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GREENHOUSE GAS EMISSIONS FROM CANADIAN AGRICULTURE: POLICIES AND REDUCTION MEASURES

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SUMMARY

Current reports indicate that during the 21st century, global warming of 1.5° C and 2° C will be exceeded. Total greenhouse gas (GHG) emissions continue to increase in Canada, with the agricultural sector contributing approximately 10 per cent of these. Since GHG emissions are closely tied to population growth, it is imperative to act now to mitigate emissions because the agricultural sector is under pressure to increase production as the population grows. Estimates are that the world's population will grow from 7.7 billion in 2019 to 9.7 billion by 2050.

There is no one solution that will effectively mitigate GHG emissions in all regions. Different regions in Canada have different challenges and capacities to address their GHG emissions. Guidelines, programs, policies, and best management practices need to consider these regional differences to ensure their success. They also need to support sustainable development, food security, poverty eradication, justice, and equality.

The key to designing successful regional policies is having carbon accounting programs that the industry is willing to use. Even though there are accounting schemes (globally, federally, and provincially), they are not consistent and have limited monitoring and verification of actual carbon reductions. In addition, producers do not use them due to the large amounts of paperwork and small economic benefit. Regularly monitored, seamless carbon accounting programs can be adopted within subsectors of the agricultural industry and within similar climatic regions to help determine potential carbon sinks and opportunities to minimize GHG emissions, as well as identify best policies for each region and subsector.

Data from carbon accounting programs need to be shared and communicated to help align industry, provincial and federal GHG inventory programs. These data need to be included in the National Inventory Report for a better overall view of GHG emissions and the effects on them of programs and policies.

Adoption of a federal, provincial, and municipal carbon tax can also be an effective solution but there are many barriers to the carbon tax, including general public opinion. To make the carbon tax successful, there must be increased communication between policy-makers, agri-businesses, and the general public to help identify contexts and barriers to its adoption.

Successful measures and practices for reducing agricultural GHG emissions tend to support technological solutions and do not face significant barriers to uptake, such as no-till practices, optimizing animal feed and additives, feed grain processing for improved digestibility and genetic selection and breeding, to name a few. Many of these techniques are already supported by provincial best management practices and farm stewardship programs.

Finding policy solutions that increase farm net income while reducing GHG emissions in Canada is possible and will be the most successful. A few modeling tools are currently available to producers to assess GHG emissions of a variety of land uses and farm activities. The more user-friendly the models are, the more producers and businesses will use them, and the more data will be captured and used to improve GHG emission estimations and predictions, and mitigate GHG emissions from Canadian agriculture.

ABSTRACT

Despite numerous national and international climate conferences, meetings and workshops leading to various greenhouse gas (GHG) emission targets and agreements since the 1970s, total GHG emissions in Canada continue to increase. They reached 729 megatonnes of carbon dioxide equivalent (Mt CO_2 eq) in 2018, with the Canadian agricultural sector contributing approximately 10 per cent of total GHGs emitted. Different regions of the country contribute different levels, face different challenges and have different capacities to address their GHG emissions.

Designing climate guidelines, programs, policies and adopting best management practices (BMPs) that promote relevant local and regional adaptation and mitigation efforts is important. Mechanisms such as setting a carbon price, cap-and-trade systems and tax-based policies contribute to decreased GHG emissions. GHG emissions in Canada are regulated at the federal level via a national carbon pricing policy and provinces have set limitations on GHG emissions via pricing or taxation. Agriculture has the potential to mitigate GHG emissions by applying BMPs that reduce emissions and increase carbon storage in soils. Meanwhile, the pressure is increasing on the agricultural sector to increase production, both for local commodities and those destined for export, to feed a growing population.

This paper explores agricultural policies and measures that encourage farmers and producers across Canada to reduce their GHG emissions. Specifically, national and provincial measures and implications are presented and compared to international measures and outcomes. Finally, recommendations are made for future climate policy research and adoption.

POLICY RECOMMENDATIONS

- Design, implement and regularly monitor and evaluate detailed, seamless carbon accounting programs. These programs can be adopted within subsectors of the agricultural industry and within relatively similar climatic regions such as municipalities and counties. Two objectives will be reached: (1) determine potential carbon sinks and opportunities to minimize greenhouse gas emissions within each subsector of the agricultural industry; and (2) identify best policy frameworks for every region and every subsector.
- Implement, monitor and evaluate the adoption of a federal, provincial and municipal carbon tax. Increased communication between policy-makers and the agri-business community will identify contexts for adopting a carbon tax, as well as barriers to its adoption. All feedback will be incorporated into designing a more generally approved measure.
- Implement, monitor and evaluate the adoption of carbon pricing measures.
- Communicate and share data from carbon accounting programs so that industry, provincial and federal greenhouse gas inventory programs are aligned and included in the National Inventory Report.

INTRODUCTION

INTERNATIONAL EMISSION REDUCTION

Since the first World Climate Conference held in Geneva in 1979, a series of workshops, meetings and conferences have brought international scientists and politicians together to establish a target for global CO_2 emissions. In 1988, the target was to reduce global CO_2 emissions by 20 per cent of 1988 levels by 2005. In 1992, the United Nations Framework Convention on Climate Change was signed at the Earth Summit in Rio de Janeiro, with a goal to reduce CO_2 emissions by 2000 to the 1990 levels. Since the first Conference of the Parties in Berlin in 1995, countries have gathered regularly to negotiate international agreements, set targets for greenhouse gas (GHG) emissions and discuss mechanisms to reach these targets. The International Panel on Climate Change (IPCC), established in 1988 by the World Meteorological Organization and the United Nations Environmental Programme, assesses the science related to climate change and has served as the basis for determining emission targets and timelines at international negotiation gatherings.

Climate change is a global problem that requires urgent collective action. As stated in the Sixth Assessment Report (IPCC 2021): "Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in GHG emissions occur in the coming decades." Different countries contribute different amounts of GHGs to the atmosphere, they face different challenges and have different capacities to address climate change. However, GHGs accumulate over time and mix in the atmosphere, emissions from one region affect another and co-operation among jurisdictions is required to mitigate emissions. It is important to design climate policies that promote adaptation and mitigation efforts and also support sustainable development, food security, poverty eradication, justice and equality. Policy approaches by national and local governments include adaptation planning, decision-making and implementation, providing support and relevant frameworks to institutions, to the private sector and to communities and civil society. Policy measures that address climate change mitigation use mechanisms such as setting a carbon price, cap-and-trade systems and tax-based policies, such as a carbon tax aimed at reducing GHG emissions. In some countries, fuel taxes have also contributed to decreased GHG emissions.

