Climate Stressor Scenarios: Final Report

Regional Economic Impact of Climate Change in B.C. Examined Through Scenario Analysis

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Definitions

Adaptation: actions taken to reduce the negative impact or benefit from changes in the external environment.

Adaptive capacity: ability of a system to change when the external environment in which it is operating is changing.

Anthropogenic climate change: changes in the earth's climate caused by human emissions of greenhouse gases and land use changes.

Autonomous adaptations: adjustments individuals make in response to climate change in the absence of government incentives or action. For example, a producer may choose to upgrade his or her irrigation infrastructure to improve the farm's productivity or pilot a new variety of crop which they judge to be better suited to the regional climate.

Planned adaptations: adaptive actions taken by government to provide public goods or incentives to motivate action by the private sector. Governments may choose to participate in planned adaptation because certain adaptation actions have benefits that cannot be captured by private individuals, resulting in under-investment. Some examples would include development of new irrigation infrastructure, land-use arrangements and property rights, water pricing and training for the private and public sector (capacity building)[1].

[1] Rosenzweig and Tubiello (2007)

Executive Summary

Background

Climate change projections indicate that over the coming decades B.C. agriculture will have to deal with very significant changing conditions. Projected climate impacts include: increases in the number of hot days, changes in precipitation patterns, more frequent and intense extreme weather events such as droughts, and associated effects such as flooding, erosion, excess moisture, wild fires and pest outbreaks. This will mean more risk and operational complexity for farmers, and will also impact Ministry of Agriculture programs such as Production Insurance and Agricultural Emergency Management. The scale and rate of climate change is anticipated to go beyond anything previously experienced and will require concerted adaptations for the B.C. agriculture sector to maintain growth and profitability. To begin addressing these needs, the Ministry of Agriculture, through the Growing Forward 2 program, is funding programming to direct and support agriculture sector adaptation at the regional and farm levels.

Without government involvement in adaptation programming, producers will make some adjustments to practices in response to climate and market forces. Adaptations that are beyond the scope of an individual producer may be neglected until there is a climate event that highlights the weakness the adaptation seeks to fortify. Investment in innovative practices that mitigate the impacts of climate change and have benefits beyond an individual producer's profitability, such as industry resilience, will be underfunded by private interests.

This report discusses illustrative scenarios in which agricultural regions of B.C. are faced with conditions consistent with climate projections for the 2030s. The analysis is intended to indicate what might be at stake in terms of reduced industry revenues if no adaptive actions are taken by government or private stakeholders. This analysis is not an evaluation of specific adaptive actions (e.g. improved farm drainage), but rather shows the benefit of planning and preparation similar to the Ministry's adaptation programming.

Approach

The analysis technique used was chosen following a comprehensive literature review of climate change, economic analysis, agriculture and adaptation (separate report, completed in November 2014). More technical and complex methods were not chosen due to time constraints, data availability, and modelling capacity limitations. Scenario analysis is a practical approach that enables decision makers to analyze how critical uncertainties will evolve under a set of assumptions, and to determine how best to proceed in that particular state of the world. The scenarios presented in this document were developed collaboratively with experts in the fields of agrology, climate science, adaptation and economics. The scenarios pertain to the Cowichan, Cariboo, Peace, and Okanagan regions.

Adaptations reduce the negative impact of a climate stressor on farm cash receipts and three cases (low, medium, and high) are presented to show a range of implementation extent and adaptation effectiveness. The economic benefit of adaptation is calculated as the difference between industry revenues (or farm cash receipts) with adaptation and without adaptation when a climate stressor event occurs in the year 2035. The values presented are for industry revenues in a single year (2035) but the economic benefit of adaptation is a constant share of industry revenues in each case (with the exception of the Cariboo Region).

The "without adaptation" scenario is an illustrative "bookend" that must be qualified by the fact that adaptation work has already begun through knowledge dissemination and planning. Even without direct government involvement producers will continue to adapt to challenging conditions, although potentially not to the degree necessary to cope with the unprecedented changes anticipated due to climate change. Similarly, the complete adaptation scenario is unlikely, since not all adaptations are suited to unique production systems and it will not be possible to anticipate all climate change vulnerabilities. For this reason, the case with adaptation still depicts negative impacts of undesirable weather conditions.

Results

In the Okanagan Valley, the benefit of adaptation to extreme heat and drought ranges from $58 million in the case in which there is low effectiveness or implementation of adaptation to $154 million in the case with high effectiveness. Drought and water availability is also an issue in the Cowichan Valley; in this scenario economic benefits of adaptation are between $5 million and $14 million. In the Peace region, the impact of cumulative years of drought and extreme precipitation during the fall harvest demonstrates an economic benefit of adaptation between $19 million and $37 million. Through adaptation to changing precipitation patterns in the Cariboo, the economic benefit for the cattle industry is between $24 million and $65 million.

Table 1: Economic Benefit of Climate Change Adaptation – All Regions

Region	Commodities	Climate Stressors	Adaptations	Case	Benefit of Adaptation ($M)
Cowichan	mixed: dairy, poultry, cattle, vegetables, berries, wine grapes	less winter snow summer drought	regional water planning, increased water storage, irrigation efficiency	Low Medium High	**$5** **$9** **$14**
Cariboo	beef cattle, forage crops	increased spring and fall precipitation and summer dry spells	management Intensive grazing, surface water management, irrigation	Low Medium High	**$24** **$38** **$65**
Peace	grains, oilseeds	cumulative years of drought and extreme precipitation in the fall	conservation tillage, pest monitoring, improved drainage	Low Medium High	**$19** **$25** **$37**
Okanagan	apples, grapes and 96% of B.C.'s soft fruit. Sweet cherries, B.C. VQA wines	severe drought reducing water availability	water storage and planning, increase irrigation efficiency	Low Medium High	**$58** **$96** **$154**
Total		major climate event in all 4 regions	effective implementation of all feasible agricultural adaptations	Low Medium High	**$105** **$169** **$270**

Notes

1. Low, medium and high cases reflect the effectiveness of adaptation. Low effectiveness mitigates the negative impact of the climate stressor by less than high effectiveness.
2. Total does not represent the full provincial total due to regions missing from the analysis (e.g. Fraser Valley).

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1. Introduction

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The scale and rate of climate change is anticipated to go beyond anything previously experienced and will require concerted adaptations for the B.C. agriculture sector to maintain growth and profitability. To begin addressing these needs, the Ministry of Agriculture, through the Growing Forward 2 (GF2) program, is funding programming to direct and support agriculture sector adaptation at the regional and farm levels.[2]

This report discusses illustrative scenarios in which agricultural regions of B.C. are faced with conditions consistent with climate projections for the 2030s. The analysis is intended to indicate what might be at stake in terms of reduced industry revenues if no adaptive actions are taken by government or private stakeholders. This analysis is not an evaluation of specific adaptive actions (e.g. improved farm drainage), but rather shows the benefit of planning and preparation similar to the Ministry's adaptation programming.

1.1 Adaptation Program Overview

In 2008, in response to climate action by the B.C. government, the B.C. Agriculture Council and the Investment Agriculture Foundation of B.C. set up the B.C. Agriculture and Food Climate Action Initiative (CAI) to assist the agriculture sector with addressing the challenges, and acting on the opportunities associated with climate change. The CAI has been led by an advisory committee of agricultural producers, food processors and representatives from various government agencies.

In the spring of 2012, the CAI completed a climate change risk and opportunity assessment series for B.C. agriculture (*Adaptation Risk & Opportunity Assessment* report series).[3] Based on the findings of the assessments, the CAI has developed regional agricultural adaptation strategies with local partners in the Peace, Cowichan Valley, Delta, and Cariboo Regions. The CAI also completed a series of reports on six farm-level adaptation practices: water storage, drainage, shelterbelts, nutrient management, conservation tillage, and management-intensive grazing.

The Ministry of Agriculture is providing approximately $5.7 million for adaptation programming to be delivered by CAI over 2014-2018.[4] Three more regional adaptation strategies will be developed

[2] The Ministry of Agriculture's adaptation programming supports the B.C. government's 2010 climate change adaptation strategy, which has three focus areas: building a strong foundation of knowledge and tools; building collaborative partnerships with key stakeholders and taking action in climate sensitive sectors; and making adaptation part of B.C. Government's business.

[3] Crawford and MacNair (2012)

[4] The funding is provided through Growing Forward 2, a federal-provincial-territorial initiative.

and implemented (one for the Fraser Valley is currently underway and one for the Okanagan is planned to commence in 2015). Farm-level adaptation will be advanced through pilot and demonstration projects funded through the new Farm Adaptation Innovator Fund. . The regional strategies and the farm-level projects will contribute to greater adaptive capacity in the sector.

In addition to funding the programming delivered by CAI, the Ministry of Agriculture has completed a structured assessment of the adaptive capacity of 14 of its programs using the Adaptive Design and Assessment Policy Tool (ADAPTool). The Ministry initiated the ADAPTool pilot in 2013 to "provide the Ministry with a systematic assessment and understanding of the potential for its policies and programs to support climate change adaptation".[5] The ADAPTool report included recommendations for all the programs assessed, including priority actions for AgriStability, Production Insurance, Agricultural Emergency Management, and Invasive Alien Plant Program and Pest Management. The Ministry is developing an implementation strategy for the ADAPTool recommendations.

[5] Pilot Application: Adaptive Design & Assessment Policy Tool (ADAPTool) – Government of British Columbia Agriculture Programs. International Institute for Sustainable Development. 2013.

1.2 The Value of Climate Change Adaptation

This report estimates the economic value of climate change adaptation in the B.C. agriculture sector. However not all the benefits of adaptation are captured in this analysis. Climate change has the potential to negatively impact agricultural productivity through more frequent and severe extreme weather events, water management complexity, and the changing distributions of pests and diseases.[6] Agricultural productivity is the level of output that is generated from each unit area of land, and productivity growth is the driver of long-run economic growth. Innovation, or technological change, is a key driver of productivity growth, along with improved management practices to better combine resources. Adaptation to climate change protects agricultural productivity from the anticipated adverse effects of climate change. Innovative adaptations enable producers to capitalize on opportunities, increase productivity and drive economic growth.

There are also non-economic benefits to climate change adaptation, such as reducing psychological stress for producers who are aware of the potential impacts and have management plans in place. In the event of a major climate event, having functioning plans in place reduces costs by improving response times and establishing decision making and co-ordination channels. Avoiding interruptions in food supply chains carries economic and non-economic benefits.

Adaptations that provide a clear benefit to producers are likely to be undertaken by producers themselves ("autonomous adaptation"). However, there may also be broader benefits to the agriculture sector, government, or society in general, and if these broader benefits cannot be captured by the individual producers making the decision about how much adaptation to undertake, then there may be under-investment in adaptation from a societal perspective. This provides an economic rationale for government to provide incentives for adaptation or to provide the adaptation directly. Furthermore, there are adaptations which cannot feasibly be undertaken by individual producers acting alone, such as dikes, emergency preparedness and evacuation planning, and infrastructure like water storage and transportation. The benefits of these adaptations may be considerable, but without government involvement there may not be the collective action needed to realize these benefits.

