Toward a Low-Carbon and Climate Resilient Agriculture Sector: Policies to Increase the Adoption of Cover Crops in British Columbia

by

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Abstract

British Columbia's (BC) agriculture sector produces greenhouse gasses that contribute to climate change. The agriculture sector is also severely threatened by adverse impacts of a changing climate such as drought, flooding, soil erosion, loss of biodiversity, and more. Increasing the adoption of cover crops is one important pathway to mitigate emissions from and increase the resilience of the province's agriculture sector. However, cover crops are not being adopted to their full potential on farms given the presence of externalities that generate unpriced societal benefits from planting and maintaining cover crops, and additional barriers faced by farmers. I examine five policy measures to address the externality problem as well as alleviate barriers: expand BC's Farm Adaptation Innovator Program (FAIP); carbon sequestration payment; expand BC's Beneficial Management Practices (BMP) program; compulsory cover crop regulation; and a cover crop advisory committee. I recommend that BC expand its FAIP and BMP programs.

Keywords: Cover Crops; Nature-based Solutions; Climate Change; Policy Analysis

To the farmers of today and tomorrow.

Acknowledgements

I have a handwritten note from my grandmother, written many years ago, taped to the wall next to my desk where I did most of my research. It says, “Thankfulness is the soil in which joy grows”. My research journey would have been a lot more challenging if it had not been for the physical and emotional presence of many people. Thank you to my friends, roommates, and family for your unconditional love and support, and for engaging in many capstone conversations around the dinner table.

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List of Acronyms

AAC	Agricultural Advisory Committee
AAFC	Agriculture and Agri-Food Canada
ACS	Agricultural Climate Solutions
AFF	British Columbia Ministry of Agriculture, Food and Fisheries
APF	Agricultural Policy Framework
ARS	Agricultural Research Service
BC	British Columbia
BMP	Beneficial management practice
°C	Degree Celsius
CAP	Canadian Agricultural Partnership
CBCAIP	Canada-BC Agri-Innovation Program
CES	Climate Change Adaptation Program
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalents
CPAS	Climate Preparedness and Adaptation Strategy
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
EFP	Environmental Farm Plan
EQIP	Environmental Quality Incentives Program
FAIP	Farm Adaptation Innovator Program
FCS	Farmers for Climate Solutions
FS	Forest Service
FSA	Farm Service Agency
GHG	Greenhouse Gas
HSP	Healthy Soils Program
KTTP	Knowledge and Technology Transfer Program
MCF	Multi-Criteria Framework
MRV	Measurement, Reporting, and Verification

NbS	Nature-based Solution
NFU	National Farmers Union
NGO	Non-Governmental Organization
NRCS	Natural Resources Conservation Service
N_2O	Nitrous Oxide
RAP	Regional Adaptation Program
RCPP	Regional Conservation Partnership Projects
RGGI	Regional Greenhouse Gas Initiative
RMA	Risk Management Agency
t C ha-1yr-1	Ton of Carbon per Hectare per Year
Tg CO_2e	Teragram of Carbon Dioxide Equivalent
US	United States of America
USDA	United States Department of Agriculture

Preface

I am a settler studying and learning on the unceded territories of the xʷməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), and Səl̓ílwətaʔ/Selilwitulh (Tsleil-Waututh) Nations, whose land stewardship I greatly benefit from. I would like to acknowledge the historical and ongoing impact of agriculture and land enclosure on Indigenous lands and food systems. I would also like to recognize that sustainable agricultural movements often center white voices and expertise while appropriating methods long practiced by Indigenous Peoples. We have a collective responsibility to incorporate Indigenous land title and rights, land stewardship, and ecology meaningfully and respectfully into agricultural decision-making.

Executive Summary

British Columbia's (BC) agricultural sector is severely threatened by climate change. Despite some progress made towards reducing the sector's greenhouse gas (GHG) emissions and increasing its resilience, significant efforts remain. One effective mitigation and adaptation pathway is through increasing the adoption of cover crops. Cover crops can reduce GHG emissions and provide environmental and economic co-benefits. Cover crops can sequester up to 0.51 tons of carbon per hectare per year (t C ha-1yr-1) in BC, and the average abatement cost of increasing adoption is $51 per ton of carbon dioxide equivalent (CO_2e).

However, farmers in BC currently underutilize cover crops since many ecological services do not get priced in market economies and farmers face barriers to adoption. With a focus on annual field cropping systems, this study seeks to address the following research questions: (1) How and why are cover crops used? (2) What are the adoption rates of cover crops across agricultural regions? (3) What factors affect cover crop adoption? (4) What efforts have been and can be used in North America to address the underutilization of cover crops and reduce barriers to adoption? (5) How receptive are farmers to potential new program and policy options? The methodologies used in this study include a literature review; a scan of policies, programs, and research and development initiatives across North America; an online survey; and interviews with farmers, government representatives, agricultural consultants, an academic expert, and not-for-profit representatives.

Two policy options are recommended to address the market failure and barriers to adoption: expansion of BC's Farm Adaptation Innovator Program (FAIP) and BC's Beneficial Management Practices (BMP) program. The key criteria used to assess these policies include effectiveness in increasing the adoption of cover crops and effectiveness in reducing barriers to adoption. Other evaluation criteria included equity, administrate ease, cost to provincial government, and farmer acceptance. These recommendations are accompanied by brief implementation considerations.

Chapter 1.

Introduction

British Columbia's (BC) agricultural sector produces greenhouse gasses (GHG) that contribute to climate change. In 2019, emissions from crop production, on-farm fuel use, and the emission and sequestration of carbon dioxide (CO_2) by agricultural soils accounted for approximately 2.6 percent of BC's total GHG emissions (Ministry of Agriculture, Food and Fisheries, 2022b).[1] BC's agricultural sector is also extremely threatened by climate change. It is projected with high confidence that climate change will continue to produce strong, direct, adverse, and compounding impacts on BC's agricultural sector (Intergovernmental Panel on Climate Change, 2022; International Panel on Climate Change, 2007; Ochuodho et al., 2016).

Cover crops[2] provide a number of ecosystem services[3] that can help mitigate emissions in and increase the resilience of the province's agriculture sector to climate change. The variety of cover crops and flexibility in adoption allow farmers to tailor their application based on agricultural production systems and target specific ecosystem services (Wagg et al., 2021). Some of these services benefit farmers directly such as

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[1] According to BC's provincial inventory, crop production increased GHG emissions 13 percent (65 ktCO_2e) between 2007 and 2019. However, an additional 81 ktCO_2e (129 percent increase between 2007 and 2019) from cropland management was not accounted in the inventory. Cropland management accounted for 143 ktCO_2e of GHGs in 2019 (0.1 percent of the readjusted GHG emissions total).

[2] In this research, a cover crop is defined as a plant that is used to provide a variety of ecosystem services such as slow soil erosion, improve soil health, and increase field and/or crop resilience to extreme weather events. Cover crops may be planted over a whole field or selectively planted. Cover crop species, seeding method, seeding rate, and timing is unique to farmer objectives and conditions. Additional information about cover crops can be found in Chapter 2.

[3] An ecosystem service is defined as "any positive benefit that wildlife or ecosystems provide to people. The benefits can be direct or indirect – small or large" (National Wildlife Federation, n.d.). Four major categories of ecosystem services include provisioning, regulating, cultural and supporting services. A provisioning service is a benefit to people that can be extracted from nature, such as food, drinking water, and plants that can be made in clothing, medicine, or other materials. A regulating service is the benefit provided by ecosystem processes that moderate natural phenomena, such as decomposition, erosion and flood control, carbon storage, and climate regulation. A cultural service is a non-material benefit that contributes to the development and cultural advancement of people, such as how ecosystems play a role in culture, recreation, and the building of knowledge. A supporting service allows the Earth to sustain basic life forms, such as nutrient cycling, the creation of soils, photosynthesis, and the water cycle.

moisture and nitrogen retention on fields. Meanwhile, other services produce environmental co-benefits for society, such as carbon sequestration, for which there are few defined markets. These positive externalities mean that farmers cannot fully recover their costs from planting cover crops, and thus have less incentive to plant them. Farmers[4] also face barriers to adopting cover crops, which can be characterized into five interrelated categories that are explained in Chapter 4: financial, physical, human and social capital, knowledge, and policy and regulation.

To meet BC's climate change adaptation and mitigation targets and avoid more costly outcomes to society in the future, government intervention may be necessary to encourage investments in cover crops (Laporte et al., 2021). Cover cropping may also become increasingly valuable as climate warming progresses and adaptation is increasingly necessary to avoid costly impacts of climate change (Drever et al., 2021; Sterner & Persson, 2008).

With a focus on annual field cropping systems in BC, this study seeks to address the following research questions: (1) How and why are cover crops used? (2) What are the adoption rates of cover crops across agricultural regions? (3) What factors affect cover crop adoption? (4) What efforts have been and can be used to address the underutilization of cover crops and reduce barriers to adoption? (5) How receptive are farmers to potential new program and policy options? In this study, I use a mixed methods research approach to analyze the policy problem, develop criteria to evaluate five policy options, and determine policy recommendations.

Chapter 2 provides background information on BC's agriculture sector, how the sector is impacted by climate change, and how cover crops can be an important Nature-based Solution (NbS) to increase the resilience of the sector and mitigate climate change. Chapter 3 provides an overview of the methodologies used in this study, which include a literature review; a scan of policies, programs, and research and development initiatives across North America; an online survey; and expert interviews. Chapter 4 outlines the key factors that influence cover crop adoption. Chapter 5 presents efforts undertaken by different levels of government, non-profit organizations, and the private sector in Canada and the United States (US) to address the underutilization of cover

[4] The terms 'farmer', 'annual crop producer', and 'producer' are used interchangeably throughout the paper.

crops (market failure) and reduce barriers to adopting cover crops. A multicriteria evaluation framework to analyse policy options for BC is presented in Chapter 6, followed by descriptions of each option under evaluation in Chapter 7. The final chapters evaluate and analyze the options, make recommendations, and provide brief implementation considerations.

Chapter 2.

Background

2.1. British Columbia's Agricultural Sector

BC has eight agricultural regions: Bulkley-Nechako and Fraser-Fort George; Cariboo; Delta; Fraser Valley; Kootenay and Boundary; Okanagan; Peace; and Vancouver Island.[5] Each agricultural region possesses its own character and is known for producing a range of crops that play a large and vital role in BC's economy. In 2018, crop production (excluding unlicensed cannabis) represented 19.5 percent of total agriculture, food and seafood Gross Domestic Product (GDP) and 0.4 percent of total BC GDP (Ministry of Agriculture, Food and Fisheries & Government of Canada, 2019).

BC is experiencing cropland changes. In 2016, field crops accounted for approximately 483,000 acres (33.7 percent) of cropland and summer fallow accounted for approximately 13,000 acres (0.9 percent) of cropland (Ministry of Agriculture, Food and Fisheries, 2016). All reported crops in the province (excluding tame hay and wheat) are increasing in average yield and total production[6] despite the decline in land in crops[7] (Ministry of Agriculture, Food and Fisheries, 2016, 2019).

The number and size of farms, and acres farmed is also changing. In 2016, there were 17,528 farms in BC representing approximately 6.4 million acres (Staciwa, 2017). Nearly half of this land was owned, and the remaining land was leased from governments, non-farmers, other farmers, or rented under other arrangements such as crop-sharing (Statistics Canada, 2017). Since 2011, the number of farms have decreased 11.5 percent, nearly double the national decline of 5.9 percent, and the amount of farmed acres has decreased 0.8 percent compared to the national decline of 0.9 percent (Staciwa, 2017). Like national trends, the size of farms is generally

[5] Region definitions vary slightly by agency; however, this is not germane to the analysis.

[6] At present and before incorporating estimates of climate impacts.

[7] Land in crops has declined 3.1 percent since 2011 (Ministry of Agriculture, Food and Fisheries, 2016)

increasing, even though 67 percent of farms in 2016 were less than 70 acres (Climate & Agriculture Initiative BC, 2021a).

2.2. Climate Change Impacts on British Columbia's Agriculture Sector[8]

BC's soils, climactic conditions, and varied topography provide the conditions for farmers to grow over 200 different commodities for domestic consumption and export (Ministry of Agriculture, Food and Fisheries, 2004). However, changing environmental conditions are challenging the provincial agricultural sector. Acknowledging local variation,[9] BC's climate has warmed significantly in recent decades with increasing average annual temperatures, more extreme weather events, increasing annual precipitation and heavy rainfall events, increasing dry conditions in the summer and more extreme heat, and more frequent and severe wildfires (Climate & Agriculture Initiative BC, 2021a; Ostry & Beveridge, 2011). Projections provided by the Pacific Climate Impacts Consortium indicate that BC can expect these trends to continue (n.d.). These climate trends may lead to field agriculture's declining role in BC's economy; increased reliance on imports from other parts of Canada, the US and Mexico; increased production of nursery and greenhouse products; declines in food processing capacity; and increasing concerns surrounding food safety (Natural Resources Canada, 2019).

2.3. Opportunities for Nature-based Solutions

Nature-based Solutions (NbS)[10] are commonly defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefit" (Cohen-Shacham et al., 2016). In other words, NbS are a suite of

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[8] Appendix A outlines the climate change impacts on Canada's agriculture and agri-food sector.

[9] Each agricultural region will be impacted by climate change differently in the short-, medium-, and long-term. Appendix B provides detailed descriptions of the production systems and top climate concerns to producers occurring in each region.

[10] Similar names to NbS include Beneficial Management Practices (BMPs), soil health practices, regenerative agricultural practices, conservation practices and programs (CPPs), natural climate solutions, climate-smart adaptation strategies and conservation practices. A reason for the use of multiple terms is because different parties interpret some terms to connote government intervention into private decision-making. No universally accepted term has arisen.

protection, improved management, and restoration actions that increase the adaptive capacity[11] of ecosystems, and provide a variety of ecosystem services to farmers and society (Drever et al., 2021; Global Commission on Adaptation, 2019; Godfrey, 2017; International Union for Conservation of Nature, 2016; Norgaard et al., 2021). Commonly used NbS on agricultural lands include rotational grazing, reduced tillage, nutrient management, cover crops, and manure management (Drever et al., 2021). The impact of each NbS on GHG mitigation and environmental co-benefits will vary due to factors such as geography and type of action.

2.3.1. Cover Crops

Cover crops are used in rotations to sustain, recover, or enhance desirable ecological attributes that may be lacking in agroecosystems (Blanco-Canqui et al., 2015). Cover crops may be planted over whole fields or be selectively planted (Ontario Ministry of Agriculture, Food and Rural Affairs, 2021), and can be adapted to fit almost any production system (Sustainable Agriculture Research & Education, 2021). Examples of cover crops include legumes such as alfalfa and clover, grasses such as ryegrass and barley, brassicas such as radishes and turnips, and non-legume broadleaves such as spinach and flax. The species or cover crop mixes, seeding method, seeding rate, and timing may also vary based on conditions such as soil and agro-climatic zones of the region, and farmers' long-term objectives (Abdalla et al., 2019; Blanco-Canqui et al., 2015; Costanzo & Bàrberi, 2014; Daryanto et al., 2018; Faucon et al., 2017; Organic BC, 2019; Snapp et al., 2015; Wagg et al., 2021).

BC is one of the most favourable climates for cover crops in Canada (Farmers for Climate Solutions, 2021). Cover crops consistently ranked first, second, or third for performance in an assessment of NbS in BC that evaluated adoptability, annual GHG benefit potential, and environmental co-benefit potential (Norgaard et al., 2021).[12] The study found that cover crops can sequester between 0.11 and 0.51 tons of carbon per hectare per year (t C ha-1yr-1) in BC (Norgaard et al., 2021). Another study in BC estimates that cover cropping has an annual GHG mitigation potential in 2030 of 0.08

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[11] Adaptive capacity is defined as the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (International Panel on Climate Change, 2007).

[12] This paper provides a detailed analysis of 11 NbS.

teragrams of CO_2 equivalent (Tg CO_2e)[13] on 121,000 hectares (Drever et al., 2021). The average abatement cost of increasing adoption of cover cropping is $51 per ton of CO_2e (Farmers for Climate Solutions, 2021). Cover crops also provide environmental co-benefits. Cover crops can help reduce nutrient losses (e.g., provide organic sources of nitrogen, retain soil nutrients for following crops); improve soil quality (e.g., reduce soil erosion, add organic matter, improve soil fertility, reduce compaction, and improve soil structure); improve water quality and conservation (e.g., water management); and improve biodiversity and support pest management (e.g., improve biodiversity, reduce pest populations and weeds).[14]

Economic analyses indicate that adopting cover crops can provide high returns on investment and generate additional co-benefits. For example, cover crops may reduce input costs (e.g., of synthetic nitrogen fertilizer and herbicides); boost revenue (e.g., increase yields, sale of cover crop biomass as forage); and provide market opportunities (e.g., growing and processing cover crop seeds, planting and/or termination services). Many of these services increase over time and some only occur periodically, depending on weather conditions (Farmers for Climate Solutions, 2021).

However, despite the potential for cover crops to reduce GHG emissions and support adaptation to climate change, adoption rates remain low. In 2015, only 28.1 percent of BC farms reporting field crops used winter cover crops (Government of Canada, 2018).[15] Farm adoption by region varied between 0 and 83 percent, except for the Sunshine Coast where 100 percent of farms used winter cover crops.

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[13] For the purposes of national GHG inventories, emissions are expressed as teragrams of CO_2 equivalent (Tg CO_2e). One teragram is equal to one million metric tons or 10^{12} grams (Environmental Protection Agency, 2005).

[14] Appendix C provides a detailed overview of the major ecological services (i.e., GHG benefits and environmental co-benefits) provided by cover crops that farmers and society benefit from.

[15] There are cover cropping methods beyond winter cover cropping; however, limited disaggregate data is available.

Chapter 3.

Methodology

I use a mixed-methodology approach to gather information for analysis. This includes a literature review; a scan of policies, programs, and research and development initiatives across North America; an online survey; and expert interviews. These qualitative research methods address the research questions identified in Chapter 1.

3.1. Literature review

The literature review includes academic articles, government reports, grey literature, and farming organization documents. This information was used predominantly to inform Chapter 2 on background information and Chapter 4 on factors that influence the adoption of cover crops.

3.2. Scan of Policies, Programs, and Research and Development Initiatives

My review identifies efforts undertaken by different levels of government, non-profit organizations, and the private sector in Canada and the US to address the underutilization of cover crops (market failure) and reduce barriers to adopting cover crops. I focus on North America given the comparable institutional frameworks and geography between both countries. Findings from this policy scan are found in Chapter 5.

3.3. Online Survey

A 20-to-25-minute online survey via Qualtrics was developed and distributed with the intention of understanding trade-offs between, and receptivity of, different policy options aimed at increasing the adoption of cover crops across agricultural regions in Canada.[16] All survey respondents are 18 years old or older, are annual field crop

[16] See Appendix D for the survey questions.

producers in Canada and make land management decisions. During the development phase of the survey, I did considerable outreach with the National Farmers Union (NFU), government representatives, and an academic expert to ensure the subject area is of interest to the BC government and farmers, and that the questions are policy relevant.

