices (BMPs) to reduce (or remove) on-farm greenhouse gas emissions, while earning additional revenue from selling offsets (carbon credits) on the market.

The purpose of this paper is to understand the impacts of the carbon offset market on the agricultural industry in Alberta. To do this, two components were considered: the level of emission reductions (or removals) and the economic benefits procured. While data limitations hindered the overall analysis, the paper found emission reductions have occurred and continue to occur from agricultural quantification protocols. The majority of these reductions have occurred under one protocol. To date, no other agricultural protocols have been able to amass the same level of participation. This should warrant concerns as the Conservation Cropping Protocol was retired December 31, 2021.

In terms of why producers participate in these protocols, direct economic benefits from selling carbon credits do not outweigh adoption costs. This remains true under the current carbon price, but as the carbon price increases, carbon credits will eventually outweigh the costs, possibly improving protocol participation. Instead, it seems the main driver behind participation is the indirect economic benefits from adopting BMPs. Ensuring awareness of these benefits may improve the rate of participation. A consideration is the ability to easily quantify these benefits. Certain benefits, such as improved soil conditions or feed efficiency, may take years of hard work and management changes to show any private benefits for the producers. These factors play into risk perceptions and financial barriers, creating an obstacle towards participation. While waiting for the carbon price to increase, it is in the Alberta government's best interest to determine a method to demonstrate indirect benefits to producers.

Canada's work towards a low-carbon economy will require action across all sectors to reduce emissions, while remaining competitive in a global market. This includes the agricultural industry, as the carbon offset market can be an important tool towards reaching climate policy goals. The government of Alberta must act to address limitations under active agricultural quantification protocols, such as the limited opportunities for different types of livestock producers. With the loss of the Conservation Cropping Protocol, and without avid participation in other protocols, a stagnant market for agricultural carbon credits is likely. A key spill-over effect will include unrealized emission reductions from the agricultural industry. This paper has provided a framework of barriers to participation through a thorough overview of agricultural protocols. It is in the government's best interest to consider and address these challenges.

REFERENCES

Alberta Agriculture and Forestry (AAF). 2018. "2018 Environmentally Sustainable Agriculture Tracking Survey Final Report."

———. 2020. "2016 Census of Agriculture for Alberta."

Alberta Carbon Registries. 2021. "Alberta Emissions Offset Registry Listing." https://alberta.csaregistries.ca/GHGR_Listing/AEOR_Listing.aspx.

Alberta Environment and Parks. 2018. "Technical Guidance for the Assessment of Additionality." May 31. https://open.alberta.ca/dataset/ae43faff-6405-443d-a07a-d541d04c52f0/resource/679a62bd-7196-4665-a6b7-341af6d96578/download/assessmentadditionality-may31-2018.pdf.

Alberta Environment and Water. 2012. "Quantification Protocol for Conservation Cropping."

Asgedom, H., and E. Kebreab. 2011. "Beneficial Management Practices and Mitigation of Greenhouse Gas Emissions in the Agriculture of the Canadian Prairie: A Review." *Agromony for Sustainable Development,* 31: 433–451.

Awada, L., R. S. Gray, and C. Nagy. 2016. "The Benefits and Costs of Zero Tillage RD&E on the Canadian Prairies." *Canadian Journal of Agricultural Economic,* 64(3): 417–438.

Awada, L., W. Lindwall, and B. Sonntag. 2014. "The Development and Adoption of Conservation Tillage Systems on the Canadian Prairies." *International Soil and Water Conservation Research,* 2(1): 47–65.

Baumgart-Getz, A., L. S. Prokopy, and K. Floress. 2012. "Why Farmers Adopt Best Management Practice in the United States: A Meta-analysis of the Adoption Literature." *Journal of Environmental Management,* 96: 17–25.

Boxall, Peter C. 2018. "Evaluation of Agri-Environmental Programs: Can We Determine If We Grew Forward in an Environmentally Friendly Way?" *Canadian Journal of Agricultural Economics,* 66(2): 171–186.

Busari, M. A., S .S. Kukal, A. Kaur, R. Bhatt, and A. A. Dulazi. 2015. "Conservation Tillage Impacts on Soil, Crop and the Environment." *International Soil and Water Conservation Research,* 3(2): 119–129.

Childs, J. 2010. "Continental Cap-and-trade: Canada, the United States, and Climate Change Partnership in North America." *Houston Journal of International Law,* 32(2): 393–457.

Climate Smart Group. 2017. "Additionality Discussion Paper." Viresco Solutions. 03. https://virescosolutions.com/wp-content/uploads/2020/09/Additionality-Discussion-Paper-.pdf.