Although economy-wide regulatory approaches such as energy efficiency standards can be effective in reducing emissions, industry-specific policies can address specific industry targets and barriers to achieving them, whether economic, social or environmental.

In Canada, GHG emissions are regulated at the federal level via a national carbon pricing policy. In addition, several provinces have set limitations on GHG emissions via pricing or taxation.

THE ROLE OF AGRICULTURE IN EMISSION REDUCTIONS

Agriculture has the potential to mitigate GHG emissions by applying best management practices (BMPs) that either reduce them or encourage the capture and storage of carbon in soils. Mitigation can also be achieved by reducing the intensity of GHG emissions per unit of production, if production remains stable. In either case, a reduction in the productivity of conventional agricultural systems would likely be the consequence. Both of these efforts can be encouraged through policy. However, using regulatory approaches may endanger farms already close to the limit of economic viability and incentive approaches may not be very effective due to limitations in investment.

Reporting agricultural GHG emissions has become pressing as a significant gap exists between current public policies, nationally determined contributions and those needed to achieve the Paris agreement targets (Roelfsema et al. 2014, 2020). While GHG emissions are closely tied to population growth, median estimates are that the current 7.7 billion people worldwide in 2019 will grow to 9.7 billion in 2050 and to 10.9 billion in 2100 (UN World Population Projections 2019). To support this growing population, agriculture will need to increase production volumes while decreasing its carbon intensity, and while also keeping costs within reach for developing nations for food security. Getting ahead of the curve by acting now saves costs and lessens impacts of climate change in the future (IPCC 2018). Acting now means addressing policy gaps and putting measures in place for both adaptation and mitigation strategies. Acting now includes monitoring and evaluating current policy implementation strategies. It also allows the development of incentivized policy, the provision of economic co-benefits and nudges preferentially towards carbon reductions, as opposed to mandatory and not-so-welcome regulatory intervention and penalties.

This paper presents current agricultural policies and measures that encourage farmers and producers across Canada to reduce their agricultural GHG emissions.

NATIONAL AND REGIONAL MEASURES: CURRENT CANADIAN AGRICULTURAL POLICIES AND CARBON CREDIT SYSTEMS

Including agricultural emissions in carbon accounting schemes is a nascent development provincially, federally and globally. Consequently, there is a lack of consistent and agreed-upon standards and global measurement tools. Producers have exercised little uptake in current programs due to the ominous paperwork and the small economic benefit the programs offer, such as those in Alberta. While provinces do have policies, there is limited monitoring, verification and reporting of actual carbon reductions.

NATIONAL

Agriculture is a sector that depends on local soil and climatic conditions as well as market prices and is therefore considered a high-risk sector. Policy interventions include financial incentives to farmers (approximately C$5.7 billion) for economic stabilization programs and investments in the 21 agricultural research and development centres located across the country (Kroebel et al. 2021). The authors expressed that such policies have provided tools to increase agricultural production over time, but have also resulted in broadening the environmental impact of agriculture. There is therefore a need to study long-term policy impacts, both economic and environmental, and to adapt them so that it is profitable and sustainable to run a farming business.

Policies can be in the form of regulations where certain practices are mandated or in the form of financial incentives, such as subsidies, payment programs and tradable permits where the farmers decide to adopt BMPs. According to Weersink et al. (1998), economic instruments such as financial incentives are superior to regulatory policies in reducing the environmental impacts of agriculture. They are more cost effective as they encourage farmers and businesses with the lowest cost of making a change in their management practices to make the biggest changes. Farmers and businesses are then free to make their own choices for change and adaptation, whereas regulatory instruments allow policy-makers to make choices for them. In addition, economic instruments encourage technological innovations through financial rewards. A successful program that supports farms with incentives and payment schemes is ALUS (Alternative Land Use Services). Funded from a variety of sources, it is a community-developed and farmer-delivered program that is active in six provinces so far and encourages environmental stewardship through conservation, restoration and ecosystem services (ALUS 2021). A new initiative to promote long-term climate resiliency in the agricultural sector is the recent call for proposals for the On-Farm Climate Action Fund. This fund will provide $200 million to support farmers who adopt beneficial management practices that store carbon and reduce GHG emissions, specifically cover cropping, nitrogen management and rotational grazing practices. The objective is to improve the management of up to 792,000 hectares of land and reduce GHG emissions by 40–45 per cent by 2050 (Agriculture and Agri-Food Canada 2021).

In December 2016, the Federal-Provincial-Territorial First Ministers formed a Pan-Canadian Framework on Clean Growth and Climate Change which envisioned a system that either priced carbon rising to $50 per tonne by 2022 or that meets a cap-and-trade system with an emission reduction equivalent to the one achieved by the carbon price (Agriculture and Agri-Food Canada 2018). In late 2020, the federal government further unveiled its carbon pricing plan to increase the carbon tax to $170 per tonne by 2030.

Agricultural activities that produce GHG emissions are largely exempt from carbon pricing (ECCC 2020). Most of Canada's agricultural production occurs in the Prairie Provinces where carbon tax is strongly opposed. Some jurisdictions exempt diesel and gasoline from carbon pricing in agricultural production, while others (Alberta) do not (Agriculture and Agri-Food Canada 2018).

PROVINCIAL/TERRITORIAL

Alberta

Agriculture contributes approximately seven per cent of Alberta's GHG emissions (Government of Alberta 2021) and it is unclear whether this includes emissions from energy use (i.e., operating machinery, heating homes) and industrial processes (i.e., fertilizer manufacture). In 2018, GHG emissions in Alberta reached approximately 270 Mt CO_2 eq (ECCC 2020). This computes to 18.9 Mt CO_2 eq emitted by the agricultural sector in Alberta.

Alberta's Climate Change and Emissions Management Act, passed in 2003, was the first legislation related to climate change in Canada and has been replaced with the Emissions Management and Climate Resilience Act as of January 1, 2020 (Alberta Carbon Registries 2020). Alberta's strategy to reduce GHG emissions includes the carbon offset market. A carbon levy is applied to the price of all fuels and large emitters have an output-based system. When a producer makes a change in management that reduces emissions, this producer earns extra income and increases production efficiency.