The NFU distributed the survey to its membership on my behalf in two bi-weekly bulletins. The NFU has a distribution list of approximately 4,000 email addresses.[17] The composition of its membership is close to a full spectrum of farm types and sizes. However, most of its members are in the small-to-medium-size range for their part of the country, and many farms are certified organic or use environmentally friendly practices. The NFU distributed the survey to its BC contacts as well. Specifically, a standalone email was sent to 26 memberships[18] which includes approximately 49 individual farmers. The BC membership includes a range of farm sizes, most of which have organic or low-input production systems. The survey was also distributed to my existing network for farmers and was encouraged to be shared more widely amongst their farming communities. I also explored avenues to distribute my survey via farming associations and not-for-profit organizations; however, capacity constraints limited their abilities to distribute the survey on my behalf.

The survey received 10 survey responses, one of which did not pass the screening questions and two respondents skipped questions. Amongst the seven who completed each question, three respondents are from BC, and two respondents are from Ontario and Nova Scotia respectively.[19]

3.4. Interviews

Given the lack of survey responses, I expanded my research methodology to include interviews. 12 semi-structured interviews were conducted with farmers, government representatives, agricultural consultants, an academic expert, and not-for-

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[17] Not all NFU members are on the distribution list. Some choose not to get emails, while others do not have email addresses. Moreover, not all the email addresses are NFU members'. Some farming organizations and non-members are on the distribution list.

[18] The NFU allows people to purchase farm units of family memberships. Therefore, many couples and coworkers are on the same membership.

[19] The initial intention was to explore differences in cover crop adoption and receptivity to policy options across Canada; however, the small sample sizes do not make this possible.

profit representatives between February and March 2022.[20] The interviews were conducted via Zoom video conferencing, Microsoft Teams and telephone. The primary goal of the interviews was to gain insight into the trade-offs between policy options and to understand perspectives on government's role in overcoming barriers and increasing the adoption of cover cropping.

I used the snowballing method to acquire interview participants. Some interview questions were posed to all participants, while others were unique to the experiences and positions held by participants. Interview participants were selected based on their knowledge of farming, cover crops, and research interests.

3.5. Limitations

Time and resource constraints limited further outreach for survey and interview participation. The survey sample size is not representative of farmers across the country and should not be considered a substitute for holistic direct engagement. It would have been desirable to extend my work through direct engagement with more community-based, Indigenous, academic expert, and government perspectives. However, a general understanding of their views was derived from the interviews and survey, and from available literature.

[20] See Appendix E for sample interview questions and a list of interview participants.

Chapter 4.

Factors that Influence Cover Crop Adoption

I explore five factors that influence the adoption of cover crops and help explain the wide range of adoption rates across BC's agricultural regions. These factors are interrelated and are identified in the literature as: financial; physical; human and social capital; knowledge; and policy and regulation. Figure 4.1 provides an overview of the factors. The literature includes BC cover crop studies, cover crop studies that are broadly applicable to BC given similarities in geography and/or institutions, and literature on factors that impact the adoption of NbS.

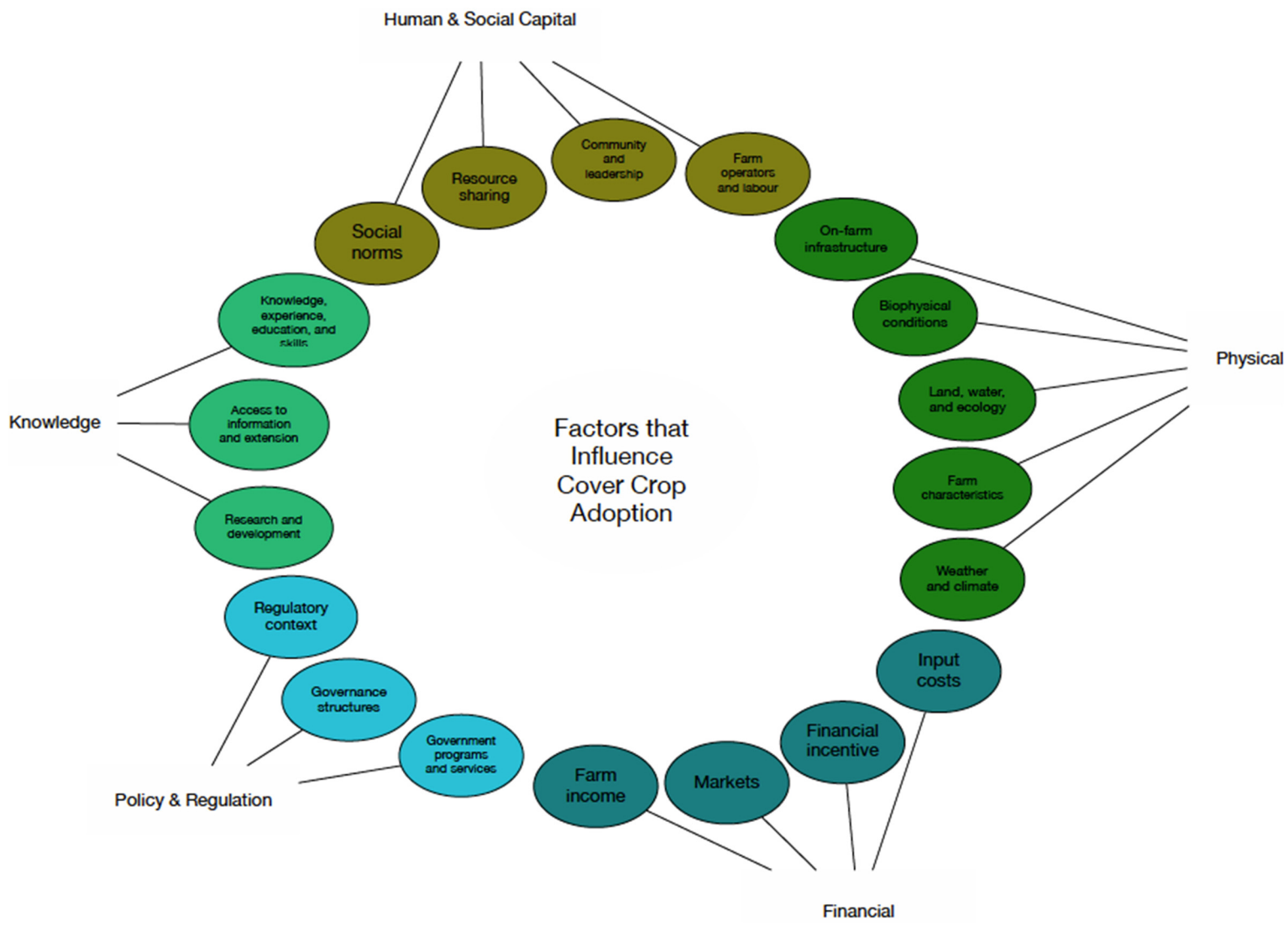

Figure 4.1 Factors that Influence Cover Crop Adoption

4.1. Financial

Sufficient and stable financial resources play a major role in cover crop adoption. Overall farm income, stability of this income, and economic setbacks, such as extreme weather, can compound and affect the ability of farmers to invest, reinvest, and innovate (Crawford & MacNair, 2012).

Costs impact adopters and non-adopters differently. Additional costs associated with cover cropping was the most common barrier limiting new adoption and the third largest challenge for Ontario farmers that grew a cover crop in 2020 (Morrison & Lawley, 2021a). In BC, costs were identified as the biggest barrier to adopting four beneficial management practices under the Canada-BC Environmental Farm Plan Beneficial Management Practices (BMP) Program (Suess et al., 2012).[21] Costs associated with cover cropping include seeds, planting, terminating, sometimes fertilization, and perceived opportunity costs due to uncertain cash crop yield effects (Daryanto et al., 2019; Krajewski, 2017; Laporte et al., 2021; Ranjan et al., 2019; Roesch-McNally et al., 2018; Sarrantonio & Gallandt, 2003; The Green Resilience Project, 2022). Some farmers also perceive a lack of facilitating infrastructure for cover crops, which include markets for alternative crops, as a barrier to adoption (Roesch-McNally et al., 2018). According to an economics report, the estimated cost of implementing cover crops is $47.98 ha-1year-1 (Farmers for Climate Solutions, 2021).[22] Moreover, a 2020 cover crop survey in Ontario found the most common financial amount spent by farms on cover crop seed was between $16 to $20 per acre (Morrison & Lawley, 2021b).[23]

Some farmers may derive cost savings from reducing their synthetic fertilizer nitrogen input and direct benefits from the sale of cover crop biomass as forage (instead of using it as green manure) during the fallow period. Cover crops may also be less costly on net than currently modeled because they deliver ecosystem services such as improved soil health and water quality (Drever et al., 2021; Fawcett-Atkinson, 2021).

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[21] The four BMPs included in the evaluation were Alternative Watering Systems to Manage Livestock; Riparian Buffer Establishment; Irrigation Management; and Wildlife Damage Prevention.

[22] Laporte et al. (2021) provides a detailed economic analysis on the direct costs associated with adopting a variety of cover crops.

[23] The amount paid for cover crop seed by responding farms varied greatly. Some farms paid less than $5 per acre while others paid more than $70 per acre.

Due to farm heterogeneity, it is unclear how the direct costs compare to the savings, and how any cost-benefit analysis will vary with different cash crop and cover crop combinations across regions of the province over time (Daryanto et al., 2019).

Financial incentives, such as cost-share programs, motivate cover crop adoption (Ranjan et al., 2019). A study concluded that monetary incentives were necessary to make adoption feasible since cover crops were perceived by farmers as expensive conservation practices (Atwell et al., 2009). Similarly, two 2020 cover crop surveys (Ontario and the Prairies) identified financial incentives as the most effective method for enabling farmers to continue using and/or increase their acres in cover crops. The Ontario survey also identified payments for storing carbon as the highest enabler for cover crop users and the second highest enabler for non-users (Morrison & Lawley, 2021b, 2021a).

4.2. Physical

The nature and condition of on-farm and surrounding physical resources plays a critical role in the ability of producers to adopt cover crops. This is especially true in terms of variability and extremes in weather; weather can challenge the existing infrastructure and available physical resources considerably (Crawford & MacNair, 2012). Performance of cover crops can also change over time because of climatic changes.[24] This may challenge farmers in having to alter adoption methods across seasons, such as changing cover crop species, mixtures, planting and termination dates, and termination methods. In the Prairies, most observed problems when adopting cover crops in the 2020 growing season pertained to a short growing season and a lack of moisture in the fall (Morrison & Lawley, 2021b). Similarly, the short growing season was identified as a large barrier to adoption in northern BC (The Green Resilience Project, 2022).

Farm characteristics also influence adoption. For example, having land that is vulnerable to erosion can motivate adoption, while a perceived absence of soil or water issues on a farm can hinder adoption (Ranjan et al., 2019). Some farm characteristics can also act as motivators and deterrents for different farmers. For example, winter

[24] Appendix B outlines the top climate concerns to producers in each agricultural region in BC.

cover crops create feeding habitat for waterfowl in the lower Fraser Valley (Bradbeer et al., 2012).[25] Depending on the cropping system and region, cover crops can also introduce new species of pests and may compete for water and nutrients (Sarrantonio and Gallandt, 2003). Motivations for using of cover crops may also differ depending on farming objectives and conditions (Conservation Technology Information Center, 2020; Pagel, 2017). As a result, different seed varieties and techniques for managing the cover crop will be used, which will pose unique barriers to adoption.

The ecological benefits associated with cover cropping (see Chapter 2: Background) act as a motivator to adoption. However, the timing of physiological processes may pose challenges to when benefits of planting cover crops are gained. In a 2020 Ontario cover crop survey, over 40 percent of respondents indicated seeing benefits from growing cover crops within one year (Morrison & Lawley, 2021a). Many of the ecological services gained by planting cover crops only increase over time while some benefits only occur periodically depending on conditions (Myers et al., 2019). The timing for reaping benefits will also differ depending on cover crop species, and management techniques used. Thus, it could take three years to cover seeding costs and five years of continual cover cropping to ensure that total benefits exceed annual costs of cover cropping (Farmers for Climate Solutions, 2021). Biophysical limits for carbon sinks (i.e., the amount of nitrogen and/or carbon the soil can absorb) also impacts the maximum adoption potential of cover crops (Farmers for Climate Solutions, 2021).

Cover crop compatibility with producers' current farming systems acts as another factor that influences adoption (Ranjan et al., 2019). For example, a study by Brennan (2017) found that much of the challenge and risk with cover cropping in tillage-intensive vegetable systems is related to cover crop residue management when fields are transitioned from a cover crop to the next cash crop. This is particularly true with small-seeded vegetables, where typical planting and cultivation equipment are not designed to operate efficiently with cover crop residue. Other studies have noted that the removal or incorporation of residue into the following planting season demands farmers' time, and can lead to difficulties for mowing, plowing, cultivation and no-tillage planting

[25] Several species of waterfowl are now dependent on agricultural habitat where they consume the aboveground biomass of cover crops (Bradbeer et al., 2012).

(Christianson et al., 2014; Sarrantonio & Gallandt, 2003). Moreover, the inconvenience and risks arising from the removal or residue incorporation is especially challenging during wet conditions (Christianson et al., 2014, Roesch-McNalley et al., 2018).

4.3. Human and Social Capital

Farmers themselves are the primary asset for enhancing the resilience of agriculture. However, the sector's human and social capital is stretched and may limit producers' willingness to adopt cover crops (Crawford & MacNair, 2012, Daryanto et al., 2019; Ranjan et al., 2019; Suess et al., 2012).

Social capital can both hinder and motivate adoption (Knowler & Bradshaw, 2007; Ranjan et al., 2019). For example, the presence of leadership in the community can serve as a positive motivator for adoption (Ranjan et al., 2019). Farmer identity, with respect to stewardship and innovation, also emerged predominantly as a motivating factor for adopting NbS (Ranjan et al., 2019). Another study found a positive relationship between strong local social networks in providing information to farmers and farmer interest in adopting new sustainability practices (Jussaume & Glenna, 2009). Community building and frequent interactions between community members has also been recognized as important for farmers to implement and sustain long-term adoption of NbS (Beever, 2021; Jussaume & Glenna, 2009; Leach et al., 2019; McCarthy et al., 2018). Meanwhile, other subjective social norms, such as (dis)trust and perceptions of government programs and neighbours' success, challenges, or inaction (positive and negative) can act as both motivations and barriers to adoption (Ranjan et al., 2019).

4.4. Knowledge

Knowledge and information are essential to all adaptive and mitigative decision-making. Scientific environmental knowledge and awareness of agricultural impacts on the environment are a motivating factor to adopting NbS (Ranjan et al., 2019). Conversely, a lack of knowledge and awareness of the environmental and financial benefits of cover crops limits motivation to adopt them (Dobb, 2014; Suess et al., 2012; Weber, 2017).

A lack of awareness on cover cropping may be due to a lack of availability and/or accessibility to spatially explicit information. There is currently a lack of robust scientific results on the net effect of cover crops, including key co-benefits and/or costs and constraints for different agricultural regions, which makes decision-making on cover crop suitability and adoption, and developing effective programming more difficult (Daryanto et al., 2018; Norgaard et al., 2021). Appreciation of the ecosystem services provided by cover crops is also currently primarily derived from studies observing a single or a subset of services instead of bundled services. This limits the understanding of factors controlling the net effect of cover crops (Daryanto et al., 2018).

(Dis)trust in the sources of information is another important factor that can either hinder or motivate adoption of NbS. In a systematic review of all US-based qualitative investigations into NbS adoption since 1996, other farmers and watersheds groups were always identified as trusted information sources that motivated adoption. Meanwhile, conservation agencies and university extension as information sources could both motivate and hinder adoption (Ranjan et al., 2019). In an evaluation of Ontario's Environmental Farm Plan (EFP) program (see Chapter 5), community acceptance of EFP representatives and a lack of trust of government authority were identified as barriers to adopting NbS (Weber, 2017).

Farming experience also contributes significantly to a farmer's ability to make effective farm management decisions. A major component of success in effectively integrating cover crops into farming operations is through a trial-and-error approach (Roesch-McNally et al., 2018). Current or prior experiences using NbS either enable or hinder future adoption, depending on whether the experience(s) was/were positive or negative (Ranjan et al., 2019). Moreover, uncertainty in the usefulness of cover cropping acts as a barrier whereas perceived reduction in risk acts as a motivator (Ranjan et al., 2019).

The literature argues that cover crop uptake in BC will require in-field demonstrations on how it can work (Norgaard et al., 2021). Moreover, farmer education (e.g., workshops and field days), expanding access to information, continued scientific research, and technical assistance can increase interest in adopting NbS and overcome existing barriers to adopting cover crops (Crawford & MacNair, 2012; Morrison & Lawley, 2021b, 2021a; Ranjan et al., 2019; Weber, 2017). It is also widely agreed that extension

plays an important role in bridging the gap between findings in the lab and practices on the farm (Wang, 2014).

4.5. Policy and Regulation

Agriculture is embedded in a complex regulatory context, whereby each agency has its own mandate which drives the policy and regulations that emerge.[26] A complex regulatory environment can create a challenging and fragmented environment for producers managing through variable or challenging conditions (Crawford & MacNair, 2012).

Provision of and knowledge about financial incentives such as cost-share programs, research and information dissemination, flexibility of government conservation programs, and technical assistance are motivating factors for adopting NbS (Ranjan et al., 2019). However, the current regulatory and policy contexts can act as barriers to adoption. Examples include inflexibility of government conservation programs; ineligibility for government programs; inadequate financial incentives; distrust in such programs (e.g., concerns regarding confidentiality, liability, and litigation); the process of applying for government NbS programs (e.g., lengthy application processes, excessive paperwork, and program complexity and requirements); lack of awareness, knowledge or understanding of the programs; program conditionalities; transaction costs; a lack of longevity of the programs; and a lack of follow up (Ranjan et al., 2019; Weber, 2017).

Literature also suggests that insecure land tenure is a disincentive to investment in soil conservation on farmland (Ranjan et al., 2019; Sawadgo et al., 2021). Farmers who engage in long-term soil conservation may sacrifice immediate income for the envisioned improvements in soil fertility and enhanced production in the future (Fraser, 2004). Since farmers who rent land have no guarantee that they will reap the benefits of long-term conservation practices, tenant farmers are expected to use management strategies that maximize short-term production, even if it compromises soil fertility. Results of a study in Delta, in the Lower Fraser Valley of BC, indicate that insecure land tenure is a real obstacle to long term soil conservation and that long-term leases are not

[26] The BC Agriculture and Food's Climate Action Initiative 2012 Provincial Report highlights this governance complexity in an Appendix (Crawford & MacNair, 2012).

a good substitute for land ownership (Fraser, 2004). This is of particular concern given nearly half of BC's farmland is leased from government or rented under other arrangements (Statistics Canada, 2017). However, intervening variables, such as paying farmers to plant grasslands (analogous to cover crop), overrides the effect of insecure land tenure and creates incentives for tenant farmers and owner-operators alike to use crop management that protects soil fertility in the long term (Fraser, 2004).

4.6. Summary

An assessment of the factors that influence cover crop adoption reveals extremely complex findings. The extent to which producers are willing and able to invest in cover cropping is defined largely by compounding factors, which may act as barriers and/or motivators for adoption. The barriers and/or motivators are not experienced equally by all farmers. Some factors may also vary between non-adopters (interest and non-interested), early adopters, and long-time adopters.