[6] For more information on anticipated climate change impact on the B.C. agriculture sector, please see the Climate Action Initiative Risk and Opportunity Assessments and the Regional Adaptation Strategy series.

2. Literature Review: Economic Impact of Climate Change and Benefit to Adaptation

The literature review explored many different analysis techniques to determine the economic impact of climate change and adaptation in B.C., finding three promising methodologies. These methodologies are Ricardian analysis, Integrated Modelling Systems (or Integrated Assessment Models) and scenario analysis. These analysis techniques are discussed below.

a. **Ricardian models, or hedonic pricing models,** are used to answer the questions: What is the economic impact of climate change, and in some cases, How is this reduced by adaptation? In this approach, hedonic pricing models are used to isolate the price effects of various characteristics, for example, the amount by which a nearby green space increases the value of a home. Applied to this project, Ricardian analysis would be used to quantify the costs of climate change by isolating the impact of various weather indicators on the price of land. The parameters derived from this technique would be used with climate projections to determine future farm land values.

   Advanced Ricardian regression techniques have used multinomial probability distributions to determine the probability that an Agro-Ecological Zone (a proxy for productivity developed by the Food and Agriculture Organization) will be present in a given district.[7] Different Agro-Ecological Zones have different net revenues and crop suitability. As these zones shift across the continent due to climate change, net revenue and crop choice will change in a given district. This method allows for one type of adaptation (changing crop mix in response to climate change) but requires advanced econometrics. The results of this study found that there would be fewer high-value Agro-Ecological Zones in Africa, resulting in a negative economic impact of climate change on the African economy.

   Ricardian analysis captures autonomous adaptations by assuming that farmers will maximize the value of land subject to climate conditions. It does not provide a good framework to evaluate planned adaptation or the impact of knowledge generating programs designed to encourage adaptation to climate change that may not immediately increase profits and as a result land values. Further research could be done by developing the necessary data which pairs detailed land use with land values. Preliminary attempts have been made using B.C. Assessment data and Land Use Inventories compiled by the Ministry of Agriculture. Several issues emerge when combining these complex data sets, so a focused research project would be necessary to complete this work.

b. **Integrated modelling systems (IMS)** in which several models work together to generate economic impacts of climate change on agriculture are the new standard in this area of analysis. The IMS approach is common at the global scale[8], and has also been used in regional climate

[7] Kurukulasuriya and Mendelsohn (2008)
[8] Tan 2003, Rosegrant (2008)

adaptation studies.[9] Climate scenarios, crop simulations, and economic models are common components of IMS used to measure impacts of climate change adaptation (Figure 1). In the figure below, the baseline scenario would model the outcome of climate change on the agriculture sector without adaptation. A representative farmer economic model would show which adaptations would be selected by allowing farmers to choose different crop types or management techniques (such as higher efficiency irrigation). A partial equilibrium (PE) economic model would demonstrate the aggregate impact on the agriculture sector. The IMS can be tailored to suit the research question through the choice of the economic model.

The IMS is created by linking several distinct models together by matching outputs of one model to inputs of another. Climate change scenarios produce future projections of daily, monthly or annual temperature and precipitation. This information is an input into hydrology models and crop simulations, which produce estimates of water availability and crop growth respectively. Based on projected crop yields and water availability, economic outcomes are estimated with farm level decision making or sector level PE models.

An integrated modelling system in which climate, water, agricultural and economic models are linked allows for the greatest amount of flexibility and specificity in modelling climate change adaptation economics. However, these models have only just begun to incorporate adaptation.[10] Most major modelling exercises use downscaled climate data in the integrated modelling approach. Developing the expertise to work with models from several different disciplines and finding or creating linkages between these models is the most difficult aspect of the analysis.

In Figure 1, each blue box represents an individual model, arrows represent outputs from one model and inputs into the next, and the final outcome is in the green box.

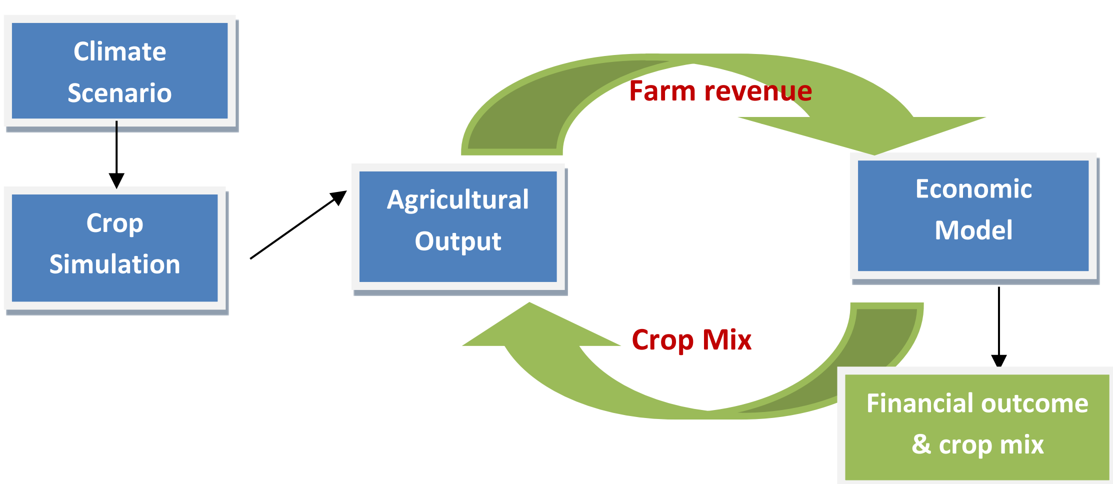

Figure 1. Integrated modelling system (Adapted from the World Bank 2010)

[9] World Bank (2008), Rosegrant (2012)
[10] Gordon et al (2014) , and work underway at AAFC Agri-Environmental Policy Research

c. **Climate scenarios** model a specific impact of climate change. Climate stressors such as sea level rise, more frequent floods, and droughts are often cited as consequences of climate change. However a great deal of uncertainty surrounds the extent, timing, and location of these climate stressors. In order to plan for these hazards without exact data on frequency or magnitude, climate stressor scenarios are built using reasonable assumptions. This approach works best with information that is currently available from the Ministry of Agriculture. Scenario analysis is a practical approach that enables decision makers to analyze how critical uncertainties will evolve under a set of assumptions, and to determine how best to proceed in that particular state of the world. The collaborative development of the scenarios has the benefit of fostering an ongoing dialogue within the Ministry about the costs and benefits of adaptation to climate change.

3. Scenario Planning for Adaptive Policy

Scenario analysis allows participants to identify major uncertainties so that the consequences of today's decisions can be evaluated. A strength of scenarios is their ability to change the assumptions decision makers have about the way the world works. For that reason, the process of scenario development is as important as the final product.[11] Scenario analysis opens up discussions about key assumptions and uncertainties and allows decision-makers to consider the impacts of several different visions of the future.

The scope and scale of climate change impacts are anticipated to exceed anything previously experienced. The scenarios presented in this document go beyond historical experiences to describe two versions of the world: one in which no adaptive actions are taken and one in which there is a concerted effort to proactively adapt to changing conditions. An agricultural producer's ability to adjust practices and management techniques on their own is described as autonomous adaptation in the economics literature. While autonomous adaptations will play an important role in adaptation to climate change, it is difficult to model individual responses to an uncertain future. Producers may lack adequate information on climate change impacts to make informed investments.

There may be broader benefits to the agriculture sector and if these broader benefits cannot be captured by the individual producers making autonomous adaptations, then there may be under-investment in adaptation from a social perspective. Some investments may be beyond the scope of a single producer and cannot work together without government involvement. There may also be distributional issues in which the producers at highest risk from climate change have the fewest resources available to adapt. This provides an economic rationale for government to provide incentives for adaptation or to provide the adaptation directly. The government's role in climate change adaptation is both to facilitate the large scale adaptations that cannot be undertaken at the farm level and to provide information and encouragement for farmers to take adaptive actions to anticipated climate stressors. Investment in adaptation may also align with other specific policy goals such as food security and increasing industry resilience.

Scenario analysis is an important step in integrated and forward-looking analysis, in which key factors that affect policy performance are identified.[12] Scenarios are internally consistent stories describing paths from the present to the future.[13] They enable decision makers to analyze how critical uncertainties will evolve under a set of assumptions, to determine how best to proceed in that particular state of the world. The scenarios in this report map quantitative climate projections to anticipated agricultural impacts. Potential adaptations to respond to the agricultural impact are discussed and a range of economic consequences are calculated.

[11] Brummell, A., and G. MacGillivray. *Introduction to Scenarios*. Scenarios to Strategy Inc., 2007.
[12] Swanson, D., Bhadwal, S. *Creating adaptive policies: a guide for policy-making in an uncertain world* (2009). The authors explain how integrated and forward looking analysis is a key characteristic of adaptive policy making and program design.
[13] Brummell, A. and Greg MacGillivray *Introduction to Scenarios and Scenario Planning* Scenarios to Strategy Inc.

The analysis indicates what might be at stake in terms of industry revenues if no adaptive actions are taken on the part of public or private stakeholders. It is not meant as a valuation of specific adaptive actions, but rather to show the benefit of planning and preparation compared to the status quo[14]. The economic benefit of climate change adaptation is calculated as the difference between industry revenues (or farm cash receipts) with adaptation and without adaptation when a climate stressor event occurs in the year 2035. The benefit to adaptation is a constant share of industry revenues each year, with the exception of the Cariboo Region in which economic benefits grow as adaptation progresses over time.

The baseline scenario allows farm cash receipts to grow at their long run historical (or most reasonable) rates of growth. The economic impact of the climate stressor without adaptation was discussed with regional agrologists as a percentage reduction in farm cash receipts from the baseline. The without adaptation scenario is somewhat unrealistic for two reasons: adaptation work has already begun through knowledge dissemination and planning, and even without direct government involvement producers will continue to adapt to challenging conditions, although perhaps not to the degree necessary to cope with the unprecedented changes anticipated due to climate change. Complete adaptation is also unlikely, since not all adaptations are suited to unique production systems and it will not be possible to anticipate all climate change vulnerabilities. For this reason, the true economic benefit is between zero and the values calculated in this report. Within the scenarios, high, medium and low cases were created to offer a range of possible outcomes depending on the degree of implementation and the effectiveness of the adaptations presented. The medium case was developed in collaboration with the regional agrologists based on their experience with significant weather events in the past.

[14] In an economic analysis of specific adaptations, for example farm drainage improvements, the results would provide decision makers with metrics such as returns on investment, benefit cost ratios and net present value.