Davey, K. A., and W. Furtan. 2008. "Factors that Affect the Adoption Decision of Conservation Tillage in the Prairie Region of Canada." *Canadian Journal of Agricultural Economics,* 56(3): 257–275.

Dobson, S., J. Winter, and B. Boyd. 2019. "The Greenhouse Gas Emissions Coverage of Carbon Pricing Instruments for Canadian Provinces." SPP Research Papers, The School of Public Policy, University of Calgary, 12(6).

Entz, M. H., V. S. Baron, P. M. Carr, D. W. Meyer, S. Smith Jr., and W. McCaughey. 2002. "Potential of Forages to Diversify Cropping Systems in the Northern Great Plains." *Agronomy Journal,* 94(2): 240–250.

Environment and Climate Change Canada (ECCC). 2016. "Pan-Canadian Framework on Clean Growth and Climate Change: Canada's Plan to Address Climate Change and Grow the Economy."

———. 2019. "Canada's Official Greenhouse Gas Inventory - GHG_IPCC_Can_Prov_Terr.csv." February 20. https://open.canada.ca/data/en/dataset/779c7bcf-4982-47eb-af1b-a33618a05e5b.

———. 2020. "Greenhouse Gas Pollution Pricing Act: Annual Report for 2019."

———. 2021. "National Inventory Report 1990-2019: Greenhouse Gas Sources and Sinks in Canada Executive Summary."

Epplin, F. M., C. J. Stock, D. D. Kletke, and T. F. Peeper. 2005. "Cost of Conventional Tillage and No-till Continuous Wheat Production for Four Farm Sizes." *Journal of the ASFMRA (American Society of Farm Managers and Rural Appraisers),* 69–76.

Feather, P. M., and G. S. Amacher. 1994. "Role of Information in the Adoption of Best Management Practices for Water Quality Improvement." *Agricultural Economics,* 11 (2–3): 159–170.

Fertilizer Canada. n.d. "4R's Across Canada: Alberta." https://fertilizercanada.ca/our-focus/stewardship/4rs-across-canada/alberta/.

Goddard, T. 2021. "Chapter 8: Climate-Change Policy for Agriculture Offsets in Alberta, Canada." In *Regenerative Agriculture*, B. Boincean and D. Dent, eds. Cham, Switzerland: Springer Nature 95–104.

Government of Alberta. 2011. "Tillage Offset Credit Update." November 15. https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/cl11618/$FILE/Information_Nov2011.pdf.

———. 2012a. "Quantification Protocol for Selection for Low Residual Feed Intake in Beef Cattle." May. https://open.alberta.ca/dataset/fa2c770e-ebb0-40a5-93e6-e85df4e43802/resource/1d57191f-a991-4162-a9df-fb574298a714/download/6744077-2012-04-quantification-protocol-selection-low-residual-feed-intake-beef-cattle.pdf.

———. 2012b. "Quantification Protocol for Conservation Cropping Version: 1.0." Alberta Environment and Water.

———. 2015. "Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions Specified Gas Emitters Regulation." September. https://open.alberta.ca/dataset/a2985519-ee0b-4b70-92a6-bdd46f7dfffc/res.

———. 2016. "Quantification Protocol for Reducing Greenhouse Gas Emissions from Fed Cattle Version 3.0." February 25. https://open.alberta.ca/dataset/ec8dce85-297c-45d2-82a6-58bbfed85a00/resource/2cd6e6a7-fd63-41c3-8a61-8f0567f90b0b/download/reducingghgemissionsfedcattle-feb25-2016.pdf.

———. 2021a. "Agricultural Carbon Offsets - Conservation Cropping Protocol." https://www.alberta.ca/agricultural-carbon-offsets-conservation-cropping-protocol.aspx.

———. 2021b. "Agricultural Carbon Offsets - All Protocol Updates." https://www.alberta.ca/agricultural-carbon-offsets-all-protocols-update.aspx.

———. 2021c. "Technology Innovation and Emissions Reduction Regulation." https://www.alberta.ca/technology-innovation-and-emissions-reduction-regulation.aspx.

———. 2022. "Agricultural Carbon Offsets – Overview." https://www.alberta.ca/agricultural-carbon-offsets-overview.aspx.

Government of Canada. 2021. "Greenhouse Gas Sources and Sinks: Executive Summary 2021." July 26. https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary-2021.html.

———. 2022. "Carbon Pollution Pricing Systems Across Canada." January 31. https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work.html.

Greiner, R., and D. Gregg. 2011. "Farmers' Intrinsic Motivations, Barriers to the Adoption of Conservation Practices and Effectiveness of Policy Instruments: Empirical Evidence from Northern Australia." *Land Use Policy,* 28: 257–265.