The unique financial, physical, and human and social circumstances in which farmers operate can considerably constrain or incentivize individual action. Knowledge, policy, and regulatory conditions also influence whether cover crops are used. Furthermore, the success of cover crops in achieving and maintaining NbS objectives is dependent on the relationship between which cover crop is selected and the field-level (i.e., physical, environmental) and structural conditions where the cover crop will be planted (i.e., financial, knowledge, human and social capital). The effectiveness of cover crops is therefore context specific, and their performance over time will vary over time depending on how the aforementioned factors affect the decisions of individual farmers.

Chapter 5.

Scan of Policies, Programs, and Research and Development

Government, industry, and the not-for-profit sector in Canadian and the US have explored many ways to address the underutilization of cover crops. Efforts include regulation, policy, programs, and research and development.

5.1. Canada

The Canadian agricultural system is organized at federal, provincial, territorial, private, and commodity group levels.

5.1.1. Federal Government

Policy[27]

Agriculture and Agri-Food Canada (AAFC) is a federal department that is responsible for federal regulation of agriculture, including policies governing production, processing and marketing of food, farm, and agri-based products. AAFC works with provinces and territories to develop and deliver policies and programs. AAFC also supports corporate and local agricultural producers and suppliers.

Most of Canada's agricultural policy is delivered through a five-year Agricultural Policy Framework (APF). The current APF (2018-2023) is called the Canadian Agricultural Partnership (CAP) and negotiations about the next APF (2024-2029) are underway. From 2018 to 2023, CAP has allocated $2 billion for cost-shared programs and activities by federal, provincial, and territorial governments and $1 billion for federal activities and programs (Canadian Agricultural Partnership, 2018).

[27] Canada also has federal policy documents and working groups, such as AAFC's 2021/22 Departmental Plan (Agriculture and Agri-Food Canada, 2021a) and Canada's climate change adaptation agriculture working group (Natural Resources Canada, 2012)

A Federal Greenhouse Gas Offset Credit System is also currently under consideration and development. This will involve regulations for the operationalization of the system; federal offset protocols that establish the approach for quantifying GHG emissions reduction for a type of project; and a tracking system to register offset projects, issue and track offset credits and share information through a public registry. One of the Environment and Climate Change Canada protocols is for enhanced soil organic carbon (2020).

Programs

One of the six programs under CAP is AgriInnovate, which seeks to accelerate the commercialization, adoption and/or demonstration of innovative products, technologies, processes or services that increase sector competitiveness and sustainability (Agriculture and Agri-Food Canada, 2018a). A second program is AgriInvest, which is a self-managed producer-government savings account designed to help producers manage small income declines, and make investments to manage risk and improve market income (Agriculture and Agri-Food Canada, 2019b). A third program is Canada's Environmental Farm Plan (EPF), which is a long-term partnership between farm organizations and the Canadian federal and provincial government based on a voluntary, self-administered educational and risk assessment approach (Smith et al., 2020).

In 2021, the federal government established the Natural Climate Solutions Fund worth $4 billion over ten years to address climate change and biodiversity loss (Government of Canada, 2021a). One of its three programs is the Agricultural Climate Solutions (ACS). Led by AAFC, ACS aims to develop and implement farming practices to tackle climate change through carbon storage and reduction in GHG emissions opportunities (Agriculture and Agri-Food Canada, 2021b). The ACS program has two streams: the Living Labs worth $185 million over 10 years, and the On-Farm Climate Action Fund worth $200 million over three years. The Living Labs brings together farmers, scientists, and other sector partners to co-develop, test, and monitor beneficial management practices (BMP) on working farms to enhance climate resilience and reduce Canada's environmental footprint. Meanwhile, the On-Farm Climate Action Fund supports farmers in adopting BMPs, including cover cropping, that store carbon and reduce GHGs.

Research and Development

The federal government operates 21 research centres across the country. The centres undertake research and maintains biological collections and resources (Agriculture and Agri-Food Canada, 2009). Two of the federal research stations are in BC (Agriculture and Agri-Food Canada, 2009). The Agassiz Research and Development Centre, located in Abbotsford, focuses its research activities in soil health management, innovative crop production systems, integrated pest management, and biodiversity enhancement (Agriculture and Agri-Food Canada, 2018b). Second, the Summerland Research and Development Centre, located in Okanagan Valley, focuses its research on the mitigation of environmental pressures, control of biological threats, and integration of sustainable production and processing systems for the delivery of high quality, value-added horticultural and agri-food products (Agriculture and Agri-Food Canada, 2018c).

5.1.2. Provincial Governments

My primary focus is on efforts undertaken by BC.[28]

Policy

Beyond federal legislation, Canadian provinces have their own climate policies. BC has legislated targets for reducing GHG emissions 40 percent below 2007 levels by 2030, 60 percent by 2040, and 80 percent by 2050 (Ministry of Environment and Climate Change Strategy, 2022). Entities can also purchase offsets under BC's Greenhouse Gas Industrial Reporting and Control Act (Ministry of Environment and Climate Change Strategy, 2021a).

Provinces also have strategic climate action plans. For example, BC has the Roadmap to 2030 (2021) and a draft Climate Preparedness and Adaptation Strategy (CPAS) (2021). Relevant, albeit limited, key actions under BC's roadmap pertaining to the agriculture sector include supporting GHG efficient practices, enhancing agricultural carbon sequestration, and seizing the potential of regenerative agriculture (CleanBC, 2021). Meanwhile, the CPAS proposes the development of regional agricultural climate

[28] There are far too any programs across Canada to cover in detail; however, I provide some additional examples from other provinces in the text and in footnotes.

adaptation plans (Ministry of Environment and Climate Change Strategy, 2021b).[29] Budget 2022 allocated $6 million to support the first phase of BC's CPAS to better respond to climate risk and reduce the impact of climate change over time (Government of British Columbia, 2022).

Programs

Federal initiatives provide funding to the provinces to undertake agriculture programs. In BC, AgriInnovate (Canada-BC Agri-Innovation Program (CBCAIP)) and the EPF are delivered by Investment Agriculture Foundation[30] (IAF). The CBCAIP is available to producers, amongst other entities (Ministry of Agriculture, Food and Fisheries, 2021c). Key priority areas include improvements in soil, water and air quality, and climate change adaptation. Funding for these key priority areas supports research and development, pilots and demonstrations, and commercialization and adoption projects. Meanwhile, the BC EPF seeks to help farmers learn how to reduce agriculture's impact on the environment, while increasing efficiency, profitability, and environmental sustainability. At no cost to the farmer, a trained EFP Planning Advisor helps farmers complete an agri-environmental risk assessment, after which an action plan is created to address the environmental issues identified (Ministry of Agriculture, Food and Fisheries, 2021d).

Provincial governments often have complementary programs that build off federal funding initiatives. For example, once a BC EPF has been completed, farmers are eligible for the BC Ministry of Agriculture, Food and Fisheries' (AFF) Beneficial Management Practices (BMP) Program.[31] This program, also administered by the IAF, provides funding (up to 100 percent to a maximum of $70,000 per farm operation) to

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[29] Another example is Manitoba's Climate and Green Plan. A $102 million Conservation Trust was established in 2018 as part of Manitoba's Climate and Green Plan to fund activities that promote the conservation of natural resources by creating, conserving, or enhancing natural infrastructure for the benefit of Manitobans (Manitoba Habitat Heritage Corporation, n.d.).

[30] AIF is an industry-led, not for profit that delivers government funded programs to the agriculture and agri-food sector of the province.

[31] A similar project exists in New Brunswick (NB). The NB government has an Environmentally Sustainable Agriculture program aimed at assisting producers to evaluate the environmental and climate risks associated with their operations, acquire knowledge and tools to address these risks, provide financial incentives to help farmers implement solutions and assist farmers to enhance their land base (Government of New Brunswick, 2018). Three of the four subprograms include environmental farm planning, agro-environmental clubs, and adoption of environmental beneficial management practices.

increase a farm's agricultural sustainability (Ministry of Agriculture, Food and Fisheries, 2021a). No funding was allocated to cover cropping projects in 2020/21 (Norgaard et al., 2021). However, Budget 2022 allocated $15 million over three years for the BMP program, along with $6 million to support the first phase of BC's CPAS to better respond to climate risk and reduce the impact of climate change over time (Government of British Columbia, 2022). Projects may include waste management, water quality, emissions control, soil and riparian integrity, and environmental impacts.

AFF also has a Knowledge and Technology Transfer Program (KTTP). The KTTP launched a 2022-2023 Spring intake period and may launch a 2022-23 Fall intake period depending on funding availability. This cost-share reimbursement program is aimed at increasing the competitiveness, resiliency, and innovation of BC's agriculture and food sector through applied knowledge and practical skill development. Amongst others, key priority areas include regenerative agriculture, climate change, and production, under which cover cropping may fall (Ministry of Agriculture, Food and Fisheries, 2021b). Stream One (Subject Matter Expert for Knowledge Development) supports activities such as conferences, events, annual general meetings, and community meetings. Recipients can receive up to $1,500. Stream Two (Hands on Learning for Skill Development) supports activities such as field days/research trials, farm tours, hands-on workshops, experiential learning, and technology training. Recipients can receive up to $7,500. A third stream (Hands on Learning Focused on Regenerative Agriculture) was introduced during the Spring intake period. Stream Three may provide up to $7,500 per activity focused on regenerative agricultural practices, and is intended for activities such as farm tours, technology training, field days, research trials, and experiential learning. Applications under all three streams undergo a merit-based evaluation and applicants must demonstrate cost-sharing contributions through cash or in-kind donation.

AFF also has a Climate Change Adaptation Program (CCAP). CCAP is delivered by the IAF and BC Agricultural Research and Development Corporation, and program activities are carried out by the Climate and Agriculture Initiative BC with support from agricultural organizations, local governments, non-governmental organizations (NGOs) and other partners (Investment Agriculture Foundation of British Columbia, n.d.). The CCAP has two sub-programs – the Regional Adaptation Program (RAP) and the Farm Adaptation Innovator Program (FAIP). The RAP defines regional strategic priorities and

delivers collaborative projects for agricultural adaptation. Of relevance to cover cropping is RAP's second phase (of two phases), which involves implementing projects within a region to achieve strategies and actions outlined in the adaptation plan developed in the first phase.[32] Completed plans include regionally specific strategies and actions. Meanwhile, FAIP delivers funding for farm-level, applied research projects on farm sites throughout the province that seek to help producers adapt to the impacts of climate change. Projects run from two to four years to allow methods to be tested over multiple growing seasons and under a variety of conditions. Projects bring together researchers, farmers, agricultural organizations, educational institutions, technical experts, and others (Climate & Agriculture Initiative BC, n.d.).[33]

Canada's eastern provinces have a Cover Crop Decision Tool, which helps guide growers in their cover crop selection process. Approximately 30 cover crop species, individually and in mixtures, are identified in this tool as suitable for Ontario, New Brunswick, Nova Scotia, Prince Edward Island and Quebec (Agriculture and Agri-Food Canada, 2019a). The user can input specific parameters and up to three beneficial criteria they are seeking. Recognizing regional differences, the tool uses probability of frost-free periods for each county in each province, and temperature and moisture to determine suitable planting windows for normal growth of cover crops. The tool then generates a graphical display indicating planting windows for favourable establishment of each recommended cover crop option. BC's AFF submitted a Request for Proposal in December 2021 for a similar cover crop decision tool.[34]

Many provinces also have regional agrologists who work within their respective bylaws and Acts to provide advice to the agricultural sector and contribute to the health

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[32] Phase one of RAP involves developing an adaptation plan specific to a region, which includes identifying and prioritizing climate issues.

[33] For example, one of the projects under the FAIP focused on better understanding which management practices work best to address intense rainfall and drought while improving soil health and avoiding unintended negative effects on soil health and emissions (Climate & Agriculture Initiative BC, 2021j).

[34] The contractor will create a "comprehensive database of cover crop species and mixtures and their characteristics which allow for crop selection based upon management objective, cash crop and suitability to grow and meet management objectives in the climate conditions of each of the BC eco-sections with capability of soil-based agricultural production" (Ministry of Agriculture, Food and Fisheries, 2021d). The minimum outputs expected by the Ministry are the database, documentation of supporting information to the dataset, and recommendations for design and functionality of the cover crop decision tool.

of the society, environment, and the economy. Often, regional agrologists work closely with staff in other branches, other ministries, First Nations, local governments, and with counterparts in other governments and agencies. Under AgriService BC, AFF has 13 regional agrologists for coastal and interior regions (Government of British Columbia, n.d.; Ministry of Agriculture, Food and Fisheries, n.d.). Their priority areas include supporting agriculture program delivery (e.g., local government planning, bylaw development, supporting agriculture advisory committees, farm practice complaints and issue management); supporting local industry development, and collection of regional intelligence; and promoting a stewardship ethic within the agriculture sector. BC also has the AgriService BC team comprised of industry knowledge experts who can connect producers to appropriate programs and services.

Research and Development

In response to climate change impacts on the agriculture sector and agriculture's contribution to provincial economies, many provinces undertake research and development efforts (internally and by third parties). For example, research was undertaken by the University of British Columbia to assess the GHG benefits (i.e., CO_2, nitrous oxide (N_2O), methane (CH_4) emission reductions and CO_2 sequestration (carbon sinks)), environmental co-benefits, and adoptability considerations of agricultural NbS (Norgaard et al., 2021).

5.1.3. Municipal Governments

BC has several regional agricultural advisory committees (AAC), such as the AAC of Maple Ridge, City of Kelowna, District of Summerland, and Regional District of Nanaimo. AACs act as a liaison between Council and the agricultural community. AACs advise their respective Councils on issues important to the agri-business community, such as land use and economic matters with respect to agriculture.

5.1.4. Non-Profit Sector

Programs

There are several non-profit organizations and regional collaborative initiatives across Canada that offer financial incentives to adopt cover crops. Programs are often

offered by conservation authorities and range in eligibility criteria. In BC, for example, the Delta Farmland and Wildlife Trust offers a Winter Cover Crop Stewardship Program to support farmers establish vegetative cover on their fields after the harvest of their cash crop in late summer/early fall. The program offers a $50-65/acre cost-share to participating farmers (Delta Farmland and Wildlife Trust, 2017). Ducks Unlimited Canada also provides financial incentives for winter cover crops of grasses, legumes, or grains as part of farmers' crop rotations for producers in the lower mainland and Courtenay-Comox Valley (Ducks Unlimited Canada, 2021). Similarly, the Shuswap Watershed Council[35] (SWC) has a Water Quality Grant Program worth $60,000 that seeks to reduce the amount of nutrients that wash off or leach out of soils into nearby creeks, rivers, and lakes within the Shuswap watershed (Fraser Basin Council, 2021). In 2020, one of the funded projects was a cover-crop trial on a farm located near Salmon Arm.

Research and Development

There are several non-profit organizations in Canada that represent the demands of a range of Canadian farmers. Among many objectives, these entities conduct cutting-edge research to support policy reform pertaining to NbS. Farmers for Climate Solutions and the NFU are very active in this space.

5.1.5. Private Sector

There are several producer associations and commodity organizations in Canada that engage with cover crops. Each entity represents different commodity groups and has their own vision and/or objectives within the Canadian agriculture and agri-food sector. For example, the Grain Farmers of Ontario led the development of a Cover Crop Action Plan in 2019 (Grain Farmers of Ontario, n.d.).[36]

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[35] The SWC represents three regional districts, two municipalities, the Secwepemc Nation, two provincial government agencies and Shuswap communities.

[36] The Ontario Cover Crop Steering Committee comprised of the Certified Crop Advisor Association, Conservation Ontario, Grain Farmers of Ontario, Innovative Farmers Association of Ontario, Ontario Agri-Business Association, Ontario Federation of Agriculture, Ontario Fruit and Vegetable Growers Association, Ontario Soil and Crop Improvement Association, and the Upper Thames River Conservation Authority. Committee resources were provided by the Ontario Ministry of Agriculture, Food and Rural Affairs.

Industry is also becoming involved in NbS. For example, Cargill agronomists in Canada work with farmers to adopt 4R Nutrient Stewardship principles (right place, right time, right rate and right source) (Cargill, 2020). These practices aim to improve the quality of water, soil, and air while contributing to the long-term profitability of the farm.

5.2. United States of America

The US agricultural system is organized at federal, state, university, private, and commodity group levels.

5.2.1. Federal Governments

Policy

The United States Department of Agriculture (USDA) is a federal agency that plays a regulatory role at the national level and funds research projects of national or regional relevance. In 2020, the USDA updated the 2018 Farm Bill to add more flexibility to when cover crops must be terminated while remaining eligible for crop insurance (United States Department of Agriculture, 2019). USDA's Farm Service Agency (FSA), Natural Resources Conservation Service (NRCS) and Risk Management Agency (RMA) developed new guidelines and policy provisions to enact these changes. The USDA also has strategic plans that pertain to cover crops. For example, the 2021 Climate Adaptation Plan and the Climate-Smart Agriculture and Forestry Strategy promote research and development, and investments in NbS, including cover crops.

Programs

The FSA administers a voluntary Conservation Reserve Program (CRP). In exchange for a yearly rental payment and cost-share assistance, enrolled farmers agree to remove environmentally sensitive land from agricultural production and plant species, such as grasses, to control soil erosion, improve water quality, and develop wildlife habitat (Farm Service Agency, 2022). Contract duration is between 10 and 15 years. The FSA also has loan programs (e.g., Operating Loans, Farm Ownership Loan Program, Conservation Loan Program) which provide funds for a wide range of purposes, including short-term equipment or operating needs or long-term infrastructure

enhancements to support increased resilience (United States Department of Agriculture, 2021a).

The NRCS administers the Conservation stewardship Program (CSP) and the Environmental Quality Incentives Program (EQIP). Both programs pay farmers a per-acre incentive rate, that varies by state, to plant cover crops (Natural Resource Conservation Service, 2021a, 2021b). EQIP also offers roughly 12 percent higher rates for multi-species mixtures since they provide a wider range of benefits. In fiscal year 2022, a $10 million climate-smart agriculture pilot project was expanded across all states and programs to support farmers, ranchers, and forest landowners (Natural Resource Conservation Service, 2021b).[37] In 2022, $38 million was also invested in EQIP through a new targeted Cover Crop Initiative to help agricultural producers in 11 states mitigate climate change through the widespread adoption of cover crops.[38]

The NRCS also has a Plant Materials Program, which evaluates cover crops used in conservation practices to support healthy soils and cropland sustainability efforts (United States Department of Agriculture, n.d.-b). The NRCS Plant Materials Centers initiate trials to better characterize performance and adaptation of commercially available cover crop varieties (United States Department of Agriculture, n.d.-a). Reports for several agricultural regions and plant guides have been developed under this program to help select appropriate cover crops, when and how to plant them, and when to terminate or incorporate the plant into the soil.