4. Climate Stressor Scenarios

4.1 Introduction to the Climate Stressor Scenarios

Climate change is expected to cause an increase in extreme weather events and stressors for agriculture in key regions of B.C., and adaptation actions can reduce the impact on the agriculture sector. The purpose of the climate stressor scenarios presented here is to highlight the risks and vulnerabilities in four agricultural regions of B.C. (Cariboo, Peace, Cowichan and Okanagan) and show the importance of adaptation that reduces the negative impacts of climate change. The regional approach was necessary because of the diversity of agriculture and climate change impacts across B.C. The regions chosen were based on the availability of adaptation information, economic significance, stage of adaptation planning and degree of regional commodity specialization. The analysis notably lacks the largest agricultural economic region, the Fraser Valley, for which a regional adaptation strategy is currently being developed. A recently published report by CAI discussed the economic impacts of the major climate stressor, flooding, in the Fraser delta region[15]. The adaptation investments go beyond the scope of projects currently underway in B.C. and are meant to illustrate the importance of further investment in adaptation programming generally. The analysis is not an evaluation of the economics of specific adaptive actions.

The scenarios present combined impacts of several climate stressors and the economic consequences associated with these impacts. The climate projections were presented to regional agrologists to determine what the expected economic impact of the climate stressor would be without adaptation. A reasonable reduction in farm cash receipts caused by the climate stressor was derived through consultations with each regional agrologist. The high, medium and low cases change the effectiveness of the adaptations presented. In the low case, adaptation has a low effectiveness against the climate stressor and farm cash receipts fall by the highest percentage. In the high case, the adaptations are highly effective at mitigating the negative impacts of climate change and farm cash receipts fall by the lowest percentage. In the Cariboo region, the without adaptation scenario shows the cattle industry continue at the long run historical rate of decline. With adaptation to climate change, producers are able to capture benefits from climate change and increase forage production and cattle sales. Again, the high, medium and low cases explore the effectiveness of the adaptations in mitigating the negative impacts of climate change.

These scenarios for Cariboo, Peace and Cowichan regions are written in such a way as to be consistent with data from the North America Regional Climate Change Assessment Program (NARCCAP) on extreme weather events. [16] This data is based on climate projections for the 2050s (with a simple adjustment applied to what they would approximately apply to in the 2030s), and is derived from 11 regional climate models following the A2 emissions scenario.[17] This information was provided by the

[15] Robbins, M and Tatebe, K (2014)

[16] The North American Regional Climate Change Assessment Program (NARCCAP) is an international program to produce high resolution climate change simulations in order to investigate uncertainties in regional scale projections of future climate and generate climate change scenarios for use in impacts research.

[17] The A2 emissions scenario is often referred to as "business as usual" and is based on the assumption of: relatively slow demographic transition; relatively slow convergence in regional fertility patterns; relatively slow convergence in inter-regional GDP per capita differences;

Pacific Climate Impacts Consortium (PCIC) at the University of Victoria and interpreted with the help of PCIC climate scientist Trevor Murdock. Additional information was gathered from PCIC's Plan2Adapt online tool for the Okanagan Valley.[18]

Regional climate model projections indicate increases in temperature and precipitation compared to historical 30-year averages. However, these will not be evenly distributed due to increased climate variability. Climate variability and extreme weather are a greater concern for agriculture than changes in annual averages. These scenarios explore situations in which past extreme weather events are further aggravated by climate change. The qualitative impact descriptions were drafted using information from the Risk and Opportunity Assessments and the Regional Adaptation Strategies produced by the CAI.

The climate stressor scenarios were then developed collaboratively with Trevor Murdock (PCIC), Emily MacNair (CAI), and Ministry of Agriculture regional agrologists representing the four regions: Geneve Jasper (Cariboo), Julie Robinson and Lori Vickers (Peace), Carl Withler and Jim Campbell (Okanagan), and Wayne Haddow (Cowichan). This approach enabled the scenarios to be consistent with the climate projections and for the climate projections to be effectively communicated to the group directly by a climate scientist. The scenarios were verified for accuracy through discussion with regional agrologists about the implications of the climate stressors, uncovering the details of how the climate stressor would impact agriculture in their regions. The adaptations presented are considered appropriate actions to address the climate stressors. The most important benefit of this approach is that it continues a dialogue within the ministry about the anticipated impacts of climate change and the potential benefits of adaptation.

4.2 Cowichan Valley

The Cowichan Valley Regional District (CVRD) stretches from the Malahat to just south of Nanaimo, and from the southern Gulf Islands to the west coast of Vancouver Island, covering approximately 3,473 square kilometres.[19]

Agricultural production in the CVRD is extremely diverse, including: dairy, poultry, cattle, greenhouse vegetables and an array of field and horticulture crops ranging from vegetables to berries to wine grapes. There are also many mixed farms in the region.[20]

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relatively slow end-use and supply-side energy efficiency improvements (compared to other storylines); delayed development of renewable energy; and, no barriers to the use of nuclear energy.

[18] http://www.pacificclimate.org/analysis-tools/plan2adapt

[19] Cowichan Valley Regional District. 2010 State of the Environment Report. June 2010, p..15. http://www.12things.ca/12things/uploads/FinalReportJune2010.pdf

[20] Crawford, E.; MacNair, E. and K Tatebe *Cowichan Regional Adaptation Strategy* (2012)

Climate Stressor Description

Stressor scenario: Less snow in winter, drought in the summer. An intense summer drought is caused by longer warm spell durations and less summer precipitation.

2030s normal climate context:

- Annual temperatures warmer by over 1°C (on average), with larger increases in summer than winter.
- Longer periods without any precipitation occur, primarily in the summer, and **consecutive dry spells are 10 days longer** than the recent past.
- **Warm spells**[21] increase in frequency by a factor of 4
- Winter precipitation is more rain than snow, resulting in lower river flow in the Koksilah, Cowichan and Chemainus rivers earlier in the summer.

Agricultural Impact

- Severely reduced water availability due to lack of precipitation and low river flow. The lack of precipitation will reduce forage crop yields, which will increase feed costs for livestock producers.
- The hot, dry summer will also reduce surface water available for livestock. In response, producers will reduce breeding stock by not buying calves from other parts of the province causing a reduction in herd size. The decline would be comparable to levels seen after the 2003 Bovine Spongiform Encephalopathy (BSE) issues, approximately a **30% reduction in herd size**.
- The final forage cut will be eliminated due to lack of irrigation water at the end of the season, which would **reduce total forage yield by 20%** if producers average three cuts per year.
- The extended warm spell may cause corn to ripen early, which would **reduce the maize yield by 10%.**

Possible Adaptations

- Regional water planning and increases in water storage.
  - On-farm water management can be expensive and require government support unless it is funded by a dedicated investor.
  - There are some opportunities for regional water storage in Cowichan Lake.
  - Producers could use water recycled for agriculture – but this would require a large infrastructure investment to move the heated water closer to agriculture.
  - Increase water storage to supply adequate water for irrigation. This will allow farmers to switch to alternative crops from dry land forage when there is less precipitation in future.
- Irrigation efficiency improvements also play an important role in water planning. Efficiency gains can extend the irrigation period or increase irrigated area if less water is wasted

[21] Warm spells throughout the climate stressors refer to the "Warm Spell Duration Index" from the CLIMDEX index of climate extremes which reflects the number of warm spells of minimum 6-day duration. Warm refers to a day being in the 90th percentile for that day of the year and warm spells in the WSDI index can occur at any time of year.

Economic Impact of Adaptation

- **Without adaptation:** Due to the diverse nature of agriculture in the Cowichan Valley, the combined effects of reduced herd size, forage production and maize yield are represented by a **decrease of 15% for total farm cash receipts from the region**.
- **With adaptation:** Regional water planning and on-farm irrigation efficiency improvements are the best suited adaptations to cope with lower river stream flow and summer precipitation. If plans are created to manage these situations and use water most efficiently during a drought**,** and irrigation use is expanded in the region, **total farm cash receipts will only drop by 5%**[22] for those dry land producers who rely on precipitation.

Benefit of Adaptation

The economic benefits of adaptation are shown in Table 2, below. In all cases the impact of the climate stressor without adaptation reduces farm cash receipts by 15%. The table depicts three adaptation cases; the low case has low implementation or effectiveness of adaptation while in the high case adaptation is widely implemented or very effective.

- **Low:** With adaptation there is still inadequate water to meet the needs of local producers and farm cash receipts fall by 10% during the drought. The benefit of adaptation is then $4.7 million.
- **Medium:** Water planning and storage is better able to mitigate the negative impacts of the climate stressor, farm cash receipts fall by 5%.
- **High:** If adaptation is able to completely mitigate the negative impacts of reduced summer precipitation long warms spells, farm cash receipts are not affected by these changing conditions. The benefit of adaptation is $14 million.

Table 2: Economic Impact of Climate Change Adaptation – Cowichan Valley

Cowichan Valley	**Low**		**Medium**		**High**	
Climate Impact	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**
Commodity	Total Farm Cash Receipts		Total Farm Cash Receipts		Total Farm Cash Receipts	
Revenue Reduction	15%	10%	15%	5%	15%	0%
Revenue in 2035 ($M)	$80	$84	$80	$89	$80	$94
Benefit of Adaptation ($M)	**$5**		**$9**		**$14**	

Notes

1. Revenues are measured by total farm cash receipts for 2013, the share of farm cash receipts in the Cowichan Valley from the 2011 Census of Agriculture, which increase by the 20-year compound annual growth rate (3%) until they are shocked by a revenue reduction in 2035.
2. Farm cash receipts are from Statistics Canada Table 002-0001
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000

[22] Of the potential agricultural land (33,200 ha) only 2,465 ha (7.4%) are currently irrigated. *Cowichan Regional Adaptation Strategy* p.3

4.3 Cariboo Region

Much of the Cariboo Region is high, rolling plateau (with multiple mountain ranges). The Fraser River winds through the region, where forage crops are produced on the benches of the river and its tributaries. The capability of the soils in much of the region are a limiting factor, but areas with better river bench soils are able to produce high quality forage as well as root vegetables and potatoes. Some valleys soils have high clay content but with careful management, can produce a range of forage and field crops.

The beef cattle sector makes up about 27% of the agricultural operations in the region (farms where beef cattle contribute more than 50% of the estimated farm income), and forage crops make up 93% of the total cropped area (50,449 hectares).[23] Crown rangeland provides about 40% of the annual forage requirements of the ranching industry. As has been the case across B.C., there has been a significant reduction in the numbers of beef cattle in the region since the early 2000s (from 57,015 in 2006 to 39,430 in 2011). [24, 25]

This scenario is structured differently than the others. Rather than a single climate event at the end of the scenario horizon, producers must actively adapt to changing climate and precipitation patterns over the next 15 years. If they are able to successfully adapt, the rate of growth for regional farm cash receipts is changed. If they are unable to adapt, the cattle industry continues in a 20-year decline of 1.6% per year. While this decline was influenced by market conditions in the early 2000s, climate change presents a similar challenge to producers.

Climate Stressor Description

Stressor scenario: increased moisture in spring and fall with higher temperatures and longer dry spells in the summer. A warm, wet winter and spring are followed by a hot, dry summer in which warm spells last longer than before and there are significantly more extremely hot days.

<u>2030s normal climate context:</u>

- Increased annual precipitation by over 10% is experienced as **heavier precipitation in the winter, spring and fall.** The wettest days in November and May are on average **10% wetter than they were from 1971-2000.**
- Rains subside in June, and the three months of July, August, and September are hot and dry.
- Warm spells[26] increase in frequency by a factor of 4.
- Temperature reaches up to 40 ^{o}C for one day, which used to occur only once in 25 years on average, and which now occurs almost every second year.

