NATIONAL BEEF SUSTAINABILITY ASSESSMENT:

ENVIRONMENTAL AND SOCIAL ASSESSMENTS

June 2016

Prepared for the Canadian Roundtable for Sustainable Beef, by Deloitte

ACKNOWLEDGEMENTS

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Special thanks to Brian McConkey, Matt Grant and Steven K. Javorek from the Science and Technology Branch at Agriculture and Agri-Food Canada, Dr. Edward Bork and Dr. John Parkins from University of Alberta, Christoph Wand from OMAFRA, Michael Alexander at Alberta Environment and Parks, Greg Bowie and to all the farmers and industry representatives who took time to answer the surveys.

Recommended citation: Canadian Roundtable for Sustainable Beef. (2016). National Beef Sustainability Assessment - Environmental and Social Life Cycle Assessments. Calgary, AB: Deloitte.

Note: The National Beef Sustainability Assessment is not intended to compare or rank beef production practices or systems. Rather, its sole intention is to provide a benchmark of the social, economic and environmental performance of the Canadian beef industry, and should be considered in its entirety.

Executive summary

Purpose

This sustainability assessment was commissioned by the Canadian Roundtable for Sustainable Beef (CRSB). The overarching goal was to conduct a life cycle assessment (LCA) of both environmental and social impacts of the Canadian beef industry, as well as an assessment of major land use parameters. The objectives, set within the context of creating a high-quality environmental and social-specific Canadian baseline for the beef industry, are three-fold and aligned with the CRSB's mission: first, to present existing sustainability efforts within the industry and through a multi-stakeholder lens; second, to implement a science-based monitoring framework to identify opportunities for continuous industry improvement; and third, to communicate results of this study to various stakeholders to reinforce the industry's transparency and give external stakeholders the opportunity to follow and influence its progress.

This nation-wide study is the first of its kind and includes a combined evaluation of the environmental and social performance of the whole Canadian beef industry. It is based on a large amount of specific data, including input from subject matter experts with expertise in environmental impacts, social issues and current beef production practices.

Furthermore, to ensure conformance of the Environmental LCA (ELCA) and Social LCA (SLCA) with ISO 14040 standard requirements and conventions, this study included a peer review by a panel of external experts.

Methods

The ELCA was conducted following ISO 14040, which is an internationally recognized standard describing the principles and framework for LCAs. The latest recommendations from the FAO Livestock Environmental Assessment and Performance (LEAP) guidelines were also applied (Food and Agriculture Organization, 2014; Food and Agriculture Organization, 2015). A literature review was conducted to ensure state-of-the-art methodological choices, and a wide panel of experts was consulted to evaluate and strengthen the various assumptions selected. Canadian-specific data were used to assess the vast majority of most relevant environmental issues. Typically, specific data and/or modelling were used for ration composition, life cycle inventory of major ration components, enteric emissions, emissions for manure, etc.

Unlike previous studies that focus solely on the farming stage, and rely on statistical sources or specific data from a limited sample of farms, this assessment provides a full life cycle overview and is based on the contribution of a sample of nearly 80 farms and feedlots across Canada, and meat packing companies representing 86% of the Canadian meat packing sector. Although the size of the sample remains modest in statistical terms, this sample provided a national picture of the Canadian industry. To address the representative limitations of the farm sample data, additional statistical data and consultation of industry experts were used to inform, balance and validate key parameters. Secondary data, including complementary research studies and models, were collected from Canadian sources or adapted to the Canadian context (e.g. Statistics Canada, Holos model, etc.). Particular effort was made to reflect the reality of farming practices in the models. For example, meat waste after the packing stage (typically during final product distribution and consumption phases) is assessed using generic sources to provide a first overview of the associated impacts. Although environmental impacts of food waste are significant, the beef industry has a limited influence on this wastage and this study did not specifically develop a model of Canadian beef consumption behaviours.

Another strength of this study is the number of environmental indicators assessed, selected in accordance with standard ISO recommendations and calculated based on recognized characterization methodologies: global warming potential, water depletion, land occupation, fossil fuel depletion, terrestrial acidification potential, photochemical oxidant formation potential, and freshwater and marine eutrophication potentials.

Calculation of the life cycle inventory (LCI) was made using SimaPro (v8.04 software), the most widely-used environmental measurement tool. This ensures transparency of results and will easily enable monitoring of Canadian beef environmental performance in the future.

It should be noted that the ELCA does not cover all environmental and health issues. For example: a) nutritional impact analysis of beef consumption was not part of the scope of the study; and b) impact of hormones was assessed through their impact on average daily weight gain only—although they are known to also impact feed conversion efficiency and beef carcass composition.

In addition to the ELCA, three impacts, which the standard methodology is not able to address satisfactorily, were assessed using more comprehensive and sometimes innovative approaches: ***water, biodiversity and carbon soil sequestration***. Water risk was assessed using Aqueduct Tools,[1] and a sensitivity analysis was performed on volumes of water required for irrigation of land or feed used for beef production. For biodiversity, an extensive literature review allowed us to categorize the different impacts of beef on biodiversity. A specific wildlife habitat indicator, developed by Agriculture and Agri-Food Canada, was used to determine the contribution of beef to the habitat capacity of agricultural land in Canada. Finally, carbon soil sequestration was assessed by estimating land use and land management changes connected to livestock operations.

The methodology used to conduct the social life cycle assessment complied with UNEP/SETAC guidelines. It relied on a risk approach with scale-based indicators including both specific and generic data. While survey data were used for the beef production and processing life cycle stages, the activities of suppliers and distributors (retailers and fast-food chains), industry associations, and the national legal and regulatory environment were assessed using generic data from secondary research. Social indicators were assessed on four-level scales, ranging from a high risk level to a very low risk level, and were built against international, national or industry standards when available, and completed with experts' judgement. In total, 76 farms and meat packing plants representing 86% of the national meat packing industry were surveyed, 16 companies in six sectors were reviewed at the suppliers' level, seven companies in two sectors for the distribution level and 11 associations were reviewed (nine provincial and two national associations).

Limitations of the SLCA include the lack of statistical representativeness for specific data, which was mitigated through a risk assessment versus an actual performance assessment. Due to the timeline and resources available, only the farm owners, meat packing plant managers and industry associations were surveyed, while their workers/employees and local communities were not consulted as part of the study. However, additional generic data were used in the results analysis to compare the results drawn from the surveys with national and industry trends and statistics.

Results

This life cycle assessment demonstrates that most impacts associated with beef production occur during cattle production, which is consistent with other studies in this area. Environmental outcomes occurring during the farming stage are mostly related to manure production and management, enteric methane production and feed consumption (including grass for land occupation). Optimizing rations so as to limit the impacts of feed production and animal digestion (and thus enteric emissions and manure N and P content) appears to be key to mitigating the environmental impact of Canadian beef production. Best practices with regard to crop production, and fertilizer application in particular, would also help reduce this environmental footprint. Other stage impacts are mostly related to meat waste.

[1] "Aqueduct's global water risk mapping tool helps companies, investors, governments, and other users understand where and how water risks and opportunities are emerging worldwide." For more details, please see: http://www.wri.org/our-work/project/aqueduct

Scenario analyses, comparing Eastern and Western production, yearling-fed and calf-fed systems and the use of hormones provide some insight into practices that could enable the reduction of environmental effects. For the first two analyses, no clear advantage of one scenario over another appears: for example, Eastern animals have a lower land footprint but consume larger amounts of harvested feed than Western animals. Similarly calf-fed animals have a shorter life cycle but their longer finishing period means they require higher amounts of harvested feed[2] than yearling-fed animals. The use of hormones in the industry clearly enables mitigation of environmental impacts quantified in this study. However, this study did not cover potential toxicity issues for lack of relevant robust data.

The literature review showed that cattle, and livestock production in general, can have contrasting impacts on biodiversity depending on the type of operating system and its location. Although cattle can negatively affect biodiversity by generating excess nutrients (if they are concentrated), and proliferating invasive species due to seed dispersal and overgrazing, they primarily affect biodiversity via their land footprint. The impacts of grazing cattle vary according to management practices, as cattle can either contribute to habitat loss (degradation) or habitat maintenance (improvement). The influence of Canadian beef on biodiversity was estimated through an index of the habitat capacity of the agricultural land used for beef production. The analysis demonstrates that beef production is using 33% of Canada's agricultural land but represents 68% of its wildlife habitat potential in terms of species breeding and feeding. This highlights the role that extensive beef production systems potentially play in helping to maintain healthy native rangelands and support the associated biodiversity. As the steward responsible for sustaining large areas of grasslands, the Canadian beef industry can assist conservation objectives by maintaining native pastures and using sustainable grazing and land management practices.

The water risk analysis based on an Aqueduct composite water score demonstrated that beef production is distributed fairly equally between water risk levels. While some extremely high risk watersheds coincide with very high beef cattle density areas, this is not always the case. Analysis of blue water usage for irrigation of beef-related land demonstrated the importance of blue water volumes mobilized (324 million cubic metres as mid-range assumption for all of Canada), particularly in Alberta and British Columbia.

Overall, the SLCA shows a majority of low and very low risks for the indicators assessed. However, it is also recognized in the interpretation of the results that some may be biased, at least in part, by the stakeholders consulted for the study (i.e. farm owners, processor managers and industry associations) through surveys. Complementary secondary research was conducted to balance these views. Topics showing discrepancies include health and safety, environmental management practices, hourly wage at the farm level and temporary foreign workers conditions at the processors' level. Indicators showing high risks include: national regulations regarding indigenous population and migrant workers, workers' income at the distributors' level, workload at cattle operations and injuries at the suppliers' level.

Conclusions

Results of the ELCA are in the range of what has previously been reported in literature. For instance, the carbon footprint of Canadian beef production at the farm gate is 11.4 kg CO_2 equivalents (eq.) per kg live weight with literature values ranging from 10 to 19 kg CO_2 eq./kg live weight. The production of 1 kg of live weight of beef requires the use of 93 m^2 of agricultural land, while two other Canadian studies, for intensive and extensive systems respectively, found a land footprint of 44 and 338.9 m^2/kg of live weight respectively (Basarab, 2012; Beauchemin, 2010). The blue water footprint of beef in this study is 235 litres per kilogram live weight or 382 litres per kg of carcass weight, while in the Water Footprint Network study, the world average blue water footprint was 550 litres/kg carcass weight (Water Footprint Network, 2015) and in Capper's study water use was reported at nearly 1,100 litres/kg live weight. The low water footprint in Canada is primarily due to the very low use of irrigation for growing cattle feed. While it reinforces the validity of the study to observe that a majority of environmental indicators fall within previously published orders of magnitude, obtaining specific Canadian figures and a precise understanding of the key parameters that influence them is key to providing the Canadian industry with the ability to improve production practices and

[2] Harvested feed as opposed to grazing

monitor progress. Most of the input and life cycle inventory (LCI) data used in this study satisfy a good quality level. The study could have been improved had a more representative Canadian corn LCI been available, as well as a more precise measure of meat waste occurring after the packers' gate.

The land use section provides key complementary information as biodiversity, water and climate change are some of the main environmental elements discussed around beef production. It highlights several areas requiring future research, in particular at localized levels, to be able to provide a more complete picture of the industry and support informed decision making in land use discussions with the broader range of stakeholders involved in those local geographies.

As a conclusion of the SLCA, we can see that some social impacts were assessed similarly based on both specific and generic data, such as workload at cattle operations, hourly wages and benefits available to meat packing plant employees. On the other hand, several other indicators show a gap when looking at stakeholders' perception of different topics, including occupational health and safety, hourly wage at the farm level, migrant workers' conditions and rights, animal welfare practices and environmental management practices.

Recommendations

This baseline report represents a key resource for developing strategies that strengthen the industry's performance in sustainability. The conclusions drawn will enable the further development of best practices and roadmaps for improvement. Despite some limitations, the study is a major benchmark executed with high transparency by the Canadian industry and was based on a wide environmental and social scope that went beyond topics usually tackled by LCAs. It can serve as a robust basis for discussion on scientifically realistic targets for the beef industry in Canada, on topics such as climate change, land use footprint or biodiversity.

Concrete recommendations in terms of management practices will be developed in the next phase of the project. With regard to the quality and representativeness of the results presented, this first assessment could be improved in the future by developing additional specific datasets, especially for those areas for which traditional ELCA faces some limitations, such as carbon sequestration, biodiversity and water impacts.

The carbon soil sequestration assessment could be refined with data more specific for each cropland, and with regionalized values representing different soil cover, soil types and climate parameters.

The biodiversity assessment can be further improved through a higher granularity of analysis, the differentiation of pasture types, accounting for grazing management intensity, the application of different policy scenarios and the inclusion of additional biodiversity measures.

A refined water risk assessment could be obtained through an analysis of water use efficiency measures at the cattle producer level. This would allow for a methodology that enables an appropriate assessment of the interaction between green and blue water footprint, and a better understanding of local water systems' coping capacity.

Regarding the social aspects, focus should be given in the next phases of the project to hotspots identified through the study as moderate and high risks. Indicators that differ from national/industry trends and statistics should also be given focus. In terms of communication, positive impacts, i.e. indicators showing very low and low risks, should also be communicated to stakeholders to balance the view of the industry and provide a complete picture of Canadian beef's social sustainability.

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List of acronyms

AAFC	Agriculture Agri-Food Canada
ABMI	Alberta Biodiversity Monitoring Institute
ABP	Alberta Beef Producers
ACI	Annual Crop Inventory
ARD	Agriculture & Rural Development
ALMA	Alberta Livestock and Meat Agency Ltd.
BCRC	Beef Cattle Research Council
BIXS	Beef InfoXchange System
BMPs	Beneficial Management Practices
CCA	Canadian Cattlemen's Association
CSS	Carbon Soil Sequestration
CRSB	Canadian Roundtable for Sustainable Beef
ELCA	Environmental Life Cycle Assessment
FAO	Food and Agriculture Organization of the United Nations
FU	Functional Unit
GET	Growth-Enhancing Technologies
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GP	Growth Promotant
GWP	Global Warming Potential
HSM	Habitat Suitability Models
ICA	Interpolated Census of Agriculture
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KPIs	Key Performance Indicators
LCA	Life Cycle Assessment
LEAP	Livestock Environmental Assessment and Performance
LUC	Land Use Change
LMC	Land Management Change
MCV	Matrix Combined Value
MSA	Mean Species Abundance
NFACC	National Farm Animal Care Council
PHA	Potential Hotspot Analysis
SLCA	Social Life Cycle Assessment
SLC	Soil Landscape of Canada
SETAC	Society of Environmental Toxicology and Chemistry
UNEP	United Nations Environment Program
VBP	Verified Beef Program
VOC	Volatile Organic Compounds
UofA	University of Alberta
WHAFI	Wildlife Habitat Availability on Farmland Indicator

Glossary

Definition of environmental impact indicators

Global warming potential

Global warming refers to the increase in the average temperature of the earth's surface, due to an increase in the greenhouse effect, caused by anthropogenic emissions of greenhouse gases (carbon dioxide, methane, nitrous oxide, fluorocarbons (e.g. CFCs and HCFCs) and others). Impacts are expressed in kg CO_2 equivalents.

Water depletion potential

Water depletion is a flow indicator and refers to the consumption of blue water. Impacts are expressed in unit of volume (m^3 or litres).

Agricultural land occupation

Agricultural land occupation assesses the agricultural land surfaces requested by the studied process during one year. Results are expressed in m^2a (annual square metres).

Fossil fuel depletion potential

Fossil fuel depletion refers to the consumption of fossil resources used for energy, namely peat, brown coal, hard coal, oil and natural gas. Impacts are expressed in oil equivalents of fossil resource.

Terrestrial acidification potential

Acidification consists of the accumulation of acidifying substances (e.g. sulphuric acid, hydrochloric acid). Deposited onto the ground by rains, acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials (buildings). Impacts are expressed in kg SO_2 equivalents.

Eutrophication potential

Eutrophication is a process whereby water bodies, such as lakes or rivers, receive excess chemical nutrients—typically compounds containing nitrogen or phosphorus—that stimulate excessive plant growth (e.g. algae). Nutrients can come from many sources, such as fertilizers applied to agricultural fields, deposition of nitrogen from the atmosphere, erosion of soil containing nutrients and sewage treatment plant discharges. ***Freshwater Eutrophication Potential*** is expressed in kg of phosphorus equivalent and ***Marine Eutrophication Potential*** is expressed in kg nitrogen equivalent.

Photochemical ozone formation potential

This pollution results mainly from chemical reactions induced by solar light between nitrogen oxides and volatile organic compounds (VOC), commonly emitted in the combustion of fossil fuels. It provokes high levels of ozone and other chemicals toxic for humans and flora. Impacts are expressed in kg NMVOC[3] equivalents.

3 Non Methane Volatile Organic Carbon compound

Land use change (LUC) and land management change (LMC)

Soil carbon stock change can occur either on land remaining in a land use category, resulting from land management practices (LMC), or on land converted to a new land use (i.e. land use change, LUC). Emissions from land use change can be either direct (i.e. occurring at the location of the studied production) or indirect (i.e. consequent to the studied production but not taking place at the location of the activities that cause the change).

Social life cycle assessment

Hotspots

Impacts showing, after analysis, a particularly high risk for one or more of the Canadian beef industry's stakeholders.

Indicators

Measures used to assess the subcategories of impacts identified in the social profile.

Stakeholders

Main groups of people affecting and/or affected by the social impacts of the Canadian beef industry throughout the life cycle.

Social profile

Set of subcategories of impacts covered by the social LCA and spread across the different stakeholders.

Subcategories of impacts

Topics identified by the UNEP/SETAC guidelines to conduct a social life cycle assessment through meaningful and common standardized aspects of sustainable development.

1 Introduction

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1.1 Background

The Canadian Roundtable for Sustainable Beef (CRSB) *is a national, multi-stakeholder initiative developed to advance existing and new sustainability efforts within the Canadian cattle industry. Through leadership, science, multi-stakeholder engagement and collaboration, continuous improvement of sustainability of the Canadian beef value chain will be achieved and recognized* (www.crsb.org). The CRSB currently has more than 40 members ranging from primary cow/calf sector organizations, environmental conservation groups and retailers to financial institutions, government partners and others. The CRSB defines sustainable beef as a socially responsible, environmentally sound and economically viable product that prioritizes Planet, People, Animals and Progress. One of the first objectives of the CRSB was to establish a baseline impact assessment on environmental, social and economic factors in the Canadian beef industry. With this objective in mind, the CRSB, with funding from its membership and provincial governments, commissioned Deloitte LLP (Deloitte) to conduct a strategic assessment of the social and environmental impacts of the beef industry, and develop a comprehensive and adaptive social and environmental sustainability strategy. The CRSB also commissioned Canfax Research Services to conduct an economic assessment of the Canadian beef industry.

In the first phase of the project, Deloitte conducted a farm-to-fork environmental life cycle assessment (ELCA) and social life cycle assessment (SLCA) study considering the impacts associated with Canadian beef production, as presented in this report. A life cycle assessment (LCA) is a standardized biophysical accounting framework used to assess the environmental performance of products, processes and services, and it provides a comprehensive approach to understanding relationships and trade-offs between environmental and social impacts. The LCA methodology has been adapted and applied to evaluate crop production, animal husbandry, meat packers, restaurants, retailers, etc. to quantify the impacts of the Canadian beef industry. To complement the life cycle assessments, a specific approach was also developed around land use and land use-related impacts (e.g. biodiversity, water risk and carbon soil sequestration). In the subsequent phases of the project, the LCA results will be used to develop a strengths, weaknesses, opportunities, threats (SWOT) analysis of the beef industry, identify key performance indicators (KPIs) and a sustainability dashboard that monitors and measures progress, and make recommendations in terms of improved beneficial management practices (BMPs) across the value chain.

By joining the Global Roundtable for Sustainable Beef (GRSB) in December 2012 and initiating the CRSB, the Canadian beef industry has made a clear statement of its willingness to improve its environmental, social and economic impacts, and contribute to constructive dialogue and actions, while recognizing the positive impacts of the Canadian beef industry. In light of the challenges faced by the beef sector in Canada, it is necessary for the industry to respond and take measures to remain competitive at both the national and international levels. A holistic food systems strategy is needed to address how supply chain members can collaborate to meet consumer needs by identifying common objectives for mutual environmental, social and economic benefits.

Beef production has both positive and negative environmental and social impacts depending on the production system features and the practices and behaviours of value chain actors along the product life cycle. From an environmental standpoint, for instance, well-managed grazing maintains the health of grasslands, improves soil quality, and preserves open space and wildlife habitat. Additionally, if well managed, carbon is sequestered in the grasses and soils of grazing or perennial rangelands, especially on marginal lands that may be unsuitable for human food crop production. However, bovine animals are also fed with grains and forages which need material and energy resources to be grown. Further, their rumination and excretion are sources of methane, nitrogen and phosphorus emissions, which have impacts on the quality of air, water and soil. From a social standpoint, beef production provides social benefits, such as job creation and local community vitality. But if not sustainably managed, activities can also have negative impacts on the living conditions of surrounding communities through water pollution or other effects. The continued sustainability of the Canadian beef industry will depend on how to manage these trade-offs for the most acceptable outcomes for beef industry stakeholders.

This study was initiated in March 2014 and includes data collected for beef production in the 2013 calendar year. The ELCA methodology used within this study is in accordance with the ISO 14040 series standards for conducting an LCA (ISO 14040, 2006a; ISO 14044, 2006b) and the SLCA is conducted in accordance with the UNEP/SETAC guidelines for SLCA. The land use methodology was built on separate ongoing research projects which all relied on the land use footprint as a key input to their analysis and developed customized approaches for biodiversity, water risk and carbon soil sequestration. The biodiversity component proposes a first-of-its-kind approach for a national-scale analysis, leveraging the habitat suitability modelling approach. The water risk section built on existing tools and methodologies, such as Aqueduct Water Risk Atlas.

Finally, it should be noted that, in addition to this study, an economic assessment (Canfax Research Services, 2015) was conducted to complete the sustainability profile of Canadian beef production, and which provides additional insights that will be taken into account in the next phases of the project.

1.2 Literature review

The first stage of the project was to perform a state-of-the-art assessment on social, environmental and land use to guide the following stages of the project in terms of methodological assumptions and data collection in particular. For the ELCA, approximately 40 quantitative studies addressing the environmental impacts of beef meat production were reviewed. The list of analyzed publications is displayed in 6.3 ELCA—List of publications included in the literature review. The majority of publications are characterized by their diversity:

- Assessed beef meat production systems were representative of several regions of the world (Sweden, US, Japan, Australia, Brazil, Canada, etc.).
- Most of the studies only consider the first stage of the beef meat life cycle (farming and in some cases slaughtering).
- Some studies intend to compare various systems: e.g. organic, extensive or conventional; various feeding practices; the use or not of growth promotants, etc.
- There is no consensus on the functional units, as it depends on the scope of the study. However, the most frequent units were “1 kg of beef - carcass weight” and “1 kg of beef - live weight”; functional units considering the nutritional value of meat (calories or nutrients) or the total production at a regional/national scale were also identified.
- Most of the studies focus on the potential impact on climate change of the beef production systems assessed, while some include one to ten additional environmental impact indicators. However, methodologies to assess the various indicators can vary from one publication to another.
- Some studies based their evaluation on the use of literature data only, while others relied on more or less detailed surveys.

Given the inconsistency of scopes and purposes, it is not directly possible to compare the results from one study to another. However, some conclusions were common to several studies, notably those having assessed the greenhouse gas emissions associated with beef meat production. Enteric methane and manure-related emissions (CH_4 and N_2O) are the main contributors to the impacts of beef meat on climate change. The carbon footprint is directly correlated to the number of days required to reach the slaughtering weight.

Due to the rising environmental concerns of agricultural systems, and in order to reduce the variability of methodological choices, several guidelines have been recently developed. In particular, the FAO LEAP Partnership aims at developing a multi-stakeholder partnership on benchmarking and monitoring of the environmental performance of the livestock sector. This partnership resulted in the recent publication of guidelines and principles to assess the environmental footprints of animal feed production and large ruminant systems (FAO, 2014) (FAO, 2015).