The NRCS Regional Conservation Partnership Projects (RCPP) program offers short-term grants to partners that assist with expanding the implementation of conservation activities (AGree, 2019). Many NGO projects to educate or incentivize cover crops have been funded through this program. For example, the Nature Conservancy and Purdue University created a Cover Crop Lease Insertion Program, whereby the lease insertion helps landowners work with their farm operators and/or managers to incorporate cover crops into their leases (The Nature Conservancy, 2021). NRCS also funds 85 locally driven, public-private partnerships via the RCPP to address

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[37] In 2021, EQIP launched a pilot project involving $10 million to support climate-smart agriculture in ten states selected based on demonstrated demand for additional support for climate-smart practices (Natural Resource Conservation Service, 2021b).

[38] States include Arkansas, California, Colorado, Georgia, Iowa, Michigan, Mississippi, Ohio, Pennsylvania, South Carolina, and South Dakota.

climate change, improve water quality, combat drought, enhance soil health, support wildlife habitat, and protect agricultural viability (United States Department of Agriculture, 2021a).

The NRCS also administers Conservation Innovation Grants which support the development of new tools, approaches, practices, and technologies to further natural resource conservation on private lands (United States Department of Agriculture, 2022). Three of the 11 projects in 2021 involved cover crops.

The RMA implements state-funded incentives to encourage cover crop planting. For example, the RMA administered a Pandemic Cover Crop Program. Farmers with coverage under most crop insurance policies were eligible for a $5 per acre premium discount from USDA if they planted cover crops during the 2021 crop year.

The US also has a land-grant university system,[39] which operates the US Cooperative Extension System (CES) in partnership with federal, state, and local governments. With offices in more than 3,000 counties and territories, the CES aims to support farmers, among others, to adapt to challenges, such as those related to technology, emergencies, and environmental protection (National Institute of Food and Agriculture, n.d.). Extension agents (i.e., land-grant institution faculty members) based at field offices and land-grant institutions conduct research and/or work with rural and urban agricultural producers to disseminate evidence-based information and technology and undertake demonstrations (Congressional Research Service, 2019; Maredia & Dwyer, n.d.).

The USDA also has a Carbon Management Evaluation Tool that helps producers calculate how much carbon their land's soil and vegetation can remove from the atmosphere (United States Department of Agriculture, 2021b).

Research and Development

There are ten regional Climate Hubs across the US. The Climate Hubs are led and hosted by the Agricultural Research Service (ARS) and Forest Service (FS), with

[39] The land-grant university system was established under the Morrill Act of 1862, whereby lands were set aside for the development of institutes of higher education to promote agricultural education.

contributions from many agencies including the NRCS, FSA, Animal and Plant Health Inspection Service and the RMA. Climate Hubs conduct research and science information synthesis; tool development, technology exchange, and implementation assistance; stakeholder education, outreach, and engagement; and national and regional governance (United States Department of Agriculture, n.d.-d). The FS Climate Change Resource Centre and USDA also curated and continue to grow an online compendium of nearly 500 adaptation approaches with numerous associated examples (Climate Change Resource Center, n.d.).

The ARS and the National Institute of Food and Agriculture support research on adaptation strategies, including adapted cultivars and crops, enhanced water and input-use efficiency, optimal production efficiency, and improved resistance to diseases and pests (United States Department of Agriculture, 2021a). Moreover, the NRCS acquires data for designing assistance through the National Cooperative Soil Survey Program. The survey provides information on soil and ecological site resources of farms across the US (United States Department of Agriculture, n.d.-c).

In collaboration with other organizations, the USDA also funded the development of an Adaptation Workbook, which producers can use to assess threats and document management choices to minimize climate change impacts to their operations (Northern Institute of Applied Climate Science, 2022).

5.2.2. States

Programs

All 50 states have agencies that are responsible for and enforce state regulations, and fund research projects that have relevance to individual states' needs. At least 29 states support cover crop education, incentive payment programs or technical assistance within their state.[40] For example, the California Department of Food and Agriculture runs a Healthy Soils Program (HSP) that provides financial incentives to California growers to implement conservation management practices that sequester carbon, improve soil health, and reduce GHGs. The HSP Demonstration Projects, a

[40] Additional information on specific State programs can be found on Food and Ag Policy's website (Economic and Environmental Risk Coalition, 2019).

secondary component of the HSP, showcases California farmers' implementation of HSP practices (California Department of Food and Agriculture, 2021). Some states such as Iowa and Illinois also provide low-interest loans, tax credits, or insurance discounts to farmers to adopt cover cropping practices. Moreover, while cost-share rates vary substantially between states and programs, few fully cover the cost (Laporte et al., 2021). For instance, North and South Dakota and Minnesota have lower cost-share per acre than the Corn Belt States.

Some states use reverse auctions as a tool to increase the adoption of cover crops. Farmers participating in the auction submit bids that reflect their cost to install new NbS. For example, Michigan state has a phosphorus reduction auction to reduce excessive phosphorus loading in the Kalamazoo River Watershed associated with agricultural sources (Delta Institute, 2021).

Like Canada's, a few Cover Crop Decision tools exist across the US. For example, the Midwest Cover Crop Council and the Northeast Cover Crop Council have developed Cover Crop Species Selector Tools that are unique to their regions. The tools provide cover crop species recommendations based on grower USDA hardiness zone and cropping system specifics (Kropp et al., n.d.; Northeast Cover Crop Council, 2021).

5.2.3. Non-Profit Sector

Programs

Efforts to increase the use of cover crops are commonly undertaken by NGOs; they work directly with farmers to provide financial and technical assistance in adopting cover crops. For example, the Ecosystem Services Market Consortium is expected to launch a national ecosystem services market program in 2022 that pays farmers for quantified, certified, and outcomes-based soil carbon, net GHGs, water quality, and water conservation credits generated from regenerative agricultural practices (Ecosystem Services Market Consortium, 2021).

There are two primary foundation programs through the DenriFund and the Walton Family Foundation that support cover crops. DenriFund supports a rye cover crop commercialization initiative to expand acreage of cover crops across Kentucky (DendriFund, 2021). Meanwhile, the Walton Family Foundation supports conservation

related initiatives focused on working lands in the Mississippi River Basin. With a goal of improving water quality, it supports NGO's, universities, grower associations, and other non-profits that work to expand the number of acres impacted by conservation in the basin (Walton Family Foundation, 2021).

5.2.4. Private Sector

Programs

Beyond publicly funded efforts, numerous private cost-share and incentive payment programs are available for crop farmers in the US. For example, farmers in Iowa are eligible for cover crop cost-share programs when they sell directly to corporations such as Cargill, Bayer, Pepsico, Keurig Dr Pepper, and Unilever (Practical Farmers of Iowa, n.d.). Eligibility requirements and the cost per acre varies across companies. The same acres for public programs can also sometimes be submitted for this privately funded program.

Companies also invest in educational and supply chain incentives for cover crops. Companies such as Kellogs, Target, PepsiCo, Danone, General Mills and MARS have joined the AgWater Challenge, led by Ceres and the World Wildlife Fund. This challenge engages companies with significant agricultural supply chains on water stewardship. Amongst other priorities, participating companies implement practices that support climate change mitigation and adaptation (Ceres, 2018). For example, efforts to support crop productivity, reduce erosion, and increase soil carbon levels are encouraged.

Similarly, Indigo seeks to sequester one trillion tons of carbon dioxide from the atmosphere by incentivising farmers to adopt regenerative agricultural practices. Satellite imagery and soil sampling are used to measure how much carbon a farm has sequestered, after which farmers can be compensated through a marketplace called Indigo Carbon (Indigo Ag, 2021). Companies such as the North Face, Barclays, Boston Consultant Group, Maple Leaf and Shopify support Indigo Carbon.

Chapter 6.

Evaluation Framework

The following chapters examine government support to address the market failure (positive externalities) and reduce barriers to adopting cover crops in BC. Addressing these concerns will also help BC meet its climate change mitigation and adaptation targets. This chapter outlines five criteria, under which there are seven measures, that are used to evaluate the trade-offs of potential options: effectiveness, equity, administrative ease, cost, and stakeholder acceptance. Table 6.1 presents a summary of the criteria and measures. Each criterion is defined and is given a score from good to poor with a numeric and colour equivalent. Each score which is informed by my research methodologies (literature, survey, interviews). A score of 1 (red) suggests poor or minimal outcomes for that criterion, a score of 2 (yellow) suggests moderate outcomes, and a score of 3 (green) suggests good or strong outcomes. The highest score a policy can receive is 18 points.

Table 6.1 Criteria and Measures

Criterion	Measure	Score
Effectiveness (/6)		
Contribution to Low-carbon Resilience	Extent to which the policy increases the use of cover crops	Good (3)
		Moderate (2)
		Poor (1)
Reduction in Barriers to Adoption	Extent to which the policy reduces the number and severity of barriers to adoption	Good (3)
		Moderate (2)
		Poor (1)
Equity (/3)		
Farmer Access	Extent to which different types of farms can access the policy	Good (3)
		Moderate (2)
		Poor (1)
Administrative Ease (/3)		
Ease of Implementation	Number and degree of changes to existing program(s) or introduction of new programs	Good (3)
		Moderate (2)
		Poor (1)
Coordination with Stakeholders	Extent to which the policy requires coordination amongst stakeholders to implement and administer	Good (3)
		Moderate (2)
		Poor (1)
Cost (/3)		
Cost to Government	Cost to provincial government to establish and administer policy per year	Good (3)
		Moderate (2)
		Poor (1)
Stakeholder Acceptance (/3)		
Farmer Support	Extent to which farmers support the policy	Good (3)
		Moderate (2)
		Poor (1)
Total (/18)		

6.1. Effectiveness

The main objective of this research is to address the underutilization of cover crops. Effectiveness assesses the extent to which the policy option increases the use of cover crops. A policy that substantially increases the use of cover crops receives a 'good' score. Second, to determine whether a policy option is sustainable, it must also reduce the number and severity of barriers to adopting cover crops. A policy that significantly reduces the extent of many barriers receives a 'good' score. For a policy option to be recommended, it must receive 'good' scores for both measures under this criterion.

6.2. Equity

Equity assesses the accessibility of the policy option to different types of farmers. This criterion considers characteristics such as location, farm size, land tenure, and administrative burden, among other categories. A policy that is equally accessible to many different types of farmers receives a ‘good’ score.

6.3. Administrative Ease

Administrative ease assesses the number and degree of changes required to existing policies or programs, or the development of new policies. A policy that requires few changes to existing policies or programs, no new policy developments, or new policies that are easy to implement receive a ‘good’ score. Second, administrative ease to implement and annually administer the option will be greater if there is less need for coordination among relevant stakeholders such as farmers, academic institutions, and government. A policy requiring more coordination amongst stakeholders receives a ‘poor’ score. The scores of these two criteria are averaged to avoid double counting.

6.4. Cost

Cost to the provincial government includes fixed costs to establish the policy as well as annual costs to operate and annually administer the policy or program. Where possible, annual costs are given as a numeric value in Canadian dollars. A policy with a low total cost receives a ‘good’ score.

6.5. Stakeholder Acceptance

Stakeholder acceptance assesses expected farmer support for the policy option. This criterion reflects factors such as actual or perceived costs to farmers, likely permanence of the program, and trust in the government or those involved in the program.

Chapter 7.

Policy Options to Address the Underutilization of Cover Crops

I analyse five provincial policy options that I have gleaned from my research to address the underutilization of cover crops. All options are in the spirit of incorporating Indigenous land title and rights, land stewardship, and ecology meaningfully and respectfully into agricultural decision-making. All options also support BC's climate change adaptation and mitigation targets and are in addition to the status quo. Evaluations undertaken by AFF would be required for all policy options, including acquiring feedback from funding recipients and/or participants, to inform future strategic planning and budget allocations.[41]

7.1. Policy Option 1: Expand the Farm Adaptation Innovator Program

This option increases funding available under the BC Ministry of Agriculture, Food and Fisheries' Farm Adaptation Innovator Program (FAIP). This option provides science-based research funding to academic institutions to increase the number of projects pertaining to cover crops and expands FAIP's reach across BC. Eligible activities may include on-farm research projects, such as on-farm trials for cover crop experimentation. Projects would run for at least three years. Project descriptions and results would be stored in a publicly available database.

The option would also foster long-term partnership building between the provincial government, academic institutions, and farmers to support cover crops adoption and increase farm resilience to climate change. The option connects farmers, beyond participants in the on-farm research projects, with agricultural extension[42] agents. Agricultural extension agents would work with farmers to disseminate useful and

[41] Implementation plans for each policy option are beyond the scope of this research. Effectiveness and equity scores are expected to be worse than indicated if funding is reduced.

[42] Agricultural extension is the application of scientific research and new knowledge to agricultural practices through farmer education.

practical information related to cover cropping, put into practice knowledge gained through the on-farm research projects, and assist farmers in using their knowledge gained to solve problems pertaining to cover crop adoption. Activities may include workshops, farm tours, field days, and peer-to-peer learning opportunities. Lessons learned from these activities would be uploaded to the same publicly available database.

7.2. Policy Option 2: Carbon Sequestration Payment

Operating under BC's current carbon offset system, the market-based instrument would generate carbon offset credits for farmers who adopt cover crops. The carbon offset refers to a reduction in GHG emissions (e.g., from a reduction in the use of fertilizers as a result of using cover crops), or an increase in carbon storage through the adoption of cover crops, that is used to compensate for emissions that occur elsewhere (GHG Management Institute & Stockholm Environment Institute, 2020a). The carbon offset credit is a transferrable instrument certified by the government to represent an emission reduction of one metric ton of CO_2e.[43] The purchaser of an offset credit (i.e. an individual or regulated firm subject to carbon reduction mandates) can "retire" it to claim the underlying reduction towards their own GHG reduction goals (GHG Management Institute & Stockholm Environment Institute, 2020a; Jaccard, 2020; Rivers et al., 2021). To be eligible to generate offset credits, cover crop users are required to achieve real, additional, quantified, verified, unique, and permanent GHG reductions or removals by following an approved provincial protocol that is consistent with the federal GHG offset protocol (Environment and Climate Change Canada, 2020). This means that the emissions reductions are otherwise unclaimed, exceed what would have occurred in a business-as-usual scenario (i.e., the use of cover crops delivers additional GHG reductions), not overestimated, and the emissions reductions are permanent (i.e., not subsequently reversed) (Fowlie, 2021; GHG Management Institute & Stockholm Environment Institute, 2020b; Jaccard, 2020; Rivers et al., 2021).

This program would also provide information to producers about cover crop species, seeding methods, seeding rates, and timing suitability based on unique producer objectives and conditions.

[43] CO_2, or an equivalent amount of other GHGs.

7.3. Policy Option 3: Expand the Beneficial Management Practices Program

This option increases funding for cover crop adoption under AFF's Beneficial Management Practices (BMP) Program. The additional funding[44] would help offset the direct costs associated with planting cover crops. Farmers would apply for a per-acre payment for unharvested cover crops, and a top-up per-acre payment if they plant cover crops and maintain less than 21 consecutive days of bare soil at any time of the year. Recipient farmers would have to abide by minimum seeding rates (e.g., 125 pounds per acre) and cut-off dates for planting depending on the cover crop species.

The per-acre payments would be calculated using a sliding scale. Criteria such as farm size, the use of organic practices, cover crop species, method of termination and regional conditions would be factored into the per-acre cost-share price. For example, farmers that are small-scale, use organic practices, plant cover crop mixtures, use no-till or do not use pesticides for termination, and/or farm in a high-risk zone (e.g., migratory path, area prone to flooding) could be eligible for a higher cost-share percentage. The program would also have a cap on total eligible acreage.

Second, the BMP Program would build the capacity of regional agrologists to provide farmers with data and technical support services to adopt cover crops that are suitable for their unique farming conditions. Capacity building could involve increasing the number of regional agrologists in the province and providing them with cover crop training. Activities undertaken by regional agrologists may include field days and farmer-to-farmer mentorship initiatives.

7.4. Policy Option 4: Compulsory Cover Crop Regulation

Inspired by the Danish government, this option requires farmers to plant cover crops.[45] The requirement to plant cover crops, and the minimum and maximum planting

[44] The actual amount of funding would be determined after an assessment of the farmland base that can be planted in cover crops.

[45] In 2016/2017, the Danish government expanded their catch crop requirement in the legislation to reduce Nitrogen loss by increasing Nitrogen use efficiency and reduce fertilizer N import. Catch crops is another term for cover crops. In Denmark, the requirement to grow catch crops is calculated as a percentage of the area of cereals, maize, oilseed rape, and other crops with a

requirements, would be calculated based on characteristics such as farm size, farm location, and cash crop(s). Farms would have flexible planting and termination dates and could apply for exemptions when they adopt other NbS, for example. Termination methods for cover crops would be limited.[46] Consultations with farmers would take place to determine more specific components of the regulation.

Farms that are obligated to plant cover crops would be required to establish cover crops plans and would incur penalties for non-compliance to planting cover crops. This regulation would also involve advancing research findings on GHG potential and environmental co-benefit potentials of different cover crop species across different agricultural land types.

7.5. Policy Option 5: Cover Crop Advisory Committee

Functioning similarly to other provincial AACs, this policy convenes a cover crop advisory committee to report to the BC Ministry of Agriculture, Food and Fisheries. The committee would identify and communicate opportunities for increasing the adoption of cover crops in BC, provide expert advice on the delivery of provincial programs related to reducing barriers to cover crop adoption, and work closely with existing regional AACs across the province.

The committee would be convened for periods of five years to align with the Canadian Agricultural Policy Framework timeline. After each five-year period, objectives and terms of reference would be re-assessed and revised as needed. Like the Nature Based Climate Solutions Advisory Committee that provides expert advice to federal departments on the delivery of the Natural Climate Solutions Fund, co-chairs would be nominated for a period of one year (Government of Canada, 2021b). Moreover, appointed committee members would consist of farmers and external cover crop experts from across the province. All members would be expected to participate in their personal capacities (i.e., not as representatives of organizations) and would be compensated for their time.

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short growing season. For farmed areas with crops with a short growing season, the maximum requirement for targeted catch crops was set to 32.6 percent of the area farmed.

[46] Fertilizer application to cover crops in autumn is not allowed in Denmark or the other Nordic countries (Aronsson et al., 2016).

Chapter 8.

Policy Analysis

This chapter evaluates the five policy options using the criteria and measures outlined in Chapter 6. Literature and findings from my interviews and survey are used to inform each score. The results of the evaluation are presented in Table 8.6 at the end of this chapter.

8.1. Analysis of Policy Option 1: Expand the Farm Adaptation Innovator Program

8.1.1. Effectiveness

a) **Score**: **Good (3)**

This policy's contribution to low-carbon resilience (i.e., increasing the use of cover crops) is fourfold. First, this option could expand temporal and spatially explicit cover crop research. This could help inform farmers on suitable adoption practices for their conditions. Second, it could provide extension services for farmers at all stages of adoption,[47] which can increase adoption. Together, these initiatives could foster partnerships between academics and farmers, and collaborations amongst farmers. These interactions have been deemed important for adopting NbS. Fourth, this option creates a comprehensive database; whereby regional information may be accessible to farmers, government, academics, and the public. Literature, interview, and survey findings highlight that education is fundamental to adopting cover crops.

A non-profit interviewee also ranked four of the policy options (excluding the compulsory cover crop regulation) from most to least likely to increase the adoption of cover crops. This policy was ranked as the third policy option.