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[23] Statistics Canada, 2011 Census of Agriculture, Farm & Farm Operator Data, catalogue no. 95-640-XWE; and Dobb, Allen 2013. Forage Production & Export Potential in BC's Central Interior. Report prepared for the BC Forage Council.

[24] Ministry of Agriculture. Cariboo Regional District Agriculture in Brief Fact Sheet. 2013.

[25] Charlton, S.; Crawford, E.; MacNair, E.; Dobb, A. and K. Tatebe. *Cariboo Regional Adaptation Strategy* (2012).

[26] Warm spells throughout the climate stressors refer to the "Warm Spell Duration Index" from the CLIMDEX index of climate extremes which reflects the number of warm spells of minimum 6-day duration. Warm refers to a day being in the 90th percentile for that day of the year and warm spells in the WSDI index can occur at any time of year.

Agricultural Impacts

- The wet spring results in lush green grass sooner in the season and earlier turn out to pasture. A wet, warm October increases grazing opportunities in the fall if frost is delayed, overall increasing the length of the grazing season on both ends.[27]
- Increased moisture in May/June, with higher temperatures, will result in favourable forage yields.
- The long warm spell causes the second cut hay forage yield to decrease. However, the first cut is above average. Farms with irrigation capacity can also benefit from the hot summer by increasing forage yield.
  - Note: There is variable irrigation use in the Cariboo Region: the Fraser River corridor is irrigated; east to Quesnel is dry land forage; the 100 Mile House area is mixed irrigation and dry land operations.
  - In the Cariboo Region, average yield for forage crops is 4 tonnes/acre when irrigated and 2 tonnes/acre for dry land crops.
- Extreme heat causes heat stress to cattle and reduces available surface water. It will take longer to finish the cattle, delaying the sale of the animals and increasing producer costs. Water constraints compound heat stress – when there is not enough water, animals are not hungry.
- Benefits from a longer grazing season, due to early turn-out to pasture and increased grazing opportunities in the fall, require additional surface water. If water and forage are not available due to extreme heat, producers will decrease the herd size, reducing their final sales revenues.

Possible Adaptations

- **Widespread adoption of Management Intensive Grazing (MiG)**, which includes planning for extreme heat by using highest elevation pastures at the peak of the summer and allows adequate rest for forage crops.
  - One producer reported that the practice with daily cattle movements increased grazing by two weeks and resulted in 25% to 100% forage yield increases.
  - Planning to maximize increased grazing opportunities if re-growth occurs in October due to delayed frosts.
  - Planning for water storage needs at higher elevations when moving cattle out of higher temperature zones.
- **Water infrastructure for irrigation and surface water**. Earthen dams are common for water storage and surface water for cattle. The current challenge is dam decommissioning due to the high costs of dam inspection and upgrades. This reduces surface water availability for cattle and irrigation at a time when producers should be increasing water storage.
  - It may be possible to expand irrigation capacity in the Fraser River Corridor and in the 100 Mile House area.
  - On-farm water storage is preferable to regional irrigation infrastructure. However, dams need to be secure enough to withstand extreme precipitation and meet stringent safety requirements.

[27] Note: temperature in the spring is a key determinant of the timing to turn cattle out to pasture; cool, wet weather delays turnout, and warm, wet weather accelerates turn out.

Economic Impact

- **Without adaptation**: The industry continues along its historical trajectory. Some producers benefit from favourable spring and fall conditions, but are also scrambling to deal with water shortages and heat stressed animals during the heat spells in the summer.
  - The result is that **farm cash receipts for cattle sales continue to fall by 1.6% annually over the next 20 years**.
  - Forage receipts remain unchanged as increases in first cut yields are offset by decreases in second cut yields.
- **With adaptation**: Encouraging the adoption of Management-intensive Grazing that considers climate change will improve planning for plant and animal heat stress. Water use planning will ultimately form a part of effective management planning, for forage production and cattle surface water needs. Increasing irrigation capacity can allow farms to benefit from the higher average temperatures and summer warm spells, overall increasing their forage yields. Together, these practices should mitigate the negative impact from drought and extreme heat caused by climate change. By planning for climate change, producers are able to capture benefits: **forage revenues increase by 5% and revenues from cattle sales grow by 3%.**

Benefit of Adaptation

The economic benefits of adaptation are shown in Table 3, below. Without adaptation the cattle industry continues to contract at an annual rate of 1.6% and the forage industry remains constant, consistent with long run industry growth trends. The table depicts three adaptation cases:

- **Low:** Adaptation has a modest impact on industry revenues and farm cash receipts for forage and cattle sales in the Cariboo, with an increase of 2% per year.
- **Medium:** Adaptation has a more significant impact on forage production, and additional forage produced can be sold to international buyers. With adaptation farm cash receipts for forage and cattle increase by 5% and 3% respectively.
- **High:** Adaptation has a positive impact on forage and cattle production and farm cash receipts, with an increase of 5% annually until 2035 for both industry segments.

Table 3: Economic Impact of Climate Change Adaptation – Cariboo Region

Cariboo	Low				Medium				High			
Climate Impact	w/o Adaptation		With Adaptation		w/o Adaptation		With Adaptation		w/o Adaptation		With Adaptation	
Commodity	Forage	Cattle	Forage	Cattle	Forage	Cattle	Forage	Cattle	Forage	Cattle	Forage	Cattle
Annual Growth	0%	-2%	2%	2%	0%	-2%	5%	3%	0%	-2%	5%	5%
Revenue in 2035 ($M)	$3	$18	$5	$41	$3	$18	$10	$50	$3	$18	$10	$77
Benefit of Adaptation	**$24**				**$38**				**$65**			

Notes

1. Revenues are measured by farm cash receipts for forage and cattle for 2013, the share of farm cash receipts in the Cariboo from the 2011 Census of Agriculture, which increase by the growth rate outlined in each case until 2035.
2. Farm cash receipts are from Statistics Canada Table 002-0001.
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000.

4.3 Peace River Region

The Peace River Regional District is the largest regional district in B.C.[28] The topography of the region is varied, with mountainous areas in the south and west and the bulk of the agricultural land located in the relatively flat northeastern portion of the region; adjacent to a similarly productive agricultural area of Alberta.

The primary agricultural commodities of the Peace Region include grains, oilseeds, forage seed, and cattle and forage. Many producers are involved in some combination of these commodities. Overall, 60% of B.C. grain and oilseeds acreage is seeded in the Peace Region.[29] While the number of cattle has dropped in recent years, the Peace Region remains a proportionally significant cattle production area in BC.[30]

Climate Stressor Description

Stressor scenario: Cumulative years of drought with excess moisture in the fall. Although annual precipitation increases by 20% on average, there continue to be dry years such as 2003 - 2008. Increased precipitation is concentrated in extreme rain events (days of heavy rain and consecutive days of rainfall) in the spring and the fall. This scenario depicts the third consecutive year of hot, dry summers in the Peace region during the 2030s and a fall with extreme rain events. The Peace Region is a large and diverse agricultural area and not all farmers will face uniform conditions.

2030s normal climate context:

- Warmer summer and an increase in frequency of warm spells[31] by a factor of 4 results in **agricultural drought** due to reduced soil moisture.
- The dry summer is aggravated by **high average temperatures.**
- Following the hot, dry summer, **precipitation in the fall comes as extreme rain events and consecutive days of rain.**
- Most precipitation occurs on the wettest days: **nearly 50% more days would classify as the wettest day of the month** from the historical record. These extreme precipitation events are most likely to occur in the spring and the fall.

Agricultural Impacts

- The cumulative impact of several years of drought **reduces average crop yield by two-thirds**, reducing it from 30 bushels per acre to 10 bushels per acre.
- Pest outbreaks are worsening and warmer winters and longer frost free periods will contribute to this problem. Grasshopper outbreaks can cause losses of **20-30% of canola plants at the beginning of the season.**

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[28] Peace River Regional District: Our History http://prrd.bc.ca/about/

[29] 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000

[30] Crawford, E.; MacNair, E. and K. Tatebe. *Peace Regional Adaptation Strategy* (2012)

[31] Warm spells throughout the climate stressors refer to the "Warm Spell Duration Index" from the CLIMDEX index of climate extremes which reflects the number of warm spells of minimum 6-day duration. Warm refers to a day being in the 90th percentile for that day of the year and warm spells in the WSDI index can occur at any time of year.

- Heavy fall rains reduce grain quality, from Grade 1 (human consumption) to Grade 3 (animal consumption), which results in a $2 per bushel reduction in the price of wheat and a $0.5 per bushel reduction in the price of oats and barley.

Possible Adaptations

- Conservation tillage to improve soil moisture retention during the drought. This practice is widely used with anywhere from 60% to 80% of producers already using this technique, in which they till their fields one out of every 10 years. While this practice is not right for all producers, encouraging those who can benefit to adopt the practice would increase the adaptive capacity of producers in the region.
- Pest outbreaks can be detected and mitigated or controlled through better monitoring and management practices. Better monitoring will allow for more proactive use of insecticides and other management practices before outbreaks seriously affect yields.
- Improved drainage for excess rain through field topography modification. There is high potential to expand this practice in the Peace Region. At present, only a few producers have laser levelled their fields. Better drainage allows farmers to get onto the fields faster after a major rain event, reducing the negative impact on grain quality.

Economic Impact of Adaptation

- **Without adaptation**: Cumulative years of drought reduce soil moisture and total production of grains falls by 60%. Pest outbreaks impact several small areas, reducing sub-regional grain yields by up to 80%. Heavy rains in the fall damage some crops and reduce the grade of the harvested grains. Overall impact**: farm cash receipts from grains and oilseeds fall by 40%.**
- **With adaptation**: Even with adaptation actions climate change will present considerable challenges to the agriculture industry. Strongly encouraging conservation tillage techniques to maximize soil moisture retention, implementing regional pest monitoring and management information, and encouraging better drainage systems for extreme precipitation events will reduce the Peace region's exposure to climate risks. However, the combined impacts of cumulative years of drought, extreme precipitation, and pest outbreaks will still negatively impact the agriculture sector, as not all farms will be able to anticipate or adapt to all impacts. The overall impact on the economy with adaptation**: farm cash receipts from grains and oilseeds fall by 20%.**

Benefit of Adaptation

The economic benefits of adaptation are shown in Table 3, below. Drought and extreme precipitation events across the region reduce farm cash receipts for grains and oilseeds by 40% to $75 million in 2035 without adaptation. The table depicts three adaptation cases:

- **Low:** Conservation tillage, pest monitoring and better drainage have limited effectiveness or the practice cannot be expanded in the region. With adaptation the economic impact of climate change is somewhat mitigated and results in a decline of 25%, to $93 million. The benefit of adaptation is $18.6 million.

- **Medium:** Adaptation is more effective in this scenario; with adaptation farm cash receipts fall by 20%, to $99 million. The benefit of adaptation is $25 million.
- **High:** Adaptation is highly effective and widely implemented and results in a decline of 10%, to $112 million. The benefit of adaptation is $37 million.