Alberta has four approved agricultural protocols for creating carbon offsets: conservation cropping, reducing GHG emissions from fed cattle, micro-generation of renewable energy and biogas production through anaerobic decomposition of agricultural materials. Conservation cropping supports less traffic and soil disturbance on cropped areas, resulting in increased organic matter and stored carbon in the soil. This is the most widely used protocol, but novel adoption is expected to be minimal since this measure has been widely adopted in the past. The fed-cattle protocol, adopted by some feedlots, supports a reduction in time spent in feedlots through improved efficiencies. A beef genetics protocol supports the use of cattle that are bred for more efficient feed use in order to reduce GHG emissions. The micro-generation protocol supports carbon offsets for either solar or wind power production, small scale and connected to the grid. The potential return is one cent per kWh at current carbon prices. This protocol has recently become operational and has not yet been widely used. The biogas protocol, adopted by large biogas plants, focuses on using agricultural waste to generate CH_4 and CO_2 used in electricity or renewable natural gas production (Government of Alberta 2020).

Since 1990 agricultural producers, especially in Alberta and Saskatchewan, have made important contributions to retaining organic material and carbon in soil for economic reasons and best agricultural management practices (Fan et al. 2019). Recent National Inventory reports have mentioned these positive developments but caution of a reversal of this trend due to financial and market pressures (ECCC 2020). Alberta's emission offset system has made important contributions (Swallow and Goddard 2013). In 2011, the government of Alberta reported a reduction of 3.2 million tonnes of CO_2 eq from the atmosphere with the adoption of approved agricultural protocols (Government of Alberta 2011). A study by the University of Alberta in 2012 collected data from Alberta agricultural producers, through a survey and direct interviews, to understand factors affecting their participation in carbon markets. They found that local markets and farm-specific factors affected participation more than global or provincial benefits. The influence of local aggregators bridging the gap between producers and companies interested in purchasing offsets appeared to be key. Unfortunately, aggregators charge high fees and do not provide sufficient technological support to producers (Nordstrom and Swallow 2012).

The Canadian Fertilizer Institute, in partnership with Alberta Innovates Bio Solutions and the Climate Change and Emissions Management Corporation (CCEMC), initiated Farming 4R Land for Alberta's producers. The goal of this initiative was to demonstrate economic, social and environmental returns by implementing a 4R Nutrient Stewardship: using the right source at the right rate, at the right time and in the right place. This program protects soil quality and minimizes nutrient loss through efficient fertilizer applications. Beneficial management practices were recommended in order to reduce emissions through the Nitrous Oxide Emissions Reduction Protocol (NERP) when producers applied fertilizers on their fields. Alberta approved the use of NERP in its regulatory carbon marketplace in 2010, and producers began earning offset credits. Adapting this protocol resulted in a net economic benefit ranging from $9/acre to about $87/acre (Canadian Fertilizer Institute 2017). Research is being conducted to measure actual nitrous oxide emission reductions using the NERP protocol and to develop verified estimates that could be included in the national inventory.

Cost-sharing and payment programs, such as Alberta's agricultural carbon offset program, encourage the adoption of BMPs and are widely implemented. However, it is unclear whether the regulatory standards are clearly designed and whether the BMPs are correctly identified for the farm or business. One option presented by Kröbel et al. (2021) is a cross-compliance approach that combines environmental policy standards with farm income support payments to cover some of the trade-offs to achieving the desired policy outcomes, such as climate resiliency and environmental sustainability. The authors also stress the importance of involving farmers and businesses in research and development projects conducted by agricultural research institutions. This promises the development of relevant, applicable and endorsable BMPs, as well as increased communication-building processes between policy-makers and the agri-business community. In addition, this allows a better way to track BMPs and their adoption, with these data more readily available for use in estimation models and national reporting systems.

Saskatchewan

Agriculture contributes approximately 24 per cent of Saskatchewan's GHG emissions (Government of Saskatchewan 2021) and it is unclear whether this includes emissions from energy use (i.e., fuel for driving) and industrial processes (i.e., fertilizer manufacture). In 2018, GHG emissions in Saskatchewan reached approximately 76.4 Mt CO_2 eq (ECCC 2020). This computes to 18.3 Mt CO_2 eq emitted by Saskatchewan's agricultural sector.

Saskatchewan's policies are found in its Climate Resilience Measurement Framework, wherein 25 resilience measures were adopted, including total of agricultural land under permanent cover, total amount of soil organic matter accumulated in cultivated land, percentage of land with 4R nutrient stewardship plan and total protected areas in Saskatchewan. In a 2020 scorecard, other than total amount of soil organic matter, which was ranked as decreasing, all indicators showed either improvements or being maintained. Approximately 0.3 per cent of agricultural land area had a 4R nutrient stewardship plan in 2019, and this was maintained (Government of Saskatchewan 2020a).

Saskatchewan is subject to the federal carbon tax. It recently lost its challenge in the Supreme Court of Canada and has been unsuccessful in negotiating an alternative plan that the federal government will accept. Saskatchewan has an output-based pricing system for large emitters. This pricing system ensures there is a carbon price that includes a federal fuel charge and a price incentive for industrial emitters to reduce their emissions, and innovate, while maintaining competitiveness for reductions.

Saskatchewan also provides incentives for BMPs for agriculture including drainage stewardship, native rangeland and grazing management, permanent tame and native forage and riparian grazing management (Government of Saskatchewan 2020b).

Manitoba

In 2018, agriculture contributed approximately 31 per cent of Manitoba's GHG emissions, excluding emissions from energy use, reaching approximately 6.7 Mt CO_2 eq (Government of Manitoba 2021).

Manitoba decided in 2018 not to establish and implement a carbon pricing system, and therefore, the federal carbon pollution pricing system applies (Government of Canada 2019), despite a recent appeal to the Supreme Court of Canada (Petz 2021). It has an output-based pricing system for large emitters (Agriculture and Agri-Food Canada 2018) and has implemented several incentive programs for the reduction of GHG emissions associated with agriculture. These include the

Canada-Manitoba Farm Stewardship Program, Covering New Ground, the Manitoba Sustainable Agricultural Practices Program, Environmental Farm Action Program, the Riparian Tax Credit and many agricultural BMPs to reduce emissions. These programs support incentive funding for these BMPs with climate change adaptation and mitigation co-benefits, commencing lifecycle assessments on everything from solar panels to beef, pork and bio-ethanol, wheat and canola (Government of Manitoba 2020).