In terms of social assessment, less literature is available, but major relevant studies and reports were reviewed, including: the Guidelines (2009) and Methodological sheets (2013) by UNEP/SETAC, articles about SLCA methodologies and their applications (Vinyes, et al., 2013) (Arcese, et al., 2015) (Vavra, et al., 2015), and the SLCAs of the dairy sector in Canada (DFS, 2012) and of beef in the United States (BASF, 2013). Findings from these documents are included throughout the report and complemented with other publications.

As for the land use assessments, more than 150 studies regarding the impacts of livestock on biodiversity (Javorek, et al., 2007) (de Baan, et al., 2015) (Food and Agriculture Organization, 2015), water risk and carbon soil sequestration were reviewed to considerer potential methodologies applicable at a national scale. Findings from these documents are included throughout the land use section of the report.

Methodological choices presented in the following sections (Goal and scope, and Environmental and Social assessments) were made based on this review and in accordance with the latest standards.

1.3 Goal and scope

1.3.1 Goal of the study

The CRSB's main objectives in commissioning this LCA study are to:

- recognize and achieve a sustainable Canadian beef industry;
- implement a monitoring framework from a continuous improvement perspective; and
- communicate the results brought by this study to affected stakeholders.

This LCA study is Phase 1 of a larger project that includes three subsequent phases, including a SWOT analysis (Phase 2), a sustainability dashboard (Phase 3), and strategy and communication support (Phase 4).
Deloitte's objectives in conducting this project are therefore to:

- provide a comprehensive analysis of the social and environmental impacts of Canadian beef production covering a farm-to-fork life cycle perspective through the evaluation of most representative scenarios and practices—Phase 1;
- improve visibility into the Canadian beef industry life cycle environmental and social impact hotspots and identify potential areas for improving environmental and social performance—Phase 1;
- identify key strengths and weaknesses that could be the focus of future research, communication, policy and beneficial management practices (BMPs)—Phase 2;
- establish key performance indicators (KPIs), targets and recommended BMPs to address the areas of concern or opportunity and to enable comparison to other countries or food industries—Phase 3;
- develop modelling and methodology tools for future benchmarking of sustainability indicators to ensure monitoring and evaluation—Phase 3; and
- support the development of a communication strategy based on the LCA results—Phase 4.

Please note that the content of this report only covers Phase 1.

1.3.2 Intended applications

The CRSB's mission is to "be a global leader in the continuous improvement and sustainability of the beef value chain through science, multi-stakeholder engagement, communication and collaboration." In keeping with the mission, this study is intended to provide an analytical basis for CRSB's definition of sustainable beef. Sustainable beef is a socially responsible, environmentally sound and economically viable product that prioritizes Planet, People, Animals and Progress. This study may be used to understand the hotspots across a range of environmental impacts, including climate change, biodiversity, water use, acidification, eutrophication, fossil fuel depletion and land use; as well as social impacts, including human rights, working conditions, governance, health and safety, and socioeconomic impacts. Ultimately, the target audience for communication of the study results is the CRSB membership, which comprises representatives and stakeholders of the entire beef supply chain.

1.3.3 LCA and land use methodology

This study was conducted following ISO 14040, which is an internationally recognized standard describing the principles and framework for LCAs. Compliance with this standard ensures the ability to both compare results with other studies and maintain methodological quality in order to use the results for public disclosure. This study adheres to these requirements to the fullest extent possible.
For the environmental LCA, attributional and consequential modelling are the two mainstream practices, and are defined as follows:

- Attributional approach: "System modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system according to a normative rule." (Curran, 2015).
- Consequential approach: "System modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change as a consequence of a change in demand for the functional unit." (Curran, 2015).

Considering the objectives of this study focusing on a clearly defined single product system at a certain point in time, the Canadian beef meat industry in 2013, an **attributional approach** was chosen.

For the land use section, the methodology is primarily based on a detailed land use footprint analysis leveraging various datasets on cattle husbandry practices in Canada. For biodiversity, the analysis focuses on the habitat change driver of biodiversity loss and, within this driver, on a single component: the state of land use. The methodology is based on habitat suitability models, which assess the suitability of land used for cattle production as habitat for different species, compared to the rest of the agricultural landscape. For water, the focus was given to widely-available global water risk indicators from Aqueduct Water Risk Atlas and estimations of irrigated land and irrigated volumes from agricultural surveys and census data to provide approximations of the water footprint required for irrigation of beef-related land. For carbon soil storage, our methodology followed the methodology used in the publication *Change in carbon footprint of canola production in the Canadian Prairie from 1986 to 2006* (Shrestha, et al., 2014), which follows McConkey et al.'s methodology, and where the authors calculated the inventory of GHG emissions associated with canola production in the major Prairies provinces of Canada (i.e. Manitoba, Saskatchewan and Alberta), including emissions and removals from land management change and land use change.

For the social LCA, the methodology complies with the UNEP/SETAC *Guidelines for social life cycle assessment of products* published in 2009 and the *Methodological sheets for subcategories in SLCA* published in 2011 by the same group of organizations. These documents present what is considered to be the most up-to-date and internationally recognized methodology for SLCA. Although this relatively new framework follows ISO 14040, some aspects differ or are amplified at certain stages of the study for the social components. This method allows for the assessment of the social impacts, both negative and positive, of a product along its life cycle.

1.3.4 System boundaries

1.3.4.1 Environmental assessment

The beef production system investigation includes all life cycle stages from farming to consumption, tracing all energy and materials used back to the extraction of resources—with one exception: secondary meat processing and packing (after the initial processing and packing done at processors) were only considered in terms of yields and beef meat waste; energy, water and material consumptions and discharge were not considered in the secondary meat processing stage (see Figure 1-2). Secondary meat processing is where raw beef is further processed into other final products (Bolognese sauce, sausage, lasagna, etc.). Literature (Roy, 2009) (Jungbluth, 2007) shows that this stage remains a minor contributor to the overall environmental impacts of the beef industry. By leaving out this production step, the beef is assumed to be delivered raw to the retailer and cooked at home or in restaurants.

Emissions from each life cycle stage are quantified, and waste management processes—including landfilling, incineration, wastewater treatment and direct land application of organic matter—are assessed. Given the diversity of cattle raising practices considered in this study, decisions regarding system boundaries are deemed particularly important for each system studied. Specifically, if manure is applied directly to soil as an immediate treatment option, emissions are included within the system boundary as a means to compare with other waste treatment options such as anaerobic lagoons. Also, emissions resulting from land application of manure stored for various lengths of time using different farm management techniques are considered to fall within the beef system boundary.

Beef meat co-products (e.g. hides, fats) and by-products (e.g. blood) are out of the scope of this study once they leave the processors. Impacts were distributed between meat and its co-products following specific allocation rules (see 1.3.9 Allocation). Following LCA standards, no allocation procedure is implemented for wasted by-products as the impacts of the production are carried by valuable co-products.

The cut-off boundary for this study ends with the consumption of beef meat and disposal of associated packaging. Since product losses at retail and the consumer level are included, impacts from the disposal of lost product are taken into account. All environmental impacts occurring post-consumption (e.g. human waste) are considered to be outside of the studied system boundaries.

Deloitte selected a representative packaging option for product delivery (see 2.2 Data used in the ELCA). It is beyond the scope of this study to consider various packaging options associated with the delivery of beef, such as bio-plastic packaging elements.

Figure 1-1 Meat packaging considered in the study

Similarly, Deloitte selected the most representative beef meat cooking option, and assessed corresponding inputs (e.g. energy) and outputs; this study did not aim to make a comparison of several cooking alternatives.

Although dairy farming represents an important proportion of Canadian beef production (~17%), dairy animals (including cull dairy cows) are excluded from the study. The Dairy Farmers of Canada (DFC) conducted their own sustainability assessment on milk production three years ago. However, the assessment was not peer reviewed and could not be used in this study. Considering the share of dairy animals in beef production, Deloitte has estimated how these animals could qualitatively contribute to or change the results of the study, based on other recent LCAs on dairy in Canada. Future studies should aim to include both dairy and beef cattle.

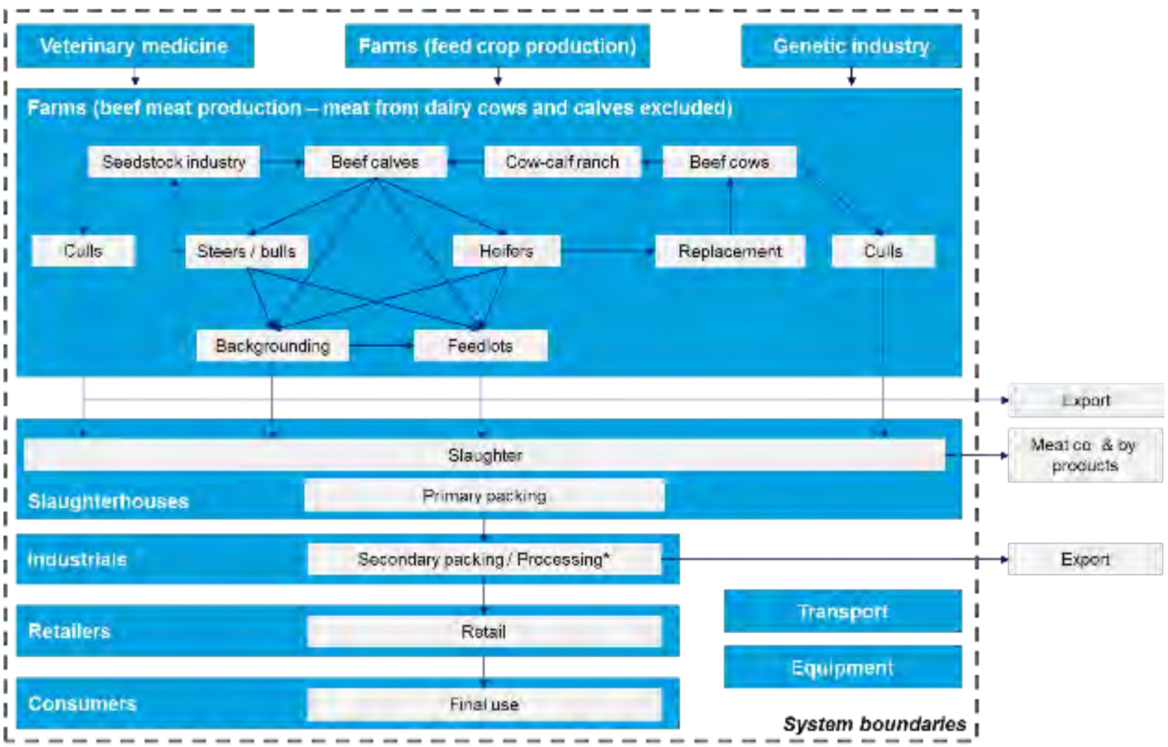

Figure 1-2 ELCA system boundaries

** Only yields and beef meat waste are considered in the secondary packing/processing stage—energy, water, material consumptions and discharge were not considered in those stages.*

Geographic, technological and time boundaries

The systems investigated represent beef produced in Canada for meat consumption. Data and assumptions are intended to reflect current equipment, processing and market conditions that prevail in Canadian beef production systems. The system is representative of Canadian production, where the large majority of the inputs are domestically produced (e.g. feed, electricity, etc.). For time boundaries, the beef system investigated represents production during 2013 or an average of the last production/financial year. For landfills, given that biomass decomposes quite rapidly, no permanent carbon storage was considered in this study; the decomposition of biomass is assumed to take place within the time boundaries of the study (100 years[4]). The gas generation phase associated with waste in landfill is considered to be complete within this timeframe.

Biogenic carbon

In this study, short-lived renewable or biogenic carbon dioxide uptake and release are considered to be neutral with respect to global warming emissions. The carbon sequestered by plants and its release through animal respiration are considered to be in steady-state with surrounding conditions, and therefore these impacts are excluded. This is in line with PAS 2050 guidance for product carbon footprint assessment. Non-carbon dioxide biogenic gases (i.e. methane) are characterized according to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report. Carbon sequestration or emissions due to potential land use change are included in the sensitivity analysis.

Capital equipment

Construction activities related to on-farm buildings have been excluded from the analysis, since there is a lack of specific data (AARD, 2010) (Dairy Farmers of Canada, 2012). Associated environmental impacts are minimal to the considered system since:

- typical farm buildings have long life spans (more than 20 years);
- DFC's study included generic data to model associated environmental impacts and showed that they were minimal; and
- DFC's study focuses on dairy farms, which are likely to need more infrastructure than beef cattle farms since the latter do not need milking equipment.

The manufacture, maintenance and decommissioning of other capital equipment are included in the investigated system.

1.3.4.2 Land use assessment

System boundaries (geographic and time boundaries) for the land use assessment are similar to the ones used in the environmental LCA. Both direct (e.g. grazing) and indirect (e.g. food grown for feed) land use were considered.

Several approaches to quantify land use impacts on biodiversity have been proposed (FAO, 2015) for a review. One of the main drivers of biodiversity loss is habitat change or land use, which is the focus of the current biodiversity assessment. The water risk assessment is largely focused on blue water (surface water and groundwater bodies) assessment.

The geographic boundaries for this section are limited to Canada's borders, as resulting impact differences are considered negligible (see 1.3.5 Exclusions and limitations). This also ensured the use of coherent datasets (e.g. Statistics Canada, Agriculture and Agrifood Canada) with uniform national coverage.

1.3.4.3 Social assessment

SLCA is a "technique that aims to assess the social and socioeconomic aspects of products and their potential positive and negative impacts along their life cycle" (UNEP/SETAC, 2009). The SLCA methodology relies on the guidelines developed by the United Nations Environment Program (UNEP). The guidelines offer a framework to assess primary socially significant themes or attributes (human rights, working conditions, health and safety, cultural heritage, governance, socio-economic repercussions). They also provide a categorization of the main stakeholder groups potentially affected by the activities (i.e. workers, local communities, society, value chain actors and consumers) and practices of the organizations involved in the product's life cycle.

[4] The time boundaries are mostly based on the time period used when defining the Global Warming Potential (GWP) of a greenhouse gas (GHG), i.e. its potential relative climate change effect per kilogram of gas. One hundred years is one of the time frames used by the Intergovernmental Panel on Climate Change (IPCC) to define the GWP of GHG and also the most commonly used in LCA.

The scope of the social assessment differs slightly from the environmental assessment. Social impacts often rely on semi-quantitative and qualitative data, requiring more time and/or resources to collect because they reflect site-specific behaviours and practices which are usually not as well documented as environmental impacts. While environmental impacts are assessed at the process level, social impacts are assessed at the organization, corporate, association and national levels, which leads to a broader representation of the system boundaries outlining the main beef life cycle stages. However, this introduces a challenge when allocating impacts to a specific product. The use of a functional unit, like those used in ELCAs, is consequently not always applicable to SLCAs, specifically when qualitative or semi-quantitative data is used.

We have chosen not to use a functional unit for this SLCA but rather to develop scale-rated indicators based on semi-quantitative and qualitative data. This characterization approach corresponds to Type 1 impact categories, which use performance reference points to assess the magnitude and significance of data collected. Thresholds rely on information such as internationally accepted levels of minimum performance. For this study, we complemented these sources of information with national standards and experts' judgement in order to cover specific topics related to the beef industry. For all indicators, we used an ordinal four-level scale that describes the risk (from high to very low) associated with the practices or situations drawn from both survey results (specific data) and secondary research (generic data).

Due to the project timeline and budget limitations, this SLCA is conducted within the system boundaries presented in Figure 1-3. Several life cycle stages compose this system: the production and processor sectors, upstream (suppliers) and downstream (retailers and fast-food chains) value chain actors, and two ancillary levels: the beef industry association level and the national regulatory and legal environment.

Due to the same limitations mentioned above, the two main groups of stakeholders that were directly consulted for this study—i.e. through a survey—were: a) beef producers (cow/calf, backgrounding and finishing operators/owners) and b) processors. Workers at these operations and sites were not consulted, nor were local communities. However, indicators assessed through the beef producers' and processors' surveys cover subcategories of impacts directly affecting those groups of stakeholders that could not be consulted. This methodological choice is one of the limitations of the study, and is discussed in more detail in section 4.6 Social LCA results' limitations and challenges.

Life cycle stages covered by the SLCA include:

- The core assessment, which relies on specific data collection through surveys, and is dedicated to the production (cattle operators) and processor (processors) levels. These areas were chosen to be more specifically analyzed based on the influence capacity of the CRSB to document and induce changes in practices and/or behaviours.
- The beef industry association assessment, which is an additional level linked to the core assessment. To assess the specific practices promoted at the industry level through professional organizations, this level is assessed through both generic and specific data collection.
- Upstream and downstream value chain actors' assessment, which relies on generic data collected from public sources for a set of companies representative of their respective industries.
- The national regulatory and legal environment assessment, which provides a general background to the study and is based on generic data collection from public sources of information.

Life cycle stages excluded from the SLCA are:

- The consumption life cycle stage. That said, some indicators covered in other life cycle stages do impact the stakeholder category "consumers". A descriptive assessment is also included based on existing results of Canada's 2009 Beef Consumer Satisfaction Survey—see section 10.6 SLCA results by life cycle stage for more details—Consumption.
- Other life cycle stages of Canadian beef production. Additional upstream suppliers, secondary processing and end-of-life management were identified but not included in our assessment, as presented in the SLCA methodological choices and assumptions section. This is in line with the UNEP/SETAC guidelines differentiating

the “conceptual system”, i.e. the system that would ideally be modelled to take into account all impacts, from the “actual system”, i.e. the system that is actually modelled based on data availability and accessibility.

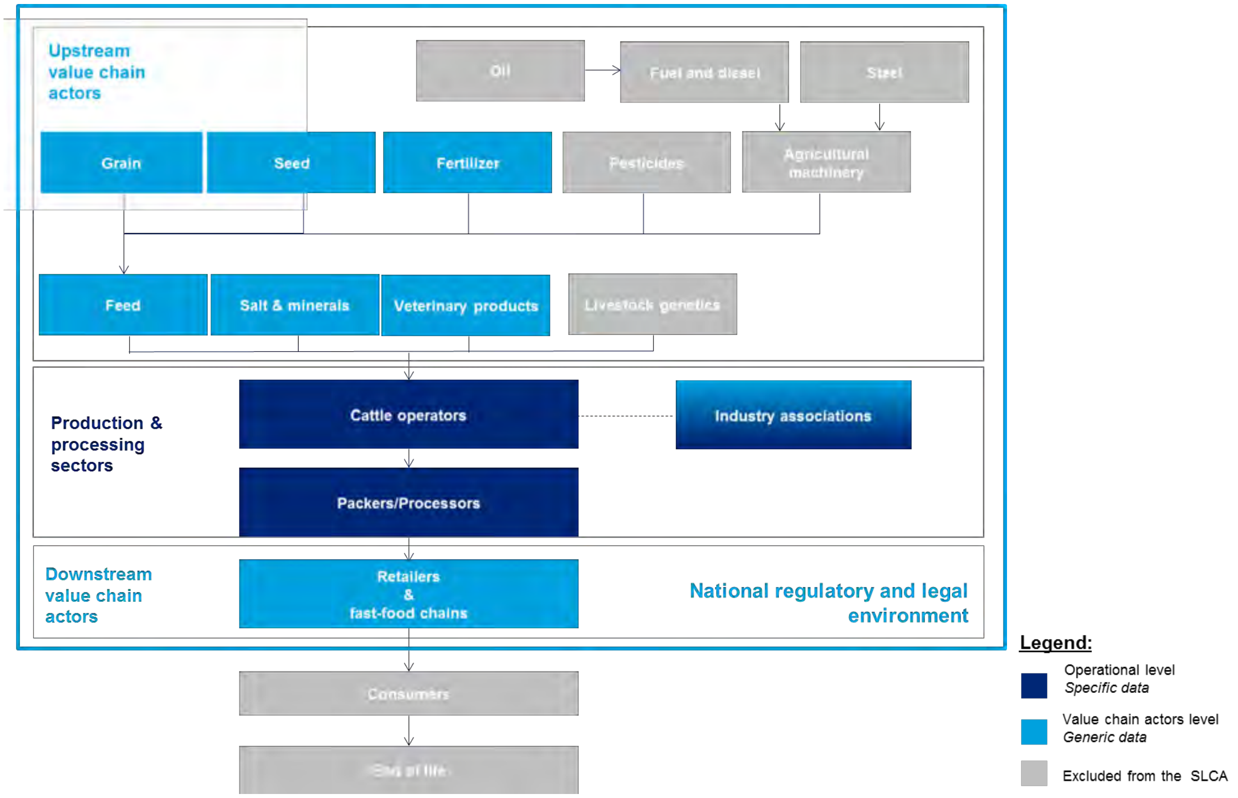

Figure 1-3 SLCA system boundaries

1.3.5 Exclusions and limitations

A range of impacts cannot be assessed through the current LCA methodology (whether environmental or social), nor the proposed land use assessment section. These impacts include:

- Development of antimicrobial resistant micro-organisms in beef production systems.
- Impacts of residual hormones and antibiotics potentially released into the environment on human and ecosystem health. However, indirect side effects of the use of hormones and antibiotics are considered in this study, given their influence on Canadian cattle performance relative to key production parameters such as the number of days on feed, weight intakes or reduced mortality rates.
- Toxicity impacts, given that current methods to measure the corresponding indicators are not adapted to agricultural production, including USETox, the most mature method. There are several reasons for this:
  - First, potentially toxic substances, such as pesticides or growth-enhancing technology substances, lack characterization factors. In some cases, toxicity potentials can be assessed but they strongly depend on local conditions, and models are still highly uncertain. Proxies could have been used as well, but here again results would not have been accurate.
  - Second, other toxic substances include metallic trace elements found in chemical pesticides and fertilizers. However, the USETox models for ecotoxicity and human toxicity do not currently apply well to metals ((JRC—European Commission, 2010)).
  - Finally, emission factors of toxic substances are very dependent on the local climate and soil conditions, and it is very difficult to model which share of the applied amounts end in air, water, soil and living organisms.
  - Given the high uncertainties on both the emission factors and the characterization factors, it was decided not to assess these potential impact indicators.
- Effects of the use of mono-culture/GMO/large spectrum pesticides (e.g. on biodiversity, bee populations, etc.).

- Impacts of the production of feed additives and their impact on the environment. This is due to a lack of Canadian data on the production of microminerals, ionophores, beta-agonists, etc. and their impacts on the environment. Note that Canadian-specific data are currently being generated on this topic and will be considered in future updates of the study.
- Effects of different breeds of cattle.
- Impacts of meat consumption (compared to recommended amount by Canada's Food Guide) on human health. LCA cannot address the epidemiologic discussion associated with meat and the definition of a balanced diet.
- Embedded historical environmental and social impacts. A historical perspective, while important in both social and environmental aspects (land privatization, fencing, First Nations removal by colonial settlers, etc.) is beyond the scope of this assessment. However, the social LCA has one indicator regarding indigenous rights from a national perspective.
- Importantly, only Canadian land use impacts were considered in this study. This seems a reasonable assumption given that the majority of feed sources for Canadian beef are sourced within Canada and that feed imports mostly originate from the US, where some of the key land use features (e.g. biodiversity values) of the crops can be assumed to be broadly similar to those in Canada.
- The biodiversity assessment focused on habitat change as a driver of biodiversity loss, since livestock is a major user of land resources and since the biodiversity value of a given piece of land can be estimated. However, the way management practices alter the biodiversity value of the landscape was not considered due to lack of data at this level. Similarly, ecosystem level impacts of beef production on landscape functionality and connectivity were not considered. The importance of other drivers of biodiversity loss, such as pollution or climate change, can be estimated from other components of this study (e.g. water, carbon of the LCA).
- Green water (rainfall water) footprint.

1.3.6 Functional unit of the ELCA

Since the main objective of the study is to enable continuous improvement, the functional unit needs to be recognizable by stakeholders. As such, the functional unit was chosen to be one (1) kilogram of boneless beef meat (excluding dairy cattle) that is then packaged, delivered and consumed. This functional unit is valid for the environmental assessment. Meat from the dairy industry is not considered in this study.