Table 4: Economic Impact of Climate Change Adaptation – Peace Region

Peace Region	**Low**		**Medium**		**High**	
Climate Impact	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**
Commodity	Grains and Oilseeds		Grains and Oilseeds		Grains and Oilseeds	
Revenue Reduction	40%	25%	40%	20%	40%	10%
Revenue in 2035 ($M)	$75	$93	$75	$99	$75	$112
Benefit of Adaptation ($M)	**$19**		**$25**		**$37**	

Notes

1. Revenues are measured by farm cash receipts for grains and oilseeds from 2013, the share of farm cash receipts in the Peace Region from the 2011 Census of Agriculture, which increase by the 20-year compound annual growth rate (6%) until they are shocked by a revenue reduction in 2035.
2. Farm cash receipts are from Statistics Canada Table 002-0001.
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000.

4.5 Okanagan Valley

Apples, grapes and 96% of B.C.'s soft fruits are grown in the South-Central Okanagan. Further north in the Kelowna-Vernon area, apples are the main tree-fruit crop. There has been a general shift away from many types of tree fruit (apples, pears, peaches, plums and apricots) in recent years, largely due to challenges with profitability. Contrary to this trend, sweet cherry production has increased substantially.

Acreage has been shifting into wine grapes and there are now almost 4,000 hectares in grape production across the region.[32] The North Okanagan has well established cattle and dairy industries and its poultry production has grown in recent years.[33]

Climate Stressor Description

Stressor scenario: drought severely impacts water availability for agriculture. Because the scope, scale and rate of climate change is expected to be more severe than anything previously experienced, this scenario models a drought in which water is so severely restricted that perennial crops such as grapes and tree fruits are affected by water shortages. The key features are:

- A warm winter causes the majority of the precipitation in winter to fall as rain.

[32] British Columbia Grape Growers Association. 2011 BC Grape Acreage Report. http://www.grapegrowers.bc.ca
[33] Crawford, E and Emily MacNair Okanagan Region Risk and Opportunity Assessment 2012

- The little snow that falls melts quickly in the spring.
- The summer is hot and dry, with an increase in consecutive dry days above the historical record.
- During the summer there are more extremely hot days compared to the period from 1970-2000.

Agricultural Impacts

- Early and rapid winter run-off combined with a hot, dry summer severely reduces water availability. Due to requirements to ensure downstream water flow, domestic and agricultural water use is severely restricted.
- Water use for irrigation has been restricted for forage and annual crops in the past; however this drought is more severe than any previous droughts. Some irrigation districts are more strongly impacted than others and have to restrict water for all agricultural producers. The lack of consistent water metering also means that there is disparity among agricultural producers in how the restrictions are implemented.
- Extreme heat causes stress to white wine grapes and tree fruits. Elevated temperatures cause the stomata on the grape leaves to close and berry development is halted for a period of a few days to a few weeks after the extreme heat event. This can reduce the berry quality if photosynthesis does not properly resume.[34] Grapes may not achieve the desired acid levels which in turn affects wine flavour. B.C. wines must compete globally, leaving them subject to “double exposure”: when climate factors reduce product quality this reduces the price premium and/or may limit sales.[35]
- Tree fruits can be negatively affected by extreme heat, including suffering from sun scald.[36]

Possible Adaptations

- Increase irrigation efficiency by encouraging the adoption of the highest efficiency delivery systems, water metering, and monthly reporting.
- Increase water storage capacity to retain winter rainfall and spring run off for summer irrigation when there is not adequate precipitation. Some water purveyors are already voluntarily increasing water storage, but additional incentives may need to be put in place to encourage these private not-for-profit entities to ensure there is adequate water available in the future.
- Overhead irrigation is often used to reduce the impact of heat scald by cooling the tree fruits. Adequate water supply is crucial for dealing with the impacts of extreme heat and extended droughts. Some netting and shade clothing can be used for tree fruits, but orchards need to be reorganized to accommodate this adaptation, which involves significant planning and investment.
- In the long run, when extreme heat and long warm spells become more common, producers will adapt by changing grape and tree fruit varieties better suited to hot climates similar to those of other wine growing regions. These high value crops will still be vulnerable to extreme weather and variable conditions.

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[34] Belleville et all (2006)
[35] ibid.
[36] Crawford, E. and Emily MacNair. Wine Grape and Tree Fruit Production Risk and Opportunity Assessment (2012).

Economic Impact

Without adaptation: If water storage capacity does not increase and irrigation efficiency remains the same, water restrictions during a hot, dry summer will negatively impact all regional agriculture. In the past, water shortages have resulted in restrictions on lower value crops, such as forage or annual crops, in order to protect high value perennials such as tree fruits and grapes**. In this scenario, tree fruits and grapes are affected: farm cash receipts for tree fruits and grapes are assumed to decrease by 10% and B.C. VQA wine sales decline by 10%.**

With adaptation: Adequate planning and efficiency gains can reduce the water restrictions. However, most adaptations for extreme heat require additional water to cool fruit. It is assumed that even with these adaptations, **farm cash receipts for tree fruits fall by 5% and B.C. VQA wine sales fall by 5%** due to price reductions caused by lower grape quality.

Economic Benefit of Adaptation

The economic benefits of adaptation are shown in Table 5, below. Climate change stressors reduce cash receipts for tree fruits, wine grapes, and wine by 10%. The table depicts three adaptation cases:

- **Low:** Adaptation measures have low effectiveness, reducing the decline in revenue to 7%. The resulting benefit of adaptation is $57.8 million.
- **Medium:** Adaptation measures are more effective and implemented more widely, the decline in industry revenues is 5%. The resulting benefit of adaptation is $96.3 million.
- **High:** Adaptation measures are highly effective and industry revenues decline by 2%. The resulting benefit of adaptation is $154.1 million.

Table 5: Economic Impact of Climate Change Adaptation – Okanagan Valley

Okanagan Valley	Low				Medium				High			
Climate Impact	w/o Adaptation		With Adaptation		w/o Adaptation		With Adaptation		w/o Adaptation		With Adaptation	
Commodity	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine
Revenue Reduction	10%	10%	7%	7%	10%	10%	5%	5%	10%	10%	2%	2%
Revenue in 2035 ($M)	$376	$1,358	$388	$1,403	$376	$1,358	$397	$1,434	$376	$1,358	$409	$1,479
Benefit of Adaptation ($M)	**$58**				**$96**				**$154**			

Notes

1. Revenues are measured by farm cash receipts for tree fruit and grapes from 2013 which increase by the 10-year compound annual growth rate (4%) until they are shocked by a revenue reduction in 2035. B.C. VQA wine sales from 2014 increase at the 10-year compound annual growth (9.4%) rate until revenues fall in 2035 due to drought and extreme heat conditions.
2. Farm cash receipts are from Statistics Canada Table 002-0001
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000
4. B.C. VQA wine sales are from the B.C. Wine Institute http://www.winebc.org/press_room/statistics/

4.6 Factors Contributing to the Uncertainty of the Estimates

This analysis describes the potential impact on industry revenues of major climate stressors anticipated due to climate change. There is no attempt made to quantify the impact of climate change on producer costs, nor to evaluate the cost of various adaptations. Producers will evaluate farm-level adaptations for their cost effectiveness and government should evaluate individual adaptive actions in detail to determine their total costs, social benefits and distributional effects. This is a partial analysis and research should be pursued in more detail to fully explore the economic impacts of adaptation in the B.C. agriculture context.

Reasons Why the Analysis May Understate Impacts

Factors which might cause the estimates of the economic benefits of adaptation to be higher than calculated include the focus on revenues from farming activities, the choice of long run growth rates in revenues, global impacts and trade effects, and assumptions about the impact of extreme weather and increased weather variability. This report examined only impacts on farm cash receipts or direct wine sales. Processing, transportation, tourism and other indirect or induced impacts are excluded.

Long run historical growth rates were used to project farm cash receipts into the future. In some cases these growth rates were below recent industry growth, implying that the impact to a larger industry in 2035 would be more significant than shown here.

Climate change is anticipated to have strong impact on agriculture across the globe. All agriculture regions will be dealing with adaptation in the coming decades. If major international production regions, such as California, struggle with climate change, international agricultural prices and trade flows will be much different than they are today. If agricultural commodities are worth more in the future due to scarcity, the economic impacts will be larger.

In this analysis, the nominal value of farm cash receipts or wine sales continues to grow at the long run compound annual rate of growth until 2035 and is then shocked by a climate stressor event. The only exception to this is the Cariboo Region scenario, in which cattle industry revenues are assumed to continue a long run decline of 1.6 % per year. More recently, cattle industry revenues have fallen by 8% per year (between 2008 and 2013). However, year to year growth is highly variable. If the cattle industry continues to contract at the pace set more recently, economic benefits in 2035 could be much larger if adaptation helps reverse this trend.

Finally, because the climate is changing, the past is not a good guide to the future. Extreme weather and weather variability are anticipated to be much larger than those experienced in the past, according to climate projections. While the scenarios attempt to capture this, the agrological information provided is based on past professional experience in the agriculture sector and the analyst's own assumptions. These assumptions could significantly underestimate the actual impacts of extreme events in the future, since they rely on past experience. Examples where "surprises" have already occurred include the 2013 floods in southern Alberta, the devastation caused by Hurricane Sandy in New Jersey and New York in 2012, and the current extended drought in California. While these events are not direct evidence of anthropogenic climate change, they are the types of extreme weather events projected to increase with climate change.

Reasons Why the Analysis May Overstate Impacts

Factors which may cause the estimates to overstate the economic impact of the climate stressors on the regional agriculture economy include: use of climate projections which assume no effective co-ordinated effort to significantly reduce greenhouse gas emissions, and the analyst's assumptions regarding economic impacts and choice not to discount the impacts to present value dollars.

The climate change projections provided by the PCIC for regional extreme weather and overall climate trends are based on Global Climate Models (GCMs) which use the A2 emissions scenario. If major global climate change agreements are reached and effectively implemented, the world would move onto a lower emissions trajectory and possibly reduce the impact of climate change. However, these positive results of a climate agreement are more significant for climate change occurring in the distant future, from 2070 to 2100. For the period considered in this analysis, up to 2035, existing carbon dioxide concentrations and current emissions are more significant. In other words, most of the change depicted here for the 2030s is the result of emissions already in the atmosphere now, and significant emission reductions made in future would only impact climate change beyond the time horizon of this analysis.

Regarding discounting and present values, it is noted that economic experts suggest the use of very low (or zero) discount rates in the case of climate change, where there are strong intergenerational impacts.[37] The scenarios presented here do not use any discount rate, which places upward pressure on the estimates, implying that the true value in present dollar terms could be lower. In the Okanagan, Peace, and Cowichan scenarios the economic benefits are a constant share of industry revenues in each adaptation case. For the Cariboo, economic benefits from adaptation grow over time as a share of industry revenues.