Other Provinces and Territories

In 2018, agriculture contributed approximately three per cent of British Columbia's GHG emissions (Government of British Columbia 2020). Total GHG emissions reported by the province reached 67.9 Mt CO_2 eq; the contribution from agriculture computes to 2.0 Mt CO_2 eq (Government of British Columbia 2020).

In 2018, agriculture contributed approximately 9.6 per cent of Quebec's GHG emissions, corresponding to 7.8 Mt CO_2 eq (Government of Quebec 2020). In Ontario, agriculture is responsible for five per cent of GHG emissions (Government of Ontario 2021). Total GHG emissions in Ontario reached approximately 160 Mt CO_2 eq; the contribution from agriculture computes to eight Mt CO_2 eq (ECCC 2020).

While British Columbia has an explicit price-based system and carbon tax at $35 and Alberta has a carbon price of $30 per tonne (Agriculture and Agri-Food Canada 2018), Ontario and Quebec have a cap-and-trade system with a carbon price of $15-$20. Carbon pricing is not uniform in relation to agriculture across the provinces. In addition, there is a lack of data that affects the resulting calculation of whether agricultural land is acting as a sink for GHG emissions.

In 2018, 82 per cent of agricultural soils showed net carbon releases in the atmosphere in Ontario (OMAFRA 2018). Although science confirms agricultural practices can turn land into a carbon sink (Gan et al. 2014), these practices have no policy regulating their adoption.

HOW DO THESE POLICIES COMPARE TO INTERNATIONAL POLICIES AND MEASURES?

International governance mechanisms include national offset systems, expanding voluntary carbon markets and government and industry-led cost-share programs (ECCC 2019). Carbon offsets are not enough as emissions continue to rise (Colombo and Rocamora-Montiel 2018; Kragt et al. 2017; Niles et al. 2016) and a suite of policy instruments are required to protect against soil degradation and desertification and enhance efficiency in the food supply chain (IPCC 2019; Monahan et al. 2020). In the land sector, carbon markets are challenging to implement. The EU, Switzerland, the Republic of Korea, Quebec and California all have emission trading systems (ETS) (Narassimhan et al. 2018), but none have included non-CO_2 (methane and nitrous oxide) emissions from agriculture. New Zealand is considering ways to incorporate agriculture into its ETS. Lack of implementation is due to several reasons: the large number of heterogeneous buyers and sellers; the difficulties of monitoring, reporting and verifying emissions from biological systems introduce potentially high levels of complexity (Wilkes et al. 2017); adverse costs passed on to consumers; the impact on social equity (such as food prices) (Grosjean et al. 2018; Haites 2018); carbon leakage that detracts from jurisdictions being the first adopters; and either losing trade or business to a jurisdiction without carbon pricing (Fellmann et al. 2018). Border adjustments, whereby products coming from jurisdictions without carbon pricing are taxed, can reduce leakage but may exacerbate regional inequality (Böhringer et al. 2012) and contravene WTO rules.

Because agriculture is an important component of its economy, New Zealand is considering incorporating agricultural non-CO_2 gases into existing national ETSs. Although some producer groups have raised concerns, there is generally greater acceptance of the need for climate policies in agriculture (New Zealand Productivity Commissions 2018; IPCC 2019). The issue is complex due to the large number of participants (buyers and sellers) and debate centres around whether obligations should be at the individual farm level or the processor level (ICCC 2018; Beca Ltd. 2018). There is discussion of treating methane, a short-lived gas, differently than nitrous oxide, a long-lived gas (Allen et al. 2016) with respect to its CO_2 equivalent calculation. The recent IPCC report distinguishes between fossil methane and other methane sources and differentiates between the global warming potentials (IPCC 2021).

POLICY OUTCOMES

Carbon pricing is environmentally effective and relatively low cost. It includes carbon taxes, fuel taxes, carbon markets (cap-and-trade systems or ETSs) or baseline and credit schemes and voluntary markets (IPCC 2019). Cap-and-trade systems are generally more cost effective, but the design of the systems is critical. These policies have demonstrated efficiency and effectiveness in other sectors (IPCC 2019). As the agricultural sector in Canada, and globally, has not yet been fully exposed to carbon pricing, finding the right system for a specific context is a work in progress. For effectiveness, agricultural carbon policies will need to be adapted and co-ordinated globally, and considerations of consumption policies, especially those that reduce food spoilage and waste, are required (OECD 2015).

Successful policies support technological solutions to emission reductions and do not face significant barriers to uptake. Such technical measures include adopting zero emissions on farm machinery and equipment, no-till practices, optimizing animal feed and additives, feed grain processing for improved digestibility, genetic selection and breeding and policies that support expanding the use of anaerobic manure digestions, using nitrification inhibitors and expanding the use of controlled-release and stabilized fertilizers (Ahmed et al. 2020). BMPs and farm stewardship programs support many of these techniques.

IMPLICATIONS OF GHG EMISSION REDUCTIONS ON THE ECONOMY

GHG emission reductions have important benefits for international trade, contrary to opinions that there is only an economic downside to GHG emission reduction measures that increase the cost of agricultural production. Certifications are important to consumers as they become more mindful of climate change and the environment. International standards are shaping global trade expectations and increasing understanding of sustainability, as well as the science of accounting, verification and reporting. Some of these initiatives increase their farm output value over traditional commodity prices (Banerjee et al. 2013). Internationally, many standards and certifications have emerged for sustainability in relation to sustainable bio-economy in trade, as outlined in Table 1 (Priefer et al. 2017; Johnson 2017; Bennich and Belyazid 2017).

Examples of standards and certification schemes focusing on land and climate appear in Table 1. There are certifications specific to particular crops and also more general international good practice guidelines, voluntary standards and jurisdictional (EU) approaches (Scarlat and Dallemand 2011; Stattman et al. 2018; ISEAL Alliance 2020). Other frameworks, such as the Global Bioenergy Partnership, focus on monitoring land and biomass use through a set of indicators that are applied across partner countries, promoting technology (knowledge) transfer (GBEP 2017).

Recent focus is on imported deforestation, which occurs from increasing demand and trade in unsustainable forest and agricultural products by tracing supply chain impacts from producer to consumer (Pendrill et al. 2019). Research and implementation efforts aim to improve supply chain transparency and promote commitments to zero deforestation (Gardner et al. 2018; Garrett et al. 2019; Newton and Benzeev 2018; Godar and Gardner 2019; Godar et al. 2015). France has developed specific policies on imported deforestation that are expected to eventually include a zero deforestation label (Government of France 2018).