The functional unit can be scaled to more tangible values for targeted stakeholders. For example, the results could be expressed for one (1) tonne or one (1) serving of consumed beef meat.

A sub-functional unit is added to focus on the scope "cradle-to-farm-gate" given the predominance of this stage, and to ease comparison with previously published studies. The corresponding functional unit is one (1) kg of beef "live weight" at the farm gate. Additionally, functional unit adjustment recognizing the contribution of packing operations is also presented. In this case, the sub-functional unit used is one (1) kg of bone-free meat at the packer's gate. A focus on any other relevant stage could be proposed to enable easier use of the results by the targeted stakeholders (easier comparison with other agricultural products for instance).

Aside from viewing the product systems on the basis of a consumed weight, this study does not consider any additional product functions. While there are multiple ways to define the functional unit, the functional unit expressed in terms of a consumed quantity presents an effective external communication tool for the CRSB. Also, by including delivery and consumption in the functional unit definitions, this study considers product waste at retail, restaurant and consumer levels.

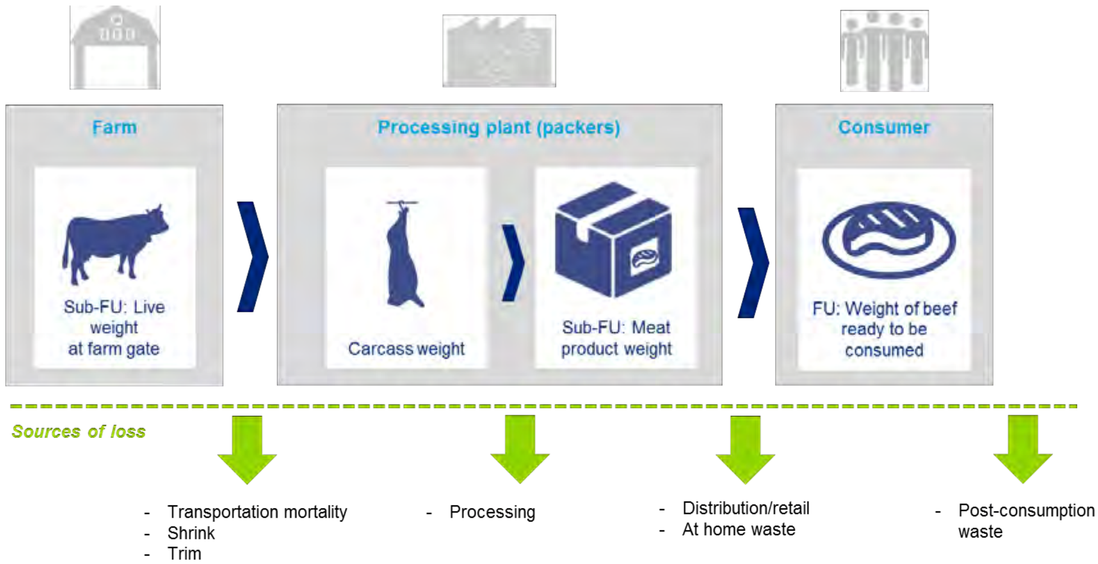

Figure 1-4 ELCA functional units

1.3.7 Studied product systems

To provide a comprehensive analysis of the environmental impacts of the entire Canadian beef production system, the study covered the following:

- **East vs West management practices**
  Production practices differ across Canada and have positive or negative impacts on the LCA. Winter confinement (barn) feeding predominates in Eastern Canada, whereas extensive winter grazing/feeding (bale, swath or stockpiled grazing) is much more common in the West due to drier and clearer winters. A regional distinction therefore allows a proper representation of the Canadian beef industry.

- **Cow/calf, backgrounding and grassing, and finishing operations**
  The three main steps of the cattle production chain are modelled separately to assess the different realities of the Canadian beef industry. The differences between feeding practices in Western and Eastern Canada are also taken into account. Since methane emissions (e.g. from enteric fermentation) and nitrous oxide (e.g. from manure spread on land or crop fertilization) are critical environmental issues associated with cattle, the shortest and longest life cycles were examined in order to provide a range representing common industry practices.

- **Several feed scenarios**
  Detailed rations of forage and grains are modelled using specific data on the different regional feed types (e.g. hay, straw, corn silage, barley, mineral supplements, dried distillers grains (DDGs)). Each has different potential impacts depending on production (e.g. fossil fuel use, fertilizer, irrigation water, yield), nutrient composition (e.g. protein content), digestibility (e.g. enteric fermentation), manure emissions, etc.

1.3.8 Cut-off criteria for initial inclusion of inputs and outputs

In accordance with ISO 14040, processes may be excluded when their contributions to the total system's impact are less than 1% or if credible information from literature, farmers and experts is not readily available. Cut-off criteria are ideally based on environmental relevance; however, it is sometimes impractical or infeasible to use this approach given the underlying data collection efforts needed to understand life cycle environmental impacts. Using cut-off criteria is meant to avoid intensive data collection efforts around environmentally insignificant processes, and a practical approach for developing cut-off criteria is on the basis of mass and energy. In this study, mass flows with an aggregate contribution of less than 2% of inputs to a life cycle stage are omitted from the inventory analysis. It is believed that these criteria do not affect the final results. Sometimes pesticides or other chemical inputs are below the 2% mass threshold, but still have a significant environmental impact. The literature review results are used to identify where this is relevant so that appropriate inputs can be included in the study.

1.3.9 Allocation

Allocation is necessary when a process has a multifunction purpose and generates multiple outputs. The ISO standard suggests the following procedure be used for allocation in multifunction processes (ISO, 2006):

- Allocation should be avoided, wherever possible, either through division of the multifunction process into sub-processes, and collection of separate data for each sub-process, or through expansion of the systems investigated until the same functions are delivered by all systems compared.
- Where allocation cannot be avoided, the allocation should reflect the physical relationships between the environmental burdens and the functions, i.e. how the burdens are changed by quantitative changes in the functions delivered by the system.
- Where such physical causal relationships alone cannot be used as the basis for allocation, the allocation should reflect other relationships between the environmental burdens and the functions.

Specific allocation decisions are discussed in detail for each product system in their respective chapters. When allocation situations arise in this study and that system sub-division and expansion are not applicable, allocation on the basis of physical causal relationships (e.g. beef system outputs) and other relationships, such as mass-weighted economic value, are made (e.g. leather and other by-products).

Allocation is not conducted in the SLCA.

1.3.10 Sensitivity/scenario modelling

The results of any study are only as useful as the questions it attempts to answer. As such, this study considers a variety of "what if" scenarios designed to investigate parameters of special interest. The influence of the following parameters was investigated:

- Allocation method between beef and by-products on the farm
- Cattle feed composition
- Use of growth promotants
- Inclusion of carbon soil sequestration and emission
- Energy use at beef processing plants
- Product losses at the retail and consumer levels
- "Best" and "worst" case scenarios based on a combination of the above parameters for each product system, i.e. 1) calf directly sent to finishing, and 2) calf backgrounded, sent to grass and then sent to finishing
- Increase/decrease of the Canadian herd by +/- 10% (Land use assessment: biodiversity and soil stock of carbon)
- Localized modelization of water sources (Land use assessment: water risk)
- Land use / management change scenarios (Land use assessment: soil stock of carbon)

1.3.11 Data categories

1.3.11.1 Environmental data categories

The following environmental data categories are included in this study:

- Raw materials (e.g. feed)
- Other physical inputs, such as water and land
- Chemicals, fertilizers and pesticides
- Energy

- Direct substance emissions to air, water and soil
- Products and co-products
- Solid waste
- Waste water quantity and treatment technology

Focusing on the farm stage, Figure 1-5 presents the detailed categories included in the study.

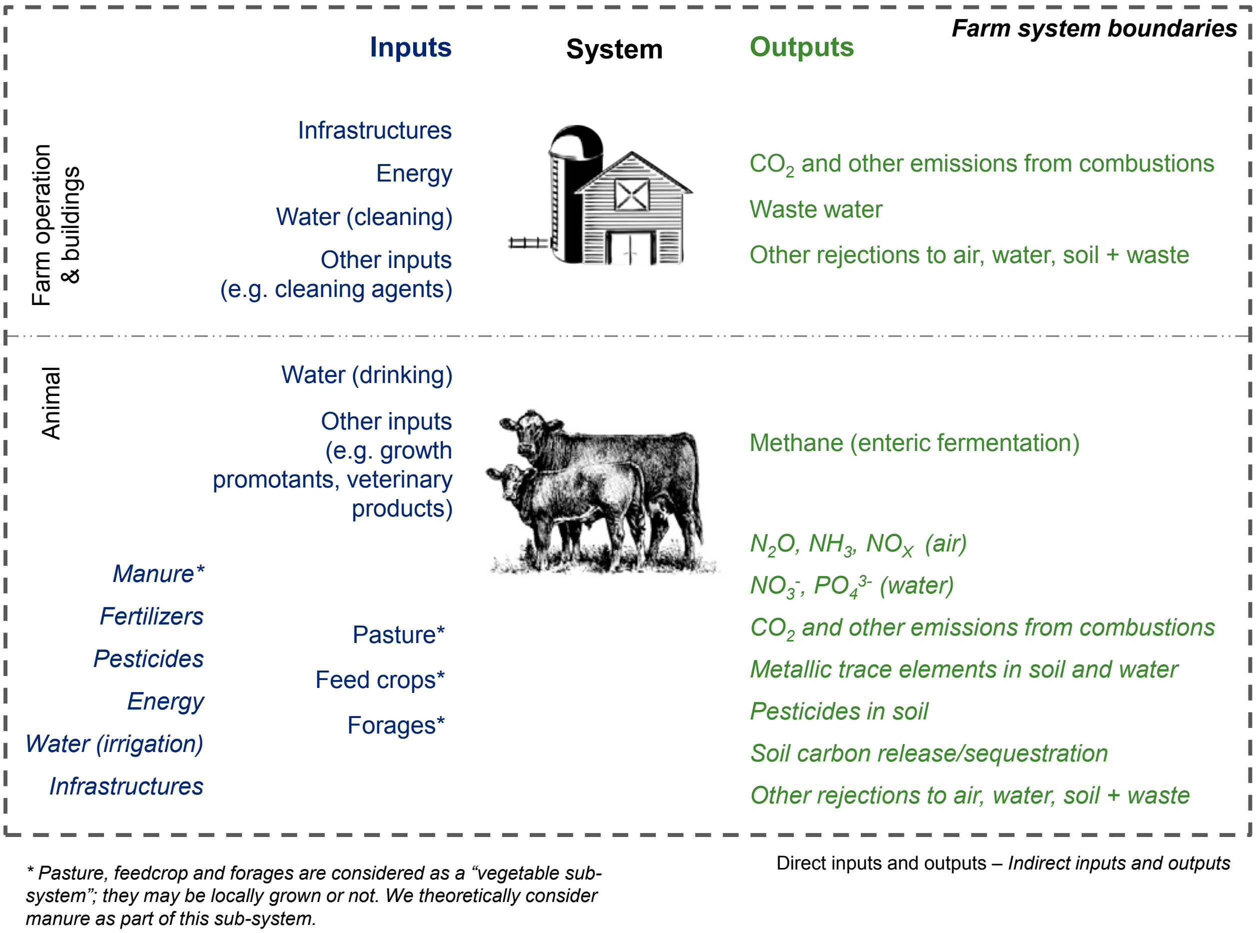

Figure 1-5 Farm system boundaries and environmental data categories considered

1.3.11.2 Land use data categories

The combination of data sources leveraged in the land use assessment is presented in Figure 1-6.
A first series of data sources is used to produce the beef land cover footprint while thematic data (biodiversity, irrigation and soil stock of carbon soil) per land cover type is used for each respective stream of analysis.

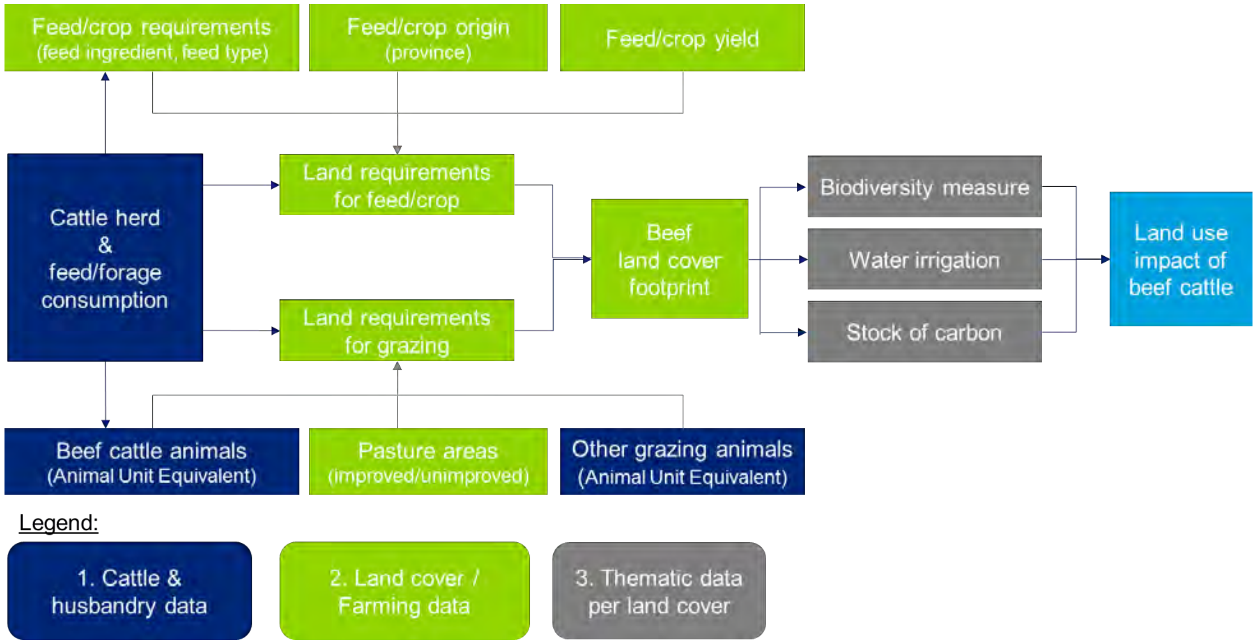

Figure 1-6 A simplified representation of the information flow in assessing land use impact of beef

1.3.11.3 Stakeholders and subcategories of social impacts

The UNEP/SETAC guidelines identify five main groups of stakeholders and associated subcategories of impacts. They have been defined according to international agreements (conventions, treaties, etc.) and cover the list of most relevant actors and impacts for products at each life cycle stage.

This list of stakeholders and their related subcategories of impacts is completed and refined based on the literature review to better reflect both the Canadian and beef industry contexts. As appropriate, UNEP/SETAC guidelines subcategories not relevant to the study are identified and justified for exclusion in the SLCA life cycle inventory analysis section.

The figure below outlines the social profile of the Canadian beef industry value chain that is considered for this assessment and further detailed in the SLCA life cycle inventory analysis section.

Please note that “the proposed stakeholder categories are deemed to be the main group categories potentially impacted by the life cycle of a product” (UNEP/SETAC, 2009). However, this does not always imply that each subcategory of impact is assessed through the point of view of the stakeholder category the impact belongs to. Indeed, the UNEP/SETAC methodological sheets provide guidance as to how these impacts can be assessed at different levels, including from another stakeholder category perspective. Due to time and budget limitations, this study does not include the consultation of all stakeholders. For more details regarding the source of data used for the assessment and the stakeholders consulted, see section 1.5.

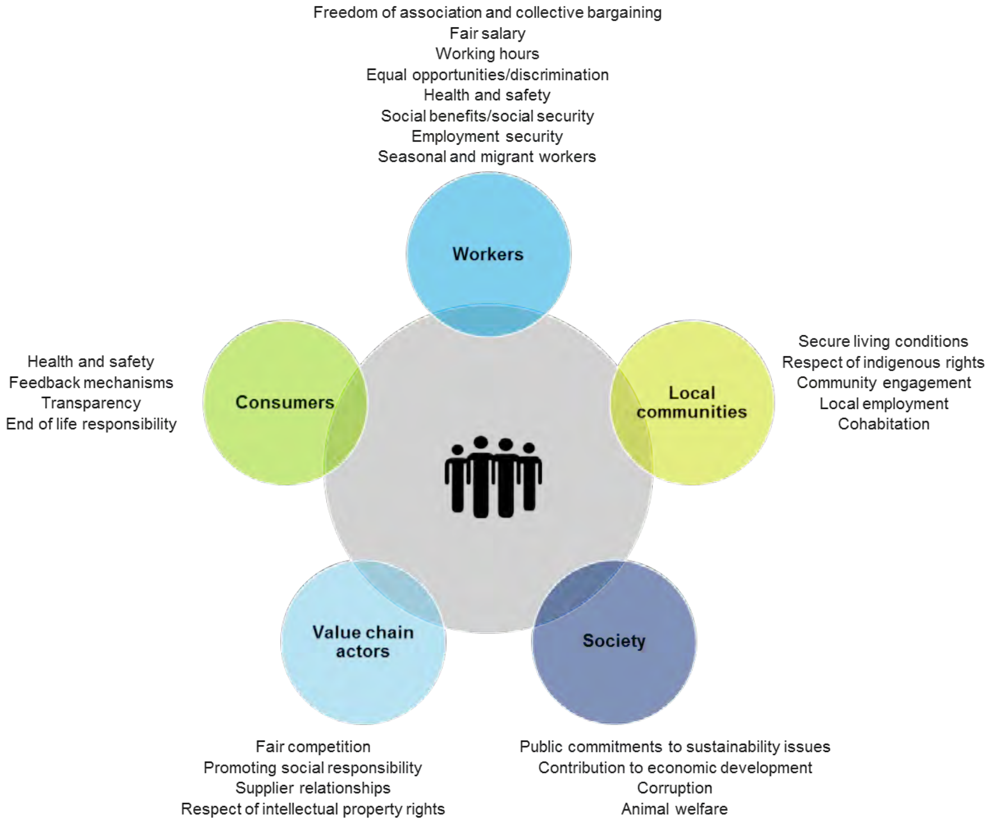

Figure 1-7 Subcategories of impacts sorted by affected stakeholders

1.3.12 Data requirements

The data requirements to perform a detailed ELCA and SLCA are different for each LCA type. The cattle production systems are assessed using specific primary data collected from Canadian farmers (over 70 farming operations responded in each stream, providing comprehensive, although not statistically representative, information on their activities). Data for the beef processing component were solicited from processors representing 86% of the Canadian meat packing industry in 2013.[5]

For the ELCA, other generic, industry aggregate information is used for system background data and includes production of raw materials and crops, waste management options, electricity generation methods, emission data from transports and production of fuels. Already existing environmental models for these elements were used and adjusted according to specific information. For instance, models for crop cultivation were tailored to consider inputs (e.g. pesticides, fertilizers) and outputs (e.g. yields) representative of the crops used to feed Canadian beef cattle. Generic information was collected from a myriad of sources. These sources include Agriculture and Agri-Food Canada, the Census of Agriculture (Statistics Canada), provincial agricultural departments, producer organizations (e.g. CCA, OMAFRA), academia and others.

For the land use section, the primary data collection from the ELCA surveys was leveraged to support the development of an average ration for the Canadian beef herd. Industry reports and statistics were then used to connect the rations with provincial yields representative of the crops used to feed Canadian beef cattle. For the biodiversity section, the WHAFI (Wildlife Habitat Availability on Farmland Indicator) developed by Agri-Canada and used at the soil landscape polygon scale was customized at the provincial level. Water risk assessment required a water risk indicators atlas as well as agriculture statistics on irrigation. Carbon soil sequestration assessment required provincial estimates of soil stock of carbon per land cover types.

[5] For confidentiality reasons, the name and owners of the processors involved in the survey are not included in this report

For the SLCA, generic data used to inform indicators included national statistics and reports, as well as publicly available corporate information to assess companies' practices throughout the value chain. In addition, complementary secondary research was conducted to validate survey-based indicators and identify potential discrepancies between perspectives drawn from sources both internal and external to the industry. This exercise aimed at gaining a better understanding of the perception gap between industry actors and the general public.

1.3.13 Data quality requirements

Data quality is addressed in each product system chapter, and evaluation criteria and requirements are outlined in section 6.9 Data quality.

Background data for both product systems use inventory data from the ecoinvent v3 database, including, for example, on-site fuel and transportation. The *ecoinvent Life Cycle Inventory (LCI)* database is the strongest database available to practitioners to date, and is valued for its comprehensiveness and methodological consistency, ensuring a high degree of comparability in final results. If needed, a LCI from the ecoinvent database could be modified to fit the local context by adjusting the background data, such as the electric mix. The Agri-footprint database, developed by Blonk Consultants, is also used for background data such as agricultural inputs.

The land use section compiles information from several sources of information, both specific and generic. For biodiversity, the indicator used needed to be scientifically sound, spatially explicit so as to be overlaid with cattle land use and available at the national level. Some of the datasets (e.g. habitat suitability matrices or soil stock of carbon per province and per land cover type) had not been previously leveraged for such national scale analysis and warranted ongoing data quality checks. The data quality of those custom-made datasets was noticeably improved throughout the life of this research project as the various review cycles allowed for multiple data consistency checks.

In the SLCA, limits to the data used are identified at each life cycle stage. The data used to assess each indicator are not extracted from any existing database, but rather compiled from diverse sources of information. Specific data were collected through surveys to beef producers (farm owners), processors (managers) and industry associations. Generic data were collected through secondary research. For more details, please refer to 4.4 SLCA results by life cycle stage.

1.3.14 Inventory analysis

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. For each stage of the product system in this study, an inventory of significant flows to and from the environment, as well as internal material and energy flows, are produced. The generated inventories provide data on hundreds of internal and elemental flows for each product system; however, it is not feasible to include all of these flows in the report. Therefore, the following, and most relevant, inventory data are selected and presented in detail for all systems:

- Fossil carbon dioxide (fossil CO_2)
- Non-renewable energy (fossil fuels)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Ammonia (NH_3)
- Nitrates (NO_3^-)
- Sulfur dioxide (SO_2)
- Nitrogen oxides (NO_x)
- Particulates
- Non-methane volatile organic compound (NMVOC)
- Land occupation and biodiversity
- Biochemical oxygen demand (BOD)

- Water

1.3.15 Impact assessment methods

1.3.15.1 Environmental assessment

Each product under consideration in the product comparison has been evaluated based on a range of environmental impact indicators, including:

- climate change impacts (measured in kilograms of CO_2 equivalents and following the standard convention of the most recent IPCC methodology using a 100-year time frame);
- midpoint indicators using the ReCiPe v1.05 impact assessment method, including photochemical oxidant formation,[6] terrestrial acidification, freshwater and Ph, particulate matter formation, ozone depletion, agricultural land occupation, water depletion and fossil fuel depletion; and
- biodiversity and land use.

These impact categories are described further in the Glossary—Definition of the environmental impact indicators. All of the impact assessment methodologies chosen are considered to have wide international acceptance, have been published in leading scientific journals and are used in a variety of LCA applications. Most importantly, the methods and the impact categories chosen are relevant given the study geography and agricultural nature of the production systems examined.

1.3.15.2 Land use

The land use assessment focused on providing a robust description of one key component of the industry—its land footprint, and on three key features of that component, i.e. habitat suitability, irrigation level and stock of carbon. While setting a baseline and building the foundation for an informed discussion on the land footprint impact of Canadian beef, this descriptive part of the land use assessment section is not an impact assessment per se. Attempts to qualify the land footprint impact of Canadian beef are rather arrived at through a combination of a scenario description approach (biodiversity, stock of carbon), an estimate of land use/land management changes (stock of carbon) or through a localized water catchment simulation (water risk). For biodiversity specifically, the biodiversity value (WHAFI) of land production was compared under different scenarios of beef production to identify the contribution of beef production to biodiversity changes. All those approaches, however, generated methodological challenges around attribution of impact and difficulties around correlation identification vs causal relationship demonstration. The limitations of those impact assessment methods are presented and discussed extensively in their respective sections.