[47] This policy option targets early adopters, potential adopters, and non-interested non-adopters. These categorizations are taken from an article by Carlisle (2016).

b) Score: **Good (3)**

Table 8.1 outlines the number and severity of barriers this policy option could reduce. In Table 8.1 and subsequent tables addressing the potential impact of a policy on the barriers, a '+' bullet indicates a potential reduction of the barrier while a '-' bullet indicates a potential amplification of the barrier.

Average Effectiveness Score: 3

Table 8.1 Barriers Affected

Financial Barriers	+ Existing adoption rates demonstrate that farmers currently lack financial support to adopt cover crops as part of their land management practices. This policy may reduce producer costs associated with on-farm trials for different cover cropping mixtures to determine cover crop suitability. + This policy subsidizes financial costs associated with farmer-to-farmer learning events and limit costs associated with conducting personal cover crop assessments - Policy may rely heavily on producers to be involved in the research, which can be costly to farmers in terms of time commitments and field space - Conducting research may involve planting cover crops in places where other cash crops could have otherwise been grown
Physical Barriers	+ Policy may help farmers learn about and pursue effective management techniques for cover crop residue or deal with challenges with existing wildlife in the area + Project timelines of at least three years could reduce physical barriers of observing limited benefits in short time periods. In the 2020 Ontario cover crop survey, over 40 percent of farms responded that they saw benefits from growing cover crops within one year (Morrison & Lawley, 2021a).
Human and Social Capital Barriers	+ The presence of agricultural extension agents in the community may serve as a positive motivator for adoption and/or help reduce fears associated with adopting new NbS, as indicated by Ranjan et al. (2019). + The stronger the local social networks are in providing information to farmers, the more interest farmers have in new production methods aimed at improving agricultural sustainability (Jussaume & Glenna, 2009) + Often, farmers are not proximate to academic institutions with agricultural programming. This can lead to missed opportunities for on-farm research, guided by professional researchers. As indicated by a non-profit interviewee, this policy may be useful for breaking down distance barriers between farmers and academic institutions. + Extension-based programs that involve regular and interactive meetings with producers may significantly increase the adoption of practices that improve the sustainability of agricultural production systems (Leach et al., 2019) + An Australian study highlighted that support from technical experts, and family or friends is crucial for producers to implement and sustain long-term practice change (Beever, 2021). Evidence from another Australian study suggests that follow up activities from these actors help to keep producers motivated to continue with the practice change process (McCarthy et al., 2018). - Agriculture extension can hinder adoption (Ranjan et al., 2019). For example, a lack of trust in agricultural agents may deter farmers from participating in research and/or workshops.

Knowledge Barriers	+	Existing adoption rates demonstrate that farmers currently lack considerable information to effectively adopt cover crops. This policy option could contribute to more robust scientific results on the net effect of cover crops, to make decision-making on cover crop adoption easier.
	+	As indicated in the literature and interviews, farmer education, greater access to information, continued scientific research and technical assistance can aid in increasing interest in adopting NbS and overcoming existing barriers to adopting cover crops (Morrison & Lawley, 2021b, 2021a; Ranjan et al., 2019; Weber, 2017).
	+	Cover crop uptake requires in-field demonstrations on how it works (Norgaard et al., 2021)
	+	Additional literature, interviews, and survey results identified farmer-to-farmer learning as an important method of gaining information. For example, my survey respondents indicated that they turn to other farms as a primary source of information. This highlights the need for peer-to-peer learning opportunities, which will be available through this policy.
	+	Interview findings suggest that farmers are less willing to adopt NbS that have not been trialed and confirmed as effective in their region. Expanding temporal and spatially specific research on the performance of cover crops and offering educational opportunities in different regions (e.g., workshops, field days) can help farmers reduce uncertainties with cover crops and enable more realistic assessments of options under varying conditions.
	+	Spatially explicit data is helpful for prioritizing regions across the province for investment and participation in this policy
	+	It is widely agreed that extension plays an important role in bridging the gap between findings in the lab and practices on the farm (Wang, 2014). As mentioned by a government employee, this program puts theory into practice. An overarching theme that came from the interviews was that extension would significantly reduce farmers' knowledge barriers to adopting cover crops. For example, a government employee said farmers have always indicated that they place a high value on being provided with extension. During their career in the provincial public service, they have frequently heard that farmers want to have "people" that come to their farms and provide them with information and services. Similarly, an NGO representative said the policy would increase producer knowledge and help them address concerns about the unknowns of cover cropping. The NGO representative also mentioned that this program would improve knowledge around planting cover crops so that producers are reaping the most benefit possible from their use.
	+	Establishing long-term relationships between farmers, academic institutions, and the government will help fulfill the need for acquiring baseline data and long-term data collection. The need for long-term funding and thinking, and baseline and long-term data were identified as existing gaps by nearly all interviewees.
	+	A primary limitation to providing effective scientific guidance on how to plant cover crops is a lack of long-term data and good science, as identified by many interviewees. Undertaking rigorous research is fundamental to evidence-based decision making.
	+	Policy option creates a comprehensive database for farmers, government, academics, and the public pertaining to cover crop adoption. As mentioned by a farmer interviewed, this can help inform farmers on what cover crops work in what areas.
Policy and Regulatory Barriers	-	Concerns regarding confidentiality were expressed by participants in Ontario's EFP program, which deterred their participation (Weber, 2017). Similarly, confidentiality may be difficult in terms of the database given the desire of spatially explicit information.

Note: Bullets with '+' indicate a potential reduction of the barrier while bullets with '-' indicate a potential amplification of the barrier.

8.1.2. Equity

Score: **Good (3)**

Some survey respondents indicated that they have never applied for funding to plant cover crops since they do not meet eligibility criteria given their small size. The flexibility in eligible research projects and ability to target equity deserving producers could provide access to the policy by many groups of farmers regardless of farm size, farm location and cash crop(s) grown. Moreover, testing over multiple growing seasons and under a variety of conditions provides farmers operating in different parts of the province with flexibility in gaining concrete results, should conditions outside their control (e.g., extreme weather events) occur in one or more of the growing seasons.

8.1.3. Administrative Ease

a) Score: Good (3)

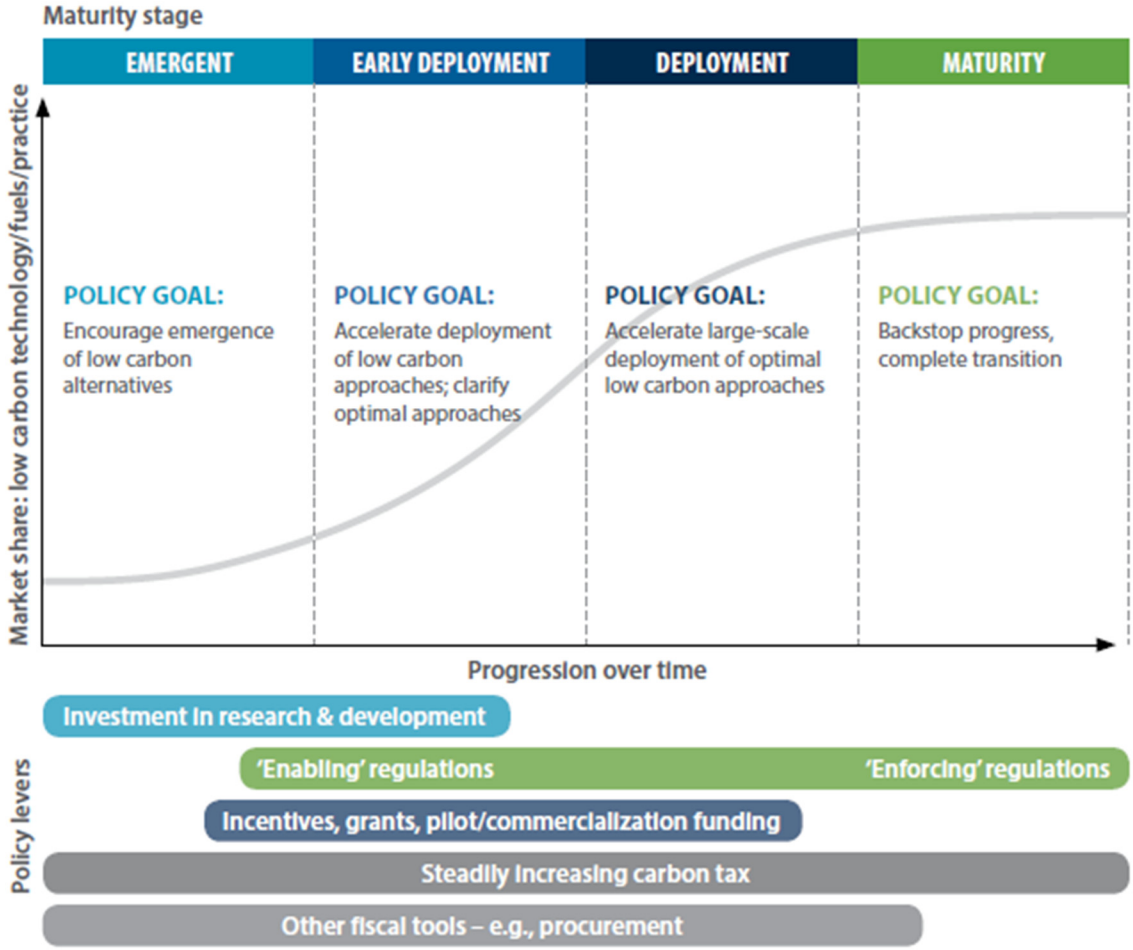
This policy would be relatively easy to implement since it builds off the existing FAIP. AFF could also draw lessons from Canada's implementation plans for the 10-year Living Labs program, Canada's three-year On-Farm Climate Action Fund, and America's well-established land-grant university system (as indicated by a not-for-profit interviewee) to help alleviate unknowns and risks associated with implementing the option. However, some challenges may arise when developing the database and keeping it up to date.

According to BC's market readiness indicators[48] (see Figure 8.1), this policy takes place during the 'emergent' and 'early deployment' stages (CleanBC, 2021), which

[48] BC developed a series of market readiness indicators to inform the types of actions needed to drive decarbonization and help measure actions' progress. The indicators address key issues, including market share of technologies, reflecting the extent to which low-emission solutions are being adopted; cost of transitioning to low-emission solutions; workforce and skills readiness, reflecting BC's capacity to adopt new approaches; and economic and social opportunities, pointing to important co-benefits. The four stages of maturity include 'emergent', 'early deployment', 'deployment', and 'maturity'. Based on these indicators, agriculture's overall current state of market readiness is in the 'emergent' stage and will be at the 'early development' stage by 2030 (CleanBC, 2021).

means it can be implemented now. The academic interviewee agrees that the option could be immediately implemented and is low risk since the science is well established.

Figure 8.1 Stages of Market Readiness



Adapted from: Victor, D.G. et al. 2019. Accelerating the Low Carbon Transition: The case for stronger, more targeted, and coordinated international action. The Brookings Institution; and Meadowcroft, J. et al. 2021. Pathways to Net Zero: A decision support tool. Transition Accelerator Reports

b) Score: Moderate (2)

This option would require coordination and buy-in from farmers and academics to implement and administer. Coordination amongst government and academic institutions may not be challenging since there is considerable willingness to collaborate across levels of government and different academic groups, as highlighted by the academic interviewee. However, coordination challenges may arise with farmers.

Average Administrative Ease Score: 2.5

8.1.4. Cost

Score: Moderate (2)

This option would have moderate costs to the provincial government. Costs include funding for on-farm research projects, hiring agriculture agents, and the costs associated with the activities they undertake with farmers.

For reference, in 2021, the Government of Canada announced $185 million over 10 years for the Living Labs, which fosters collaborations with relevant stakeholders to evaluate BMPs, and $200 million over three years for the On-Farm Climate Action Fund, which provides funding to farmers to adopt BMPs.

Stakeholder Acceptance

Score: Good (3)

All farmers interviewed expressed that talking to other farmers and/or personal trials are critical avenues for acquiring information and determining which cover crops would be effective on their farm. Many of the farmers interviewed also expressed strong support for extension services to advise on promising practices of cover crops.

Some farmers may not support this policy for reasons such as government's involvement in the program, resistance to taking advice from government, and/or suspicion about data being collected from their property. These concerns were raised in the literature and by interviewees (an agricultural consultant and government employee). Some farmers may also be skeptical of expert advice given their hesitance that extension agents are trying to sell them something. This was raised by one farmer, both consultants and one non-profit employee in their respective interviews. However, these farmers do not represent a large fraction of the farming population to offset the good rating.

8.2. Analysis of Policy Option 2: Carbon Sequestration Payment

8.2.1. Effectiveness

a) Score: Moderate (2)

A policy option that provides a financial incentive to plant cover crops and educational material on cover crops to producers has the potential to significantly increase the adoption of cover crops. However, there may be complexities in the operation of an offset market that could affect the effectiveness the policy in increasing the adoption of cover crops.[49]

In addition, a non-profit interviewee that ranked four of the policy options from most to least likely to increase the adoption of cover crops ranked the carbon sequestration payment as the second most effective policy option.

b) Score: Moderate (2)

An overview of the number and extent to which this policy option has the potential to reduce barriers to adoption is provided in Table 8.2.

Average Effectiveness Score: 2

[49] Addressing the operational complexities is beyond the scope of this paper.

Table 8.2 Barriers Affected

Financial Barriers	+ Additional costs associated with cover cropping was the most common barrier limiting new adoption and the third largest challenge for Ontario farmers that grew a cover crop in 2020 (Morrison & Lawley, 2021a). This option can significantly reduce the financial barriers of adopting cover crops. + Two 2020 surveys (Ontario and Prairies) identified financial incentives as the most effective method for enabling farmers to continue using and/or increase their acres in cover crops. In addition, the Ontario survey identified payments for storing carbon as the highest enabler for cover crop users and the second highest enabler for non-users (Morrison & Lawley, 2021b, 2021a). In BC, cover crops can sequester between 0.11 and 0.51 tons of carbon per hectare per year (t C ha-1yr-1) (Norgaard et al., 2021). + In another study, perennial vegetation such as cover crops were perceived by farmers as expensive conservation practices. Thus monetary incentives are necessary to make adoption feasible (Atwell et al., 2009).
Human and Social Capital Barriers	+ An agricultural consultant interviewee thought this option would encourage partnerships between academic institutions and research that is taking place on farms, since there is limited lack of long-term data available. Community building and frequent interactions between community members has been recognized as important for farmers to implement and sustain long-term adoption of NbS (Beever, 2021; Jussaume & Glenna, 2009; Leach et al., 2019; McCarthy et al., 2018).
Knowledge Barriers	+ Nearly all interviewees, regardless of their roles, identified limited access to reliable information pertaining to cover crop adoption as a considerable barrier to adopting the NbS. Recognizing that continued research helps overcome barriers (Ranjan et al., 2019), this option would contribute to reducing knowledge barriers to using cover crops. + The need for long-term funding and thinking, and baseline and long-term data were identified as existing gaps by nearly all interviewees and in the literature. The monitoring of carbon would provide helpful data on sequestration rates and capacities of soil and could help improve future planting of cover crops.
Policy and Regulatory Barriers	+ In an evaluation of Ontario's EFP program, inadequate financial incentives was identified as a barrier to adopting NbS (Weber, 2017). This option would reduce this policy barrier. + In the same Ontario EFP program evaluation, inflexibility of government conservation programs discouraged NbS adoption (Weber, 2017). Without the specificity of the policy and its operations, it is not possible to ascertain the extent of the barriers. There will be some but how well they are addressed is a function of policy design and outside my scope. - The agriculture sector has seen retraction of carbon-credit eligibility for certain practices, and invalidated credits can lead to significant financial losses for farmers (Lokuge & Anders, 2022)

Note: Bullets with '+' indicate a potential reduction of the barrier while bullets with '-' indicate a potential amplification of the barrier.

8.2.2. Equity

Score: Poor (1)

The potential reductions in number and severity of barriers to adoption may not be reaped by all types of farmers. Depending on the farm size, the administrative burden of participating in program may not be worth it. For example, the financial return (price per ton of carbon) for applying for the carbon sequestration payment may be worth less than the time required to apply for a small-scale farmer. This was flagged by a government representative. Three of my seven completed survey respondents also indicated that a reason for not applying for funding to plant cover crops was because funding was not large enough to warrant their application. On average, these farmers plant crops on two acres or less.

Regardless of farm size, the permanence eligibility criterion for an offset may pose challenges for farmers with limited land availability (i.e., replacing land for cash crops with cover crops). Some farms may also be excluded if there is a minimum scale specified in the program. Farmers on rented land are also less likely to apply for funding since benefits of cover cropping accrue over time (Fraser, 2004; Ranjan et al., 2019; Sawadgo et al., 2021).

Moreover, the additionality eligibility criterion for an offset will disadvantage farmers that already adopt cover crops. As highlighted by a farmer and employee of a non-profit during their respective interviews, soil has carbon absorption limits. Thus, the program is likely to benefit farmers who have limited carbon in their soil more than farmers who have been using cover crops for many years and cannot further increase their soil carbon levels.

8.2.3. Administrative Ease

a) Score: Poor (1)

This option would have to be acknowledged and approved for the province’s existing carbon offset system. According to Norgaard et al.'s (2021) feasibility study of NbS using a multi-criteria framework, the methods for planting cover crops are not close to operational for robust measurement, reporting, and verification feasibility since the

methods development are not widely accepted and have high uncertainty (Norgaard et al., 2021).

Moreover, according to BC's market readiness indicators (see Figure 8.1) and expressed by a government representative interviewee, this policy takes place during the 'early deployment and 'deployment' stages (CleanBC, 2021). This means considerable additional investment in research and development would be needed prior to implementing this option.

b) Score: Moderate (2)

This policy would require some coordination between the administrator of the program[50] and farmers over time to monitor carbon levels in the soil. This option would also require meetings, contracts, and undertaking ongoing audits and economic assessments.

Average Administrative Ease Score: 1.5

8.2.4. Cost

Score: Poor (1)

Most costs to the government would be for the robust measurement, reporting, and verification (MRV) required to design and administer carbon sequestration credits. As indicated by Norgaard et al., feasibility for a carbon sequestration payment is very costly (2021).

8.2.5. Stakeholder Acceptance

Score: Moderate (2)

The farmers interviewed unanimously expressed strong support for this policy option since it financially compensates farmers for the adoption of cover crops. Similar results were found in my survey: all seven respondents who completed the survey

[50] Some of AFF's programs are administered by a third party. For example, the CCAP is delivered by the IAF and the BC Agricultural Research & Development Corporation.

indicated that they support this policy option.[51] However, if this program was outcomes-based (i.e., based on amount of carbon sequestered), compensation would only be provided if farmers met the eligibility criteria (i.e., real, additional, quantified, verified, unique and permanent). Literature suggests that some farmers may be reluctant to participate in an outcomes-based carbon credit system. With current carbon-offset prices and the emissions level per farm, offset-credit revenues may be inadequate in covering the foregone costs of implementing emission-reduction practices (Lokuge & Anders, 2022).