Table 1. Standards and Certifications for Sustainability in a Bio-economy

			Environmental						Socio-economic		
Scheme Program or Standard	**Commodity/ processes**	**Type of Mechanism**	**GHG Emissions**	**Biodiversity**	**Carbon Stock**	**Soil**	**Air**	**Water**	**Land-use**	**Land Rights**	**Food Security**
Intl. sustainability and carbon certification	All feedstocks, all supply chains	Cert.	+	+	+	+	+	+	+	+	+
Roundtable on sustainable biomaterials EU	Biomass for biofuels and biomaterials	Cert.	+	+	+	+	+	+	+	+	+
Sustainable agriculture	Various agricultural crops and commodities; linked to rain forest alliance	Technical Network		+	+	+	+	+	+	+	+
Roundtable on sustainable palm oil RED	Palm oil products	Cert	+	+	+	+	+	+	+	+	+
Bioenergy ISO 13065 2015	Biomass and bioenergy, including conversion processes	Standard	+	+	+	+	+	+	+	+	+

Adapted from IPCC (2019)

IMPLICATIONS OF GHG EMISSION REDUCTIONS ON WHOLE FARM SYSTEM ECONOMICS AND COST-BENEFIT ANALYSES

The Economics of Land Degradation Initiative provides common guidelines for economic assessments of land degradation (Nkonya et al. 2013). Sustainable land management and restoring and rehabilitating degraded lands are high-return actions from environmental, economic and social perspectives. Practices that stimulate soil carbon and nutrients, in principle, should deliver the same yields with less input and hence be economically viable. A suite of case studies conducted in various settings across the world showed that each dollar invested into land restoration activities could yield between $3 to $6 of economic returns over a 30-year period (Nkonya et al. 2015, 2016). One three-year study of Canada's 4R Fertilizer program documented an increase in profit for P.E.I. potato farmers from $80-$120 per acre (Fertilizer Canada 2017). It is probable that a suite of policy instruments will be required in addition to cap-and-trade, carbon pricing and supply-side measures (IPCC 2019; Franks and Hadingham 2012).

RECOMMENDATIONS FOR POLICY RESEARCH AND FUTURE MEASURES

POLICY AS A DRIVER FOR CHANGE

Agricultural policies addressing climate change mitigation have been discussed for some time. Although much work is occurring in relation to emission inventories and guidelines, instrumental agricultural policy-making and the research surrounding it are in their infancy. Each jurisdiction has its specific soils, agricultural and food production practices, as well as its own climate context, and global directives may not be context-appropriate. For instance, while it is well-documented that a diet with less meat is healthier and more sustainable, in some areas of the world people need to eat more red meat (IPCC 2019). A carbon price advances agricultural mitigation but at a cost to food security that plays out in food calorie losses that could trigger undernourishment. This may have disproportionate impacts on developing countries (Frank et al. 2017).

NEXT STEPS IN POLICY RESEARCH

A great body of knowledge exists regarding agricultural land management practices that can turn land from a source to a sink for GHGs (IPCC 2019). However, there is a lack of evidence regarding the efficiency and effectiveness of specific policy instruments that will encourage uptake of these practices. Disparate studies have been conducted on policies such as greening provisions in the Common Agricultural Policy of the European Union in Italy (Solazzo et al. 2016), and grey literature exists (Harris et al. 2009). The Organisation for Economic Co-operation and Development (OECD) concluded that in order to be as cost effective as possible, market-based mitigation policies are required (OECD 2015). Due to constraints related to food security, distributional impacts on producers, emission leakages and institutional capacity challenges such as monitoring, reporting and verification of emission reductions, a widespread implementation of effective mitigation policies is required in the agricultural sector. Policies including beneficiaries pay, for example, with respect to methane production from enteric fermentation, are the most efficient in increasing agricultural productivity and implementing a tax on emission-intensive consumer products such as meat and dairy (OECD 2015; Baumol and Oates 1988). However, such policies may not be the most palatable policies for government, industry or the general public since meat and dairy products are typically considered necessity commodities with little elasticity in demand (Lockwood and Taubinsky 2017). Strategies could be considered that improve consumer uptake and acceptability of a potential carbon tax imposition on agricultural products, although one major concern for both government and industry is the impact on the economy (Carattini et al. 2018). The authors also address public opposition to carbon taxes and suggest that understanding public attitudes toward environmental taxation enables policy-makers to design carbon taxes so that they are acceptable to voters and passed into legislation. Policy research opportunities and design option suggested by

Carattini et al. (2018) include: (1) phasing in carbon taxes gradually; (2) earmarking (hypothecation) tax revenues for additional climate change mitigation; (3) redistributing taxes to improve fairness and ease the impact on low-income households; and (4) information sharing and communication through public consultations to address voter concerns at a relatively early stage of designing a carbon tax. The importance of communication seems to be largely neglected. Perceptions of a carbon tax may improve over time with continued efforts for regular reporting, transparency and more visibility of the effects of carbon taxes, improving the credibility of governments and policy-makers and increasing adoptability.

CONCLUSIONS

There is an opportunity to find policy solutions that combine increasing farm net incomes while reducing agricultural GHG emissions in Canada. Agriculture is a sector that emits significant amounts of GHG emissions in Canada, and with targets of achieving net zero emissions by 2050, consideration of agricultural practices, policies and models for calculating emissions is timely. While all three Prairie Provinces in Canada practise BMPs and encourage farm stewardship programs, Alberta agriculture is currently subject to more carbon pricing.

With more than two billion people employed globally by the agricultural sector, it has complicated objectives in relation to food security, biodiversity, nutritional needs and livelihoods alongside climate goals (Ahmed et al. 2020). Nevertheless, to achieve net zero emissions in Canada by 2050, the agricultural sector will need to be a part of the solution.

Many GHG emission estimation models have been developed and the user-friendly models are available for farmers and agri-businesses willing to determine their overall carbon footprint and to explore options for reducing their emissions (Fouli et al. 2021). The more user-friendly models are developed and the more producers and businesses use them, the better the model validation processes and the higher the communication and trust between policy-makers and the agri-business community. The more real data are available for modelling long-term calculations and estimations, the more accurate the information in the National Inventory Reports and the more accessible these reports become. Upscaling model use and BMPs through policy and practice is increasingly important and key to the sustainability of agricultural production in Canada and globally.

REFERENCES

Agriculture and Agri-Food Canada. 2018. "Agriculture and Climate Change Policy. Financial Impacts of Carbon Pricing on Canadian Farms." http://multimedia.agr.gc.ca/pack/pdf/carbon_price_presentation1-eng.pdf.