1.3.15.3 Social assessment

Depending on both data availability and the level of relevance of subcategories of impacts, the assessment is based on different types and sources of data including:

- Specific/primary data based on survey results sent to cattle operators, meat processors and associations within the Canadian beef industry
- Generic/secondary data based on publicly available information regarding national laws and regulations, value chain actors and associations within the Canadian beef industry (when specific data were not available)

The social assessment is therefore made at three different levels, namely:

- country level: existence of regulations impacting the Canadian beef industry's performance;
- industry level: engagement and impact of the CRSB and other industry associations through initiatives, policies, commitments and values that influence the practices of actors throughout the product life cycle; and

[6] These terms are defined in the glossary

- operational level: engagement and impact of operational organizations (i.e. cattle operators, processors and value chain actors) towards the different groups of stakeholders previously identified (i.e. workers, local communities, society, value chain actors, and consumers).

As a reminder, it should be noted that because our methodology mainly relied on semi-quantitative and qualitative data, the results of the SLCA were not expressed using the functional unit used to express the results of the ELCA. Instead, SLCA results are presented using a set of four-scaled and colour-coded indicators—see 4.2 SLCA methodological choices and assumptions for more details.

1.3.16 Calculation tool used for the ELCA

SimaPro 8.0.4 (Pré Consultants)[7] was used to perform the environmental impact assessment, and more particularly the connection of the reference flows with the corresponding life cycle inventories. Excel and Tableau software have both been used to analyze and interpret data and results from the land use and social life cycle impact assessment.

1.4 Critical review considerations

To ensure conformance of the ELCA and SLCA with ISO 14040 standard requirements and conventions in performing LCAs, this study includes a peer review by an external experts panel presented in 6.1, and review comments on the goal and scope are included in 6.2. The land use section, while not following a classical LCA ISO standard, has also been reviewed by the critical review process.

1.5 Overview of study's data sources

Each stream of assessment (ELCA, land use-related assessments and SLCA) relies on various data sources complementary to each other to strengthen the overall quality of each stream and of the study itself. A sample of surveys, specifically conducted for this study, is used to inform the ELCA, land use-related assessments and SLCA. Their results are then compared to and complemented with external references and subject matter expert judgement.

Table 1.1 Data sources

Study stream	Data sources	Comments
ELCA	*Specific and generic data, depending on availability and accessibility*	*Approach: risk assessment vs performance assessment*
- Cattle operations	77 surveys Subject matter expert judgement Industry statistics (StatCan, AgCensus, etc.) Reports	Survey results (specific data) completed with comments based on reports, regulations and statistics (generic data). Validation of key inputs through sample survey results comparison with literature and statistics
- Processors	Surveys covering 86% of the Canadian meat processing industry	Survey results (specific data) completed with comments based on reports, regulations and statistics (generic data)
- Other players in the value chain	Generic data (publicly available information on selected companies and sectors)	Downstream value chain operations assessed
Land use		

[7] http://www.pre-sustainability.com/simapro

Study stream	Data sources	Comments
- Water risk	Aqueduct Water Risk Atlas (WRI) Irrigation prevalence at provincial level (Water Irrigation Survey)	Complementary to the water depletion indicator covered by the ELCA
- Biodiversity	Wildlife Habitat Capacity Index (AAFC) Industry statistics (Annual Cropland Inventory) Feed requirements from survey sample and literature	Methodology developed according to latest development of FAO/LEAP biodiversity methodologies
- Carbon soil sequestration	Soil organic carbon change (AAFC)	
SLCA	*Specific and generic data, depending on availability and accessibility*	*Approach: risk assessment vs performance assessment*
- Cattle operations	76 surveys Experts' judgement Statistics Reports	Survey results (specific data) completed with data based on reports, regulations and statistics (generic data)
- Processors	Surveys covering 86% of the Canadian meat production industry Statistics Reports	Survey results (specific data) completed with comments based on reports, regulations and statistics (generic data)
- Value chain	Generic data (publicly available information on selected companies and sectors)	Upstream and downstream value chain companies assessed
- Associations	Specific data completed with generic data when not available	Provincial and national associations of the beef industry assessed
- National laws and regulations	Generic data (publicly available information)	Canadian laws and regulations assessed

2 Environmental life cycle assessment

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2.1 Canadian beef production system

2.1.1 General description of the process

As described previously in the goal and scope, the studied system includes the Canadian beef production system, from farm-to-fork.

Figure 2-1 details the flows included in the model.

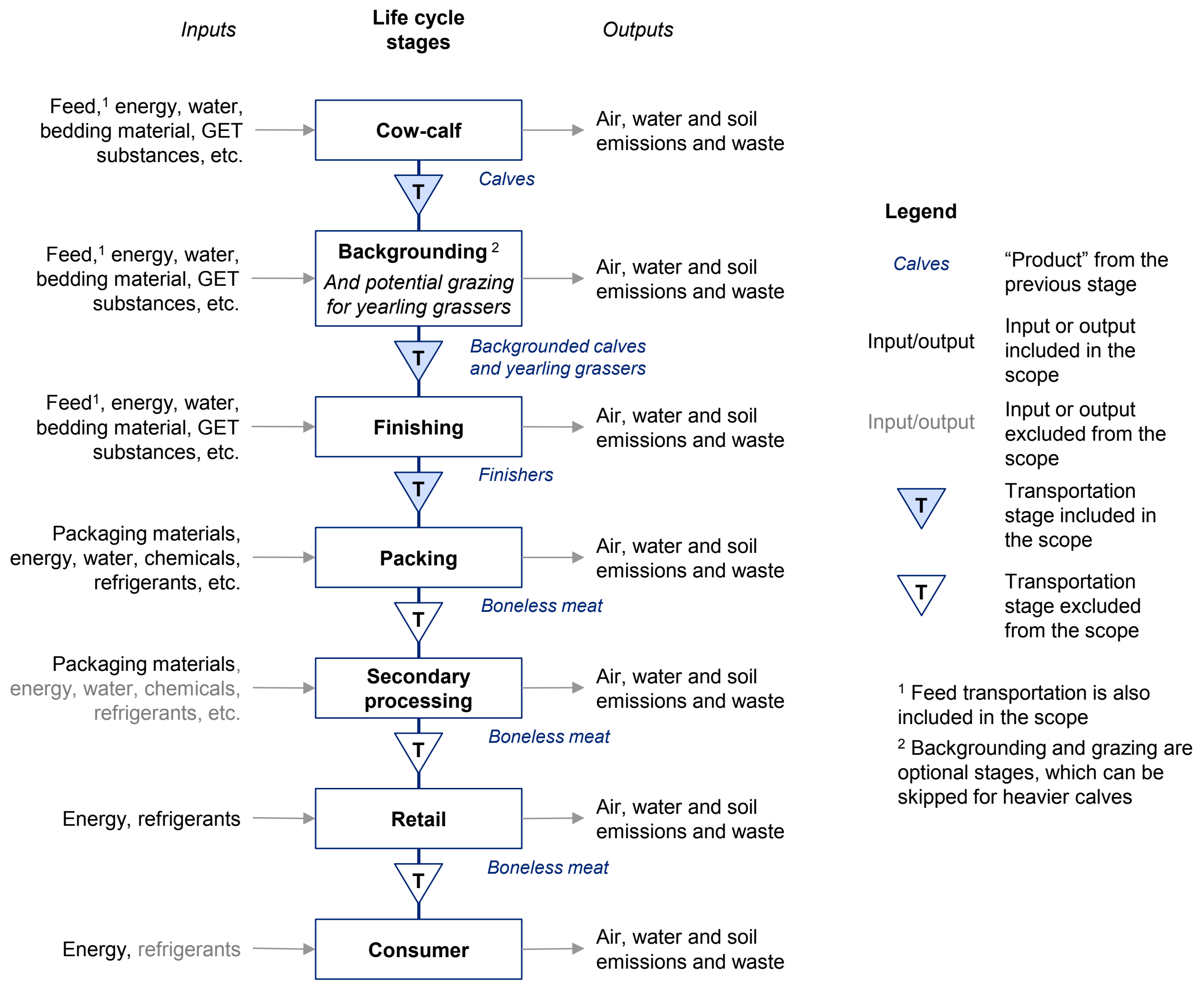


Figure 2-1 Flow diagram of the Canadian beef meat production

2.1.2 Considering a variety of farming practices

Canada's beef cow herd is located primarily in the West (87%), while the dairy herd is mainly located in the East (77%). Dairy cattle represents approximately 17% of Canadian annual beef production and has been excluded from this study (see Goal and scope).The West tends to have larger herds. Average herd size in Alberta counts 232 head according to Statistics Canada, compared to 68 head in Ontario.[8] Further, Western animal confinement is limited compared to animals bred in the East, given more favourable climatic conditions, and reduced precipitation in particular. Western animals thus spend more time grazing and require lower amounts of feed. In addition, barley dominates Western feed rations, while corn is predominant in the East.

[8] "Average" herd size includes all beef cattle on an operation, not just beef cows. Typical herd sizes for beef operations that rely upon beef cattle for income is known by industry participants to be larger than the Statistics Canada data, with partnerships and other reporting issues reducing the reported number.

The majority of calves are weaned in the fall (October or November) at about seven to eight months of age and can follow one of several alternative interim programs before being placed in feedlots on full (concentrate) feed rations—rations with a high ratio of grain to roughage—until slaughter. There are three main production systems for beef cattle characterizing the stages from weaning through slaughter:

- Calf-fed animals: the heavier calves (600-700 lb at weaning) are normally placed on a high energy grain feeding program after weaning for up to 225 days, and are ready for slaughter between 14 and 15 months of age. Calves are thus sent to finishing right after weaning.
- Backgrounded animals: medium-weight calves (500-600 lb at weaning) at weaning are normally placed on a lower energy backgrounding feeding program before being placed on a high energy grain feeding program for slaughter between 15 and 18 months of age. Calves are thus sent to backgrounding before being finished in feedlots.
- Yearling grassers (yearling-fed animals): the lighter calves (350-500 lb at weaning), after being backgrounded, are put on grass the following spring. They are left on pasture for an extra 120-150 days before being sent to feedlot. After high energy finishing feeding programs, they are ready for slaughter between 18 and 24 months of age.

Figure 2-5, Figure 2-6 and Figure 2-8 visually illustrate some features of the calf-fed and yearling-fed systems.

To favour animal growth (i.e. accelerate weight gain and thus reduce animal lifespan before slaughter), backgrounders, grassers and finishers can be implanted with hormones.

The present study aims to encompass a variety of practices representative of Canadian beef production. The following systems have been studied: Eastern and Western production systems, calf-fed and yearling-fed production systems, implanted and hormone-free animals. Given the predominance of Western beef production, this scenario was chosen as baseline.

The calf-fed and yearling-fed systems were chosen as they represent the two extremes (backgrounder being the middle range) and provide a range of environmental impacts of the production system. Further, in the study's sample, very few animals were backgrounded and directly sent to finishing. Deloitte obtained the following distribution: 59% of yearling-fed animals and 41% of calf-fed, which was in line with industry figures.

2.1.3 Considering the full animal cohort

In this study, we considered meat from the beef industry only, i.e. meat from finishing animals and from culled suckler cows. To assess the impacts of meat production, it is necessary to consider the full cycle of production, i.e. the impacts of the animal at the various stages of its growth, but also of the cows, the bulls and replacement animals that enabled the production of this finishing animal, which compose the animal cohort.

The animal cohort modelled in this study is displayed in Figure 2-2. Taking into account the mortality rates of each animal, this chart presents the number of days needed to obtain one finishing animal for each animal category.

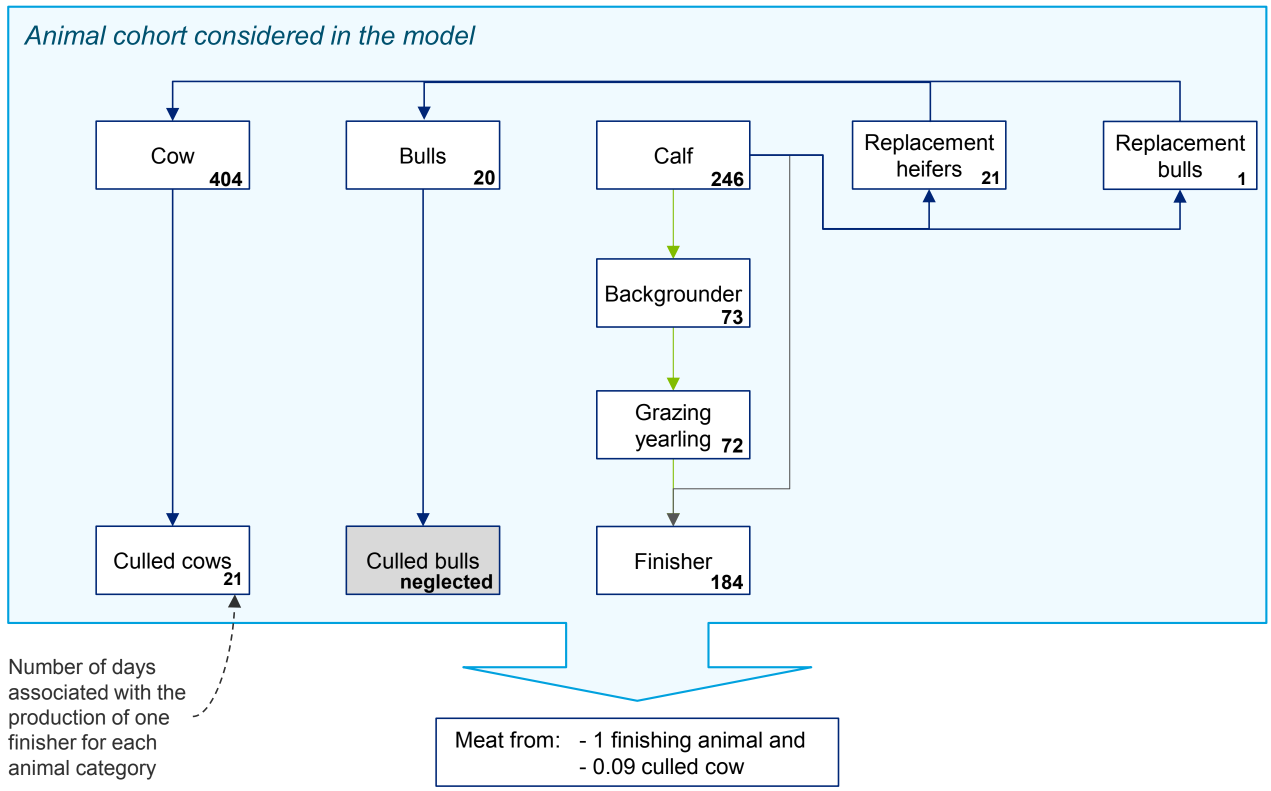


Figure 2-2 The animal cohort considered in the model
Reading key: the production of one finisher requires 404 days (i.e. 1.11 years) for one cow, given birth frequency and mortality.

2.1.4 Modelling the farming stage

The majority of data used to model the farming stage came from farmers via a survey (see 2.2 Data used in the ELCA). Farming practices are very diverse, as are the types of operation (some farms specialize in cow/calf operations, or finishing, while some farms raise calves from birth to finishing), the herd sizes, the lifespan of the animals, etc.
A modular model was built to identify a representative animal and to consider various scenarios. To do so, data were processed so all inputs (e.g. feed, water, energy, land) and emissions (e.g. enteric methane, manure-related emissions) were expressed as 'per animal' and 'per day'. Data could finally be combined considering an average duration of each production stage (e.g. backgrounding, finishing). Figure 2-3 describes this modular model.

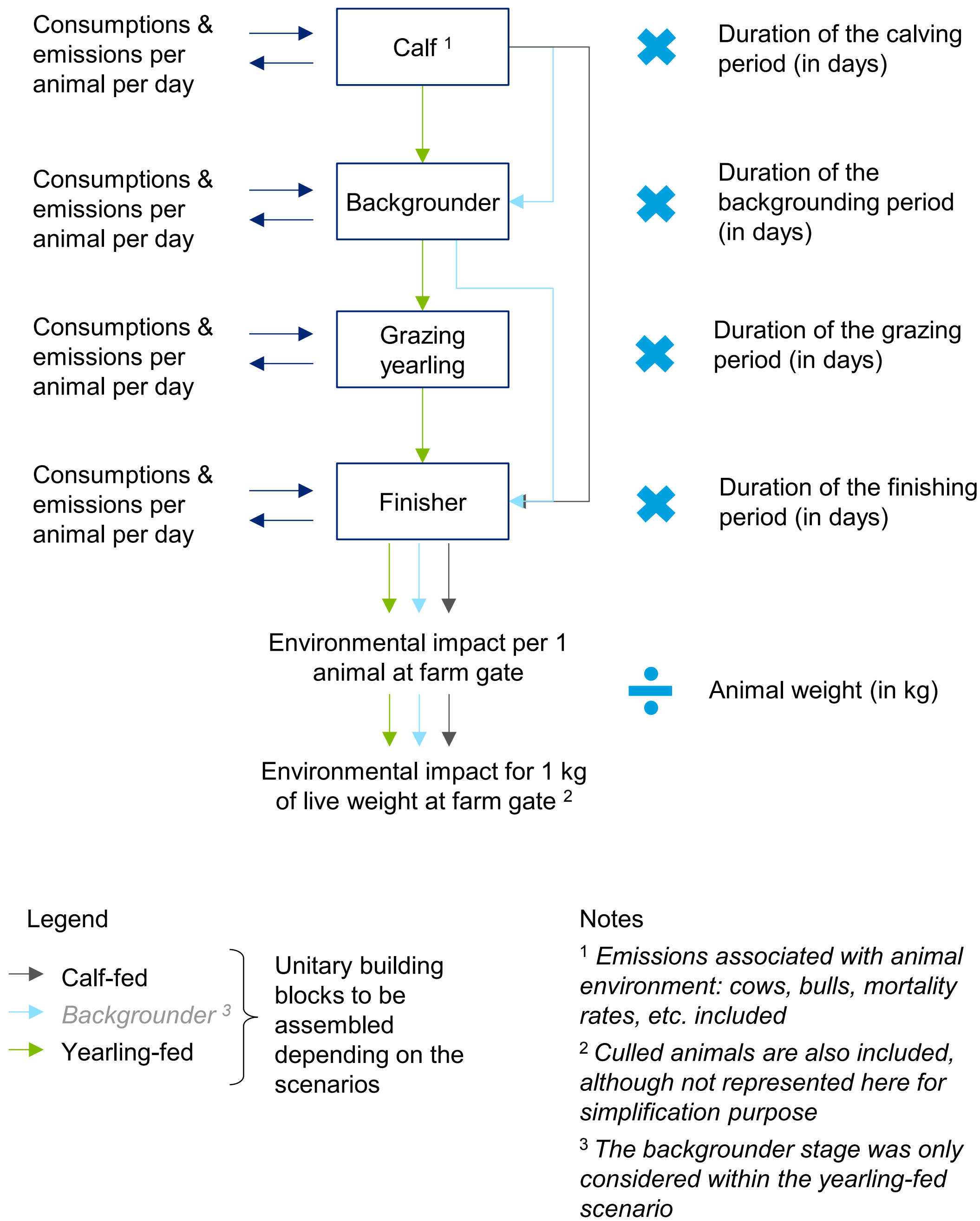


Figure 2-3 A modular model built to consider the variability of farming practices

2.2 Data used in the ELCA

2.2.1 Data collection strategy and data quality assessment

Primary data are collected for the life cycle stages that have a significant contribution to the overall impacts from beef consumption, i.e. farming and meat processing. Furthermore, representative data are needed for the CRSB to make informed decisions on how to develop their supply chain strategy, in addition to communicating the LCA results, insights and observations to affected stakeholders. The remaining life cycle stages (e.g. secondary meat processing, retail and consumption) are represented by generic data from LCA databases or literature. These stages have less of an impact on the overall life cycle results.

2.2.1.1 Farming operations

Data on farming operations are based on primary data collected at the farm level through a specific survey developed for this study, as well as on experts' judgement and industry statistics. Surveys were sent via provincial beef producers associations and contacts working in the industry to obtain a sample as representative as possible of Canadian cattle production, both in terms of operational diversity (i.e. cow/calf, backgrounding and finishing operations) and in terms of geographic distribution. Farmers received both the environmental and social sections of the surveys and could choose to respond to one or both of them. This is the first survey conducted on such a large geographic scale while covering a large spectrum of topics at both the social and environmental levels. Both surveys consisted of a wide range of data requests, enabling us to build a baseline of indicators to help inform future decision making and strategy development processes for the industry, while providing an assessment of the current situation.

The result sample gathered for this ELCA is composed of 77 surveys, with the geographical distribution presented in Table 2.1, along with the provincial breakdown of Canadian beef cattle.

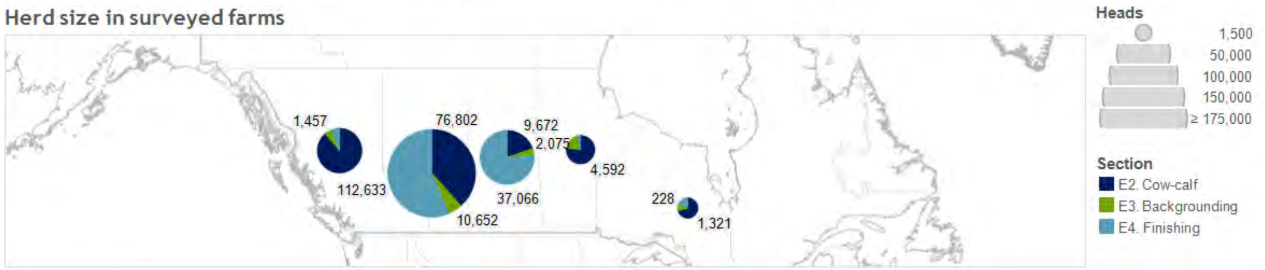
Table 2.1 Provincial breakdown comparison of beef cattle and ELCA survey sample

Province	Beef cows	ELCA survey respondents
BC	5%	8 (10%)
AB	40%	34 (44%)
SK	30%	18 (23%)
MB	13%	9 (12%)
ON	7%	7 (9%)
QC	4%	0 (0%)
Atlantic	1%	1 (1%)

Table 2.1 demonstrates a relative alignment of our sample with the national beef cattle distribution, with the exception of Québec. While we attempted to get respondents in Québec, we were not successful. The fact that the survey was not translated into French played a significant role, as we not able to reach out to the francophone beef farmers community.

This sample is not large enough to be considered statistically representative of the sector, considering that there are about 68,500 farms with cattle operations in Canada. As such, our approach was not to provide an assessment of the actual country-level performance of this life cycle stage, but rather to provide an assessment of the potential impacts of the practices observed in this limited sample of the sector, to be put into perspective by other references relevant for Canadian cattle operations (e.g. surveys on specific aspects, national statistics and other reports addressing the impacts assessed in this ELCA).

Our sample covered a total herd of almost 300,000 beef cattle, with the detailed breakdown of the number of animals and type of operations presented below (Figure 2-4).



Section	West				East	Grand Total
	BC	AB	SK	MB	ON	
E2. Cow-calf	24,818 (21%)	76,802 (66%)	9,672 (8%)	4,592 (4%)	1,313 (1%)	117,197 (100%)
E3. Backgroun..	1,457 (9%)	10,652 (68%)	2,075 (13%)	1,150 (7%)	228 (1%)	15,562 (100%)
E4. Finishing	1,560 (1%)	112,633 (74%)	37,066 (24%)	200 (0%)	320 (0%)	151,779 (100%)
Grand Total	27,835 (10%)	200,087 (70%)	48,813 (17%)	5,942 (2%)	1,861 (1%)	284,538 (100%)

Figure 2-4 ELCA survey sample—surveyed herd size by province and type of operation

2.2.1.2 Meat packers

The scope of assessment of this life cycle stage includes meat processors in Canada. These meat processors or packers constitute the next step of the beef life cycle after farming operations. Packers handle the slaughtering, processing, packaging and distribution of meat to downstream value chain actors (mainly, retailers and restaurants). As described earlier, secondary beef processing is not included in the scope of our assessment given the complexity and diversity of options for this processing stage.