Greiner, R., L. Patterson, and O. Miller. 2009. "Motivations, Risk Perceptions and Adoption of Conservation Practices by Farmers." *Agricultural Systems,* 99: 86–104.

Haugen-Hozyra, K. 2009. "Lessons Learned in Alberta's Carbon Market." Climate Change Central. March. https://ecoservicesnetwork.ca/media/uploads/contributor-19/Lessons%20Learned%20in%20Alberta%27s%20Carbon%20Market%20FINAL.pdf.

Lamba, P., G. Filson, and B. Adekunle. 2008. "Factors Affecting the Adoption of Best Management Practices in Southern Ontario." *The Environmentalist,* 29(1): 64–77.

Liu, T, R. J. Bruins, and M. T. Heberling. 2018. "Factors Influencing Farmers' Adoption of Best Management Practices: A Review and Synthesis." *Sustainability 10(2)* 432.

Manley, J., G. van Kooten, K. Moeltner, and D. W. Johnson. 2005. "Creating Carbon Offsets in Agriculture Through No-Till Cultivation: A Meta-Analysis of Costs and Carbon Benefits." *Climatic Change,* 68: 41–65.

Martens, J. R., M. H. Entz, and M. D. Wonneck. 2015. "Review: Redesigning Canadian Prairie Cropping Systems for Profitability, Sustainability, and Resilience." *Canadian Journal of Plant Science,* 95: 1049–1072.

Palm-Forster, L., S. Swinton, and R. Shupp. 2017. "Farmer Preferences for Conservation Incentives that Promote Voluntary Phosphorus Abatement in Agricultural Watersheds." *Journal of Soil and Water Conservation,* 72(5): 493–505.

Pannell, D. J. 2008. "Benefits, Private Benefits, and Policy Mechanism Choice for Land-Use Change for Environmental Benefits." *Land Economics,* 84(2): 225–240.

Pannell, D., G. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson. 2006. "Understanding and Promoting Adoption of Conservation Practices by Rural Landholders." *Australian Journal of Experimental Agriculture,* 46: 1407–1424.

The Prasino Group. 2014. "Nitrous Oxide Emission Reductions Protocol (NERP) Validation Study Report Year One." Emission Reduction Alberta. June 3. https://eralberta.ca/wp-content/uploads/2017/05/NERP-Validation-Study-Report-Year-1-.pdf.

Prokopy, L., K. Floress, J. Arbuckle Jr., S. P. Church, F. Eanes, Y. Gao et al. 2019. "Adoption of Agricultural Conservation Practices in the United States: Evidence from 35 Years of Quantitative Literature." *Journal of Soil and Water Conservation,* 74(5): 520–534.

Prokopy, L., K. Floress, D. Klotthor-Weinkauf, and A. Baumgart-Getz. 2008. "Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature." *Journal of Soil and Water Conservation,* 63(5): 300–311.

Ranjan, P., S. P. Church, K. Floress, and L. S. Prokopy. 2019. "Synthesizing Conservation Motivations and Barriers: What Have We Learned from Quantitative Studies of Farmers' Behaviors in the United States?" *Society & Natural Resources,* 32(11): 1171–1199.

Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig et al. 2014. "Agriculture, Forestry and Other Land Use (AFOLU)." In: *Climate Change 2014: Mitigation of Climate Change. Conribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* O. Edenhofer et al., eds. Cambridge and New York: Cambridge University Press.

Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar et al. 2008. "Greenhouse Gas Mitigation in Agriculture." *Phil. Trans. R. Soc. B,* 363: 789–813.

Snyder, C., T. Bruulsema, T. Jensen, and P. Fixen. 2009. "Review of Greenhouse Gas Emissions from Crop Production Systems and Fertilizer Management Effects." *Agriculture, Ecosystems & Environment,* 133 (3–4): 247–266.

Statistics Canada. 2013. "Farm Environmental Management Survey 2011." Minister of Industry.

———. 2018. "Alberta Has the Most Beef Cattle in Canada and the Second Largest Total Farm Area." March 23. https://www150.statcan.gc.ca/n1/pub/95-640-x/2016001/article/14808-eng.htm.

———. 2021. "Table 32-10-0130-01 Number of Cattle, by Class and Farm Type (x 1,000)." CANSIM (database). March 1. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210013001.

Thomassin, D. 2013. "The Benefit Cost Analysis of the Agricultural Producer's Position as it Relates to the Nitrous Oxide Emission Reductions Protocol." Emission Reduction Alberta. https://eralberta.ca/wp-content/uploads/2017/05/NERP-Producer-Final-Cost-Benefit-Report-.pdf.