———. 2021. "Helping Farmers to Reduce GHGs and Improve Resiliency to Climate Change." Government of Canada news release. August 12. https://www.canada.ca/en/agriculture-agri-food/news/2021/08/helping-farmers-to-reduce-ghgs-and-improve-resiliency-to-climate-change.html?mc_cid=12c6f87700&mc_eid=fb926dadf4.

Ahmed, J., E. Almeida, D. Aminetzah, N. Denis, K. Henderson, J. Katz et al. 2020. "Agriculture and Climate Change. Reducing Emissions Through Improved Farming Practices." McKinsey and Company. https://www.mckinsey.com/~/media/mckinsey/industries/agriculture/our%20insights/reducing%20agriculture%20emissions%20through%20improved%20farming%20practices/agriculture-and-climate-change.pdf.

Alberta Carbon Registries. 2020. Alberta Emission Performance Credit Registry. CSA Group and the Government of Alberta: Alberta Environment and Parks. https://alberta.csaregistries.ca/GHGR_Listing/About.aspx.

Allen, M. R., J. S. Fuglestvedt, K.P. Shine, A. Reisinger, R.T. Pierrehumbert, and P.M. Forster. 2016. "New Use of Global Warming Potentials to Compare Cumulative and Short-lived Climate Pollutants." *Nature Climate Change*, 6(8), 773–776. https://doi:10.1038/nclimate2998.

ALUS. 2021. https://alus.ca/.

Banerjee, A., E. Rahn, P. Läderach, and R. van der Hoek. 2013."Shared Value: Agricultural Carbon Insetting for Sustainable, Climate-Smart Supply Chains and Better Rural Livelihoods." CIAT Policy Brief No. 12. Centro Internacional de Agricultura Tropical (CIAT), 6.

Baumol, W. J., and W. E.Oates. 1988. *The Theory of Environmental Policy. Cambridge*: Cambridge. Online ISBN: 9781139173513. https://doi.org/10.1017/CBO9781139173513.

Beca Ltd. 2018. "Assessment of the Administration Costs and Barriers of Scenarios to Mitigate Biological Emissions from Agriculture." https://www.mpi.govt.nz/dmsdocument/32146/direct.

Bennich, T., and S. Belyazid. 2017. "The Route to Sustainability: Prospects and Challenges of the Bio-Based Economy." *Sustainability*, 9(6), 887. doi:10.3390/su9060887.

Böhringer, C., J. C. Carbone, and T. F. Rutherford. 2012. "Unilateral Climate Policy Design: Efficiency and Equity Implications of Alternative Instruments to Reduce Carbon Leakage." *Energy Economics*, 34, S208–S217. https://doi.org/10.1016/j.eneco.2012.09.011.

Canadian Fertilizer Institute. 2017. "Alberta: Farming 4R Land. Supporting Farmers and Communities with Practical Tools to Implement Best Management Practices that Protect Soil Quality and Grow Agriculture." https://eralberta.ca/wp-content/uploads/2017/05/Nutrient-Stewardship-Report-1.pdf.

Carattini, S., M. Carvalho, and S. Fankhauser. 2018. "Overcoming Public Resistance to Carbon Taxes." Wiley Interdisciplinary Reviews: Climate Change, 9(5), e531. doi:10.1002/wcc.531.

Colombo, S., and B. Rocamora-Montiel. 2018. "Result-oriented Agri-environmental Climate Schemes as a Means of Promoting Climate Change Mitigation in Olive Growing." *Outlook on Agriculture*, 47(2), 141–149. http://doi.org/10.1177/0030727018770931.

Environment and Climate Change Canada (ECCC). 2019. "Carbon Pollution Pricing: Options For a Federal GHG Offset System." https://www.canada.ca/en/environment-climate-change/services/climatechange/pricing-pollution-how-it-will-work/federal-offset-system.html.

———. 2020. "National Inventory Report 1990–2018: Greenhouse Gas Sources and Sinks in Canada." http://publications.gc.ca/collections/collection_2020/eccc/En81-4-1-2018-eng.pdf.

Fan, J., B. G. McConkey, B. C. Liang, D. A. Angers, H. H. Janzen, R. Kroebel et al. 2019. "Increasing Crop Yields and Root Input Make Canadian Farmland a Large Carbon Sink." *Geoderma*, 336: 49–58. http://doi.org/10.1016/j.geoderma.2018.08.004.

Fellmann, T., P. Witzke, F. Weiss, B. Van Doorslaer, D. Drabik, I. Huck et al. 2017. "Major Challenges of Integrating Agriculture into Climate Change Mitigation Policy Frameworks." *Mitigation and Adaptation Strategies for Global Change*, 23(3): 451–468. https://doi.org/10.1007/s11027-017-9743-2.

Fertilizer Canada. 2017. "Getting 4R Sustainability Right. Fertilizer Canada: 4R Nutrient Stewardship Sustainability Report." Agriculture and Agri-food Canada.

Fouli, Y., M. Hurlbert, and R. Kröbel. 2021. "Greenhouse Gas Emissions from Canadian Agriculture: Estimates and Measurements." University of Calgary School of Public Policy.

Frank, S., P. Havlik, J-F. Soussana, A. Levesque, H. Valin, E. Wollenberg et al. 2017. "Reducing Greenhouse Gas Emissions in Agriculture Without Compromising Food Security?" Environ. Res. Lett. 12. (10). Https://doi.org/10.1088/1748-9326/aa8c83.

Franks, J. R., and B. Hadingham. 2012. "Reducing Greenhouse Gas Emissions from Agriculture: Avoiding Trivial Solutions to a Global Problem." *Land Use Policy,* 29(4): 727–736. https://doi.org/10.1016/j.landusepol.2011.11.009.

Gan, Y., C. Liang, Q. Chai, R. L. Lemke, C. A. Campbell, and R. P. Zentner. 2014. "Improving Farming Practices Reduces the Carbon Footprint of Spring Wheat Production." Nat. Commun. 5: 5012.

Gardner, T. A., M. Benzie, J. Börner, E. Dawkins, S. Fick, R. Garrett et al. 2018. "Transparency and Sustainability in Global Commodity Supply Chains." *World Development*, 121: 163–177. https://doi.org/10.1016/j.worlddev.2018.05.025.