Specific data were collected from a sample of packers representing 86% of total Canadian beef production. For confidentiality reasons, further details of the plants included in this assessment will not be mentioned in this report.

2.2.2 Description of activity data used

2.2.2.1 Farm activity data used

Cattle description

- Stage duration:

To consider the full animal cohort as presented before, it is necessary to consider the duration of each animal stage. Figure 2-5 presents the stage duration used in our model.

To obtain the stage duration model, data from the survey were slightly revised based on literature review (AARD, 2010; Basarab, 2012; Beauchemin, 2010) and expert judgement. Indeed, the average durations obtained from the surveys were longer than the durations which are traditionally observed in the literature. Clarification on the adjustments is provided in Appendix 6.6.

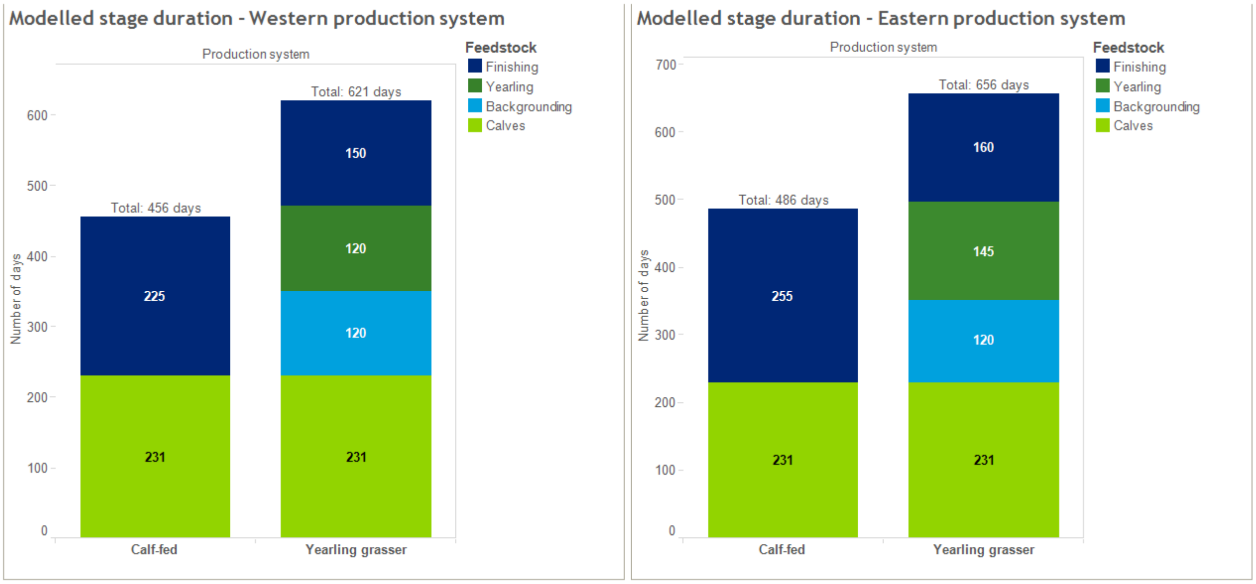


Figure 2-5 Stage durations used in the model (Sources: survey and literature)

- Time spent in pasture

Average time spent in pasture by the animals of the herd is set out in Table 2.2. These data were directly obtained from the survey and from industry experts on period durations.

Time spent on pasture (i.e. not in confinement) needs to be distinguished from time spent grazing (i.e. with no grain-feeding). For all but Western cows, time spent in pasture was considered equal to time spent grazing, i.e. animals are grass-fed only and are grain-fed when confined. For Western cows, however, it was assumed that feeding not only takes place during confinement (75 days), but also during part of their time on pasture (75 days as well, out of the 290 days on grass), assumption based on expert judgement[9] and existing literature (Kaleil, 2013) (see Figure 2-6). This adjusted figure corresponds to the higher end of the range, so that the environmental impacts of feed are not underestimated.

Table 2.2 Time spent on pasture per animal category (Source: survey)

Animals	Time spent in pasture (% of stage duration)	
	West	East
Calves	97%	86%
Cows	80%	48%
Bulls	79%	50%
Backgrounded heifers	25%	7%
Backgrounded steers	25%	7%
Yearling heifers	92%	48%
Yearling steers	92%	48%
Finished heifers	0%	0%

[9] Communication with experts – Brenna Grant (Canfax), Greg Bowie and Thomas Lynch-Staunton (Alberta Beef Producers) in July 2015

Animals	Time spent in pasture (% of stage duration)	
	West	East
Finished steers	0%	0%

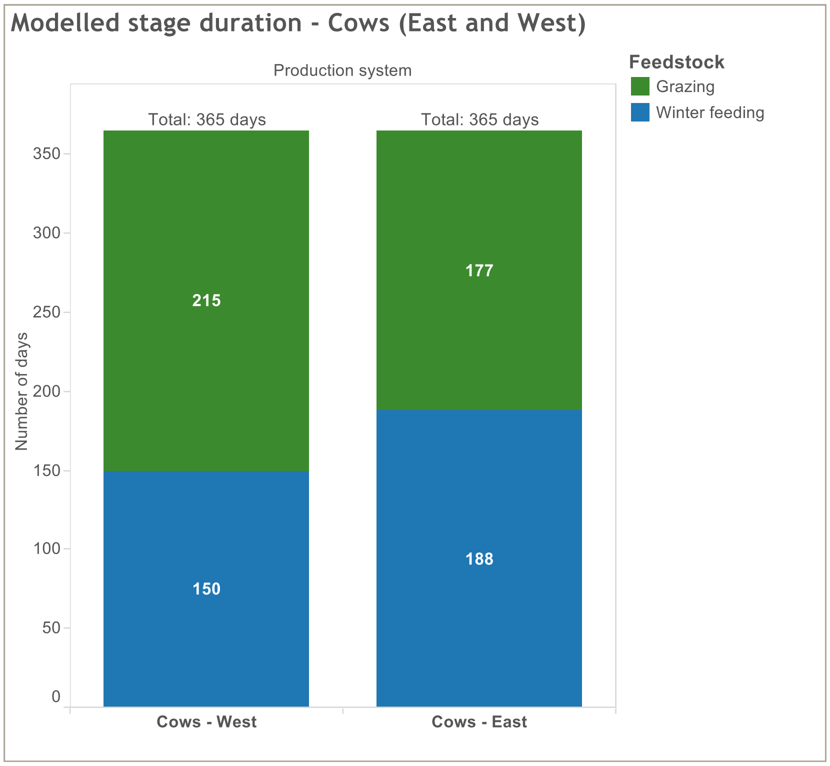


Figure 2-6 Time spent grazing and confined for cows throughout the year (Sources: survey and literature)

- Time spent on feed

The duration of the feeding period is indicated in the table below. Except for the finishing stage, the duration of each period is similar for calf-fed animals and yearling-fed animals.

Table 2.3 Duration of feeding period for each animal category

Animal type	Gender	West (days)	East (days)
Calves	MF	8	33
Backgrounders	M	90	112
	F	90	112
Yearling grassers	M	10	75
	F	10	75
Finishers	MF—calf-fed	225	255
	MF—yearling-fed	150	160
Cows	F	150	189

Bulls	M	78	183

- Mortality and replacement rates

Table 2.4 summarizes the data obtained from the farm surveys with regard to mortality rates. These data were in line with what was observed in the Alberta Agriculture and Rural Development study (2010). See 6.6 for comparison.

Table 2.4 Mortality rates used in the study (Source: survey)

Animals	Mortality rates (%)
Calves	3%
Cows	1%
Bulls	1%
Backgrounded heifers	2%
Backgrounded steers	2%
Yearling heifers	1%
Yearling steers	1%
Finished heifers	2%
Finished steers	2%

The average cow replacement rate obtained from the survey is 9%.

- Finishing and culled animal weight

Further, as the functional unit refers to an amount of meat produced, the environmental impacts associated with beef production at the farm gate were expressed per quantity unit of meat produced, i.e. divided by the mass of finishing and culled animals, which is presented below. Meat obtained from culled bulls is negligible compared to meat obtained from finishers and culled cows, and was thus excluded.

The values were reviewed by cattle farming experts, and were considered in the range of what is traditionally observed (AARD, 2010; Basarab, 2012; Beauchemin, 2010). See 6.6 for comparison.

Table 2.5 Finishing and culled animals' live weights used in the study (Sources: survey and literature)

Animals	Live weight at farm gate (lb)	
	West	East
Culled cows	1,381	1,381
Finishers	1,350	1,550

According to expert opinion,[10] the heavier weights for finishers in the East is explained by heavier breed prevalence in the East (e.g. Continental breeds) and response of feedlots to market requirements from packers. Packers in the East indeed request heavier animals to compensate for a shortage of animals. As a consequence, feedlots in the East feed

[10] Christoph Wand, Livestock Sustainability Specialists and Brian Pogue, Beef Cattle Program Lead – Ontario Ministry of Agriculture, Food and Rural Affairs

their calves heavy regardless of their origin (probably half or more of fed cattle in the East are now Western in origin) to provide heavier animals to the packers.
The heavy weight of cows is also explained by the heavy breed. By comparison, cow carcass weight data from Federal & Provincial Slaughter in our 2013 baseline year is as follow:

- West: 676 lb at 50% dressing percentage = 1,352 lb (very close to the Western Cow/Calf Survey number of 1,381 lb)
- East: 648 lb at 50% dressing percentage = 1,296 lb (pulled lower due to Holsteins)

Given the expert commentary on the combined importance of breed and feedlot responses to market demand on finishers' weights, 1,381 lb for both the East and West culled cows' weights appears to be the best assumption, as no data justifying a change were identified.

Feed rations

In the present model, feed rations are used to assess several environmental impacts:

- enteric CH_4 emissions and manure-related emissions;
- indirect environmental impacts of beef, i.e. the environmental impacts associated with feed production; and
- land use-related assessments: land occupation and land use-related impacts presented in the section on Land use-related assessments: biodiversity, water risk and carbon soil sequestration.

***Note*: The average rations obtained from the surveys do not represent diets that producers would actually feed, but encompass the variety of feeding practices of the surveyed farms.**

When compared to minimum nutritional requirements required by animals at all stages to grow and be healthy, average rations were sometimes underestimated or overestimated. This was identified through industry expert discussions[11] and review of previous studies (Kaleil, 2013). Consequently, data were adjusted to meet "realistic" daily intake recommendations: feed compositions (i.e. share of each feed in the overall ration) were used (see Figure 2-7), while amounts were adjusted to reach recommended daily dry matter intake (DMI), based on Anele's equations (Anele et al., 2014). This adjustment gives a more realistic feed ration and subsequent impact.

DMIs were obtained based on animal mid-weights (for calves, backgrounders, yearlings and finishers—see Figure 2-8) and end-weights (for cows and bulls). If most of these weights come from the survey, the latter provided an average animal weight of 1,333 lb for Eastern bulls, which was abnormally low, and adjusted to match Western bull weight (1,773 lb). Further, due to sample limitations, literature data were used to model an average ration for the Eastern finishers (Centre d'Etude sur les Coûts de Production en Agriculture, 2012). For homogeneity purposes, the literature data were adjusted similarly, also taking into account the daily DMI recommendations from the US National Research Council (2015). Figure 2-7 below displays the feed composition used in this study. Within the long list of feedstock mentioned in our survey, ten of them met over 98% of the feed rations' dry matter requirement for cows at all production stages. Those ten feedstocks were: energy supplement (barley, corn, wheat, oat grain and screening pellet); forage (hay, barley silage, corn silage, grass silage and straw); and protein supplement (dried distiller grains). Other feedstock considered in the study but which didn't contribute significantly to cattle diets were mill run pellet, soybean, triticale, alfalfa, millet hay, oat silage, pea silage, triticale silage, wheat silage, canola meal and soymeal. Those are included under the "cut-off" category in Figure 2-7.

Furthermore, farm surveys highlight that most feed (more than 70%) is produced locally, i.e. on beef farms, and the majority of purchased feed comes from the same province, within a radius of 50 km (AARD, 2010).

Finally, no differences were made within the feedstock categories independently of their final use (animal age or producing region): a given feedstock was modelled similarly for all regions and animal ages (in the land use section, a finer approach is proposed, considering province-specific yields).

[11] Discussion with Brenna Grant (Canfax), Thomas Lynch-Staunton and Greg Bowie (Alberta Beef Producers), July 2015

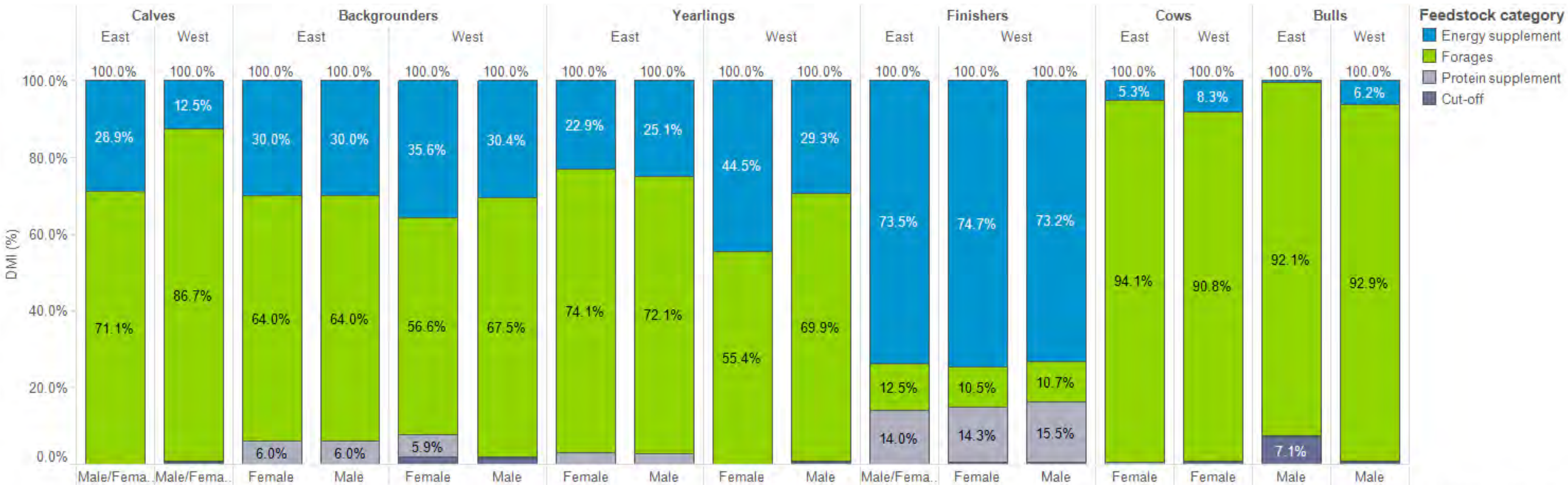


Figure 2-7 Overall composition of animal feed rations (animals on grass excluded)

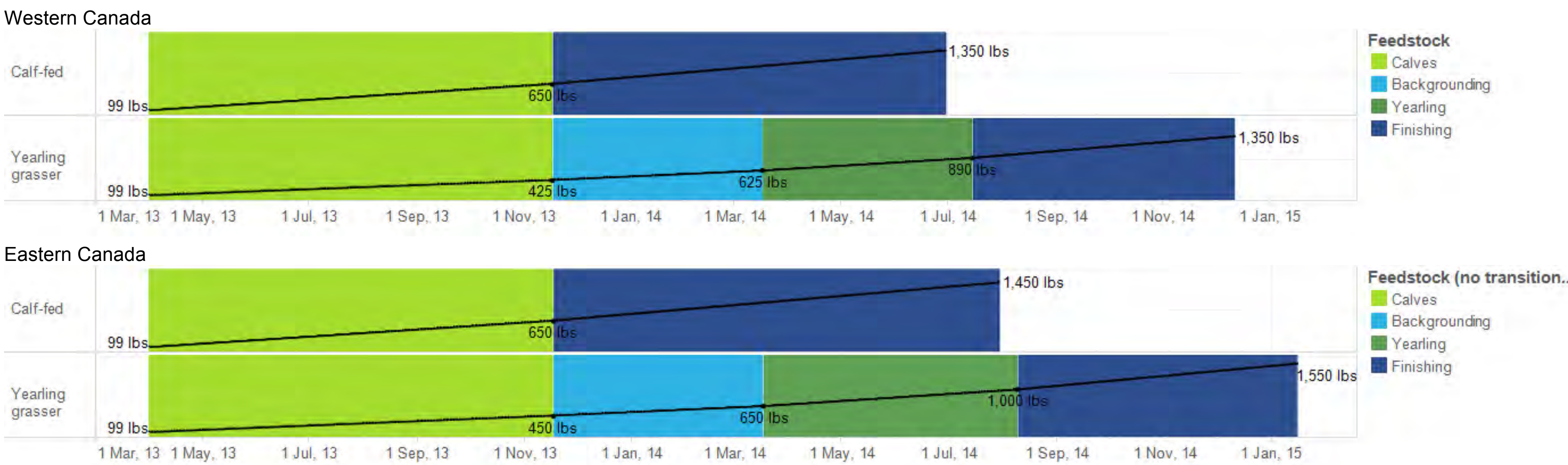


Figure 2-8 Animals' mid-weight used to assess daily DMI based on Anele 2014

Feed waste

Feed losses may occur during harvest and storage, and feed can be wasted during animal feeding. Losses and wastage rates were obtained from (Legesse et al., 2015) and are presented in Table 2.6. Harvest losses are considered already included in feed LCIs. However it was not possible to clearly distinguish harvest from storage losses. Consequently, the values used to model storage losses are likely to be overestimated, as losses occurring at harvest are also included. This is a conservative assumption, and has a limited impact on the final results (a few percent at maximum).

Table 2.6 Feed losses and waste rates used in the study

Feed type	Storage losses	Wastage
Hay	12%	20%
Silage	12%	5%
Energy and protein supplements	3%	0%

Land use

Data collected from the surveys enabled an assessment of land directly used required by animals on the farm. All animals but finishers require on average $57m^2$ of land per day per animal, mostly tame and native pasture areas. Finishers, in contrast, only require $0.6m^2$ of land per day per animal.

Indirect land use associated with cropland is assessed through the life cycle inventories used to model crops and forages environmental impacts (see Table 2.23).

Water use

- Animal water consumption

Water consumption by animals is not easily measurable by farmers and therefore generic data on cattle daily water consumption from Alberta Agriculture and Rural Development (2010) were used. Table 2.7 displays water daily intake values used in the study. These data were in line with other literature sources (Alberta Agriculture Food and Rural Development, 2005). The type and origin of water consumed by animals was part of the survey (see section 5.3.4 *Water use*).

Table 2.7 Water daily intake used in the study—based on AARD (2010)

Animals	Water consumption (L/head/day)
Calves	8
Cows	41.5
Bulls	45
Backgrounders	20.5
Yearlings	32
Finishing animals	38

Indirect water consumption associated with cropland (water for irrigation, for input production such as fertilizers or pesticides) is embedded in the life cycle inventories used to model crops and forages environmental impacts (see Table 2.23). Most LCIs were adjusted for irrigation to match current Canadian practices.

Indeed, either because feed LCIs assumed that irrigation in Canada was minor and neglected it, or because extensive production systems from other countries were used as proxies, most feed LCIs did not consider irrigation volumes. In fact, reviewing the 2014 Agricultural Water Survey (Statistics Canada, 2015), it appeared that irrigation is a limited practice across Canada. However the overall impact of irrigation is still significant, due to the substantial volumes of water used on irrigated areas.

The Agricultural Water Survey for 2014 provided data regarding the share of crop being irrigated, as well as the volume used on irrigated surfaces (Statistics Canada, 2015). These data are set out in Table 2.8.

Table 2.8 Irrigation data from 2014 Agricultural Water Survey

Crop type	Share of cultivated area being irrigated (2011)	Irrigation Intensity (2012 & 2014 Canadian average)
Field crops[12]	1.7%	2,800 m^3/ha
Forages crops[13]	1.8%	3,100 m^3/ha

According expert judgement, irrigation on tame pasture is rare.[14] Figures from the Agricultural Water Survey were revised to reflect this practice and enable adjustments to the feed LCI. Adjustments were also made to reflect provincial distribution of beef land requirements (see Land use assessment section). Final values are displayed in Table 2.9.

Table 2.9: Irrigation data used to adjust feed crop LCIs

Crop type	Share of cultivated area dedicated to beef being irrigated (2011)	Irrigation Intensity (2012 & 2014 Canadian average)	Average crop irrigation level
Field crops	3.1%	2,800 m^3/ha	87.4 m^3/ha
Hay	3.4%	3,100 m^3/ha	105.4 m^3/ha
Tame pasture	0%	n/a	0 m^3/ha

- Energy consumption

Energy consumption was also collected from the survey. Table 2.10 summarizes the average consumption per animal per day. Although slightly inferior, these values are in the same range of the data found in literature, as demonstrated in Appendix 6.6 (AARD, 2010).

[12] Field crops includes **annual field crops** and tame forages, including **barley** and potatoes
[13] Forage crops includes **hay—**any cultivated grass or legume crop that has been (or will be) cut and dried principally for hay or ensilage and **improved pasture—**land that has been altered from its natural state by seeding, draining, irrigating, fertilizing or brush- or weed-control measures
[14] Communication with Brenna Grant, Canfax and Rich Smith, Alberta Beef Producers

Table 2.10 Energy consumption per animal and per day (Source: survey)

Energy	Consumption (per head per day)
Electricity (kWh/day)	0.04
Natural gas (cf/day)	0.05
Diesel (litres/day)	0.02
Gasoline (litres/day)	0.003
Waste water (litres/day)	0.17

2.2.2.2 Transport

There are several stages of transport all along the life cycle of beef production. Considering the scope of this study, in which the impacts of secondary processing, retail and consumption are limited to the impacts generated by food waste, transportation steps from packing to final consumer are not included. Table 2.11 summarizes the assumptions for each of the transportation steps.

For lack of better data, for all transportation stages, default loading status from the ecoinvent v3 database were used: an occupation of 80% of truck capacity when the truck is loaded and, for the return, 20% of the emissions of the first trip are dedicated to the return trip.

Table 2.11 Consideration of transportation steps & main assumptions

Transportation step	Assumption
Feed transportation	Farm surveys highlight that most feed (more than 70%) is produced locally, i.e. on beef farms, and the majority of purchased feed comes from the same province, within a radius of 50 km (AARD, 2010). Consequently, an average value of 15 km travelled by each ton of feed is considered here. Transportation distances can be shorter for cow/calf operations and much longer for feedlots, however the impacts of feed transportation are not significant on the overall results.
Cow/calf farms to feedlots or backgrounding farms	Average distance of 300 km—estimate based on (AARD, 2010).
Backgrounding farms to feedlots[15]	Average distance of 300 km—estimate based on (AARD, 2010).
Feedlot to packing plants	Encompasses transport from feedlot to packing plants, including potential transportation through auction market. A 300 km distance is used—estimate based on (AARD, 2010).
Packing to secondary processing plants	Excluded

[15] In the survey, very few farms—and with low herd size—were specialized in grazing yearling only. As such, no transportation stage was considered between backgrounding and yearling grazing stages.

Transportation step	Assumption
Processing plants to retailers	Excluded
Retailers to consumers' home	Excluded

Further, transportation of animals to processors results in a weight reduction, depending on the conditions to which animals are exposed during transport. Similar to the AARD study, an average live-to-shrunk weight ratio of 96% was used (AARD, 2010).

2.2.2.3 Packing

Surveyed packers provided data related to production level, dressing rates, carcass-to-bone-free-meat ratio, energy consumption, water use, and other inputs and outputs. Most of the outputs were obtained from the National Pollutant Release Inventory. For confidentiality purposes, most data obtained from the packers are not detailed in this report. During packing, bone-free meat is obtained. Packing thus yields a variety of by-products such as hides, blood, fat and bones. To convert the live weight into carcass and bone-free meat weights (Figure 2-10), the ratios described were used (AARD, 2010; Canadian Food Inspection Agency, 2015; Agriculture and Agri-Food Canada, 2015; Anon., 2014-2015).