The economic impacts of the extreme climate events are based on agricultural professionals' knowledge and experience in the sector and the analyst's own economic assumptions. These could be over-estimates of the impact on industry revenues, but have been judged to be reasonable through the collaborative development of the scenarios.

The scenarios make no attempt to quantify the costs of specific adaptive actions. Additional costs borne by producers are only captured as lower revenues if producers were to choose to reduce the scale of operations in response to stressful conditions. Many of the consequences of climate change will be felt through increased producer costs. On-farm investments involve additional costs to producers to receive the benefits of adaptation while negative consequences such as erosion or replanting will result in higher input costs. Costs of adaptations may be borne by the producer or the government, depending on the scale of the adaptation. Impacts of climate change may also impose additional costs

[37] Stern, N. H. The Economics of Climate Change: The Stern Review. Cambridge, UK: New York : Cambridge University Press, (2007). Print

on either industry or government, depending on who is liable for the losses. There is also no accounting for the costs to government for yield loses which may trigger agricultural insurance payments.

5.0 Directions for Future Research

During the course of this project several areas of future research were identified. Some pertain to more detailed analysis of the questions addressed in this paper, while others address policy and research gaps regarding the implementation of adaptation in the B.C. agriculture sector.

In assessing the economic impact of climate change adaptation on the agriculture sector, the most prominent research gap was the lack of a partial equilibrium economic model of the B.C. agriculture sector. With the current focus on jobs and economic growth, there are more questions about the economic value of programs and policies. While the Ministry of Finance has a macro-economic model to simulate the provincial economy, this has little applicability to the agricultural sector, which is small relative to other major economic drivers in B.C. The diverse nature of the B.C. agriculture sector also warrants a specialized effort to develop a model that accurately reflects regional differences in production. The agriculture sector also has a wealth of data available through Statistics Canada, and specialized resources should be available to answer detailed questions about the state of the agriculture economy based on in depth knowledge of this data. Closer partnership with Agriculture and Agri-Food Canada, to improve the accuracy of the B.C. component of AAFC's partial equilibrium model of Canadian agriculture, is another way to address this knowledge gap. Access to a partial equilibrium model would facilitate the implementation of an Integrated Assessment Model to address climate change impacts.

Another under-utilized set of resources for economic information is the B.C. Agricultural Land Use Inventories. These rich data sources are primarily used for bylaw planning and information for municipalities. Combining these with B.C. Assessment data would be beneficial for both B.C. Assessment and the Ministry of Agriculture. This would provide detailed information about land values, as estimated by B.C. Assessment, and how the land is being used. While this has been attempted before, there are many discrepancies between the two data sets. A dedicated project would be necessary to properly match and clean the data, but in doing so would greatly increase the accuracy of the assessment information and add another layer of information to the Land Use Inventories. This type of data would be highly useful for a Ricardian analysis in which the price of land is decomposed into its various components and could help identify the value of certain adaptations such as drainage and irrigation.

With respect to research needed to successfully adapt to climate change, The Handbook on Climate Change and Agriculture lists water supply modelling as the top research priority. [38] Sufficient water supply, management and monitoring are identified in some way in all of the CAI risk and opportunity assessments as well as in the CAI regional adaptation strategies. Water supply modelling informs drainage planning and water storage for irrigation and livestock. The best available information on water availability is listed in the June 2010 Drought Response Plan as key knowledge to inform responses to

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[38] Dinar, Ariel, and Robert O. Mendelsohn. *Handbook on Climate Change and Agriculture*. Cheltenham, Glos, UK ; Northampton, MA: Edward Elgar, (2011). Print

drought conditions. Other drought preparedness research listed in the Drought Response Plan, drafted for the Ministry of Environment (MoE), includes the following, to:

a. monitor and characterize streamflows and lake levels; (MoE in partnership with other organizations)
b. deliver seasonal volume forecasts based on meteorological, hydrometric and snowpack data and the use of hydrological models (MoE)
c. provide regular updates on streamflow and groundwater data on the internet (MoE)
d. develop, refine and maintain hydrological hazard and risk models to guide community planning and emergency response (MoE)
e. monitor water levels in priority aquifers through the Provincial Observation Well Network (MoE)
f. monitor snowpack conditions using automated and manual techniques to support streamflow forecasting (MoE)
g. monitor the Drought Code and Fire Danger Class (MoE to access Ministry of Forest Resource data)
h. maintain infrastructure and systems that support monitoring, data collection and data processing (MoE), and
i. conduct data quality assurance and auditing on water and snow related data collected using up-to-date standards (MoE).

A follow-up on the implementation of the Drought Response Plan would also be a worthwhile use of Ministry of Agriculture resources, since the agriculture sector is so exposed to drought risks.

6.0 Summary and Conclusions

6.1 Summary

This report summarizes the development of climate stressor scenarios used to estimate the economic impact of climate change on the B.C. agriculture sector. A comprehensive literature review revealed Ricardian analysis and Integrated Modelling Systems as preferred analysis techniques, but one which require a great deal of data and modelling complexity. Scenarios have been used to analyze the impact of particular climate stressors and to spark conversations about critical uncertainties and future preparedness.

The economic benefit of climate change adaptation is calculated as the difference between industry revenues (or farm cash receipts) with adaptation and without adaptation when a climate stressor event occurs in the year 2035. The values presented are for industry revenues in a single year (2035) but the economic benefit of adaptation is a constant share of industry revenues in each case (with the exception of the Cariboo Region). Adaptations reduce the negative impact of a climate stressor on farm cash receipts and three cases are presented for the extent of implementation and the effectiveness of the adaptation. In the Okanagan Valley, the benefit of adaptation to extreme heat and drought ranges from $58 million in the low effectiveness case to $154 million in the high effectiveness case. Drought and water availability are also issues in the Cowichan Valley, and in that scenario economic benefits of adaptation are between $5 million and $14 million. In the Peace Region, the impact of cumulative years of drought and extreme precipitation during the fall harvest demonstrates an economic benefit of adaptation between $18 million and $37 million. Through adaptation to changing precipitation patterns in the Cariboo, the economic benefit for the cattle industry is between $24 million and $65 million.

Factors that might cause the estimates to be higher than calculated include the focus on revenues from farming activities, the choice of long run growth rates in revenues, global impacts and trade effects, and assumptions about the impact of extreme weather and increased weather variability. Factors that may cause the estimates to overstate the economic impact of the climate stressors on the regional agriculture economy include:, use of climate projections which assume no effective co-ordinated global effort to significantly reduce greenhouse gas emissions, and the analyst's assumptions regarding economic impacts and choice not to discount the impacts to present value dollars.

The scenarios make no attempt to quantify the costs of specific adaptive actions. Additional costs borne by producers are only captured as lower revenues if producers choose to reduce the scale of operations in response to stressful conditions. Many of the consequences of climate change will be felt through increased producer costs.

Several research and policy issues were identified. If detailed answers to economic impact questions are of interest, more detailed data collection and analysis tools are necessary. Close collaboration between B.C. government agencies and with other levels of government would also facilitate adaptation efforts that provide benefits beyond individual producers or the agriculture sector.

6.2 Conclusions

The climate stressor scenarios provide an indication of what might be at stake if the sector is unprepared for the coming changes. When considering potential lost industry revenues due to extreme weather events, which are projected to be more frequent and more severe with climate change, there are considerable benefits to adaptation. The simple analysis conducted here echoes what other researchers have found when identifying agriculture as a sector of the economy particularly exposed to climate change.[39] More rigorous analysis of the economic impact of climate change and adaptation on the B.C. agriculture sector could be pursued further for more accurate and detailed results. While most adaptations will provide benefits beyond preparation to climate change, they are not costless and each investment must be evaluated individually.[40]

The process of developing the scenarios also had the substantial benefit of providing a platform to gather experts from the fields of climate science, agriculture, adaptation and economics to discuss the issue, evaluate the consequences of inaction, and continue an ongoing dialogue within the Ministry of Agriculture.

The value of the Ministry's climate change adaptation program is in supporting the agriculture sector and the Ministry to plan and prepare for anticipated climate changes. Current programs address regional and farm level planning for climate change through information sharing, planning, and pilot and demonstration projects. In the future, integrated collaboration with other natural resource sectors, other agencies, and other jurisdictions will continue to be required to move forward with adaptation planning and to address barriers to useful adaptations.

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Appendix 1: Scenario Results

Economic Impact of Climate Change Adaptation – Cowichan Valley

Cowichan Valley	**Low**		**Medium**		**High**	
Climate Impact	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**
Commodity	Total Farm Cash Receipts		Total Farm Cash Receipts		Total Farm Cash Receipts	
Revenue Reduction	15%	10%	15%	5%	15%	0%
Revenue in 2035 ($M)	$80	$84	$80	$89	$80	$94
Benefit of Adaptation ($M)	**$5**		**$9**		**$14**	

Notes

1. Revenues are measured by total farm cash receipts for 2013, the share of farm cash receipts in the Cowichan Valley from the 2011 Census of Agriculture, which increase by the 20-year compound annual growth rate (3%) until they are shocked by a revenue reduction in 2035.
2. Farm cash receipts are from Statistics Canada Table 002-0001.
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000

Economic Impact of Climate Change Adaptation – Cariboo Region

Cariboo	**Low**				**Medium**				**High**			
Climate Impact	**w/o Adaptation**		**With Adaptation**		**w/o Adaptation**		**With Adaptation**		**w/o Adaptation**		**With Adaptation**	
Commodity	Forage	Cattle	Forage	Cattle	Forage	Cattle	Forage	Cattle	Forage	Cattle	Forage	Cattle
Annual Growth	0%	-2%	2%	2%	0%	-2%	5%	3%	0%	-2%	5%	5%
Revenue in 2035 ($M)	$3	$18	$5	$41	$3	$18	$10	$50	$3	$18	$10	$77
Benefit of Adaptation	**$24**				**$38**				**$65**			

Notes

1. Revenues are measured by farm cash receipts for forage and cattle for 2013, the share of farm cash receipts in the Cariboo from the 2011 Census of Agriculture, which increase by the growth rate outlined in each case until 2035.
2. Farm cash receipts are from Statistics Canada Table 002-0001.
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000.

Economic Impact of Climate Change Adaptation – Peace Region

Peace Region	Low		Medium		High	
Climate Impact	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**	**w/o Adaptation**	**With Adaptation**
Commodity	Grains and Oilseeds		Grains and Oilseeds		Grains and Oilseeds	
Revenue Reduction	40%	25%	40%	20%	40%	10%
Revenue in 2035 ($M)	$75	$93	$75	$99	$75	$112
Benefit of Adaptation ($M)	**$19**		**$25**		**$37**	

Notes

1. Revenues are measured by farm cash receipts for grains and oilseeds from 2013, the share of farm cash receipts in the Peace Region from the 2011 Census of Agriculture, which increase by the 20-year compound annual growth rate (6%) until they are shocked by a revenue reduction in 2035.
2. Farm cash receipts are from Statistics Canada Table 002-0001.
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000.