Garrett, R. D., S. Levy, K. M. Carlson, T. A. Gardner, J. Godar, J. Clapp et al. 2019. "Criteria for Effective Zero-deforestation Commitments." *Global Environmental Change*, 54: 135–147. https://doi.org/10.1016/j.gloenvcha.2018.11.003.

Global BioEnergy Partnership (GBEP). 2017. "The Global Bioenergy Partnership: A Global Commitment to Bioenergy." Food and Agriculture Organization of the United Nations, 4.

Godar, J., and T. Gardner. 2019. "Trade and Land Use Telecouplings." In *Telecoupling: Exploring Land-use Change in a Globalised World*, C. Friis, J. Ø. Nielsen, eds. Cham, Switzerland: Springer International Publishing, 149–175.

Godar, J., U. M. Persson, E. J. Tizado, and P. Meyfroidt, 2015. "Methodological and Ideological Options Towards More Accurate and Policy Relevant Footprint Analyses: Tracing Fine-scale Socio-environmental Impacts of Production to Consumption." *Ecol. Econ.*, 112: 25–35. https://doi.org/10.1016/j.ecolecon.2015.02.003.

Government of Alberta. 2011. "Agricultural Carbon Offsets – Information for Alberta's Offset Market: Advance Notice of Upcoming Changes to Protocols." https://www1.agriculture.alberta.ca/$Department/deptdocs.nsf/ba3468a2a8681f69872569d60073fde1/2e6e7bd43e2f18448725734f007441ee/$FILE/Information%20Update.pdf.

———. 2020. "Agricultural Carbon Offsets – All Protocols Update." https://www.alberta.ca/agricultural-carbon-offsets-all-protocols-update.aspx.

———. 2021. "Climate Change in Alberta. How the Causes and Impacts of Climate Change Could Affect Alberta's Environment, Health and Economy." https://www.alberta.ca/climate-change-alberta.aspx.

Government of British Columbia. 2020. “Provincial Greenhouse Gas Emissions Inventory.” https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory.

Government of Canada. 2019. “Manitoba and Pollution Pricing.” manitoba and pollution pricing - Canada.ca.

Government of France. 2018. “Ending Deforestation Caused by Importing Unsustainable Products.” November 14. https://www.gouvernement.fr/en/ending-deforestation-caused-by-importing-unsustainable-products.

Government of Manitoba. 2020. “Mitigation Activities in Agriculture.” https://www.gov.mb.ca/.

———. 2021. “Agriculture and Climate Change: Agricultural Greenhouse Gas Emissions.” Agriculture and Resource Development. https://www.manitoba.ca/agriculture/environment/climate-change/agriculture-and-climate-change.html.

Government of Ontario. 2021. “Climate Change and Agriculture.” Ministry of Agriculture, Food and Rural Affairs. http://www.omafra.gov.on.ca/english/engineer/facts/climatechange.htm.

Government of Quebec. 2020. “Inventaire Québécois des émissions de gaz à effet de serre en 2018 et leur évolution depuis 1990.” https://www.environnement.gouv.qc.ca/changements/ges/2018/inventaire1990-2018.pdf

Government of Saskatchewan. 2020a. “Climate Resilience in Saskatchewan.” 2020 Report.

———. 2020b. “Farm Stewardship Program.” https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/canadian-agricultural-partnership-cap/environmental-sustainability-and-climate-change/farm-stewardship-program-fsp.

———. 2021. “Emissions in Saskatchewan.” https://www.saskatchewan.ca/business/environmental-protection-and-sustainability/a-made-in-saskatchewan-climate-change-strategy/emissions-in-saskatchewan.

Grosjean, G., S. Fuss, N. Koch, B. L. Bodirsky, S. De Cara, and W. Acworth. 2016. “Options to Overcome the Barriers to Pricing European Agricultural Emissions.” *Climate Policy*. https://doi.org/10.1080/14693062.2016.1258630

Haites, E. 2018. “Carbon Taxes and Greenhouse Gas emissions Trading Systems: What Have We Learned?” *Climate Policy*, 18: 955–966. https://doi.org/10.1080/14693062.2018.1492897.

Harris, D., G. Jones, J. Elliott, J. William, B. Chambers, and R. Dyer. 2009. “RMP/5142 Analysis of Policy Instruments for Reducing Greenhouse Gas Emissions from Agriculture, Forestry and Land Management.” https://www.fcrn.org.uk/sites/default/files/climate-ag-instruments.pdf.

Intergovernmental Panel on Climate Change (IPCC). 2018. “Summary for Policymakers.” *Global Warming of 1.5°C. World Meteorological Organization, 32.* https://www.ipcc.ch/sr15/chapter/spm/.

———. 2019. “Climate Change and Land.” https://www.ipcc.ch/site/assets/uploads/2019/11/SRCCL-Full-Report-Compiled-191128.pdf.

———. 2021. “Summary for Policymakers.” Climate Change 2021: The Physical Science Basis. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

Interim Climate Change Committee (ICCC). 2018. “Interim Climate Change Committee Terms of Reference and Appointment.” Ministry for the Environment, 7.

ISEAL Alliance. 2020. “Sustainability Standards.” https://www.isealalliance.org/about-iseal/who-we-are.

Johnson, F. X. 2017. “Biofuels, Bioenergy and the Bioeconomy in North and South.” *Industrial Biotechnology*, 13: 289–291. https://doi.org/10.1089/ind.2017.29106.fxj.

Kragt, M. E., N. P. Dumbrell, and L. Blackmore. 2017. “Motivations and Barriers for Western Australian Broad-acre Farmers to Adopt Carbon Farming.” *Environmental Science and Policy*, 73: 115–123. http://doi.org/10.1016/j.envsci.2017.04.009.

Kröbel, R., E. C. Stephens, M. A. Gorzelak, M-N. Thivierge, F. Akhter, J. Nyiraneza et al. 2021. “Making Farming More Sustainable by Helping Farmers to Decide Rather Than Telling Them What to Do.” Environ. Res. Lett. 16 055033. https://doi.org/10.1088/1748-9326/abef30.

Lockwood, B. B., and D. Taubinsky. 2017. “Regressive Sin Taxes.” Working Paper 23085. NBER Working Paper Series. National Bureau of Economic Research. https://www.nber.org/system/files/working_papers/w23085/w23085.pdf.

Monahan, K., B. Filewod, J. McNally, and S. Khalaj. 2020. “Nature-Based Solutions: Policy Options for Climate and Biodiversity.” Smart Prosperity Institute. https://institute.smartprosperity.ca/sites/default/files/nbsreport.pdf.