2.2.2.4 Secondary processing, retail and consumption activity data used

Data used to model operations

- Secondary processing

As described in the goal and scope, only the impacts associated with packaging and meat waste occurring during secondary processing were considered for this stage.

An average packaging system is included and data are based on public data sources (Greenext, 2015). The corresponding data are presented in Table 2.12 below.

Table 2.12 Packaging description for 1 kg of bone-free meat (generic data from literature)

Packaging material	Amount (g of material/kg of bone-free meat)
Primary packaging	
Polystyrene tray	0.056
Polyethylene protection film	0.0095
Secondary packaging	
Corrugated board box	0.028
Tertiary packaging	
Polyethylene wrapping film	0.0013
Wood pallet	0.035

The LCIs used to model the impacts of the production and end-of-life (see next paragraph) of these packaging materials are displayed in 6.6.

Meat waste occurring at this stage is described hereafter (see Figure 2-9).

- Retail

The impacts associated with energy consumption and leaks of refrigerant gases associated with an average storage in chilled conditions were assessed. For lack of better data, values based on Deloitte expertise, and built in the French context, have been implemented. They are presented in Table 2.13.

Table 2.13 Retail inputs description for 1 kg of bone-free meat (generic data from literature)

Inputs	Amount (kWh/kg of bone-free meat)[16]
Energy consumptions	
Electricity	1.6
Natural gas	0.11
Heavy fuel	6.1
Leaks of refrigerant gas	**(kg of refrigerant/kg of bone-free meat)**
R404a	0.000079
R408a	0.0000086
R22	0.000054

- Consumption

Data related to storage and cooking of beef meat were used to study environmental impacts related to the consumption of 1 kg of bone-free meat in a household. Only data related to energy consumption were taken into consideration due to the lack of available data on refrigerant leakage for residential fridges.

Storage

Annual electrical consumption of a fridge was obtained from the report *Energy consumption of Major Household Appliances Shipped in Canada—Trends for 1990–2010.* The average storage capacity of fridges is about 23 litres. For simplification, it was considered that 1 kg of beef meat occupies 1L of fridge volume. Further, the average duration of storage in chilled conditions (4°C /40 °C or below) was set to three days, as recommended by general food safety tips of the Government of Canada (values implemented in the model are displayed in Table 2.14).

Cooking

A "standard" cooking scenario was defined as follows:

- An electric cooking-range used to cook the steaks and corresponding annual electric consumptions (Natural Resources Canada's Office of Energy Efficiency, 2012)
- Three minutes cooking for a medium-rare steak
- Two sessions with one pan are needed to cook 1 kg of meat

Corresponding electricity consumption is displayed in Table 2.14.

Table 2.14 Storage and cooking description for 1 kg of bone-free meat (generic data from literature)

Energy consumption	Amount (kWh/kg of bone-free meat)

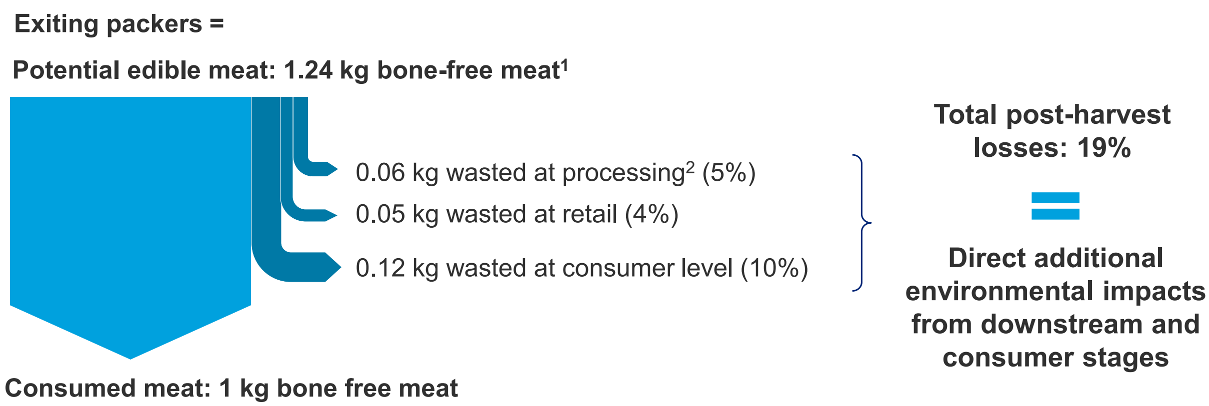
[16] Includes meat and packaging weight

Energy consumption	Amount (kWh/kg of bone-free meat)
Storage	
Electricity	0.008
Cooking	
Electricity	0.14

Meat wasted at the consumer level is also considered and described in the following paragraph.

- Meat waste

Environmental impacts generated by meat wasted at the secondary processing, retail and consumption stages are taken into consideration. North American figures from the FAO assessment on food wastage were used (Food and Agriculture Organization of the United Nations, 2011). Figure 2-9 displays the values used in our study.



[1] Considering meat waste. In this diagram, only meat waste is considered, see above for by-products

[2] Losses refer to trimming spillage during additional industrial processing

Figure 2-9 Meat waste occurring during secondary processing, retail and at consumer level

Overall, several successive ratios are used to determine the amount of bone-free meat finally eaten by the consumer from the live weight exiting farms. The global picture is provided in Figure 2-10.

Data used to model end-of-life of meat and packaging waste

- Packaging waste

Since data on other provinces were lacking, average recycling rates for Canada are based on rates in provinces having implemented an Extended Producers Responsibility scheme (EPR) (Ontario, Québec, Manitoba), weighted by recovered tons for recycling (PACNEXT, 2014). The rates are thus likely to be overestimated, but packaging end-of-life remains a minor contributor to the overall environmental impacts of meat production. Since there is limited incineration in Canada, remaining waste fractions are assumed to be landfilled.

Table 2.15 Packaging material flow recycling and landfilling rates (generic data from literature)

Packaging material flow	Recycling rate	Landfilling rate
Plastics	61%	39%
Paper and board	29%	71%

Meat waste
As previously mentioned, incineration remains marginal in Canada. Meat waste is thus assumed to be landfilled.

2.2.3 Life cycle inventory data

LCIs used in this study are displayed in Appendix 6.5. When necessary, clarifications on the choice of the LCIs are presented hereafter, in 2.3 ELCA methodological choices and assumptions.

2.3 ELCA methodological choices and assumptions

This chapter provides a description of the main methodological choices and assumptions used in this study:
- The first section on allocation explains how the impacts were distributed between the various by-products of the processes included in the study.
- The second section describes the models that were used to assess the environmental impacts of Canadian beef consumption.

As far as possible, models developed specifically for the Canadian context were used. When Canadian data were missing, other data sources were used as proxies. These data were selected because they were judged the most relevant in terms of accuracy, completeness and timeliness, as well as geographic and technological representativeness.

2.3.1 Allocation

As described in the goal and scope, allocation methods, which enable the repartition of the impacts between several by-products of a process, have been selected in accordance with relevant standards.

2.3.1.1 Feed

Among the feeds and forages considered in the model, barley, corn and oats generate by-products (such as straw), while canola meal and soybean meals are by-products of oil production in and of themselves. LCIs from a previous study from Alberta Agriculture (2014) were used to assess the environmental impacts generated by the production of these feeds (see 2.3.2.5 Feeds). In particular, economic allocation was used to allocate the environmental impacts of feed by-product ingredients (such as soymeal and canola meal) because physical relationships of feed materials differed significantly from one feed type to another depending on nutritional content (i.e. energy, protein and essential amino acid) (Food and Agriculture Organization, 2014). Moreover, the prices of feed ingredients often reflect their nutritional value. Therefore, economic allocation was the best option possible to allocate environmental impacts of feed ingredients and their by-products in a consistent manner and on the basis of a meaningful relationship between nutritional values and prices (Food and Agriculture Organization, 2014).

2.3.1.2 Manure

All manure produced by cattle was assumed to be used to grow beef feed crops. No allocation rule was implemented (see section 2.3.2.5 *Feeds*).

2.3.1.3 Beef meat and by-products

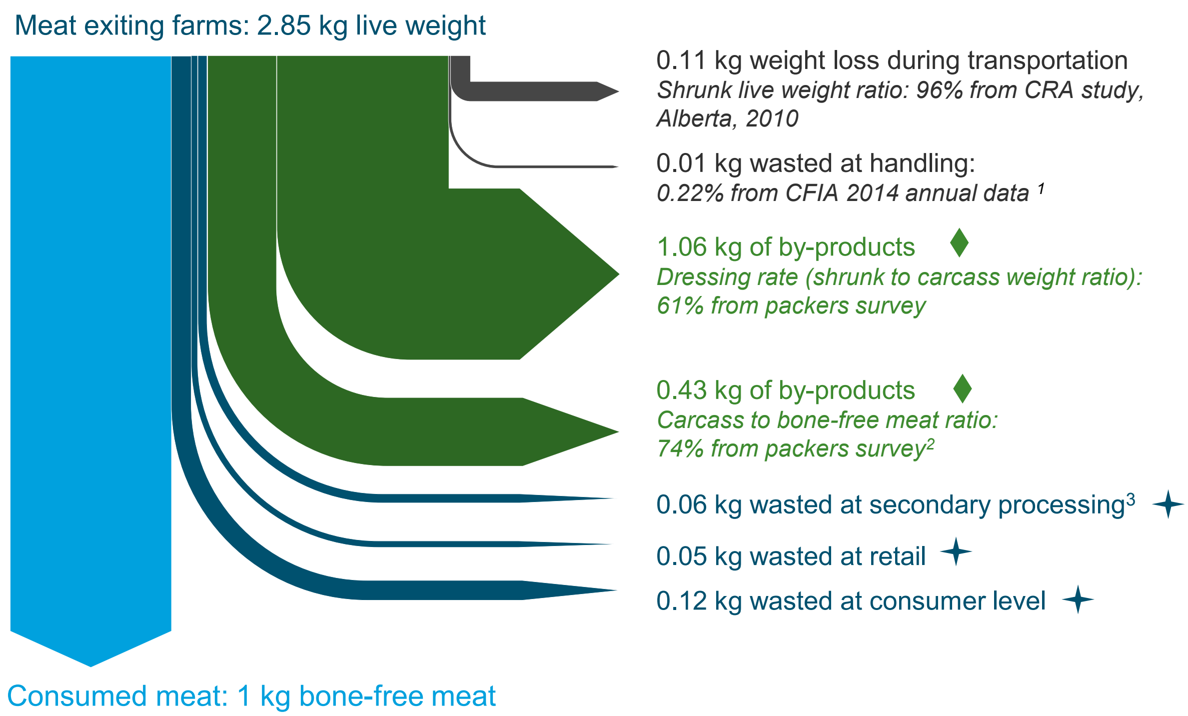
To split the impacts between meat and its by-products—e.g. hides, offal, blood, bones, etc.—an economic allocation was used, as recommended by FAO LEAP Partnership guidelines (Food and Agriculture Organization, 2015). Meat waste impacts were fully attributed to meat production. Figure 2-10 summarizes the successive ratios to obtain bone-free meat from live weight.

From the surveyed packers, we obtained the economic values of meat and by-products, which were then used for the economic allocation (see Table 2.16; see also Figure 2-10 for ratios to convert live weight to bone-free meat at packers' gate and at consumer level). Appendix 6.7.1 details the approach to distribute the environmental impacts between meat and by-products.

Following ISO 14040-44 guidelines, a sensitivity analysis was performed on this allocation choice, comparing economic to mass allocation.

Table 2.16 Figures used for allocation (Source: survey)

Allocation	Economic allocation of meat compared to other by-products	Mass allocation rates used for sensitivity analysis
Meat (carcass weight)	95%	61%
Meat (bone-free weight, at the consumer level)	90%	45%



[1] Death during transport to slaughter and condemnation at slaughterhouse
[2] Average yield of retail cuts from beef carcasses varies depending on the fatness and muscling of the animal, and the type of cuts produced
[3] Losses refer to trimming spillage during additional industrial processing

♦ Part of the impacts of farming and packing is attributed to these by-products, following an **economic allocation.** Given the amounts of by-products and their economic value, they are apportioned 10% of the farming and packing stage environmental impacts, i.e. **meat is allocated 90%** of these impacts.

✦ Due to lack of Canadian specific data, waste figures are from FAO (2011). These figures are consistent with other literature sources. Overall, 19% of edible meat is wasted through the food chain, resulting in **direct additional environmental impacts.**

In grey and dark blue: wasted fractions | In dark green: by-products | In light blue: final edible fraction

Figure 2-10 Considering the impacts of by-products and waste along the food chain

2.3.2 Other environmental LCA methodological choices and assumptions

2.3.2.1 Infrastructure

As previously described (see section 1.4.1), construction activities related to on-farm buildings have been excluded from the analysis.

2.3.2.2 Methane emissions from enteric fermentation

Enteric fermentation results in methane emissions that vary according to the gross energy intake (GEI). The GEI depends on the dry matter intake (DMI), which is linked to the energy required by animals to maintain and gain, according to their weight, and the energy contained in feed. The survey performed includes data on animal weight and the ration of each animal so the calculation of gross energy intake per type of animal is possible based on these data. However, a simplified approach was preferred, considering that the survey did not produce a sample set representative of the entire Canadian territory.

The GEI of an animal can be estimated from the DMI, considering that GEI = 18.45 x DMI. DMIs were calculated based on the mid-weight and the equations from Anele et al. (2014).

To obtain daily enteric emission values, DMI is multiplied by the methane emission factor (Ym). The calculation method, based on the IPCC guidelines (2006) as well as data sources, is detailed in Appendix 6.5. Calculated daily methane enteric emissions are indicated in Table 2.17.

While similar conditions of age, gender, weight and location (East or West) lead to a similar Ym, DMI may vary depending on the ingested diet. In particular, DMI is different depending on whether animals are fed or grazing. This potential difference of DMI between animals of the same category (e.g. backgrounders on feed or on grass) explains the difference of enteric methane emissions.

Table 2.17 Methane enteric emissions from beef cattle

<table>
<tr><th rowspan="2">Animal type</th><th rowspan="2">Feed management</th><th rowspan="2">Gender</th><th rowspan="2">Region</th><th colspan="2">Enteric methane (g CH4/day)</th></tr>
<tr><th>Yearling-fed system</th><th>Calf-fed system</th></tr>
<tr><td rowspan="4">Calves (> 3 months)</td><td rowspan="2">on grass</td><td rowspan="4">M/F</td><td>East</td><td>50.7</td><td>70.4</td></tr>
<tr><td>West</td><td>53.1</td><td>76.4</td></tr>
<tr><td rowspan="2">on feed</td><td>East</td><td>93.7</td><td>138.8</td></tr>
<tr><td>West</td><td>92.2</td><td>145.5</td></tr>
<tr><td rowspan="8">Backgrounders</td><td rowspan="4">on grass</td><td rowspan="2">M</td><td>East</td><td>118.5</td><td>-</td></tr>
<tr><td>West</td><td>113.1</td><td>-</td></tr>
<tr><td rowspan="2">F</td><td>East</td><td>118.5</td><td>-</td></tr>
<tr><td>West</td><td>113.1</td><td>-</td></tr>
<tr><td rowspan="4">on feed</td><td rowspan="2">M</td><td>East</td><td>121.1</td><td>-</td></tr>
<tr><td>West</td><td>115.3</td><td>-</td></tr>
<tr><td rowspan="2">F</td><td>East</td><td>121.1</td><td>-</td></tr>
<tr><td>West</td><td>115.3</td><td>-</td></tr>
<tr><td rowspan="8">Yearlings</td><td rowspan="4">on grass</td><td rowspan="2">M</td><td>East</td><td>181.7</td><td>-</td></tr>
<tr><td>West</td><td>166.6</td><td>-</td></tr>
<tr><td rowspan="2">F</td><td>East</td><td>181.7</td><td>-</td></tr>
<tr><td>West</td><td>166.6</td><td>-</td></tr>
<tr><td rowspan="4">on feed</td><td rowspan="2">M</td><td>East</td><td>181.7</td><td>-</td></tr>
<tr><td>West</td><td>166.6</td><td>-</td></tr>
<tr><td rowspan="2">F</td><td>East</td><td>181.7</td><td>-</td></tr>
<tr><td>West</td><td>166.6</td><td>-</td></tr>
<tr><td rowspan="3">Finishers</td><td rowspan="3">on feed</td><td>M/F</td><td>East</td><td>108.2</td><td>83.5</td></tr>
<tr><td>M</td><td>West</td><td>139.2</td><td>121.3</td></tr>
<tr><td>F</td><td>West</td><td>139.2</td><td>121.3</td></tr>
<tr><td rowspan="4">Cows</td><td rowspan="2">on grass</td><td rowspan="4">F</td><td>East</td><td>278.5</td><td>278.5</td></tr>
<tr><td>West</td><td>278.5</td><td>278.5</td></tr>
<tr><td rowspan="2">on feed</td><td>East</td><td>278.5</td><td>278.5</td></tr>
<tr><td>West</td><td>278.5</td><td>278.5</td></tr>
<tr><td rowspan="4">Bulls</td><td rowspan="2">on grass</td><td rowspan="4">M</td><td>East</td><td>417.7</td><td>417.7</td></tr>
<tr><td>West</td><td>417.7</td><td>417.7</td></tr>
<tr><td rowspan="2">on feed</td><td>East</td><td>417.7</td><td>417.7</td></tr>
<tr><td>West</td><td>417.7</td><td>417.7</td></tr>
</table>

The emissions from replacement animals are considered similar to:

- the emissions of backgrounders between the weaning date and one year old; and
- the emissions of yearlings from one year old to the date of first calving.

2.3.2.3 Emissions from stored manure or manure in pasture

Whether excreted on pasture or in barns and stored, manure is a source of several elements released into soil, water and air. Figure 2-11 summarizes the main manure-related emissions and nutrient losses and their potential effects on various environmental impact indicators.

Only emissions related to manure production and storage were modelled in this study. Emissions related to manure use (e.g. fertilization of fields) were allocated to the processes using manure (e.g. crops), and are thus encompassed in the crop LCIs models. This avoids any double counting and follows the recommended approach in the FAO LEAP guidelines (FAO LEAP Guidelines, 2015): "emissions associated with manure management up to the point of field application are assigned to the animal system, and emissions from the field were assigned to the crop production system". Manure excreted on pastures is thus included in the animal system.

Feeding practices, linked to different DMI and digestibility that induce different manure compositions, as well as manure management practices, may influence the quantity of nutrients released into soil, water and air. For the calculation of emissions from manure, the ration composition obtained from the survey as well as the DMI were used to assess the percentage of digestible nutrients in feed and total nitrogen excretion in manure, based on the equations from Anele *et al.* (2014). Phosphorus content of manure, however, was obtained from generic data collected through secondary research.

Assumptions and literature sources are detailed in the following paragraphs for methane, nitrous oxide, ammonia, nitrogen oxides, nitrates and phosphate emissions.

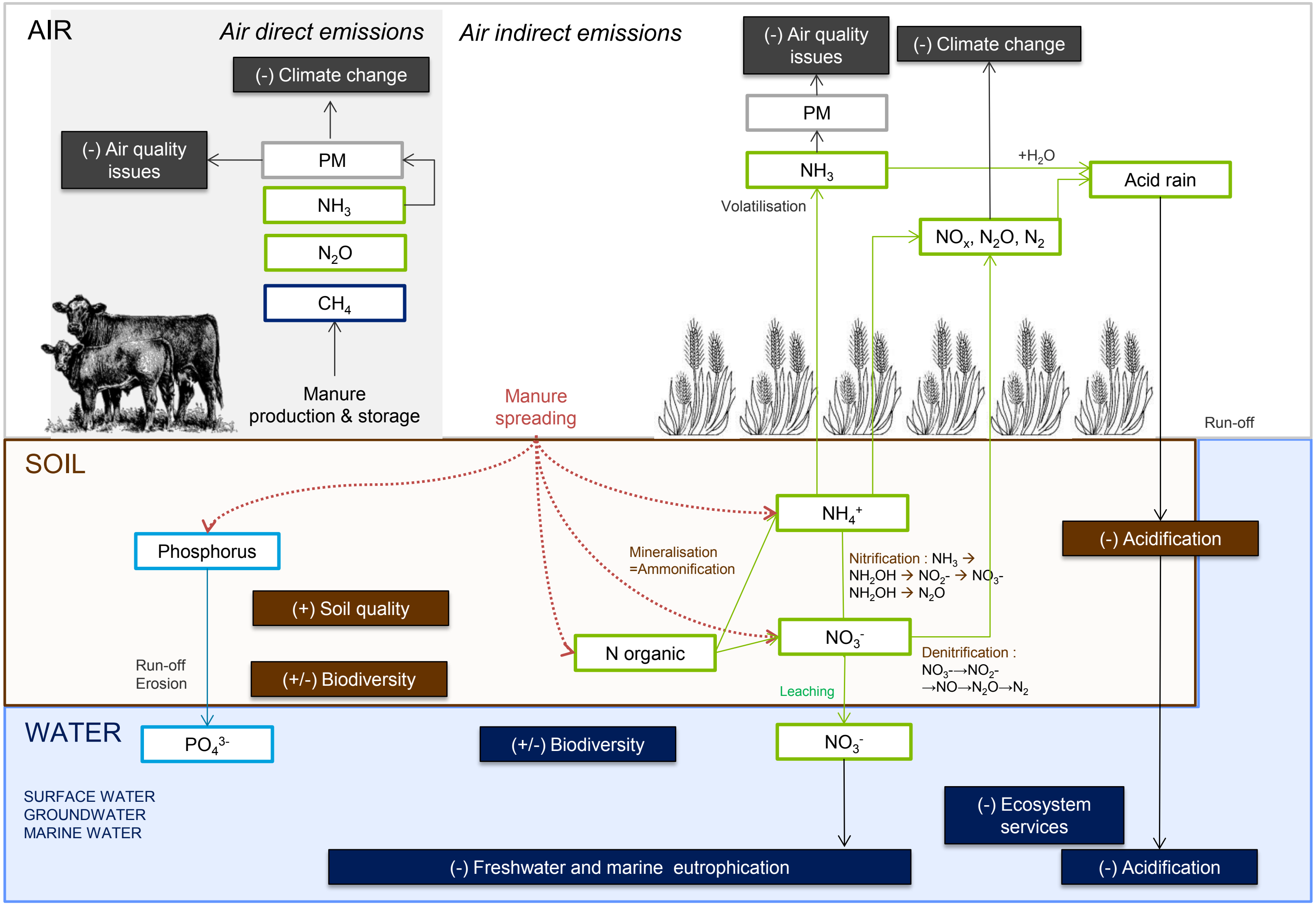


Figure 2-11 Simplified representation of manure-related emissions in soil, air and water and environmental impacts

Note: CH_4: methane; N: Nitrogen; N_2: dinitrogen; N_2O: nitrous oxide; NH_3 and NH_4^+: ammonia and ammonium; NO_3^-: nitrate; NO_x: nitrous oxides; PM: particulate matter; PO_4^{3-}: phosphate.

(-): negative effect on the considered environmental impact; (+): environmental benefit.

Methane (CH_4) emissions

Anaerobic fermentation of manure is responsible for methane emissions during manure storage (such as bedding pack or outside piles, manure composting and in pasture). The quantity of emitted methane depends on the quantity of volatile solids excreted in manure and the methane producing capacity, which are closely related to feed intake, as well as the methane conversion factor (which depends on the manure management system used).

The calculation method is based on the Holos model adapted from the IPCC guidelines (2006) (Little et al., 2008). The methane emissions from manure are calculated based on the average diet provided to animals. Detail on the approach is set out in Appendix 6.5. Daily methane emissions from manure are shown in Table 2.18.

Nitrous oxide (N_2O) emissions

Nitrous oxide emissions are a product of direct emissions from manure throughout storage and deposition in pastures, as well as from indirect emissions from nitrogen volatilization and leaching. The calculation method is based on the Holos model adapted for Canada from IPCC guidelines (2006) (Little et al., 2008). It is detailed in Appendix 6.5 as well as the data sources.