Farmer interviewees expressed concerns about whether the policy would accomplish the goal of sequestering carbon (i.e., have a tangible effect on the climate), whether the science is advanced enough to MRV, and/or whether the policy would create unintended consequences. For example, two farmers raised concerns about the financialization of farmland, where farmland could become prioritized for sequestering carbon rather than producing food. This policy may also create a reliance on a payment for planting cover crops, as indicated by a farmer interviewee.

All seven respondents who completed the survey indicated they are likely to apply for this program.[52] However, one farmer interviewee said their willingness to apply would depend on the administrative burden associated with the option.

8.3. Analysis of Policy Option 3: Expand the Beneficial Management Practices Program

8.3.1. Effectiveness

a) Score: Good (3)

A policy option that provides a financial incentive to plant cover crops and access to the support services of regional agrologists has the potential to significantly increase the adoption of cover crops up to the limit of the funding provided. In addition, a non-profit employee that ranked four of the policy options from most to least likely to increase

[51] In terms respondents' support for this policy option, six respondents 'strongly support' and one respondent 'somewhat supports' this option.

[52] In terms of respondents' likelihood of applying for the carbon sequestration payment, three respondents are 'extremely likely to apply', and four respondents are 'somewhat likely to apply'.

the adoption of cover crops ranked the cost-share program as the most effective. If farmers cannot financially justify adopting cover crops on their own, the financial support acquired through the cost-share program can help alleviate those costs.

b) Score: Good (3)

Table 8.3 provides an overview of the number and extent to which this policy option potentially reduces barriers to adoption.

Average Effectiveness Score: 3

Table 8.3 Barriers affected

Financial Barriers	+ Additional costs associated with cover cropping was the most common barrier limiting new adoption and the third largest challenge for Ontario farmers that grew a cover crop in 2020 (Morrison & Lawley, 2021a). Financial barriers were also selected as a top barrier in my survey. This option can significantly reduce the financial barriers of, and financial risks associated with, adopting cover crops. + As indicated by a government employee interviewee, there will not be much adoption of a new NbS without financial compensation. Thus, this policy will bring momentum for increasing the adoption of cover cropping. + Cost-sharing is a motivating factor for adopting NbS (Ranjan et al., 2019). Two 2020 cover crop surveys (Ontario and Prairies) identified financial incentives as the most effective method for enabling farmers to continue using and/or increase their acres in cover crops (Morrison & Lawley, 2021b, 2021a). + In another study, perennial vegetation such as cover crops were perceived by farmers as expensive conservation practices. Thus monetary incentives are necessary to make adoption feasible (Atwell et al., 2009). + As indicated by a government employee, covering the cost of seed will not effectively increase the adoption of cover crops. As a cost-share program, producers will have more ownership of their practices and a stronger willingness to maintain their land. This was expressed by an agricultural consultant. + Regional agrologists can limit farmers' needs to undertake trials and/or conduct their own research - As indicated by a farmer and agricultural consultant, there is concern that farmers may stop planting cover crops once the cost-share program is no longer available
Physical Barriers	+ Regional agrologists can help farmers overcome physical barriers associated with planting cover crops, such as wildlife, residue management, and extreme weather events.
Humans and Social Capital Barriers	+ Regional agrologists contribute to social capital by providing information in a direct way to farmers
Knowledge Barriers	+ A lack of education on cover crops is reflected through existing adoption rates. Two farmer interviewees identified the lack of regional agrologists in BC as a barrier. Several interviewees, regardless of their roles, also acknowledged the important role that regional agrologists have in knowledge transfer, incentivizing climate friendly agriculture, and providing extension services. Extension support by regional agrologists is expected to increase adoption rates. + Option 3 reduces several educational barriers. For example, the option builds capacity of regional agrologists to deliver workshops and facilitate field days and/or farmer-to-farmer learning opportunities. These activities provide producers the opportunity to see how practices and technologies can be applied to their own operations. + Since performance of cover crops depends on several complex factors, this policy builds knowledge capacity of regional agrologists to support farmers' decision-making on cover crops in unique contexts.

Note: Bullets with '+' indicate a potential reduction of the barrier while bullets with '-' indicate a potential amplification of the barrier.

8.3.2. Equity

Score: Good (3)

Given the diversity of farmer objectives and conditions, the sliding scale payment system reduces the number and severity of barriers faced by a diversity of farmer

groups. For example, the program would provide higher payments for the use of organic practices, cover crop mixings, and no-till, which can sometimes be more expensive for farmers. Similarly, farmers that are small-scale and/or farm in a high-risk zone (e.g., migratory path, area prone to flooding) would be eligible for a higher cost-share percentage. In addition, flexible cut-off dates allow farmers who grow a diversity of cash crops to be eligible for funding. The maximum total eligible acreage would also ensure that large farms do not receive a disproportionate share of the funding.

Although building capacity of regional agrologists would benefit all farmers across the province, farmers with limited knowledge about and experience in cover cropping would benefit more than farmers with substantial knowledge about and experience in planting cover crops.

As with any program, details must be carefully thought through to address any potential inequities. There may be some characteristics of farms that disadvantage them in accessing the program; however, the features described in this option have a high degree of equity on net. The high cost to government may also require scaling back the program (e.g., selecting regions where the gains of cover cropping may be highest). This may lead to equity concerns.

8.3.3. Administrative Ease

a) Score: Moderate (2)

This program does not require the creation of a new program; however, some changes would be required to AFF' existing BMP program. Changes include hiring additional regional agrologists and providing them with cover crop training and resources, and minor changes to the eligibility evaluation process for cost-share funding. Challenges may also arise when determining who receives funding when funds are limited.

The policy is inspired by elements of existing cost-share programs, which BC can draw from. The policy also builds off Farmers for Climate Solutions' 2021 Budget recommendations, which were written by experts who undertook rigorous research and cost-benefit analysis. Their analysis supports the argument that the policy is realistic for BC's existing context and is deployable now. However, according to BC's market

readiness indicators, this policy takes place during the 'early deployment' and 'deployment' stages (CleanBC, 2021). This means additional investment in research and development would be required before implementing this option.

b) Score: Moderate (2)

This program would require some coordination between farmers receiving the financial payments, regional agrologists, and program administrators and evaluators.

Average Administrative Ease Score: 2

8.3.4. Cost

Score: Poor (1)

This option would have a significant cost to the provincial government. Costs would include hiring more regional agrologists and providing them with cover crop training, and funding for the cost-share program. In line with existing BMP program conditions, this stream could provide a maximum of $70,000 per farm operation to adopt cover crops. While the cost could be reduced by lowering the amount allocated, that would also reduce the effectiveness of the program.

8.3.5. Stakeholder Acceptance

Score: Good (3)

In the interviews with farmers where questions about extension were asked, all farmers expressed the importance of support services and information dissemination since they are currently major barriers to adopting cover crops. Financial incentives are also extremely attractive to farmers, as identified in the literature, interviews, and survey. All my survey respondents support this policy; however, their likelihood in applying varied.[53]

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[53] In my survey, all six respondents indicated that they support this policy (four respondents 'strongly support' and two respondents 'somewhat support'). In terms of their likelihood of applying for funding under this program, two respondents were 'extremely likely to apply', three respondents were 'somewhat likely to apply', one respondent was 'not very likely to apply', and one respondent was 'not at all likely to apply.'

8.4. Analysis of Policy Option 4: Compulsory Cover Crop Regulation

8.4.1. Effectiveness

a) Score: Good (3)

This option has the potential to significantly increase the adoption of cover crops given its compulsory nature. In addition, as indicated by a farmer and government representative, this option would be efficient in getting unused land into production.

b) Score: Poor (1)

The option would be highly ineffective in reducing barriers to adoption. Table 8.4 provides an overview of the number and extent to which this policy option potentially reduces barriers to adoption.

Average Effectiveness Score: 2

Table 8.4 Barriers Affected

Financial Barriers	+ The policy may reduce costs associated with limiting fertilizer use (e.g., nitrogen fertilizer). However, the other costs are much larger than the potential cost reduction associated with reduced fertilizer input costs.
Knowledge Barriers	+ The research component of the policy option advances research findings on GHG potential and environmental co-benefit potentials of different cover crop species across different agricultural land types. This could help farmers make more informed decision about cover crops given their unique conditions and objectives (through forced trial and error). - Unless paired with considerable information and outreach prior to the regulation, it will not immediately reduce knowledge barriers associated with effective cover crop adoption.

Note: Bullets with '+' indicate a potential reduction of the barrier while bullets with '-' indicate a potential amplification of the barrier.

8.4.2. Equity

Score: Poor (1)

The regulation may impact farms differently based on farming characteristics and/or practices. Some farms would need to abide by the regulations while others would be exempt. Some farm characteristics and/or practices that should deem farmers worthy

of exemption may be dismissed, leaving those farmers more disadvantaged. For example, exemption rules may be complex and disadvantage smaller farms who have less capacity to deal with the regulatory requirements. Farmers on rented land may also be more disadvantaged than farmers who own their land, since they are investing in benefits that may not be realized by themselves (Fraser, 2004; Ranjan et al., 2019; Sawadgo et al., 2021).

8.4.3. Administrative Ease

a) Score: Poor (1)

Although BC's provincial institutional framework is compatible with a regulation that requires compulsory action, it would be extremely challenging to define what is considered successful cover cropping, as highlighted by several interviewees. Moreover, oversight and monitoring of farms would be extremely complex. However, lessons could be drawn from the Danish government's 2016/2017 compulsory catch crop requirements.

Moreover, research examining the feasibility of adopting NbS using a multi-criteria framework ranked the methods of planting cover crops as "not close to operational" for robust MRV feasibility. Although the methods are developed, they are not widely accepted, and have high uncertainty (Norgaard et al., 2021). Similarly, according to BC's market readiness indicators, this policy takes place during the 'maturity' stage (see Figure 8.1) (CleanBC, 2021). This means additional investment in research and development, and incentives funding would be required before implementing this option.

b) Score: Poor (1)

This option would require significant coordination amongst the compliance officers and farmers.

Average Administrate Ease Score: 1

8.4.4. Cost

Score: Moderate (2)

Option 4 would have moderate costs to the provincial government. Most costs to the government are incurred through monitoring compliance since MRV feasibility are costly (Norgaard et al., 2021). However, most of the overall financial burden would be borne by producers.

8.4.5. Stakeholder Acceptance

Score: Poor (1)

Farmers who already plant cover crops support this policy because it would require most other farmers to do so as well. The regulation would remove any cost saving the non-adopters have relative to the adopters of cover crops, and ensure other farmers are delivering ecological services that benefit society. Meanwhile, non-adopters (both interested and non-interested), who make up a larger percentage of the farmers who can plant cover crops, would oppose this policy. Gaining farmer acceptance is challenging when adoption rates are low; farmers want to confirm that cover crops have worked on other farmers' land that is like their own. My survey and interview findings reflect these trade-offs.

Producers express that they are already heavily regulated, and their expenses are often extremely high. Mandating a compulsory cover crop regulation would cause considerable backlash, as indicated by nearly all interviewees, and further damage the relationship that currently exists between farmer and the government, as indicated by a government representative interviewee.

8.5. Analysis of Policy Option 5: Cover Crop Advisory Committee

8.5.1. Effectiveness

a) Score: Poor (1)

Although Option 5 may improve the strategic direction of the provincial government in terms of best methods of increasing the use of cover crops, this policy would, at most, minimally increase the adoption of cover crops. Moreover, the NGO employee that ranked four of the policy options from most to least likely to increase the use of cover crops ranked the provincial advisory committee as the least effective policy option.

b) Score: Moderate (2)

Table 8.5 provides an overview of the number and extent to which this policy option potentially reduces barriers to adoption.

Average Effectiveness Score: 1.5

Table 8.5 Barriers Affected

Humans and Social Capital Barriers	+ Option 5 builds community by connecting farmers from across the province. As illustrated in literature and interviews, social cohesion and peer support are extremely important factors for adopting NbS such as cover crops.
Knowledge Barriers	+ As recognized by the BC Ministry of Agriculture (2022), AACs are an effective method of connecting local governments with their farm communities to share knowledge and information + There was a recognition amongst many interview participants, including a farmer, government, and a not-for-profit representative, that government decision-making should be grounded in the reality of farming. Hearing from farmers directly in terms of the challenges they face and how they would like government to support them overcome those barriers to adopting cover crops would help reduce some knowledge barriers + Recognizing that cover crop performance varies considerably by conditions, the diversity of perspectives on the committee provides the opportunity to determine whether cover crop application methods will work in different regions, under different conditions.

Note: Bullets with '+' indicate a potential reduction of the barrier while bullets with '-' indicate a potential amplification of the barrier.

8.5.2. Equity

Score: Good (3)

This policy would allow the voices of all groups of farmers to be represented. Farmers would also be compensated for their time. Furthermore, participant tenure of five years may allow change-over and the inclusion of more farmers representing several diverse groups. Although personal commitments and time constraints may limit some farmers' abilities to participate, it is expected that the AAC members would raise concerns and represent all the voices of their community.

8.5.3. Administrative Ease

a) Score: Good (3)

Although a new advisory committee is required, there are several federal and provincial AACs to use as models. For example, the Nature Based Climate Solutions Advisory Committee provides expert advice to federal departments on the delivery of the Natural Climate Solutions Fund.[54] Moreover, AFF and the Agricultural Land Commission already support AACs by sharing information, sharing best practices, and making knowledgeable personnel available (Ministry of Agriculture, 2022).

Similarly, according to BC's market readiness indicators, this policy takes place during the 'emergent' and 'early deployment' stages (see Figure 8.1) (CleanBC, 2021). Thus, this option is relatively easy to implement and could be implemented now.

b) Score: Moderate (2)

Option 5 would require some coordination to establish and annually administer the AAC. The AAC would also need to work closely with existing regional AACs across the province, of which there are many. Despite remote meeting options, coordinating meeting time with a diversity of schedules may be challenging.

Average Administrative Ease Score: 2.5

[54] AFF also has an Indigenous Advisory Council on Agriculture and Food.

8.5.4. Cost

Score: Good (3)

The major cost of this option would be associated with compensating participating AAC members for their time. Relative to other policy options, this policy option would likely have the lowest cost to the provincial government to establish and annually administer.

8.5.5. Stakeholder Acceptance

Score: Moderate (2)

As confirmed in the interviews, farmers believe government decision-making must be informed by practitioners so that policy/programs are useful for whom they are intended to serve. Moreover, decision-making should be made in partnership with producers who will be adopting cover crops on their farms. Farmers therefore support this option in terms of grounding government decisions in practical knowledge and applicability, under the condition that the committee is representative. However, my survey had mixed responses in terms of farmer support and likelihood of participating in the AAC.[55] Farmer interviewees also recognized that farmers are busy and that several AACs exist already in BC.

[55] In terms of policy support, 4 respondents 'strongly support' and one respondent 'somewhat supports' this policy option. Meanwhile, 2 respondents indicated that they 'somewhat oppose this option. In terms of respondents' likelihood of participating in the AAC, 1 respondent indicated that they are 'extremely likely to apply', while 3 respondents were 'somewhat likely to apply' and 3 were 'not very likely to apply'.

8.6. Evaluation Summary

Table 8.6 Evaluation of Policy Options Summary

	Option 1: Expand the Farm Adaptation Innovator Program	Option 2: Carbon Sequestration Payment	Option 3: Expand the Beneficial Management Practices Program	Option 4: Compulsory Cover Crop Regulation	Option 5: Cover Crop Advisory Committee
Effectiveness					
Contribution to Low-carbon Resilience	Good (3)	Moderate (2)	Good (3)	Good (3)	Poor (1)
Reduction in Barriers to Adoption	Good (3)	Moderate (2)	Good (3)	Poor (1)	Moderate (2)
Effectiveness Score (/6)	**6**	**4**	**6**	**4**	**3**
Equity					
Farmer Access	Good (3)	Poor (1)	Good (3)	Poor (1)	Good (3)
Equity Score (/3)	**3**	**1**	**3**	**1**	**3**
Administrative Ease					
Ease of Implementation	Good (3)	Poor (1)	Moderate (2)	Poor (1)	Good (3)
Coordination with Stakeholders	Moderate (2)	Moderate (2)	Moderate (2)	Poor (1)	Moderate (2)
Administrative Ease Score (3)	**2.5**	**1.5**	**2**	**1**	**2.5**
Cost					
Cost to Government	Moderate (2)	Poor (1)	Poor (1)	Moderate (2)	Good (3)
Cost Score (/3)	**2**	**1**	**1**	**2**	**3**
Stakeholder Acceptance					
Farmer Support	Good (3)	Moderate (2)	Good (3)	Poor (1)	Moderate (2)
Stakeholder Acceptance Score (/3)	**3**	**2**	**3**	**1**	**2**
TOTAL (/18)	**16.5**	**9.5**	**15**	**9**	**13.5**

Chapter 9.

Recommendations

Given the evaluation results outlined in Chapter 8, and since literature suggests that economic instruments are most effective when used as part of a mix of policy tools (Kenny et al., 2011), this study recommends pursuing policy options 1 and 3.[56] First, I recommend the BC Ministry of Agriculture, Food and Fisheries pursue policy option 1, which involves expanding the Farm Adaptation Innovator Program (FAIP) by increasing funding to academic institutions for on-farm research projects and offering extension to farmers through agricultural extension agents. Given the benefits associated with research funding and the successful track records of extension programs across North America, this program could aid in increasing the adoption of cover crops in the province and has the potential to significantly reduce the number and severity of barriers to adopting this NbS. All farmers may benefit from the program including equity deserving groups. Despite costs to the provincial government and potential coordination challenges amongst government, producers, and academic institutions, they should not be large. This option is also strongly supported by producers, as indicated in existing literature and the interview findings.

Second, I recommend the BC Ministry of Agriculture, Food and Fisheries pursue policy option 3, which involves expanding the Beneficial Management Practices (BMP) Program by providing additional funding to cover crops projects and increasing the capacity of BC's regional agrologists. As indicated in the literature, and survey and interviews findings, financial compensation may be one of the most effective methods of increasing the adoption of this NbS.[57] Despite the significant costs to the provincial government, this policy is expected to reduce the severity of several barriers, financially compensate farmers for the ecological services they provide society, and address equity concerns.[58] Thus, this option is strongly supported by farmers. This policy option would

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[56] Interestingly, the Living Labs program is in line with policy option 1, and the On-Farm Climate Action Fund (under ACS) is in line with policy option 3.

[57] Financial compensation may be effective so long as the funding is sufficient (Weber, 2017) and not time limited.

[58] High costs to government may require scaling back the program (e.g., selecting specific regions where the gains to cover cropping may be highest). This creates equity problems as a

also require some changes to the existing BMP program and some coordination between farmer recipients, program administrators and evaluators, and regional agrologists.

Policy option 1 and 3 complement each other given their market readiness (see Figure 8.1). CleanBC's climate roadmap to 2030 identifies programs such as option 1 as part of the 'emergent' and 'early development' stages, which means the option can be implemented immediately. Meanwhile, option 3 falls mainly under the 'early deployment' and 'deployment' stages, which means efforts such as Option 1 are required before implementing policies like option 3.