Economic Impact of Climate Change Adaptation – Okanagan Valley

Okanagan Valley	Low				Medium				High			
Climate Impact	**w/o Adaptation**		**With Adaptation**		**w/o Adaptation**		**With Adaptation**		**w/o Adaptation**		**With Adaptation**	
Commodity	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine
Revenue Reduction	10%	10%	7%	7%	10%	10%	5%	5%	10%	10%	2%	2%
Revenue in 2035 ($M)	$376	$1,358	$388	$1,403	$376	$1,358	$397	$1,434	$376	$1,358	$409	$1,479
Benefit of Adaptation ($M)	**$58**				**$96**				**$154**			

Notes

1. Revenues are measured by farm cash receipts for tree fruit and grapes from 2013 which increase by the 10-year compound annual growth rate (4%) until they are shocked by a revenue reduction in 2035. B.C. VQA wine sales from 2014 increase at the 10-year compound annual growth (9.4%) rate until revenues fall in 2035 due to drought and extreme heat conditions.
2. Farm cash receipts are from Statistics Canada Table 002-0001.
3. Regional shares of production and farm cash receipts from 2011 Census of Agriculture http://www29.statcan.gc.ca/ceag-web/eng/data-type-selection-type-donnees?geoId=590000000
4. B.C. VQA wine sales are from the B.C. Wine Institute http://www.winebc.org/press_room/statistics/

Appendix 2: Technical Notes

The tables and notes below show how the economic benefits of adaptation were calculated using a computational model.

Cowichan Valley Scenario

	Low		Medium		High	
	No Adaptation	With Adaptation	No Adaptation	With Adaptation	No Adaptation	With Adaptation
FCR Reduction	**15%**	**10%**	**15%**	**5%**	**15%**	**0%**
2014	$40,041,278	$42,396,648	$40,041,278	$44,752,017	$40,041,278	$47,107,386
2015	$41,375,430	$43,809,279	$41,375,430	$46,243,128	$41,375,430	$48,676,977
2016	$42,754,035	$45,268,978	$42,754,035	$47,783,922	$42,754,035	$50,298,865
2017	$44,178,574	$46,777,314	$44,178,574	$49,376,054	$44,178,574	$51,974,793
2018	$45,650,578	$48,335,906	$45,650,578	$51,021,235	$45,650,578	$53,706,563
2019	$47,171,629	$49,946,430	$47,171,629	$52,721,232	$47,171,629	$55,496,034
2020	$48,743,359	$51,610,616	$48,743,359	$54,477,872	$48,743,359	$57,345,129
2021	$50,367,459	$53,330,251	$50,367,459	$56,293,043	$50,367,459	$59,255,835
2022	$52,045,673	$55,107,184	$52,045,673	$58,168,694	$52,045,673	$61,230,204
2023	$53,779,805	$56,943,322	$53,779,805	$60,106,840	$53,779,805	$63,270,358
2024	$55,571,716	$58,840,640	$55,571,716	$62,109,565	$55,571,716	$65,378,489
2025	$57,423,333	$60,801,176	$57,423,333	$64,179,019	$57,423,333	$67,556,862
2026	$59,336,644	$62,827,035	$59,336,644	$66,317,426	$59,336,644	$69,807,817
2027	$61,313,706	$64,920,395	$61,313,706	$68,527,083	$61,313,706	$72,133,772
2028	$63,356,643	$67,083,504	$63,356,643	$70,810,365	$63,356,643	$74,537,227
2029	$65,467,648	$69,318,687	$65,467,648	$73,169,725	$65,467,648	$77,020,763
2030	$67,648,992	$71,628,344	$67,648,992	$75,607,697	$67,648,992	$79,587,049
2031	$69,903,016	$74,014,959	$69,903,016	$78,126,901	$69,903,016	$82,238,843
2032	$72,232,144	$76,481,093	$72,232,144	$80,730,043	$72,232,144	$84,978,992
2033	$74,638,876	$79,029,398	$74,638,876	$83,419,920	$74,638,876	$87,810,442
2034	$77,125,799	$81,662,611	$77,125,799	$86,199,423	$77,125,799	$90,736,234
2035 FCR ($M)	**$79.7**	**$84.4**	**$79.7**	**$89.1**	**$79.7**	**$93.8**
Benefit of Adaptation ($M)	**$4.7**		**$9.4**		**$14.1**	

Notes:

1. Total farm cash receipts (FCR) were used to capture the diverse agricultural production in the Cowichan Valley.
2. Cowichan Valley FCR were estimated from total B.C. FCR 1993-2013 (Statistics Canada Table 002-0001 http://www5.statcan.gc.ca/cansim/a05?lang=eng&id=0020001) to which is applied the 2% Cowichan Valley share derived from the 2011 Census of Agriculture.
3. The Cowichan Valley share of FCR was assumed to stay constant throughout the forecast period, and was applied to total B.C. FCR from 2011 onwards.
4. The compound annual growth rate in FCR (3%) was calculated for 1993 - 2013 and then applied to 2013 FCR to derive the 2014 - 2035 series shown in the table.
5. The Cowichan Valley FCR forecasts for 2014-2035 were then reduced by the percentages noted in the “No Adaptation” and “With Adaptation” columns.
6. Economic benefit of adaptation was calculated for 2035 as the difference between FCR with and without adaptation, shown in millions of nominal dollars.
7. Low, medium, and high cases show a range of adaptation implementation extent and adaptation effectiveness.

Cariboo Region Scenario

	Low				Medium				High			
	No Adaptation		With Adaptation		No Adaptation		With Adaptation		No Adaptation		With Adaptation	
Sector	**Forage**	**Cattle**	**Forage**	**Cattle**	**Forage**	**Cattle**	**Forage**	**Cattle**	**Forage**	**Cattle**	**Forage**	**Cattle**
FCR Increase	**0%**	**-1.6%**	**2%**	**2%**	**0%**	**-1.6%**	**5%**	**3%**	**0%**	**-1.6%**	**5%**	**5%**
2014	$3,250,112	$25,931,640	$3,315,114	$26,880,359	$3,250,112	$25,931,640	$3,412,617	$27,143,892	$3,250,112	$25,931,640	$3,412,617	$27,670,957
2015	$3,250,112	$25,516,734	$3,381,416	$27,417,966	$3,250,112	$25,516,734	$3,583,248	$27,958,208	$3,250,112	$25,516,734	$3,583,248	$29,054,505
2016	$3,250,112	$25,108,466	$3,449,045	$27,966,325	$3,250,112	$25,108,466	$3,762,411	$28,796,955	$3,250,112	$25,108,466	$3,762,411	$30,507,231
2017	$3,250,112	$24,706,731	$3,518,025	$28,525,652	$3,250,112	$24,706,731	$3,950,531	$29,660,863	$3,250,112	$24,706,731	$3,950,531	$32,032,592
2018	$3,250,112	$24,311,423	$3,588,386	$29,096,165	$3,250,112	$24,311,423	$4,148,058	$30,550,689	$3,250,112	$24,311,423	$4,148,058	$33,634,222
2019	$3,250,112	$23,922,440	$3,660,154	$29,678,088	$3,250,112	$23,922,440	$4,355,461	$31,467,210	$3,250,112	$23,922,440	$4,355,461	$35,315,933
2020	$3,250,112	$23,539,681	$3,733,357	$30,271,650	$3,250,112	$23,539,681	$4,573,234	$32,411,226	$3,250,112	$23,539,681	$4,573,234	$37,081,729
2021	$3,250,112	$23,163,046	$3,808,024	$30,877,083	$3,250,112	$23,163,046	$4,801,895	$33,383,563	$3,250,112	$23,163,046	$4,801,895	$38,935,816
2022	$3,250,112	$22,792,437	$3,884,184	$31,494,624	$3,250,112	$22,792,437	$5,041,990	$34,385,070	$3,250,112	$22,792,437	$5,041,990	$40,882,607
2023	$3,250,112	$22,427,758	$3,961,868	$32,124,517	$3,250,112	$22,427,758	$5,294,090	$35,416,622	$3,250,112	$22,427,758	$5,294,090	$42,926,737
2024	$3,250,112	$22,068,914	$4,041,105	$32,767,007	$3,250,112	$22,068,914	$5,558,794	$36,479,120	$3,250,112	$22,068,914	$5,558,794	$45,073,074
2025	$3,250,112	$21,715,812	$4,121,928	$33,422,347	$3,250,112	$21,715,812	$5,836,734	$37,573,494	$3,250,112	$21,715,812	$5,836,734	$47,326,728
2026	$3,250,112	$21,368,359	$4,204,366	$34,090,794	$3,250,112	$21,368,359	$6,128,570	$38,700,699	$3,250,112	$21,368,359	$6,128,570	$49,693,064
2027	$3,250,112	$21,026,465	$4,288,453	$34,772,610	$3,250,112	$21,026,465	$6,434,999	$39,861,720	$3,250,112	$21,026,465	$6,434,999	$52,177,717
2028	$3,250,112	$20,690,042	$4,374,222	$35,468,062	$3,250,112	$20,690,042	$6,756,749	$41,057,571	$3,250,112	$20,690,042	$6,756,749	$54,786,603
2029	$3,250,112	$20,359,001	$4,461,707	$36,177,424	$3,250,112	$20,359,001	$7,094,586	$42,289,299	$3,250,112	$20,359,001	$7,094,586	$57,525,933
2030	$3,250,112	$20,033,257	$4,550,941	$36,900,972	$3,250,112	$20,033,257	$7,449,316	$43,557,978	$3,250,112	$20,033,257	$7,449,316	$60,402,230
2031	$3,250,112	$19,712,725	$4,641,960	$37,638,991	$3,250,112	$19,712,725	$7,821,781	$44,864,717	$3,250,112	$19,712,725	$7,821,781	$63,422,341
2032	$3,250,112	$19,397,321	$4,734,799	$38,391,771	$3,250,112	$19,397,321	$8,212,870	$46,210,658	$3,250,112	$19,397,321	$8,212,870	$66,593,458
2033	$3,250,112	$19,086,964	$4,829,495	$39,159,607	$3,250,112	$19,086,964	$8,623,514	$47,596,978	$3,250,112	$19,086,964	$8,623,514	$69,923,131
2034	$3,250,112	$18,781,573	$4,926,085	$39,942,799	$3,250,112	$18,781,573	$9,054,690	$49,024,887	$3,250,112	$18,781,573	$9,054,690	$73,419,288
2035	**$3,250,112**	**$18,481,067**	**$5,024,607**	**$40,741,655**	**$3,250,112**	**$18,481,067**	**$9,507,424**	**$50,495,634**	**$3,250,112**	**$18,481,067**	**$9,507,424**	**$77,090,252**
2035 FCR ($M)	**$21.7**		**$45.8**		**$21.7**		**$60.0**		**$21.7**		**$86.6**	
Benefit of Adaptation ($M)	**$24.0**				**$38.3**				**$64.9**			

Notes:

1. Farm cash receipts (FCR) for forage production and cattle for years 1993-2013 were accessed from Statistics Canada Table 002-0001 http://www5.statcan.gc.ca/cansim/a05?lang=eng&id=0020001.
2. The Cariboo Region's share of B.C. FCR was calculated based on acreage shares (17% forage, 18% cattle) reported in the 2011 Census of Agriculture.
3. The compound annual growth rates in FCR were calculated for 1993 - 2013. Derived forage FCR were highly variable but had no overall growth between 1993 and 2013, while there was an average decline of 1.6% per year in derived cattle FCR during that period.
4. In the case without adaptation, it was assumed forage FCR and cattle FCR continue to follow the long run historical downward trends.
5. In the case with adaptation, modest annual growth rates were assumed, ranging from 2% to 5% as shown in the table.
6. Low, medium, and high cases show a range of adaptation implementation extent and adaptation effectiveness.
7. The 2035 FCR is the sum of the forage and cattle FCR projected for 2035.
8. The economic benefit of adaptation was calculated as the difference between the FCR with adaptation and with no adaptation.