Direct and indirect N_2O emissions depend on the quantity of nitrogen excreted in manure. This quantity depends on the feed intake and the assimilation capacity of each animal. The nitrogen excretion is calculated based on ration composition and daily dry matter intake.

With regard to the transformation of N into N_2O, the share of N that is directly emitted, the fraction of N that is lost by volatilization, the share of the volatilized nitrogen that is transformed into N_2O and the share of leached N transformed into N_2O are data from Little et al. (2008), depending on the manure storage conditions. The fraction of nitrogen leached was calculated based on the methodology of Rochette et al.'s (2007) for estimating N_2O soils in Canada. According to the IPCC (2006), it is assumed that leaching only occurs in pastures. Indeed, in pens, catch basins are often implemented to collect the residual nutrient losses by run-off (Miller, 2011) (Alberta Agriculture, 2000). In addition, soil in pens is often compacted, which limits the nutrient losses by leaching. On this basis, the assumption was made that no N losses occur during storage. This assumption was also made in the Holos tool to determine the indirect N_2O emissions from N leaching. In Canada, although leaching on pastures can be very low (Government of Alberta, 2009) (Thiessen Martens & Entz, 2011), it cannot be considered null.
The total daily nitrous oxide emissions, from direct and indirect sources, are shown in Table 2.19.

Ammonia (NH_3) emissions

As with N_2O emissions, ammonia emissions depend on the quantity of nitrogen excreted in manure.
The emissions are calculated based on the equation proposed by Chai et al. (2014). Ammonia emissions are calculated for manure storage, manure composting and on pasture. Based on the information collected through the survey, it is considered that manure is stored as bedding pack or as outside piles, or composted, but cumulative practices were not studied. Daily ammonia emissions per animal are shown in Table 2.20.

Table 2.18 Methane emissions from manure from beef cattle

Animal type	Manure management	Gender	Region	CH4 emissions from manure (g/day)	
				Yearling-fed system	Calf-fed system
Calves on grass	in pasture	M/F	East	1.2	1.6
			West	1.2	1.8
Calves on feed	deep bedding		East	2.0	2.9
			West	2.0	3.1
	solid storage		East	2.0	2.9
			West	2.0	3.1
	composting		East	2.0	2.9
			West	2.0	3.1
Backgrounders on grass	in pasture	M	East	2.6	-
			West	2.4	-
		F	East	2.6	-
			West	2.4	-
Backgrounders on feed	deep bedding	M	East	37.2	-
			West	35.5	-
		F	East	37.2	-
			West	35.5	-
	solid storage	M	East	4.4	-
			West	4.2	-
		F	East	4.4	-
			West	4.2	-
	composting	M	East	1.1	-
			West	1.0	-
		F	East	1.1	-
			West	1.0	-
Yearlings on grass	in pasture	M	East	4.3	-
			West	4.0	-
		F	East	4.3	-
			West	4.0	-
Yearlings on feed	deep bedding	M	East	73.8	-
			West	67.7	-
		F	East	73.8	-
			West	67.7	-
	solid storage	M	East	8.7	-
			West	8.0	-
		F	East	8.7	-
			West	8.0	-
	composting	M	East	2.2	-
			West	2.0	-
		F	East	2.2	-
			West	2.0	-
Finishers on feed	deep bedding	M/F	East	41.2	31.8
		M	West	50.2	43.7
		F	West	50.2	43.7
Finishers - storage	solid storage	M/F	East	4.8	3.7
		M	West	5.9	5.1
		F	West	5.9	5.1
Finishers - composting	composting	M/F	East	1.2	0.9
		M	West	1.5	1.3
		F	West	1.5	1.3
Cows on grass	in pasture	F	East	6.9	6.9
			West	6.9	6.9
Cows on feed	deep bedding		East	117.1	117.1
			West	117.1	117.1
	solid storage		East	13.8	13.8
			West	13.8	13.8
	composting		East	3.4	3.4
			West	3.4	3.4
Bulls on grass	in pasture	M	East	10.3	10.3
			West	10.3	10.3
Bulls on feed	deep bedding		East	175.6	175.6
			West	175.6	175.6
	solid storage		East	20.7	20.7
			West	20.7	20.7
	composting		East	5.2	5.2
			West	5.2	5.2

Table 2.19 Total nitrous oxide emissions from beef cattle manure

Animal type	Manure management	Gender	Region	TOTAL N2O emissions (g/day)	
				Yearling-fed system	Calf-fed system
Calves on grass	in pasture	M/F	East	1.9	2.6
			West	1.8	2.7
Calves on feed	deep bedding		East	1.8	2.8
			West	1.8	3.0
	solid storage		East	1.3	2.0
			West	1.3	2.2
	composting		East	14.6	22.5
			West	14.3	23.8
Backgrounders on grass	in pasture	M	East	4.4	-
			West	4.1	-
		F	East	4.5	-
			West	4.1	-
Backgrounders on feed	deep bedding	M	East	1.9	-
			West	1.8	-
		F	East	1.9	-
			West	1.8	-
	solid storage	M	East	1.4	-
			West	1.3	-
		F	East	1.4	-
			West	1.3	-
	composting	M	East	15.5	-
			West	14.6	-
		F	East	15.5	-
			West	14.6	-
Yearlings on grass	in pasture	M	East	5.9	-
			West	5.1	-
		F	East	5.9	-
			West	5.1	-
Yearlings on feed	deep bedding	M	East	3.0	-
			West	2.8	-
		F	East	3.0	-
			West	2.8	-
	solid storage	M	East	2.2	-
			West	2.0	-
		F	East	2.2	-
			West	2.0	-
	composting	M	East	24.5	-
			West	22.4	-
		F	East	24.5	-
			West	22.4	-
Finishers on feed	deep bedding	M/F	East	3.3	2.5
		M	West	4.4	3.7
		F	West	4.4	3.7
Finishers - storage	solid storage	M/F	East	2.4	1.8
		M	West	3.2	2.7
		F	West	3.2	2.7
Finishers - composting	composting	M/F	East	26.4	19.8
		M	West	35.4	29.6
		F	West	35.4	29.6
Cows on grass	in pasture	F	East	8.7	8.7
			West	8.2	8.2
Cows on feed	deep bedding		East	4.5	4.5
			West	4.5	4.5
	solid storage		East	3.3	3.3
			West	3.3	3.3
	composting		East	36.5	36.5
			West	36.5	36.5
Bulls on grass	in pasture	M	East	13.0	13.0
			West	12.3	12.3
Bulls on feed	deep bedding		East	6.7	6.7
			West	6.7	6.7
	solid storage		East	4.9	4.9
			West	4.9	4.9
	composting		East	54.3	54.3
			West	54.3	54.3

Table 2.20 Ammonia emissions from beef cattle

Animal type	Manure management	Gender	Region	NH3 emissions (g NH3/day)	
				Yearling-fed system	Calf-fed system
Calves on grass	in pasture	M/F	East	3.5	2.6
			West	1.8	2.7
Calves on feed	deep bedding		East	1.8	2.8
			West	1.8	3.0
	solid storage		East	1.3	2.0
			West	1.3	2.2
	composting		East	14.6	22.5
			West	14.3	23.8
Backgrounders on grass	in pasture	M	East	4.4	-
			West	4.1	-
		F	East	4.5	-
			West	4.1	-
Backgrounders on feed	deep bedding	M	East	1.9	-
			West	1.8	-
		F	East	1.9	-
			West	1.8	-
	solid storage	M	East	1.4	-
			West	1.3	-
		F	East	1.4	-
			West	1.3	-
	composting	M	East	15.5	-
			West	14.6	-
		F	East	15.5	-
			West	14.6	-
Yearlings on grass	in pasture	M	East	5.9	-
			West	5.1	-
		F	East	5.9	-
			West	5.1	-
Yearlings on feed	deep bedding	M	East	3.0	-
			West	2.8	-
		F	East	3.0	-
			West	2.8	-
	solid storage	M	East	2.2	-
			West	2.0	-
		F	East	2.2	-
			West	2.0	-
	composting	M	East	24.5	-
			West	22.4	-
		F	East	24.5	-
			West	22.4	-
Finishers on feed	deep bedding	M/F	East	3.3	2.5
		M	West	4.4	3.7
		F	West	4.4	3.7
Finishers - storage	solid storage	M/F	East	2.4	1.8
		M	West	3.2	2.7
		F	West	3.2	2.7
Finishers - composting	composting	M/F	East	26.4	19.8
		M	West	35.4	29.6
		F	West	35.4	29.6
Cows on grass	in pasture	F	East	8.7	8.7
			West	8.2	8.2
Cows on feed	deep bedding		East	4.5	4.5
			West	4.5	4.5
	solid storage		East	3.3	3.3
			West	3.3	3.3
	composting		East	36.5	36.5
			West	36.5	36.5
Bulls on grass	in pasture	M	East	13.0	13.0
			West	12.3	12.3
Bulls on feed	deep bedding		East	6.7	6.7
			West	6.7	6.7
	solid storage		East	4.9	4.9
			West	4.9	4.9
	composting		East	54.3	54.3
			West	54.3	54.3

Nitrogen oxides (NO_x) emissions

Nitrous oxide is a product of the nitrification and denitrification processes. According to the document produced by EMEP/EEA in 2013 (European Environment Agency, 2013), solid manure emits 0.094 kg NO_x/animal/year for cattle (other than dairy cattle). In the reference, no distinction is made between animals. In the absence of more specific data, the same NO_x emissions are applied to all animal types. Since the ecoinvent NO_x are expressed as NO_2, the emissions are converted to NO_2 to be compatible with the ecoinvent database. As such, solid manure emits **0.000395 kg NO_2/animal/day**.

Further study on the NO_x emissions from manure would be needed to improve the model and obtain more accurate results regarding the impacts resulting from NO_x emissions.

Nitrates (NO_3^-) emissions

Nitrate losses can result from either manure leaching into groundwater or manure running-off to surface water. Due to the shortage of data relating to the quantification of N loss by leaching and run-off in the different storage systems, and as explained above, it is assumed that leaching only occurs in pastures.

Further study on the N losses by leaching and run-off during storage would be needed to accurately estimate the N losses specific to Canadian beef breeding systems. A sensitivity analysis with different fraction of N leached during storage was performed and this analysis is included in the report.

The calculation of the fraction of leached nitrogen was described previously, as it is used for the calculation of indirect N_2O emissions (see 6.7 ELCA—Detailed methodological assumptions). Thus, the fraction of nitrogen that is leached is estimated as 21.5% for Western Canada and 39.3% for Eastern Canada. Since nitrate is the most soluble ion, it is assumed that 100% of N lost by leaching and run-off is lost as nitrate (and may then be transformed into nitrite or ammonium).

The quantity of nitrogen leached as NO_3^- to water is calculated by subtracting the quantity of nitrogen emitted as N_2O per animal per day from the quantity of nitrogen excreted by animals per day. The results are set out in Table 2.21.

Table 2.21 Nitrogen lost as nitrate in surface water in pasture for beef production

Animal type	Manure management	Gender	Region	N03- losses by leaching and run-off (g NO3-/day)	
				Yearling-fed system	Calf-fed system
Calves	in pasture	M/F	East	82.0	114.7
			West	44.8	62.6
Backgrounders	in pasture	M	East	198.9	-
			West	103.0	-
		F	East	198.8	-
			West	103.0	-
Yearlings	in pasture	M	East	257.8	-
			West	128.4	-
		F	East	257.8	-
			West	128.4	-
Cows	in pasture	F	East	383.7	383.7
			West	209.5	209.5
Bulls	in pasture	M	East	570.5	570.5
			West	311.5	311.5

Phosphate (PO_4^{3-}) emissions

Phosphorus losses result from:

- Leaching of soluble phosphate to groundwater
- Run-off of soluble phosphate to surface water
- Erosion of soil particles containing phosphorus

As for nitrate, it is assumed that phosphorous losses only occur in pastures. Indeed, P losses mostly occur from run-off and erosion. Erosion only occurs in pasture, while run-off occurs in pasture but also during storage. In pens, catch basins are often implemented to collect the residual nutrient losses by run-off and P is not volatile. Consequently, it is considered that no P losses occur during storage.

The phosphorous losses were modelled based on the SALCA emissions model developed by (Prasuhn, 2006). This method allows the calculation of phosphorous losses per surface area. The calculation method and the source of data are set out in in 6.7.

Phosphate losses are distributed to each type of grazing animal according to the quantity of phosphate excreted per animal type. Phosphate losses depend on the phosphorous content of manure, which is related to the feed intake and the assimilation capacity of the animals. Contrary to nitrogen excretion, it was not possible to estimate phosphorus excretion in manure due to the lack of data on the phosphorus content of the diet. Hence, the quantity of phosphorus excreted in manure was calculated based on the data from the Census of Agriculture (Statistics Canada, 2006). The data were from 2001, which is the limiting factor of this approach. While the Census of Agriculture has been updated since 2001, no data on the phosphorus excretion per head per type of cattle are publicly available. We recognize however that this area is an opportunity for future research.

Based on these data, the total daily phosphorus as phosphate lost in pasture during beef production is set out in Table 2.22.

Table 2.22 Daily phosphate lost by run-off, leaching and erosion in pasture during beef production

	Phosphate lost to water (g PO43-/head/day)
Cows	3.6
Bulls	4.1
Calves	1.2
BG Heifers	1.8
BG Steers	1.9
Yearling Heifers	2.4
Yearling Steers	2.6
Finished Heifers	-
Finished Steers	-
Conversion rate: P to PO43-	3.13

The inability to link P excretions from the P content of the feed is a gap of the study, and is considered an area for future research. P mobility (e.g. greater in the East than in the West) and the migration risk (depending on the soil structure, etc.) should also be investigated to refine the assessment of the potential impacts.

2.3.2.4 Carbon emissions/storage due to land use and land use change

Carbon release/storage due to land use and land use change assumptions are described in section 8 Carbon soil sequestration.

2.3.2.5 Feeds

For major feeds (barley, corn, hay, wheat, oats, canola and pea), LCIs previously established for Alberta were used (AARD, 2014). Other feeds were modelled using LCIs from other databases (ecoinvent or Agri-footprint), potentially adjusted when relevant and possible.

Two major adjustments were made. First, irrigation levels were adapted to match current Canadian irrigation practices (see section dedicated to water use in *2.2.2.1 Farm activity data used*). Second, Alberta Agriculture LCIs were based on the assumption of 5% of nitrogen needs met by organic fertilizer supply. However, given cattle excretion of manure, this assumption is likely to be underestimated for beef feed crops, as they are mostly produced on farm or nearby. Manure amounts are thus likely to be higher. When assessing overall manure excreted by the

cohort, and corresponding nitrogen content, assuming all manure was allocated to feed crops is equivalent to meeting 22% of crops' N needs with organic fertilizer supply, which is a consistent value.[17] Alberta Agriculture LCIs were thus adjusted, to reduce the volume of chemical fertilizers from 95% to 72% of crop nitrogen supply.
Feed LCIs and potential adjustments are set out in Table 2.23.

Hay is an important component of animal rations. However, no Canadian LCI was available. An extensive Swiss production was used as proxy, but adjusted with organic and synthetic nitrogen fertilization as described in Legesse *et al.* (2015). 19% of hay cropped areas were considered supplied with 50 kg N/ha from synthetic fertilizer, and 19% supplied with 50 kg N/ha from manure, which for one average hectare of hay corresponds to a fertilization of 9.5 kg N from synthetic fertilizer and 9.5 kg N from manure.

The outcome in terms of carbon footprint (115 g CO_2 eg./kg of "as fed" hay) is in line with Wiens' work on alfalfa grass hay (140g CO_2 eq./kg of "as fed" hay).

In addition, no Canadian data were found to model feedmill processing. However, data related to the processing of energy feed, protein feed and DDGS were found in the ecoinvent v3 database and were used as proxies for Canadian practices (Table 2.21).

[17] Discussion with Dr. Karen Beauchemin and Dr. Tim McAllister from AAFC

Table 2.23 Used feed LCIs

Feed	Used LCI		Source and assumptions
Energy supplement	Barley	Barley, AB, grain	AAFD (2014) (AARD, 2014)—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Corn	Corn, grain	AARD (2014)—based on US production, irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Mill run pellet	Wheat, grain, AB	Wheat grain LCI from AARD (2014) used as proxy (minor amount of mill run pellet in animal feed rations)—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Oat grain	Oats, grain, at farm, Alberta, no-tillage, milled system	AARD (2014)—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Screening pellet	Energy feed, gross {GLO}| corn grain to generic market for energy feed | Alloc Rec[18]	ecoinvent v3 energy feed LCI adapted with corn LCI from AARD (2014)
	Soybean	Soybean	Soybean LCI from AARD (2014) used as proxy (minor amount of soybean silage in animal feed rations), AARD inventory based on US production—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Triticale grain	Triticale, at farm/FR mass	French triticale LCI from Agri-footprint (2014) (Blonk Agri-footprint BV., 2014) used as proxy (minor amount of triticale silage in animal feed rations)
	Wheat	Wheat, grain, AB	AARD (2014)—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
Forages	Alfalfa	Alfalfa-grass mixture, Swiss integrated production {CH}| production | Alloc Rec	Swiss alfalfa LCI from ecoinvent v3 used as proxy (minor amount of alfalfa in animal rations)
	Barley silage	Barley, AB, silage	Barley grain LCI from AARD (2014) adapted for yield to model a barley silage LCI
	Corn silage	Corn, silage	Corn grain LCI from AARD (2014) adapted for yield to model a corn silage LCI
	Grass silage	Hay	Hay LCI used as proxy
	Hay	Hay	Hay, Swiss integrated production, extensive {CH}| production | Alloc Rec, U from ecoinvent v3—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Oat silage	Oats, silage, at farm, Alberta, no-tillage, milled system	Oat grain LCI from AARD (2014) adapted for yield to model an oat silage LCI
	Pea silage	Peas, silage, at farm, Alberta, no-tillage, milled system	AARD (2014)—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Straw (for feed)	Barley, AB, straw	Barley straw LCI calculated from barley grain LCI from AARD (2014), using dry matter allocation factors of French barley grain and straw LCI from Agri-footprint (58.5:41.5)
	Triticale silage	Triticale, at farm/FR mass	French triticale LCI from Agri-footprint (2014) used as proxy (minor amount of triticale silage in animal rations)
	Wheat silage	Wheat, silage, AB	Wheat grain LCI from AARD (2014) adapted for yield to model a wheat silage LCI
Protein supplement	Canola meal	Canola meal, AB	AARD (2014)—irrigation adapted to match average Canadian practices; organic and chemical fertilizers adjusted to meet cattlemen's practices
	Dried distiller grains	Distiller's dried grains with wolubles {GLO}| market for | Alloc Rec	ecoinvent v3 global dried distiller's grain LCI used as proxy
	Tubs	Protein feed, 100% crude {GLO}| corn grain to generic market for energy feed | Alloc Rec	ecoinvent v3 energy feed LCI adapted with corn LCI from AARD (2014) used as proxy

[18] Alloc Rec in ecoinvent LCIs stands for "allocation, recycled content". In this approach, the impacts of multi-product processes are allocated between the co-products, based on physical, economical, mass or other properties. A cut-off is applied to end-of-life treatment processes (energy recovery, for instance) and to recyclable by-products.

2.3.2.6 Land use

Land use was assessed following the calculation logic described in Figure 2-3 above. The corresponding formula to obtain land use per kilogram of live weight is the following:

$$\left. \begin{array}{c} \sum_{cohort}(dLUa * \ ta) + \\ \sum_{cohort} \sum_{ration}(F * iLUa) + \end{array} \middle/ \mathrm{Wfa} \right.$$

Where:

- $\mathrm{dLU_a}$ = direct land used per animal stage per day
- $\mathrm{t_a}$ = duration of the animal stage (mortality rates included)
- F = feed amount per animal stage
- $\mathrm{iLU_a}$ = indirect land used to grow one kilogram of feed
- $\mathrm{W_{fa}}$ = weight of finishing animals (finishers and culled animals)

2.3.2.7 Water footprint

Similar to land use, the water footprint encompasses a direct (animal consumption) and an indirect footprint (water use to grow feeds). The same formula as previously described is used to assess water consumption per kilogram of live weight:

$$\left. \begin{array}{c} \sum_{cohort}(dWIa * \ ta) + \\ \sum_{cohort} \sum_{ration}(F * iWIr) + \end{array} \middle/ \mathrm{Wfa} \right.$$

Where:

- $\mathrm{dWI_a}$ = direct water intake per animal stage per day
- $\mathrm{t_a}$ = duration of the animal stage (mortality rates included)
- F = feed amount per animal stage
- $\mathrm{iW_{Ir}}$ = indirect water used for irrigation, per kg of feed
- $\mathrm{W_{fa}}$ = weight of finishing animals (finishers and culled animals)

Note: the LCA indicator “water depletion” focuses on the blue water footprint, i.e. volumes of rainwater (green water) and of freshwater necessary to dilute polluted water (grey water) are excluded as they are out of scope.

2.3.2.8 Hormones and antibiotics

The “indirect” environmental impacts/benefits of the use of hormones is considered in this study given their influence on the number of days on feed, weight gains, reduced mortality rates, etc. (see 2.5.5.4 Comparison of beef production with or without the use of hormones).

It is recognized that hormones, as well as antibiotics, can reach terrestrial and aquatic ecosystems by two main routes: direct manure and urine deposition by pasture animals, or manure application on agricultural lands. This exposure of terrestrial and aquatic ecosystems has potential environmental impacts, mostly due to toxicity effects. Further, residues from these substances may bioaccumulate and bioamplify along the food chain, but the potential effects of residues on ecosystems and human health are still not well known, according to literature (European Executive Agency for Health and Consumers, 2013). A deeper risk assessment study would be necessary to evaluate the potential health and environmental impacts related to the use of these substances.

2.3.2.9 Electricity production model

Agri-footprint (Blonk Agri-footprint BV., 2014) life cycle inventory for Canada electricity mix is used in this study (electricity mix, AC, consumption mix, at consumer, < 1kV/CA energy). Used energy mix in this LCI was compared to the latest International Energy Agency figures (International Energy Agency, n.d.). The values are similar, and given that contribution of electricity to environmental impacts is minor, no modification of the LCI was made.

Table 2.24 Electricity mix used in the study

Electricity produced from:	IEA (2012)	Agri-footprint LCI Electricity mix, AC, consumption mix, at consumer, < 1kV/CA energy
Coal	10.0%	12%
Oil	1.1%	1%
Gas	10.6%	10%
Biofuels	1.4%	2%
Waste	0.0%	0%
Nuclear	15.0%	15%
Hydro	60.0%	59%
Geothermal	0.0%	0%
Solar PV	0.1%	0%
Solar thermal	0.0%	0%
Wind	1.8%	2%
Tide	0.0%	0%
Other sources	0.0%	0%

2.3.2.10 Packing

The LCIs used to model the impacts of resource consumption and pollutant emissions at the processing and packing stage are displayed in Appendix 6.6.

2.3.2.11 Secondary processing, retail and consumption stage: end-of-life of operational waste and packaging

To assess the impacts of meat and packaging waste, the cut-off method is applied, i.e. only the impacts of waste transportation and disposal are included. Potential impacts and benefits from waste recovery are not attributed to the system producing the waste, but to the system using the recovered energy/secondary material. Corresponding impacts are thus excluded from the scope of this study.

To assess the environmental impacts of landfilled waste, the ecoinvent LCI *Municipal solid waste {RoW}*| *treatment of, sanitary landfill* | *Alloc Rec, U* was used. In particular, this LCI enables the evaluation of short-term emissions to air via landfill gas incineration and landfill leachate (although these latter are minor).

Given the minor environmental impact associated with waste treatment, replacing this landfill LCI with a composting LCI does not affect the results; this was tested via a sensitivity analysis.