9.1.1. Implementation Considerations

As highlighted in the literature and my interviews, the success of these two policy options partially depends upon long-term funding availability and long-term strategic thinking of the BC government. The success of these programs is also influenced by the opportunity costs associated with applying (e.g., administrative burden of applying/participating, funding amount received), eligibility restrictions, and how well these programs are advertised.[59]

To overcome farmer hesitance of government involvement, collaboration with farmers during the program development phase has shown to increase trust in program participation (Weber, 2017). Moreover, as seen in the literature, my interviews and survey respondents, farmers act as a primary source of information for each other when making climate-friendly farming decisions. Thus, all policy and programs should keep this top of mind.

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tradeoff. It may also be administratively burdensome to determine who receives funding when it is limited.

[59] Many of my survey respondents (5) indicated they have never applied for funding to plant cover crops because they are not aware of any such projects. Amongst several survey options, farming unions, YouTube or similar and other farmers were identified as the top main sources of information they turn to when seeking help to make decisions about climate friendly farming practices. Thus, a variety of mediums should be used to advertise the programs.

9.1.2. National Recommendation

I recommend Agriculture and Agri-Food Canada update its national census survey to contain questions specific to cover cropping.[60] This will help address the lack of spatially explicit data pertaining to cover crops, which is a recurring barrier addressed in the literature and my interviews. Amongst several benefits, this information can also help Canada address existing policy gaps, establish new baseline data, and measure long-term environmental impacts of cover crops.

[60] Ontario's 2020 cover crop survey (Morrison & Lawley, 2021a), the Prairies' 2020 cover crop survey (Morrison & Lawley, 2021b) and my survey (see Appendix D for my survey questions) provide examples of suitable questions.

Chapter 10.

Conclusion

BC's agricultural sector contributes to climate change and is also severely threatened by climate change. Despite some progress made in BC towards reducing GHG emissions and increasing the resilience of the agricultural sector, significant efforts remain. One effective pathway to mitigate emissions and increase the resilience of the province's agriculture sector is through increasing the adoption of cover crops. As indicated throughout this research, cover crops are mutually beneficial to farmers and the environment; cover crops have several benefits, including GHG benefits, environmental co-benefits, and economic co-benefits. However, farmers currently underinvest in cover cropping since they are not compensated for the ecological services they provide society, and they are presented with several unique and shared barriers to adopting the NbS.

Cover crops are incredibly complex; the cover crop species, seeding method, seeding rate, and timing are all dependent upon the goals for that cover crop (Licht, 2019). Moreover, the benefits of ecosystem services reaped by cover crop users may differ over time based on a variety of conditions. This makes land management decision-making increasingly difficult.

This study has demonstrated the need for government support to encourage the adoption of cover crops, reduce barriers to adopting cover crops, and compensate farmers for the ecological services they provide to society. Through an extensive policy analysis, I recommend the BC Ministry of Agriculture, Food and Fisheries expand the Farm Adaptation Innovator Program (FAIP). To effectively implement this program, the government should play a coordination and funding role to connect farmers with other farmers and academic institutions. I also recommend the BC Ministry of Agriculture, Food and Fisheries expand the Beneficial Management Practices (BMP) Program. This option is expected to help offset some costs associated with planting cover crops and offers cover crop knowledge and technical assistance from regional agrologists. Both policies will help BC achieve its climate change adaptation and mitigation targets. I also

recommend that AAFC update their census survey to contain questions pertaining to cover crops.

Future research should explore whether compensation models would differ across regions of BC given the sheer diversity in farming conditions, farmer objectives, factors affecting adoption, and crops grown. Moreover, although livestock is beyond the scope of this project, cover crops can be widely used on ranches. This presents an opportunity for expanding the use of cover crops to livestock production systems.

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Appendix A.

Climate Change Impacts on Canada's Agriculture and Agri-food Sector

The agriculture and agri-food system is a multidimensional supply chain that contributes significantly to the Canadian economy (Agriculture and Agri-Food Canada, 2020). Canada is the fifth-largest exporter and importer of agriculture and agri-food products in the world. Primary agriculture, including crop production, is a key component in this system. In 2021, crop production represented approximately 0.9 percent of total GDP in Canada.

Canadian agriculture continues to evolve in response to challenges, opportunities, and market developments. Besides producing private goods such as food and fiber, and industrial goods such as bioenergy, agriculture can provide many public goods and services or positive externalities such as wildlife habitat, preservation of natural flora, landscape aesthetics, improve water quality, decrease GHG emissions, increase carbon sequestration, and the maintenance of livelihoods for smallholder farmers, which are often undervalued (Boody et al., 2005; Schmidt et al., 2012; Skolrud et al., 2020; United Nations Environment Programme, 2020).

Since the 1970s, the number of farms in Canada has decreased by half, average farm size has doubled, and farm value per acre has almost quadrupled (Agriculture and Agri-Food Canada, 2020). Of particular importance to these evolutions is the sector's susceptibility to changes in climate and climate variability.

It is projected that climate change will continue to produce a strong direct adverse impact on Canadian crops (Ochuodho et al., 2016). The Intergovernmental Panel on Climate Change has estimated with high confidence that regions, including Canada, are projected to experience an increase in the probability of compound events with higher global warming (2021). Specifically, concurrent heatwaves and droughts are likely to become more frequent, and concurrent extremes at multiple locations will become more frequent, including in crop-producing areas, at 2 degrees Celsius (°C) and above compared to 1.5°C global warming (IPCC, 2021).

Climate change also exacerbates land degradation processes. This can occur through increases in rainfall intensity, flooding, drought frequency and severity, dry spells, heat stress, wind, sea-level rise and wave action, and permafrost thaw (Intergovernmental Panel on Climate Change, 2019). The agricultural sector is already experiencing land use pressures, including changes in crop yields and agricultural pests and diseases, with subsequent impacts on food security. For example, climate change increases air pollution from forest fires, leads to biological changes such as increases in plant and animal pathogens in staple crops, physically degrades land and water used in agriculture, threatens the livelihoods of Canadian farmers, and raises the costs of food (Ostry & Beveridge, 2011). However, these impacts vary by province and territory, over time, and by cropping system.

Appendix B.

Production Systems and Climate Concerns Across British Columbia's Agricultural Regions

The following section describes the production systems and climate issues of top concern to producers occurring in each agricultural region in BC. The projections are for the 2050s and use a baseline historical period of 1961 to 1990, unless otherwise noted.[61]

a) Bulkley-Nechako and Fraser-Fort George

The Bulkley-Nechako and Fraser-Fort George region represented 7 percent of farms in BC in 2016 (1,239 farms), whereby cattle ranching, and forage products are the most common agricultural activities. Other agricultural production includes dairy and other livestock, grains, horticultural crops and beekeeping (Climate & Agriculture Initiative BC, 2021b).

Using the baseline historical period 1971 to 1990, there are four climate issues of top concern to producers in this area. First is the increasing wildfire risk due to the build of up fuels from mountain-pine beetle die-off and human management of wildfires. In 2018, for example, wildfires burned over 1.354 million hectares of land and destroyed structures on more than 60 agricultural properties. Secondly, growing degree days are projected to increase faster in this area than in other parts of BC. Combined with a longer growing season, this is likely to lead to shifts in crop suitability in some areas and potentially new production opportunities. However, increasingly unpredictable shifts in precipitation and temperature create challenges with timing for key farming activities. A third concern is the warmer and drier summer conditions. Many producers are considering irrigation given drier conditions during production season. As of 2016, approximately 1.4 percent of the region's agricultural land was under irrigation. In 2018, the Northwest, Upper Fraser West, Upper Fraser East, and Nechako regions reached level 2 and level 3 drought ratings.[62] Finally, the region is likely to experience significant

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[61] The information provided in the following paragraphs are from the Climate & Agriculture Initiative BC.

[62] The Canadian Drought Monitor monitors and reports drought in the country. Drought classes range from D0 to D4; D0 indicates abnormally dry conditions, and D1 to D4 indicates moderate to

shifts in the region's biogeoclimatic zones, which would likely result in shifts in agricultural pests associated with the zones (Climate & Agriculture Initiative BC, 2021b).

b) Cariboo

The Cariboo region represented 5 percent of farms in BC in 2016 (919 farms), whereby beef cattle operations represent approximately 25 percent of the agricultural sector in the region, forage crops make up almost all the total cropped area, and crown range provides about 40 percent of the annual forage needs for the ranching industry. Livestock production and a diversity of horticulture crops also grow in the region (Climate & Agriculture Initiative BC, 2021c).

This area has five climate issues of top concern. Firstly, climate change is contributing to the increase in number and severity of wildfires in the region. This region has experienced many significant wildfires in the past decade, including 2009, 2010, and 2012. More recently, in 2017 and 2018, approximately 1.1 million hectares of land in the region were burned. Secondly, the region is experiencing warmer and drier summers and increased precipitation in the winter and spring. These conditions are reducing water supply while increasing the water requirements for crops and livestock, and make the region more susceptible to erosion, runoff, and flooding. In fact, many agricultural properties in the region were impacted by flooding in summer of 2019 and spring of 2020. Thirdly, producers in the region are particularly concerned with increasingly unpredictable storm events, freeze/thaw cycles and temperature/precipitation fluctuation, which have implications for entire crop cycles. Fourthly, this area is experiencing emerging agricultural pests and has been significantly affected by the mountain pine beetle outbreaks partly given to reductions in extreme cold winter temperatures. Finally, wildlife and ecological systems are changing, which is altering forage productivity. Producers are also noticing changes in wildlife populations and distribution (Climate & Agriculture Initiative BC, 2021c).

c) Delta

The Delta region represented 8 percent of the farms in the Metro Vancouver Regional District in 2016 (185 farms). However, it earned 23 percent of the area's total gross farm receipts. Delta has a range of field crop and livestock operations, as well as 50 percent of the province's potato acreage and 40 percent of the province's vegetable

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exceptional drought. Each category is based on the percentile chance of those conditions occurring (Agriculture and Agri-Food Canada, 2022).

greenhouses. The region also has forage, berry, dairies, and small-scale poultry operations (Climate & Agriculture Initiative BC, 2021d).

This region has four climate issues of top concern to producers. Firstly, most of Delta's agricultural lands are less than two meters above sea level, which means they are susceptible to risks of coastal flooding. By 2100, sea level in the Georgia Basin is projected to rise by 1.2 meters due to climate change. High tide, storm surge conditions, and coastal flooding can harm crops, livestock, and farm infrastructure. Secondly, sea level rise, earlier peak flows in the Fraser River and drier summers present water supply and salinity management challenges. Climate change is causing the need for more irrigation, and the irrigated water drawn from the Fraser River has potential to become saltier during key irrigation periods. Thirdly, average precipitation is projected to increase during spring and fall, leading to challenges for managing planting and harvesting. This will impact the drainage infrastructure that most producers in Delta have, as seen in the fall 2021 flooding. Finally, the increasing variability and extreme conditions are creating uncertainty in the timing of critical production activities, including planting, pollination and harvesting (Climate & Agriculture Initiative BC, 2021d)

d) Fraser Valley

The Fraser Valley region represented 15 percent of the farms in the province in 2016 (2,576 farms). Average farm size is 23 hectares compared to the provincial average of 132 hectares. The region has over 50 percent of dairy, almost 40 percent of poultry and egg production and the second-highest share of field vegetables in the province. Other production in the region includes field crops for feed (primarily related to the dairy industry), berries, greenhouse and nursey, mushroom operations, and mixed production and organic farms (Climate & Agriculture Initiative BC, 2021e).

The Fraser Valley region has five top climate concerns for producers. Firstly, the warmer and drier summer conditions are impacting crop health and productivity. A 2015 report estimated that agricultural water demand in the region during dry years has nearly doubled that of wet years (192 percent) (Gulik et al., 2015). Secondly, seasonal distribution of precipitation is expected to change, whereby less rain is predicted to fall in the summer and average annual precipitation is likely to increase during spring and fall. It is also expected that rain will become more frequent and intense. In fact, precipitation in the south, including the Fraser Valley, will exceed global average changes (Ostry &

Beveridge, 2011). This will cause runoff challenges, such as preparing fields, planting, and harvesting. Thirdly, climate change may increase the size and frequency of large floods on the Fraser River, which would have damaging consequences for agricultural operations in the region and would impact the entire province's food supply and related infrastructure since the region has much of BC's food storage, food processing and agricultural spin-off industries. Fourthly, pest populations are shifting because of warming temperatures. Spotted wing drosophila and western corn rootworm are threatening berry and fruit growers, and forage and sweet corn producers respectively. Finally, there will be a substantial increase in the average number of days per year over 30°C in the region by the 2050s, whereby dairy, poultry and berries are particularly vulnerable (Climate & Agriculture Initiative BC, 2021e).

e) Kootenay and Boundary

The Kootenay and Boundary region represented seven percent of the farms in the province in 2016 (1,157 farms). These farms vary significantly in size, primarily because of differences in production types due to soil and climactic factors. The Regional District of East Kootenay averages 205 hectares, where ranching is common on larger acreages and forage and pasture represent approximately 95 percent of cultivated land in the area. Meanwhile, the Regional District of Central Kootenay averages 40 hectares, where tree fruit orchards, market gardens and dairies are more prominent. This region also has 10 percent of BC's organic farms (Climate & Agriculture Initiative BC, 2021f).

This region has four climate issues of top concern to producers. Firstly, expected warmer and drier summer conditions are expected to increase demand for irrigation. Some water systems have already been unable to meet peak demand. For example, the Boundary regional district reached the most extreme drought level of 4 in 2017. Secondly, the region has increased risks to wildfires, where smoky conditions have resulted in poor air quality impacting crop and livestock health across the region. Thirdly, the region is experiencing more variability in seasonal conditions due to shifting and unpredictable temperature and precipitation patters, and an increase in extreme events. This may lead to shifting crop suitability, reducing viability of current crops and varieties, and increasing the potential for others. Finally, the spring is considerably prone to flood risks in this region. Much of the agricultural land in the region follows valley floors and rivers, and is therefore vulnerable to flooding (Climate & Agriculture Initiative BC, 2021f).

f) Okanagan

The Okanagan region represented 19 percent of the farms in the province in 2016, whereby 39 percent of the province's certified organic farms are located. The northern areas of the region have foraging, dairy, and cattle ranching, Meanwhile, the central and south produce most of BC's tree fruit and wine grapes and is one of the largest producers of these crops in Canada. The Okanagan also has beekeeping, greenhouse and nursery production, vegetable and melon farming, and sheep/lamb production (Climate & Agriculture Initiative BC, 2021g).

Of particular concern to this region is the warmer winter temperatures, and warmer and drier summers. Surface water, which makes up 66 percent of the Okanagan Basin's total water supply and provides water for 75 percent of the irrigated agricultural land in the area, is particularly vulnerable to impacts from prolonged drought. A second concern is the increase in number and distribution of problem species which enable new species to establish in the region. Specifically, spotted wing drosophila and brown marmorated stink bug are emerging insect pests of concern. Thirdly, extreme precipitation events can damage riparian areas through bank erosion and silting and can cause a loss of productivity on agricultural lands near riparian corridors. More rapid snowmelt and earlier peak stream flows from warmer winter temperatures are creating excess run-off. This can cause erosion, debris flows, washouts, and landslides. Finally, the region is experiencing extreme wildfires, which is destroying agricultural land (Climate & Agriculture Initiative BC, 2021g).

g) Peace

The Peace region represented 8 percent of farms in BC in 2016 (1,311 farms), whereby almost all crop land is non-irrigated. Key agricultural commodities include grains, oilseeds, forage seed, and cattle and forage. Many producers are involved in a combination of these commodities. The average farms size is over 600 hectares, and the region produces almost 75 percent of BC's grain and 98 percent of its canola (Climate & Agriculture Initiative BC, 2021h).

There are four primary climate concerns in this region. Firstly, overall annual precipitation is projected to increase, with less falling as snow and more likely to fall in extreme events. In addition to hotter summers, these changes could increase the need for extra water storage and irrigation, given most crops in the region are unirrigated and rely on precipitation for their moisture. Moreover, much of the region's agricultural land is

located above river valleys, which poses economic and technical challenges for developing irrigation infrastructure. Secondly, more intense, and frequent extreme precipitation events are expected to occur. This can result in flooding, runoff, and erosion. In the short and medium term, the range and types of crops grown could also increase. However, the window of temperate crop yield improvement will close and reverse in the long term, rapidly reducing crop yields (Environment and Climate Change Canada, 1997). Thirdly, increasing variability in weather and seasonal conditions, and timing and frequency of extreme conditions, is causing challenges for farm management decision making. Finally, increasing average annual temperatures, especially in the winters, are likely to create favourable conditions for new pests. Moreover, warmer temperatures, an increase in growing degree days, and longer growing seasons may bring some advantages; however, experimentation may be risky (Climate & Agriculture Initiative BC, 2021h).

h) Vancouver Island

The Vancouver Island region represented 15 percent of farms in BC in 2016 (2,678 farms). Production in this region is highly diverse, with farm operations having small average incomes, and around 17 percent of the agricultural acreage is leased (Climate & Agriculture Initiative BC, 2021i). The region produces a variety of agriculture commodities, including horticulture crops, livestock, and poultry. Approximately 10 percent of BC's dairy operations and 20 percent of beekeeping takes place in this region. Moreover, most agricultural land is dedicated to forage production.

This region has four primary climate concerns. Firstly, dry periods in the summer and more extreme heat events hinder agricultural production throughout much of the region and is increasing demand for irrigation. In fact, the Koksilah (Cowichan Valley), and the Tsolum (Comox Valley) watersheds have already experienced challenges to meet peak demands. Secondly, pest pressure is expected to increase in the region due to warming temperatures, changing precipitation patterns, variability, and extremes. Thirdly, the region is experiencing increasing variability and shifting crop suitability across production seasons. Finally, changes in precipitation and extreme precipitation events are making it harder to manage runoff and drainage on farmland. Low-lying farmland is especially vulnerable to seasonal floods that can damage winter crops and impact production in other seasons. Wet conditions can also reduce opportunities

associated with longer growing seasons by limiting access to fields (Climate & Agriculture Initiative BC, 2021i).

Appendix C.

Ecological Services of Cover Crops

This appendix provides an overview of the major ecological services that cover crops provide to farmers and society.

Greenhouse Gas Benefits

Research examining the climate benefits and feasibility of adopting NbS using a multi-criteria framework assessed planting cover crops as having a 'somewhat positive impact' on long-term GHG benefits performance; however, benefits decrease over time (Norgaard et al., 2021).

Carbon Sequestration

The National Academies of Sciences, Engineering and Medicine reported that sequestering carbon dioxide from the air will form a significant part of the world's efforts to reduce net GHG emissions, and noted agricultural lands can play a considerable role (2019). Compared to soils under natural vegetation, cropland soils are depleted in soil organic carbon. Cropland soils act as a huge potential carbon sink, whereby cover crops can be an important soil carbon sequestration strategy (Carlisle, 2016; Chahal et al., 2020; Poeplau & Don, 2015). A study estimates that cover cropping in BC has an annual GHG mitigation potential in 2030 of 0.08 Tg CO_2e on 121,000 hectares (Drever et al., 2021). Recognizing that the effects of cover crops on GHG emissions will vary by cash crop grown and region, another study found that cover crops can sequester between 0.11 and 0.51 tons of carbon per hectare per year (t C ha-1yr-1) in BC (Norgaard et al., 2021). A third study undertaken by the University of Guelph in Southwestern Ontario confirmed that the amount of carbon stored in soil was between 11 to 22 percent greater with cover crops than without cover crops (Chahal et al., 2020). Meanwhile, in a study in Washington US, where climate and soil properties are similar to the Pacific Maritime Zone in BC, ryegrass cover crop sequesters 0.49 t C ha-1 year-1 (Poeplau & Don, 2015).