Peace Region Scenario

	Low		Medium		High	
	No Adaptation	**With Adaptation**	**No Adaptation**	**With Adaptation**	**No Adaptation**	**With Adaptation**
FCR Reduction	**40%**	**25%**	**40%**	**20%**	**40%**	**10%**
2014	$20,638,651	$25,798,313	$20,638,651	$27,518,201	$20,638,651	$30,957,976
2015	$21,940,904	$27,426,130	$21,940,904	$29,254,539	$21,940,904	$32,911,356
2016	$23,325,327	$29,156,659	$23,325,327	$31,100,436	$23,325,327	$34,987,991
2017	$24,797,104	$30,996,380	$24,797,104	$33,062,805	$24,797,104	$37,195,656
2018	$26,361,747	$32,952,183	$26,361,747	$35,148,996	$26,361,747	$39,542,620
2019	$28,025,115	$35,031,394	$28,025,115	$37,366,820	$28,025,115	$42,037,673
2020	$29,793,438	$37,241,798	$29,793,438	$39,724,584	$29,793,438	$44,690,157
2021	$31,673,339	$39,591,673	$31,673,339	$42,231,118	$31,673,339	$47,510,008
2022	$33,671,857	$42,089,821	$33,671,857	$44,895,809	$33,671,857	$50,507,785
2023	$35,796,477	$44,745,596	$35,796,477	$47,728,636	$35,796,477	$53,694,715
2024	$38,055,156	$47,568,945	$38,055,156	$50,740,208	$38,055,156	$57,082,734
2025	$40,456,353	$50,570,441	$40,456,353	$53,941,804	$40,456,353	$60,684,529
2026	$43,009,060	$53,761,325	$43,009,060	$57,345,413	$43,009,060	$64,513,589
2027	$45,722,837	$57,153,546	$45,722,837	$60,963,782	$45,722,837	$68,584,255
2028	$48,607,847	$60,759,809	$48,607,847	$64,810,463	$48,607,847	$72,911,771
2029	$51,674,896	$64,593,620	$51,674,896	$68,899,861	$51,674,896	$77,512,344
2030	$54,935,468	$68,669,335	$54,935,468	$73,247,291	$54,935,468	$82,403,202
2031	$58,401,775	$73,002,219	$58,401,775	$77,869,034	$58,401,775	$87,602,663
2032	$62,086,799	$77,608,499	$62,086,799	$82,782,399	$62,086,799	$93,130,199
2033	$66,004,340	$82,505,425	$66,004,340	$88,005,786	$66,004,340	$99,006,509
2034	$70,169,068	$87,711,335	$70,169,068	$93,558,758	$70,169,068	$105,253,603
2035 FCR ($M)	**$74.6**	**$93.2**	**$74.6**	**$99.5**	**$74.6**	**$111.9**
Benefit of Adaptation ($M)	**$18.6**		**$24.9**		**$37.3**	

Notes:

1. B.C. farm cash receipts (FCR) for grains and oilseeds for 1993-2013 were from Statistics Canada Table 002-0001 http://www5.statcan.gc.ca/cansim/a05?lang=eng&id=0020001.
2. Compound annual growth rates for the period 1993-2013 were calculated.
3. The share of grain and oilseed production in the Peace Region was calculated based on the 2011 Census of Agriculture.
4. 2013 B.C. farm cash receipt for grains and oilseeds were assumed to grow by the 1993 - 2013 annual growth rate of 6% until 2035.
5. Peace Region shares were calculated as total grains and oilseeds FCR multiplied by share of total acreage in the Peace, which was 60% in 2011.
6. The forecast for 2014-2035 was then reduced by the percentage noted in the "No Adaptation" and "With Adaptation" columns.
7. Benefit of adaptation was calculated for 2035 as the difference between FCR with adaptation and without adaptation, shown in millions of nominal dollars.
8. Low, medium, and high cases show a range of adaptation implementation extent and adaptation effectiveness.

Okanagan Scenario

	Low				Medium				High			
	No Adaptation		With Adaptation		No Adaptation		With Adaptation		No Adaptation		With Adaptation	
Commodity	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine	Tree Fruit and Grapes	Wine
FCR Reduction	10%	10%	7%	7%	10%	10%	5%	5%	10%	10%	2%	2%
2014	$139,094,329	$204,419,832	$143,730,806	$211,233,827	$139,094,329	$204,419,832	$146,821,791	$215,776,490	$139,094,329	$204,419,832	$151,458,269	$222,590,484
2015	$145,676,899	$223,710,732	$150,532,796	$231,167,756	$145,676,899	$223,710,732	$153,770,061	$236,139,106	$145,676,899	$223,710,732	$158,625,957	$243,596,130
2016	$152,586,859	$244,822,095	$157,673,087	$252,982,831	$152,586,859	$244,822,095	$161,063,906	$258,423,322	$152,586,859	$244,822,095	$166,150,135	$266,584,059
2017	$159,841,342	$267,925,717	$165,169,386	$276,856,574	$159,841,342	$267,925,717	$168,721,416	$282,810,479	$159,841,342	$267,925,717	$174,049,461	$291,741,336
2018	$167,458,426	$293,209,604	$173,040,373	$302,983,258	$167,458,426	$293,209,604	$176,761,672	$309,499,027	$167,458,426	$293,209,604	$182,343,619	$319,272,680
2019	$175,457,181	$320,879,508	$181,305,754	$331,575,492	$175,457,181	$320,879,508	$185,204,802	$338,706,147	$175,457,181	$320,879,508	$191,053,375	$349,402,131
2020	$183,857,730	$351,160,593	$189,986,321	$362,865,946	$183,857,730	$351,160,593	$194,072,049	$370,669,515	$183,857,730	$351,160,593	$200,200,640	$382,374,868
2021	$192,681,307	$384,299,275	$199,104,017	$397,109,251	$192,681,307	$384,299,275	$203,385,824	$405,649,235	$192,681,307	$384,299,275	$209,808,534	$418,459,211
2022	$201,950,319	$420,565,222	$208,681,996	$434,584,063	$201,950,319	$420,565,222	$213,169,781	$443,929,956	$201,950,319	$420,565,222	$219,901,458	$457,948,797
2023	$211,688,419	$460,253,550	$218,744,700	$475,595,335	$211,688,419	$460,253,550	$223,448,887	$485,823,192	$211,688,419	$460,253,550	$230,505,167	$501,164,977
2024	$221,920,573	$503,687,228	$229,317,925	$520,476,802	$221,920,573	$503,687,228	$234,249,494	$531,669,852	$221,920,573	$503,687,228	$241,646,846	$548,459,426
2025	$232,673,138	$551,219,699	$240,428,909	$569,593,689	$232,673,138	$551,219,699	$245,599,423	$581,843,016	$232,673,138	$551,219,699	$253,355,195	$600,217,006
2026	$243,973,942	$603,237,763	$252,106,406	$623,345,688	$243,973,942	$603,237,763	$257,528,049	$636,750,972	$243,973,942	$603,237,763	$265,660,514	$656,858,897
2027	$255,852,367	$660,164,721	$264,380,780	$682,170,211	$255,852,367	$660,164,721	$270,066,388	$696,840,538	$255,852,367	$660,164,721	$278,594,800	$718,846,029
2028	$268,339,445	$722,463,820	$277,284,093	$746,545,947	$268,339,445	$722,463,820	$283,247,192	$762,600,698	$268,339,445	$722,463,820	$292,191,840	$786,682,826
2029	$281,467,947	$790,642,024	$290,850,212	$816,996,758	$281,467,947	$790,642,024	$297,105,055	$834,566,580	$281,467,947	$790,642,024	$306,487,320	$860,921,315
2030	$295,272,488	$865,254,138	$305,114,904	$894,095,943	$295,272,488	$865,254,138	$311,676,515	$913,323,812	$295,272,488	$865,254,138	$321,518,931	$942,165,617
2031	$309,789,633	$946,907,325	$320,115,954	$978,470,902	$309,789,633	$946,907,325	$327,000,168	$999,513,287	$309,789,633	$946,907,325	$337,326,489	$1,031,076,865
2032	$325,058,012	$1,036,266,043	$335,893,279	$1,070,808,244	$325,058,012	$1,036,266,043	$343,116,790	$1,093,836,379	$325,058,012	$1,036,266,043	$353,952,057	$1,128,378,580
2033	$341,118,440	$1,134,057,456	$352,489,055	$1,171,859,371	$341,118,440	$1,134,057,456	$360,069,464	$1,197,060,648	$341,118,440	$1,134,057,456	$371,440,079	$1,234,862,563
2034	$358,014,045	$1,241,077,349	$369,947,846	$1,282,446,594	$358,014,045	$1,241,077,349	$377,903,714	$1,310,026,090	$358,014,045	$1,241,077,349	$389,837,516	$1,351,395,335
2035	**$375,790,403**	**$1,358,196,604**	**$388,316,750**	**$1,403,469,825**	**$375,790,403**	**$1,358,196,604**	**$396,667,647**	**$1,433,651,971**	**$375,790,403**	**$1,358,196,604**	**$409,193,994**	**$1,478,925,192**
2035 FCR ($M)	**$1,734.0**		**$1,791.8**		**$1,734.0**		**$1,830.3**		**$1,734.0**		**$1,888.1**	
Benefit of Adaptation ($M)	**$57.8**				**$96.3**				**$154.1**			

Notes:

1. Farm cash receipts (FCR) for 1993-2013 for B.C. tree fruits and grapes were accessed from Statistics Canada Table 002-0001 http://www5.statcan.gc.ca/cansim/a05?lang=eng&id=0020001.
2. Compound annual growth rates for 2003-2013 were calculated (4% tree fruits and 6% grapes) and used to derive projections for 2014-2035.
3. BC VQA wine sales were accessed from the B.C. Wine Institute http://www.winebc.org/press_room/statistics/.
4. Compound annual growth rates for 1993-2013 (16%) and 2003-2013 (9%) were calculated.
5. From 2015 onwards wine sales are assumed to grow at the 10-year annual growth rate (slower growth as the market matures).
6. During the forecast period, 2014-2035, annual FCR and wine sales were reduced by the percentage noted in the “No Adaptation” and “With Adaptation” columns.
7. The benefit of adaptation was calculated as the difference between FCR with adaptation and with no adaptation.
8. Low, medium, and high cases show a range of adaptation implementation extent and adaptation effectiveness.