Narassimhan, E., K. S. Gallagher, S. Koester, and J. R. Alejo. 2018. “Carbon Pricing in Practice: A Review of Existing Emissions Trading Systems.” *Climate Policy*. https://doi.org/10.1080/14693062.2018.1467827.

New Zealand Productivity Commission. 2018. "Low-Emissions Economy: Final Report," 588.

Newton, P., and R. Benzeev. 2018. "The Role of Zero-deforestation Commitments in Protecting and Enhancing Rural Livelihoods." *Current Opinion in Environmental Sustainability*, 32: 126–133. https://doi.org/10.1016/j.cosust.2018.05.023.

Niles, M. T., M. Brown, and R. Dynes. 2016. "Farmers' Intended and Actual Adoption of Climate Change Mitigation and Adaptation Strategies." *Climatic Change*, 135(2): 277–295. http://doi.org/10.1007/s10584-015-1558-0.

Nkonya, E., W. Anderson, E. Kato, J. Koo, A. Mirzabaev, J. von Braun et al. 2015. "Global Cost of Land Degradation." In *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*, E. Nkonya, A. Mirzabaev, and J. von Braun, eds. Cham, Switzerland: Springer International Publishing, 117–165. https://doi.org/10.1007/978-3-319-19168-3_6.

Nkonya E., A. Mirzabaev, and J. von Braun. 2016. "Economics of Land Degradation and Improvement: An Introduction and Overview." In *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*, E. Nkonya, A. Mirzabaev, and J. von Braun, eds. Cham, Switzerland: Springer International Publishing,. 1–14.

Nkonya, E., J. von Braun, A. Mirzabaev, Q. B. Le, H.Y. Kwon, and O. Kirui. 2013. "Economics of Land Degradation Initiative: Methods and Approach for Global and National Assessments." ZEF – Discussion Papers on Development Policy No. 183, 41. https://doi.org/10.2139/ssrn.2343636.

Nordstrom, O., and B. Swallow. 2012. "Effectively Turning Knowledge to Action: Agriculture's Adoption of Alberta's Carbon Offset Protocols." University of Alberta School of Business and Department of Resource Economics and Environmental Sociology. https://learnnetwork.ualberta.ca/learnnetwork/wp-content/uploads/sites/70/2018/07/Poster-06-2012_Nordstrom-Swallow.pdf?ver=2016-06-14-112253-093.

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2018. "New Horizons: Ontario's Agricultural Soil Health and Conservation Strategy." http://www.omafra.gov.on.ca/english/landuse/soil-strategy.htm.

Organisation for Economic Co-operation and Development (OECD). 2015. *Climate Change Risks and Adaptation: Linking Policy and Economics*. Paris: OECD Publishing. http://dx.doi.org/10.1787/9789264234611-en.

Pendrill, F., M. Persson, J. Godar, and T. Kastner. 2019. "Deforestation Displaced: Trade in Forest-risk Commodities and the Prospects for a Global Forest Transition." Environ. Res. Lett. 14 (5). https://doi.org/10.1088/1748-9326/ab0d41.

Petz, S. 2021. "Manitoba Will Still Push Forward With Carbon Tax Challenge Despite Supreme Court Ruling." CBC. https://www.cbc.ca/news/canada/manitoba/brian-pallister-manitoba-carbon-tax-supreme-court-1.5963884.

Population and Development Review. 2019. "Selected Results of the 2019 UN World Population Projections." 2019. *Population and Development Review*, 45(3): 689–694. https://doi.org/10.1111/padr.12288.

Priefer, C., J. Jörissen, and O. Frör. 2017. "Pathways to Shape the Bioeconomy." *Resources*, 6 (10). https://doi.org/10.3390/resources6010010.

Roelfsema, M., M. den Elzen, N. Höhne, A. F. Hof, N. Braun, H. Fekete et al. 2014. "Are Major Economies on Track to Achieve Their Pledges for 2020? An Assessment of Domestic Climate and Energy Policies." *Energy Policy*, 67:781–796.

Roelfsema, M., H. L. van Soest, M. Harmsen, D. P. van Vuuren, C. Bertram, M. den Elzen et al. 2020. "Taking Stock of National Climate Policies to Evaluate Implementation of the Paris Agreement." *Nature Communications*, 11(1). doi:10.1038/s41467-020-15414-6.

Scarlat, N., and J-F. Dallemand. 2011. "Recent Developments of Biofuels/Bioenergy Sustainability Certification: A Global Overview." *Energy Policy*, 39: 1630–1646. https://doi.org/10.1016/J.ENPOL.2010.12.039.

Solazzo, R., M. Donati, L. Tomasi, and F. Argini. 2016. "How Effective is Greening Policy in Reducing GHG Emissions in Agriculture? Evidence from Italy." *Science of the Total Environment*, 573: 1115–1124. https://doi.org/10.1016/j.scitotenv.2016.08.066.

Stattman, S., A. Gupta, L. Partzsch, and P. Oosterveer. 2018. "Toward Sustainable Biofuels in the European Union? Lessons from a Decade of Hybrid Biofuel Governance." *Sustainability*, 10(11): 4111. https://doi.org/10.3390/su10114111.

Swallow, B. M., and T. W. Goddard. 2013. "Value Chains for Bio-carbon Sequestration Services: Lessons from Contrasting Cases in Canada, Kenya and Mozambique." *Land Use Policy*, 31: 81–89. http://doi.org/10.1016/j.landusepol.2012.02.002.

Weersink, A., J. Livernois, J. F. Shogren, J. S. Shortle. 1998. "Economic Instruments and Environmental Policy in Agriculture." *Canadian Public Policy*, vol. 14, 3. http://qed.econ.queensu.ca/pub/cpp/Sept1998/Weersink.pdf.

Wilkes, A., A. Reisinger, E. Wollenberg, and S. Van Dijk. 2017. "Measurement, Reporting and Verification of Livestock GHG Emissions by Developing Countries in the UNFCCC: Current Practices and Opportunities for Improvement." CCAFS Rep. No. 17.

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Ymène Fouli grew up in Tunisia where she studied georesources and environmental engineering. She later attended graduate school in Scotland and in the USA where she taught and conducted research in soil science. She continued with research in nutrient management and animal farming in Maryland and Saskatchewan, and later joined a consulting firm in Alberta as an environmental scientist and project manager. She currently consults independently on water and soil quality, watershed management, and climate change.

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