United Nations. 2015. "Paris Agreement." United Nations Climate Change. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

Viresco Solutions Inc. 2017. "Offset Project Plan for Selection for Feed Efficiency to Reduce Environmental Impact of Beef Cattle in Alberta." Alberta Carbon Registries. December 21. https://alberta.csaregistries.ca/GHGR_Listing/AEOR_ListingDetail.aspx?ProjectId=232.

Weersink, Alfons, David Pannell, Murray Fulton, and Andreas Meyer-Aurich. 2005. "Agriculture's Likely Role in Meeting Canada's Kyoto Commitments." *Canadian Journal of Agricultural Economics,* 53: 425–441.

West, T., and G. Marland. 2002. "A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States." *Agriculture, Ecosystems an Enviroment,* 91: 217–232.

Yanni, S., A. De Laporte, P. Rajsic, C. Wagner-Riddle, and A. Weersink. 2021. "The Environmental and Economic Efficacy of On-farm Beneficial Management Practices for Mitigating Soil-Related Greenhouse Gas Emissions in Ontario, Canada." *Renewable Agriculture and Food Systems,* 36(3): 307–320.

APPENDIX

This section provides the calculations used for Table 5. All calculations are based on work done by Thomassin (2013) and The Prasino Group (2014). The following assumptions are imposed for each calculation:

1) The farmer/aggregator carbon price split is 2/3 farmer and 1/3 aggregator.
   a. Carbon price of $30 = $20 x 2/3 = $20
   b. Carbon price of $50 = $50 x 2/3 = $33.33
   c. Carbon price of $170 = $170 x 2/3 = $113.33
2) Farmers allocate 1,000 hectares (2,471.05 acres) to canola crops.
3) Farmers all choose the basic level of 4R Stewardship.

The estimated emission reductions across soil type, per 1,000 hectares of canola crops, is as follows:

- Dark Brown Soil Zone = 173 tCO_2e per 1,000 hectares
- Brown Soil Zone = 259 tCO_2e per 1,000 hectares
- Black Soil Zone = 404 tCO_2e per 1,000 hectares

CALCULATIONS:

Carbon price of $30 per tonne:

Dark Brown Soil Zone

Additional revenue per acre = $\$\mathbf{20}\ \boldsymbol{x}\ \mathbf{173}\ tCO_2e = \frac{\$3{,}460}{2{,}471.05\ acres} = \$1.4\ per\ acre$

Brown Soil Zone

Additional revenue per acre = $\$\mathbf{20}\ \boldsymbol{x}\ \mathbf{259}\ tCO_2e = \frac{\$5{,}180}{2{,}471.05\ acres} = \$2.1\ per\ acre$

Black Soil Zone

Additional revenue per acre = $\$\mathbf{20}\ \boldsymbol{x}\ \mathbf{404}\ tCO_2e = \frac{\$8{,}080}{2{,}471.05\ acres} = \$3.27\ per\ acre$

Carbon price of $50 per tonne:

Dark Brown Soil Zone

Additional revenue per acre = $\$\mathbf{33.33}\ \boldsymbol{x}\ \mathbf{173}\ tCO_2e = \frac{\$5{,}766.09}{2{,}471.05\ acres} = \$2.33\ per\ acre$

Brown Soil Zone

Additional revenue per acre = $\$\mathbf{33.33}\ \boldsymbol{x}\ \mathbf{259}\ tCO_2e = \frac{\$8{,}632.47}{2{,}471.05\ acres} = \$3.49\ per\ acre$

Black Soil Zone

Additional revenue per acre = $\$\mathbf{33.33}\ \boldsymbol{x}\ \mathbf{404}\ tCO_2e = \frac{\$13{,}465.32}{2{,}471.05\ acres} = \$5.45\ per\ acre$

Carbon price of $170 per tonne:

Dark Brown Soil Zone

Additional revenue per acre = $\$\mathbf{113.33}\ \boldsymbol{x}\ \mathbf{173}\ tCO_2e = \frac{\$19{,}606.09}{2{,}471.05\ acres} = \$7.93\ per\ acre$

Brown Soil Zone

Additional revenue per acre = $\$\mathbf{113.33}\ \boldsymbol{x}\ \mathbf{259}\ tCO_2e = \frac{\$29{,}352.47}{2{,}471.05\ acres} = \$11.88\ per\ acre$

Black Soil Zone

Additional revenue per acre = $\$\mathbf{113.33}\ \boldsymbol{x}\ \mathbf{404}\ tCO_2e = \frac{\$45{,}785.32}{2{,}471.05\ acres} = \$18.53\ per\ acre$

About the Author

Sarah Van Wyngaarden is a graduate research assistant at the University of Alberta and recently graduated with her MSc in Agricultural and Resource Economics. Her research interests focus on agricultural economics and agricultural policy, specifically exploring the adoption of Best Management Practices to mitigate agricultural emissions.

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