Reduces nutrient losses

Nutrients such as nitrogen are required for crop growth; however, nutrients can be environmental contaminants when lost from soil to the atmosphere or hydrosphere. Thus, timing of planting cover crops is highly important depending on nutrient needs of the land (Bergtold et al., 2012; Finney et al., 2016). Legumes such as alfalfa and clover can provide organic sources of nitrogen through their nitrogen-fixing abilities, potentially displacing part of a crop's fertilizer nitrogen requirements (Ordóñez-Fernández et al., 2018; Perrone et al., 2020; Thorup-Kristensen et al., 2003; Wittwer et al., 2017). Moreover, cover crops such as ryegrass and oilseed radish can help absorb nitrogen left behind by the main crop or from manure applications, help retain soil nutrients for following crops, and can help reduce the effects of nitrogen leaching (Carlisle, 2016; Ontario Ministry of Agriculture, Food and Rural Affairs, 2021) and subsequent indirect N_2O emissions (Drever et al., 2021). Farmers who cover crop often report reduced loss of nutrients from soil erosion and leaching (Bergtold et al., 2017).

A study found that non-legume cover crops reduce direct N_2O emissions by 0.9 ± 0.11 t CO_2e ha-1 year-1 and increase indirect N_2O emissions by 0.07 ± 0.28 t CO_2e ha-1 year-1 (Abdalla et al., 2019).

Environmental Co-benefits

Soil Quality

Planting cover crops in BC has a very positive impact on soil quality performance since this co-benefit will be significantly increased by this practice, and/or benefits substantially outweigh the harms (Norgaard et al., 2021). In an Ontario cover crop survey undertaken in 2020, most farms (68 percent) reported seeing improved soil health (Morrison & Lawley, 2021a)

Reduces soil erosion

As their name implies, cover crops cover the soil. Cover crops offer large-scale environmental benefits by reducing soil erosion; top growth protects soil surfaces from wind and water erosion while roots bind and stabilize soil particles (Carlisle, 2016; Ontario Ministry of Agriculture, Food and Rural Affairs, 2021). Cover crops such as rye and barley are commonly used to cover and protect surfaces from wind and water

erosion (Basche, Archontoulis, et al., 2016; Delgado & Gantzer, 2015; Ontario Ministry of Agriculture, Food and Rural Affairs, 2021; Poeplau & Don, 2015).

Adds organic matter

Cover crops add organic matter to the soil to help moderate climate change where the amount of organic matter varies depending on species of cover crop and the conditions under which it is grown. Common cover crops planted to increase organic matter in soil include red clover, oats, rye and oilseed radish (Ontario Ministry of Agriculture, Food and Rural Affairs, 2021).

Improves soil fertility

Soil fertility contributes significantly to crop yields, and is particularly vulnerable to climate change (Mahler et al., 2015). Cover crops can boost soil productivity and subsequent crop yields (Carlisle, 2016). Cover crop species like alfalfa deliver phosphorus, another nutrient required for crop growth, to other crops through transferring nutrients from deep soils to the surface (Ontario Ministry of Agriculture, Food and Rural Affairs, 2021).

Reduces Compaction and Improves Soil Structure

The addition of plant top and root matter of cover crops help improve water infiltration and retention and decrease soil bulk density. Deep rooted cover crops can also reduce the impact of soil compaction, thereby improving soil structure (Ontario Ministry of Agriculture, Food and Rural Affairs, 2021).

Water Quality and Conservation

Planting cover crops in BC also has a very positive impact on water quality and conservation since this co-benefit will be significantly increased by this practice, and/or benefits substantially outweigh the harms (Norgaard et al., 2021).

Water Management

Depending on the variety, cover crops can help reduce moisture or help retain moisture. For example, rye cover crops reduce soil moisture in early spring through absorption into the plant (Ontario Ministry of Agriculture, Food and Rural Affairs, 2021).

Other crops such as winter rye can increase soil water storage, which can help reduce negative impacts of rainfall variability (Basche, Kaspar, et al., 2016).

In a study conducted on potential nitrate mitigation practices to improve water quality from an ecosystem services approach, vegetation-related strategies, such as cover crops, provided the greatest count of ecosystem services (Christianson et al., 2014).

Cover crops have also proven useful for flood mitigation. Following the floods in BC in 2021, a farmer's land in Chilliwack had suffered minimal damage because cover crops kept the soil rooted in place (Fawcett-Atkinson, 2021).

Biodiversity and Pest Management

Planting cover crops in BC has a somewhat positive impact on biodiversity and pest management performance since this co-benefit will be increased by this practice, and/or benefits outweigh the harms (Norgaard et al., 2021).

Improves biodiversity

Cover crops are a key management option for harnessing biodiversity-based ecosystem services (Beaumelle et al., 2021). The extent to which biodiversity is improved is dependent on the method of cover cropping. Studies have shown that cover crop mixtures, rather than one variety of cover crop, provide a positive biodiversity effect irrespective of seeding configurations (Elhakeem et al., 2019). In addition, ecosystems with high biodiversity absorb and sequester more carbon than those with low or reduced biodiversity (Lal, 2004).

Reduces pest populations and weeds

Some cover crop species may be non-hosts for pests or may release materials that are toxic to some pests (Ontario Ministry of Agriculture, Food and Rural Affairs, 2021). For example, various crops in the brassicaceae family, such as radishes, turnips, and mustards, can suppress soil pathogens and suppress invasive agricultural weeds (Brust et al., 2014; Lefebvre et al., 2018; J. Teasdale et al., 2007; J. R. Teasdale, 1996). In the 2019/2020 American national cover crop survey, 70.5 percent of the

respondents[63] said “planting green” – the practice of seeding a cash crop into a live cover crop and letting both grow simultaneously for a length of time – improved their weed control (Conservation Technology Information Center et al., 2020).

Economic Co-Benefits

There are several economic advantages to planting cover crops, some of which benefit farmers directly, and others benefit society as well.

Reduces input costs

In some cases, cover crops can help pay for themselves through reduced input costs. Some farmers may experience cost savings from reducing their synthetic nitrogen fertilizer and herbicide input. In an American national survey, 49 percent of corn producers reported reduced fertilizer costs, as did 41 percent of soybean producers, and 43 percent of wheat farmers. A similar trend appeared with herbicide savings, with reduced herbicide costs in soybeans (38.7 percent of producers), corn (39 percent), wheat (31.9 percent of producers) (Conservation Technology Information Center et al., 2020).

Revenue boost

Some farmers have experienced yield increases because of cover cropping. In 2019, American farmers reported modest boosts in soybean, corn and wheat yields of 5 percent, 2 percent and 2.6 percent, respectively because of cover crops (Conservation Technology Information Center et al., 2020). Some farmers may also derive direct benefits from the sale of cover crop biomass as forage, instead of using it as green manure, during the fallow period (Daryanto et al., 2019).

Increased adoption of cover crops would also drive economic opportunities in rural areas, such as growing and processing cover crop seed, and potential contracted

[63] The 2019/202 survey was administered by USDA’s Sustainable Agriculture Research and Education (SARE) program, Conservation Technology Information Center (CTIC), and American Seed Trade Association (ASTA). The survey received 1,172 responses from farmers from across the US, of which 19.2 percent were horticulture users of cover crops representing fruit, nut, and vegetable operations around the country.

services for planting and/or terminating cover crops (Farmers for Climate Solutions, 2021).

Generally, farmers report that the benefits associated with cover crops are at least sufficient to cover seeding costs (Bergtold et al., 2017; Roesch-McNally et al., 2018). In a study on the effectiveness of cover crops as an alternative weed control strategy for sweet corn in southern Ontario, the private benefits of cover cropping were reported to be as high as $600 ha-1 yr-1 (O'Reilly et al., 2011).

Meanwhile, in a multi-criteria assessment of 11 NbS in BC, planting cover crops has a neutral[64] financial risks/benefits impact since this co-benefit will not be impacted by this practice, or harms and benefits offset (Norgaard et al., 2021). Similarly, in the 2020 Ontario cover crop survey, 37 percent of farms reported seeing an increase in farm profit, 31 percent identified that cover crops resulted in no change to their profit, 28 percent of farmers were not able to identify the influence of cover crops on farm profit and 4 percent reported their farm had seen a reduction in their farm profit with cover cropping (Morrison & Lawley, 2021a).

[64] Cost of adoption values seem accurate as presented for direct costs; however, it is important to consider indirect costs, such as not being able to get a second crop succession in, and reduced cash crop yield from needing to plant a cover crop (i.e., having to forgo potential yield and profit) (Norgaard et al., 2021)

Appendix D.

Survey Questions

I. Opening Questions

1. Are you 18 years old or older? Yes / No.

2. Do you produce annual field crops in Canada? Yes / No.

If 'No' to either of these questions - goes to end of survey message: My sincere thanks for your valuable contribution to my research project. Your response has been recorded.

II. **Farm Management Practices**

1. On average, how many acres do you crop per year? (Include land left fallow; exclude livestock and other perennial land uses): ____

2. Has the number of acres cropped per year changed significantly over time? Yes/No

3. *If yes to Q2*, what are the two (2) top reasons for you changing the number of acres you crop per season?
    1. ___
    2. ___

4. A cover crop is a plant that is used to provide a variety of ecosystem services such as slow soil erosion, improve soil health, and increase field and/or crop resilience to extreme weather events. Cover crops may be planted over a whole field or selectively planted. Cover crop species, seeding method, seeding rate, and timing is unique to farmer objectives and conditions. Have you ever planted cover crops on your farm?
    a. Yes
    b. No

*If 'no' to Q4, skip to #11.

5. Approximately how many years have you planted cover crops on the farm? ___

6. In the past 3 years, on average what percentage of your farm is planted to cover crops on an annual basis?
    a. 1-20%
    b. 21-40%
    c. 41-60%
    d. 61-80%
    e. 81-100%

7. What are your top three (3) reasons for using cover crops?

a. Improve soil structure or soil health
b. Improve weed management
c. Add organic matter
d. Reduce nutrient losses
e. Improve soil fertility
f. Weed suppression
g. Reduce erosion
h. Sequester carbon
i. Improve water infiltration
j. Habour beneficial insects
k. Improve insect or disease management
l. Create a better walking/driving surface
m. Reduce dust
n. Increase soil nitrogen content
o. Reduce soil nitrogen content
p. Biodiversity
q. Not listed (please specify): _____

8. What is your primary method for terminating your cover crops?
   a. Mowing
   b. Tilling
   c. Spraying
   d. Winter kill
   e. Roller crimper
   f. Plastic or tarps
   g. No termination
   h. Other approach (please specify):

9. How long do you keep your cover crops for?
   a. Less than 1 year
   b. 1 year
   c. 2 years
   d. 3 years
   e. Over 3 years

10. Why do you keep your cover crops for the duration you do? _____

11. Would you recommend or not recommend using cover crops to other farmers where cover crops could be used?
    a) Strongly recommend
    b) Recommend
    c) Not recommend
    d) Not at all recommend

12. *If respondent indicates they would ‘not recommend’ or ‘not at all recommend’ cover crops to other farmers where cover cropping could apply* Why would you not/not at all recommend cover crops to other farmers where cover crops could be used?

III. Barriers & Opportunities to Use of Cover Crops

13. Whether or not you have planted cover crops, what barriers do you face or foresee in planting cover crops? (Select all that apply)
    a. I foresee/face no barriers to planting cover crops
    b. Financial
    c. Knowledge (e.g., understanding of cover crops)
    d. Seasonal/timing constraints
    e. Not listed (please specify): _____

14. Whether or not you have planted cover crops, what factors are or would be most important when making management decisions related to planting cover crops on your farm? Please rank the following options.
    - ☐ Crop rotation
    - ☐ Market prices
    - ☐ Soil health
    - ☐ Labour costs
    - ☐ Adaptation/resilience to climate change impacts
    - ☐ Reducing costs due to Greenhouse Gas (GHG) emissions
    - ☐ Machinery required
    - ☐ Not listed (please specify): _____

15. What are the main sources of information you turn to when seeking information that help you make decisions about climate friendly farming methods? (Please select top three (3) options from the list below)
    - ☐ My own past experience
    - ☐ Other farmers
    - ☐ Certified crop advisor or agronomist
    - ☐ Regional Cover Crop Councils
    - ☐ Farmer Cooperative
    - ☐ Ag media (e.g., magazines, radio, TV, social media, podcasts, etc.)
    - ☐ Producer associations
    - ☐ Agriculture and Agri-Food Canada
    - ☐ Provincial ministry of agriculture
    - ☐ Voluntary Organizations

 Farming Union

 Farmer Association

 YouTube or similar

 Training Institutes

 I do not seek information pertaining to farming decisions about climate friendly farming methods

16. Select the option that best describes your situation in the following statement: *I (fill in the blank with one of the answer choices) adjust my farming practices in response to climate change.*
    a. Frequently
    b. Sometimes
    c. Rarely
    d. Never

IV. Policy Considerations

17. Have you ever **applied for** funding to adopt cover crops on your farm? Yes / No.

18. *If 'no' to Q17: Why have you never applied for funding to adopt cover crops on your farm? Select top three (3) options from the list below.
    Funding was not large enough to warrant application

    Program's funding limited number of successful applicants

    Not interested

    I do not have enough time to apply

    I was not aware of any such programs

    I did not meet eligibility criteria

    Not listed (please specify): _____

19. *If respondent selects 'I did not meet eligibility criteria': What criteria made you ineligible? _____

20. Have you ever **received** funding to adopt cover crops on your farm? Yes / No.

21. Based on your experience in seeking funding, would you apply for funding again?
    a) Definitely would apply
    b) Probably would apply
    c) Might or might not apply
    d) Probably would not apply
    e) Definitely would not apply

22. *If respondent indicates they have received funding" What was/were the source(s) of your funding you received? (Check all that apply)
    - ☐ Federal government program
    - ☐ Provincial government program
    - ☐ Municipal government program
    - ☐ Private company
    - ☐ Non-profit organization

23. Would you support or oppose the following government actions to support the use of cover crops?

	Strongly support	Somewhat support	Neither support nor oppose	Somewhat oppose	Strongly oppose
Carbon sequestration payment	○	○	○	○	○
Per acre subsidy (cost-share program)	○	○	○	○	○
Regulation requiring that a minimum percentage of fields across my province use cover crops by a certain date	○	○	○	○	○
Convene advisory committee reporting to the agriculture ministry of my province to advise	○	○	○	○	○

on best methods to increase use of cover crops	

24. Are you likely or not likely to apply for the following programs/positions that target the use of cover crops?

	Extremely likely to apply	Somewhat likely to apply	Not very likely to apply	Not at all likely to apply
Carbon sequestration payment	○	○	○	○
Per acre subsidy (cost-share program)	○	○	○	○
Participate in advisory committee reporting to the agriculture ministry of my province to advise on best methods to increase use of cover crops	○	○	○	○

25. Is there a policy or program not already mentioned that you think would be more beneficial for increasing the use of cover crops? _____.

V. Demographics and Farming Conditions

26. Which age bracket do you fall under?
    a. 18-29
    b. 30-39
    c. 40-49
    d. 50-59
    e. 60+

27. To which gender identity do you most identify?
    a. Male
    b. Female
    c. Two-spirit
    d. Non-binary
    e. Not listed (please specify): __

28. How would you categorize yourself?
    a. Commodity crop farmer (e.g., corn, soybean, wheat, etc.)
    b. Horticultural crop or vegetable farmer
    c. Not listed (Please specify): _____

29. Is your farm certified organic? Yes / No.

30. *If farm is not certified organic*: On what percentage of your farm do you use the following organic farming practices? *(Sliding scale 0-100%)*
    a. No synthetic fertilizer
    b. No herbicide
    c. No insecticide
    d. No fungicide
    e. Biodiversity enhancement
    f. Soil building crop rotations

31. What are the first three digits of your postal code?

Appendix E.

Sample Interview Questions and Interview Participant List

Sample Interview Questions

The following questions were posed to government, academic, agricultural consultant, and not-for-profit representatives:

I. Barriers & Opportunities

1. What do you see as the top benefits to farmers for planting cover crops?

2. What are the greatest barriers to using and increasing the adoption of cover crops for farmers?

3. What role do you think government has in overcoming these barriers?

4. What challenges has government faced when trying to remove these barriers?

II. Policy Considerations

5. Please comment on the key strengths and weaknesses of the following potential policy approaches.
    a. Carbon sequestration payment
    b. Per acre subsidy (cost-share program)
    c. Compulsory cover crop regulation
    d. Convene provincial advisory committee
    e. Cooperative extension program

6. Is there a policy or program not mentioned that you think would be more beneficial for increasing the use of cover crops?

The following questions were posed to farmers:

I. Farm Management Practices

1. Please tell me about yourself and your work.

2. Can you tell me about your experience with cover crops, if any?

II. Barriers & Opportunities to Use of Cover Crops

3. Whether or not you have planted cover crops, what barriers do you face or foresee in planting cover crops?

4. Whether or not you have planted cover crops, what factors are or would be most important when making management decisions related to planting cover crops on your farm?

5. What are the main sources of information you turn to when seeking information that help you make decisions about environmentally friendly farming methods?

III. Policy Considerations

6. Have you ever **applied for** funding to adopt cover crops on your farm? If not, how come? If yes, have you ever **received** funding to adopt cover crops on your farm? If yes, what was/were the source(s) of your funding you received?

7. Based on your experience in seeking funding, would you apply for funding again?

8. Please comment on the key strengths and weaknesses of the following four potential policy approaches.
    a. Carbon sequestration payment
    b. Per acre subsidy (cost-share program)
    c. Compulsory cover crop regulation
    d. Convene provincial advisory committee
    e. Cooperative extension program

9. How likely or not likely are you to apply for the following programs/positions that target the use of cover crops? How come?
    a. Carbon sequestration payment
    b. Per acre subsidy (cost-share program)
    c. Participate in advisory committee reporting to the agriculture ministry of my province to advise on best methods to increase use of cover crops
    d. Participate in the cooperative extension program'

10. Is there a policy or program not already mentioned that you think would be more beneficial for increasing the use of cover crops?

Interview Participants

Table E.1 provides a list of the interview participants and their professional affiliations.

Table E.1 Interview Participant List

Interview Participant	Professional Affiliation/Agricultural Region
Provincial Government	
Confidential	BC Ministry of Agriculture, Food and Fisheries
Confidential	BC Ministry of Agriculture, Food and Fisheries
Confidential	BC Ministry of Agriculture, Food and Fisheries
Academic	
Confidential	Confidential
Producers	
Confidential	Vancouver Island
Graham Bradley	Good Earth Farm, Gabriola Island, British Columbia
Stuart Oke	Rooted Oak Farm, North Augusta, Ontario
Confidential	Thompson Okanagan
Not-for profit	
Confidential	Confidential
Abra Brynne	Policy Advisor, Farm Folk City Folk
Agricultural Consultants	
Confidential	Confidential
Ione Smith	Director, Upland Agricultural Consulting Ltd.