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2.4 Data quality

A data quality assessment was performed, and the outcomes are presented in 6.9 ELCA—Data quality.
Most of the data used in this study, input data as well as LCIs, are representative and reliable given the objective of the study. However there is still room for improvement on the three following aspects in particular:

- Feed LCIs: some feed LCIs such as corn, soybean or hay are not representative of Canadian production. For hay, a sensitivity analysis was performed based on the work of Wiens *et al.* (2014), which revealed a negligible change in carbon footprint of beef production. However, the influence of Canadian farming practices for corn and soybean production could not be tested for lack of available data. Having Canadian data for these crop productions could improve the results, especially for corn, which can be fed in large quantities in the East.
- Phosphorus losses from manure excreted on pasture: phosphorus excretion rates obtained from Statistics Canada are rough estimates, which do not consider the actual feeding of the animals and are likely to be overestimated for grazing animals in particular (cows, calves, bulls). Further, the models implemented to assess P losses through run-off, leaching and soil erosion are not sufficiently representative of the Canadian situation. Given the low contribution of these losses, refining this approach was considered out of scope in this study, but this could improve results in the future.
- Meat waste occurring after the packers' gate: data are based on generic sources not specific to Canada (Canadian data were available but appeared less relevant to this context). If they provided a good overview of the importance of food waste mitigation at the end of the life cycle, more accurate and representative data would help improve the overall quality of the results. This would also provide a more accurate view of the mitigation potential and strengthen key messages to concerned players (industrials, retailers, consumers) around reducing their environmental footprint.

2.5 ELCA impact assessment and interpretation

This section presents the environmental LCA results. First, the results of the baseline scenario (i.e. Western production, with 59% of yearling-fed and 41% of calf-fed animals) are presented for the following functional units:

- One (1) kg of live weight at the farm gate
- One (1) kg of carcass
- One (1) kg of bone-free meat at packers' end gate
- One (1) kg of packed boneless beef meat which is then delivered and consumed

Results for the environmental impact indicators are presented by life cycle stages, according to the stages indicated in Table 2.25. This analysis of the indicators aims to target the dominant flows and detect any data considerations/issues, while also presenting the limits of this quantification.

In a last section, scenario analyses are presented to compare Western and Eastern production, as well as calf-fed and yearling-fed systems, and review the influence of the use of GET.

Table 2.25 Stages and sub-stages in the Canadian beef industry life cycle

Life cycle stages	Environmental impacts

Life cycle stages	Environmental impacts
Farming	Environmental impacts related to the raising of the cattle such as: • Energy consumption: consumption of electricity and combustion of diesel, natural gas and gasoline for agricultural activities and operations on the farms • Enteric CH_4: emissions of CH_4 by cattle digestion • Feed ration: production, transport and use of feed rations • Manure: emissions of CH_4 and N_2O from manure on pasture and in confinement • Water: production and use of water for crop irrigation, farm operations such as cleaning and cattle's consumption • Grazing land use
Transportation between farms and packers	Environmental impacts related to transportation, including the transportation itself and to the loss of animal weight during transportation
Packing	Environmental impacts which are necessary for the processing of the cattle and the packing of the meat: energy, materials, chemicals for cleaning and disinfection and water consumption, effluents
Secondary processing	Environmental impacts related to secondary processing: packaging's production and bone-free meat losses during processing; other direct impacts (e.g. energy consumption) are excluded from the scope of the assessment
Retail	Environmental impacts related to the loss of packaged beef bone-free meat during retail; other direct impacts (e.g. refrigeration) are excluded from the scope of the assessment
Consumption	Environmental impacts related to the waste of packaged bone-free meat by consumers

2.5.1 Results for the functional unit of "one (1) kg of live weight at the farm gate"

2.5.1.1 Overall results

Table 2.26 and the graphs below present the potential environmental impacts generated by producing **one (1) kg of live weight at the farm gate.** The overall results are presented first, followed by the detailed results for the contributing stages broken down by broad indicator type.

Table 2.26 Results by analysis indicators (FU: "one (1) kg of live weight at the farm gate")

Potential impacts indicators	FU: producing one (1) kg of live weight at the farm gate"	Units	Total
Climate change	Global warming potential	kg CO_2 eq.	11.4
Resource consumption	Fossil fuel depletion	kg oil eq.	0.6
	Water depletion	Liters	235.0
Air pollution	Terrestrial acidification	g SO_2 eq.	124.1
	Photochemical oxidant formation	g NMVOC eq.	16.7
Water pollution	Marine eutrophication	g N eq.	75.8
	Freshwater eutrophication	g P eq.	5.8

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Potential impacts indicators	FU: producing one (1) kg of live weight at the farm gate"	Units	Total
Land use	Agricultural land occupation	m^2 [19]	93.1

2.5.1.2 Breakdown of indicators by life cycle stages

Figure 2-12 to Figure 2-27 present the breakdown of impact indicators by main contributors (see Table 2.26) to the environmental footprint of the production of **one (1) kg of live weight at the farm gate** in Canada.

Carbon footprint

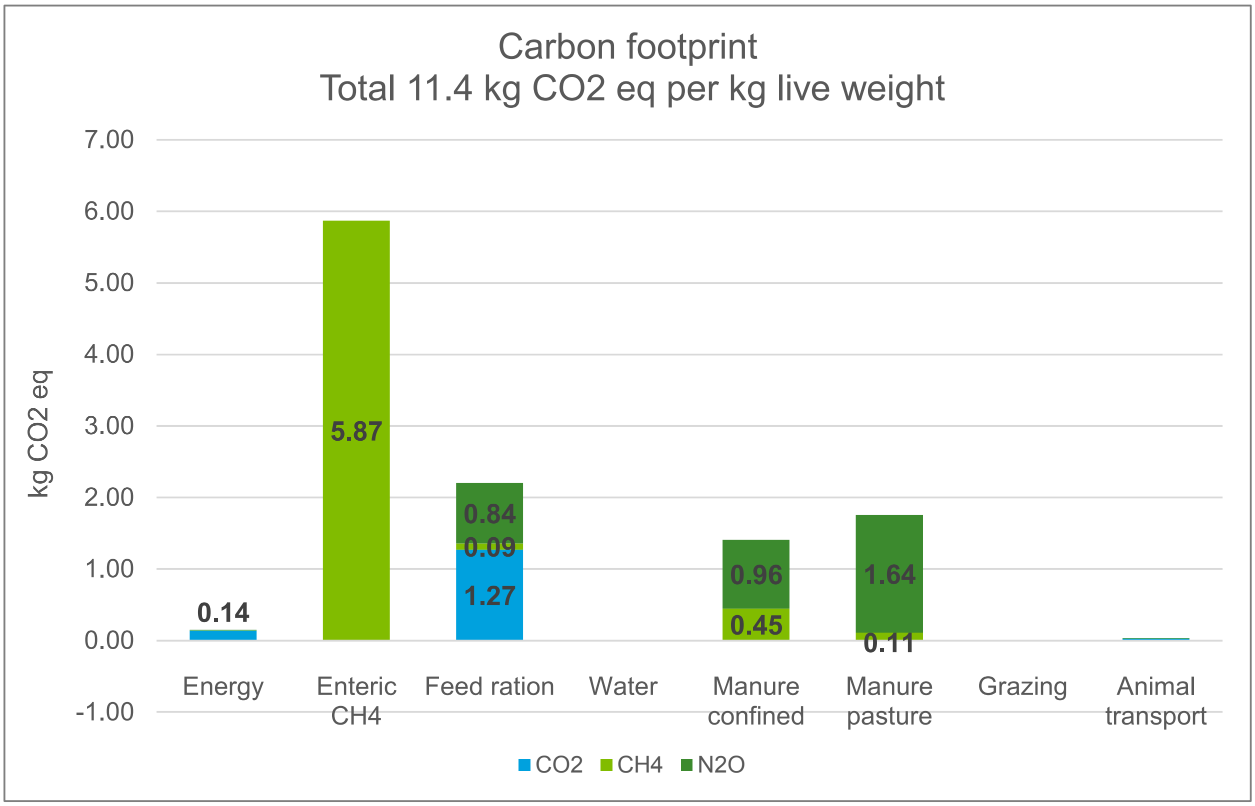

Figure 2-12 Breakdown of contributors depending on their impacts on climate change
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

11.4 kg of CO_2 equivalents are emitted to produce **one (1) kg of live weight at the farm gate**. Three gases are responsible for the large majority of the carbon footprint—CH_4 emissions, N_2O emissions and CO_2 emissions—which respectively account for 57%, 30% and 13% of total emissions. Other GHGs, such as ethane or hydrocarbons, represent less than 0.1% of total GHG emissions.

The carbon footprint is dominated by enteric emissions (51.5%), manure management (27.7%) and feed production (19.3%). Energy used by farming operations and animal transport also contributes to the carbon footprint and represents 1.3% and 0.3% of the impacts on climate change respectively.

Enteric fermentation is a natural phenomenon that results in high methane emissions. Considering that the methane global warming potential (GWP) is 25 times higher than the GWP of CO_2,[20] methane enteric emissions are the main

[19] Agricultural land occupation is normally expressed in "annual square metres" (m^2a). However, in this study, m^2a can be interpreted as square metres (m^2). Thus, the results are displayed in m^2 to facilitate the understanding by non-expert readers.
[20] For a 100-year time horizon
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contributors to the carbon footprint of beef production. These emissions are directly linked to animal feed intake, in particular the energy intake, and the capacity of animals to transform the carbon content of feed into methane during digestion. The daily DMI was obtained from Anele's equations considering animal weights (Anele et al., 2014). Methane emission from DMI was assessed following IPCC guidance, also recommended in the Holos method and the FAO LEAP guidelines (Little et al, 2008; FAO, 2015).

Manure management in pasture and during confinement, i.e. when manure is stored, is the second largest contributor to the beef production carbon footprint. Nitrous oxide is largely the main emitted gas and represents 93.7% and 68.2% of the GHGs emitted by manure excreted on pasture and stored manure respectively. In terms of amount produced, manure production and storage releases more CH_4 than N_2O. For instance, young bulls and steers at backgrounding in deep bedding in Western Canada emit ten times more CH_4 per day than N_2O (1.8 g N_2O/day/animal for 46.5 g CH_4/day/animal). However, the higher global warming potential of N_2O—1 kg of N_2O is equivalent of 298 kg of CO_2 for a 100-year time horizon—explains the higher impact of N_2O emissions on the total carbon footprint.

Emissions from manure produced in pasture and manure storage were estimated from specific data on cattle diet. In particular, the DMI, the crude protein content and the digestibility of feed influence the quantity of nutrients excreted by the animals. It is interesting to note that daily N_2O emissions per animal are higher in pasture than in confinement. For instance, manure excreted by a cow on pasture emits 8.2 g N_2O per day, while stored manure from a cow emits between 3.3 and 4.5 g N_2O per day during storage, depending on manure management practices. This is due to two factors. First, the quantity of N that is transformed into N_2O is higher for manure in pasture than for stored manure. This is due to the different environmental conditions of the manure once excreted, such as the oxygen availability or the impact of temperature on nutrient decomposition. Second, the type of feed provided also impacts the emissions. Indeed, the digestibility of concentrate is higher than for forage. As such, fewer nutrients are excreted when the forage to concentrate ratio is lower. It should be noted that, although composting shows higher N_2O—and also NH_3— emissions than other manure handling systems, this process allows the volume of the initial material to be reduced while obtaining a stable fertilizer that can be easily stored, applied to field or sold. The obtained material contains few pathogens and is rich in ammonia, which is a form of nitrogen that is directly available for N. Thus, provided that the nutrient content of the compost is taken into account in the fertilization plan, the use of compost contributes to the reduction of nutrient losses when manure is applied on field.

Regarding **feed production**, carbon dioxide is the main gas emitted, representing 56.7% of the GHG emissions due to feed production. The CO_2 emissions are mainly due to the energy production and fuel combustion related to the use of machines for hay production (e.g. swather and baler) and hay storage. The mineral fertilizers' production is also a great contributor to CO_2 emissions, in particular for crop production. Indeed, ammonia or urea production results in high CO_2 emissions. Nitrous oxide is the second largest contributor to the carbon footprint linked to feed production and represents 38.3% of the GHG emissions at this stage. N_2O emissions are due to the application of mineral fertilizers and manure. The life cycle inventories to model the impact of feed production were obtained from the literature. For most of the feeds, LCIs built in other Canadian projects were used. It was beyond the scope of this project to model the crop management practices of cattle breeders in the case of crop-livestock farming systems. Given the high contribution of feed production to the footprint, best management practices to be addressed by farmers should also cover this aspect.

Lastly, the carbon footprint of the **transport of animals** between breeding stages is driven by CO_2 emissions due to energy extraction and fuel combustion.

These results are within the range of literature. In Canada, the carbon footprints of beef production are estimated between 10.4 and 14.5 kg CO_2 equivalent/kg of live weight (AARD, 2010; Beauchemin, 2010; Vergé, et al., 2008; Basarab, 2012; Legesse et al., 2015). The main contributors to the carbon footprint are enteric emissions and manure management. In the literature, the relative proportion of GHG emissions from enteric fermentation range from 40% to 63% for the North American beef system. In particular, enteric emissions represent 53-54%, 51% and 63% for Basarab et al (2012), Alberta Agriculture and Rural Development (2010), and Beauchemin et al. (2010) for beef production in Alberta. The N_2O emissions from manure management represent 20-22%, 16% and 23% respectively.

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The reasons for these differences were due to the difference of diet and feed intake, stage duration and emissions factors.

As Canada's total GHG emissions in 2013 were estimated to be 726 Mt CO_2 eq., beef meat production accounts for approximately 2.4% of Canada's overall (i.e. including all economic sectors) GHG emissions (see 3.5.4 Greenhouse gas emissions from beef meat production paragraph). While the proportion of global impacts are very small, this still contributes to the massive global impact of climate change on most earth systems, with strong current and future consequences for people and the millions of other species the earth supports. We refer the reader to the IPCC reports to understand the wide range and complexity of these impacts.

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Water depletion

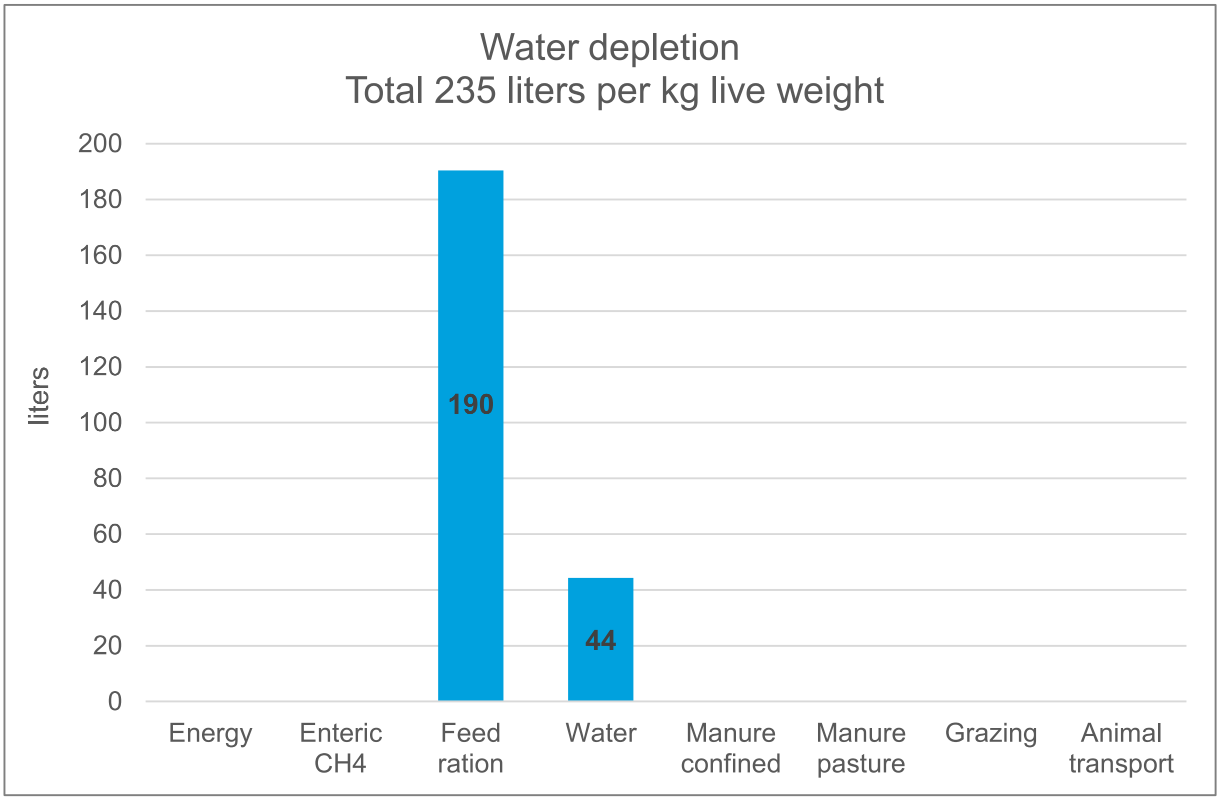

Figure 2-13 Breakdown of contributors depending on their impacts on water depletion
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

To produce **one (1) kg of live weight at the farm gate**, 235 litres of blue water (surface water and groundwater bodies) are required. Water used to grow crops is the main contributor to water depletion and represents 81% of the consumed water (indirect footprint), while animal consumption (direct footprint) represents 19%. Water use related to crop production is due to irrigation, mainly for hay, barley and maize production. It should be noted that part of the water used for irrigation and animal consumption returns to the ground. The share of water that is not “recycled” is unknown.

This result is rather low compared to results found in the literature. Indeed, the blue water footprint calculated by the Water Footprint Network amounts to 617 litres per kilogram of bone-free meat at packers’ gate (Water Footprint Network, 2015), while we obtain 508 litres at packers’ gate. The higher value from the WFN is explained by higher crop water footprints. In her assessment of the environmental impacts of the US beef industry between 1997 and 2007, Capper assessed a water consumption of 1,763 litres/kg hot carcass in 2007, which means approximately 1,100 litres/kg of live weight, considering the ratios to convert live weight to carcass weight used in the present study. These gaps can mostly be explained by low irrigation rates on feed crops in Canada (see section 3.4.2.2 Blue water footprint for further detail on irrigation practices in Canada).

To complete this water footprint assessment, the origin of water for animal consumption is detailed by water source (see Figure 2-14). This distribution was directly obtained from the farm survey. Groundwater and lake water are the main contributors, each accounting for about 32% of the animal water consumption.

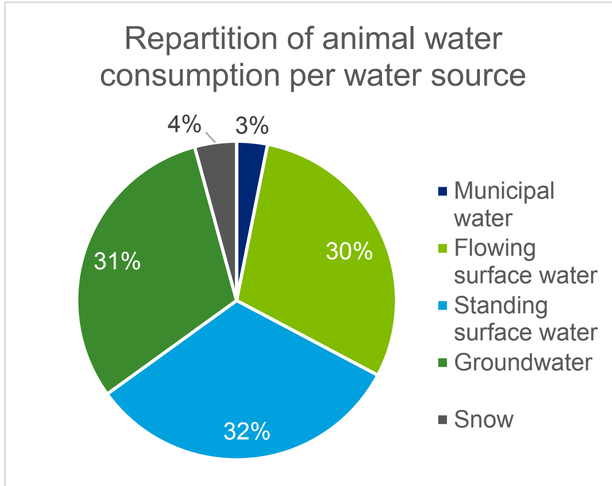

Figure 2-14 Repartition of animal water consumption per water source

Agricultural land occupation

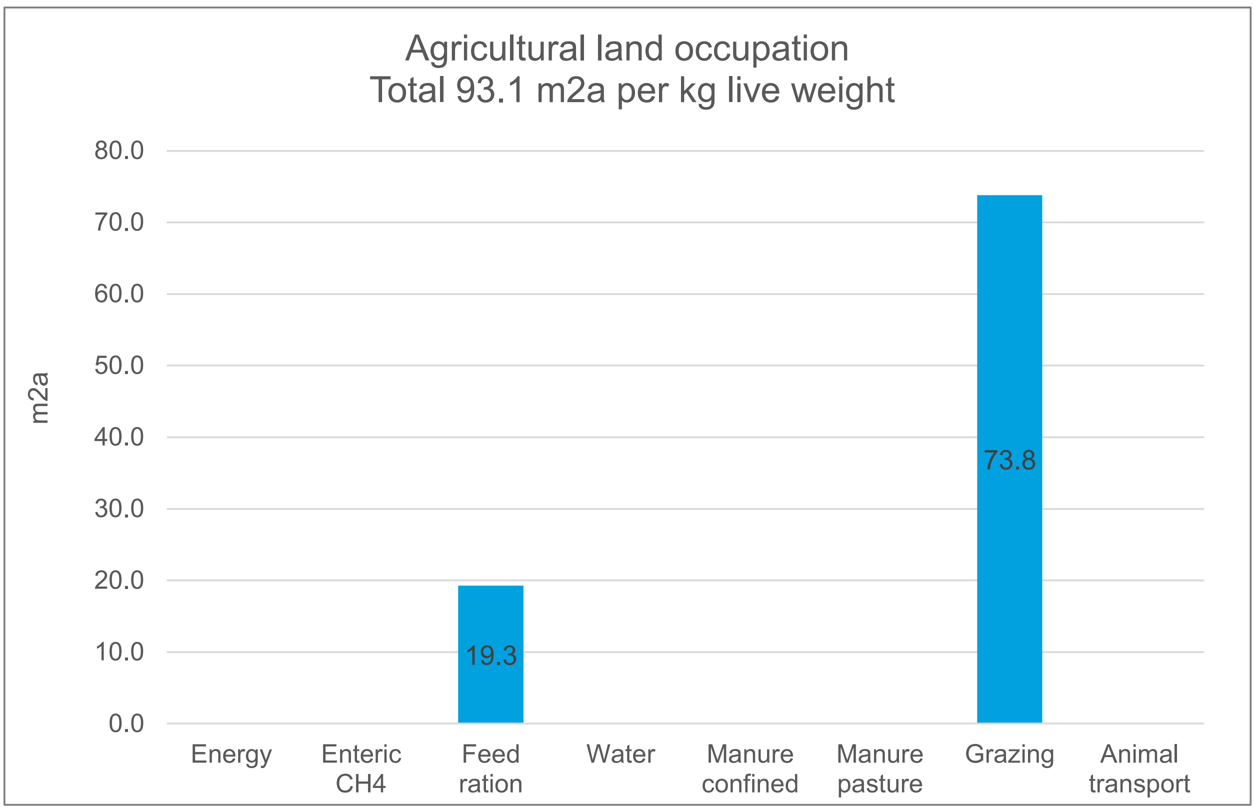

Figure 2-15 Breakdown of contributors depending on their impacts on agricultural land occupation
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

To produce **one (1) kg of live weight at the farm gate**, 93 m^2 of agricultural land are required. Pasture-dedicated areas and feed ration dedicated areas are the two major contributors to the land use footprint, with 79% and 21% respectively. Among the crops grown for rations, hay and barley take up the largest surface area of agricultural land, given that they are the two main ingredients of feed rations, especially for cows and finishers. The impact of beef production on land occupation varies among farms, as the grazing surfaces differ widely from one farm to another. Using the extreme values of the range (excluding feedlots), land occupation varies from 21 m^2 to 415 m^2/kg of live weight.

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It should be noted that this indicator does not aim to reflect the impacts of grazing management practices on soil quality and health. Further interpretation of the agricultural land occupation by the Canadian beef industry is provided in section 3 Land use assessment. In particular, it is worth noting that part of the used areas, and most of the native pasture surfaces, may not be suitable for other farming purposes, and that beef production enables farmers to take advantage of land which could not be used otherwise.

These results are within the range of literature. According to Basarab *et al.* (2012), land occupation related to intensive Canadian beef production is 43.5 m^2a/kg of live weight. Pasture represents about 74% of land use, irrespective of the farming system. For extensive systems, Beauchemin *et al.* (2010) found that land occupation was 338.9 m^2a/kg of live weight. Cederberg *et al.* (2009) found that land occupation was 175 m2/kg carcass weight, i.e. about 107 m2/kg of live weight for beef production in Brazil.

Fossil resource depletion potential

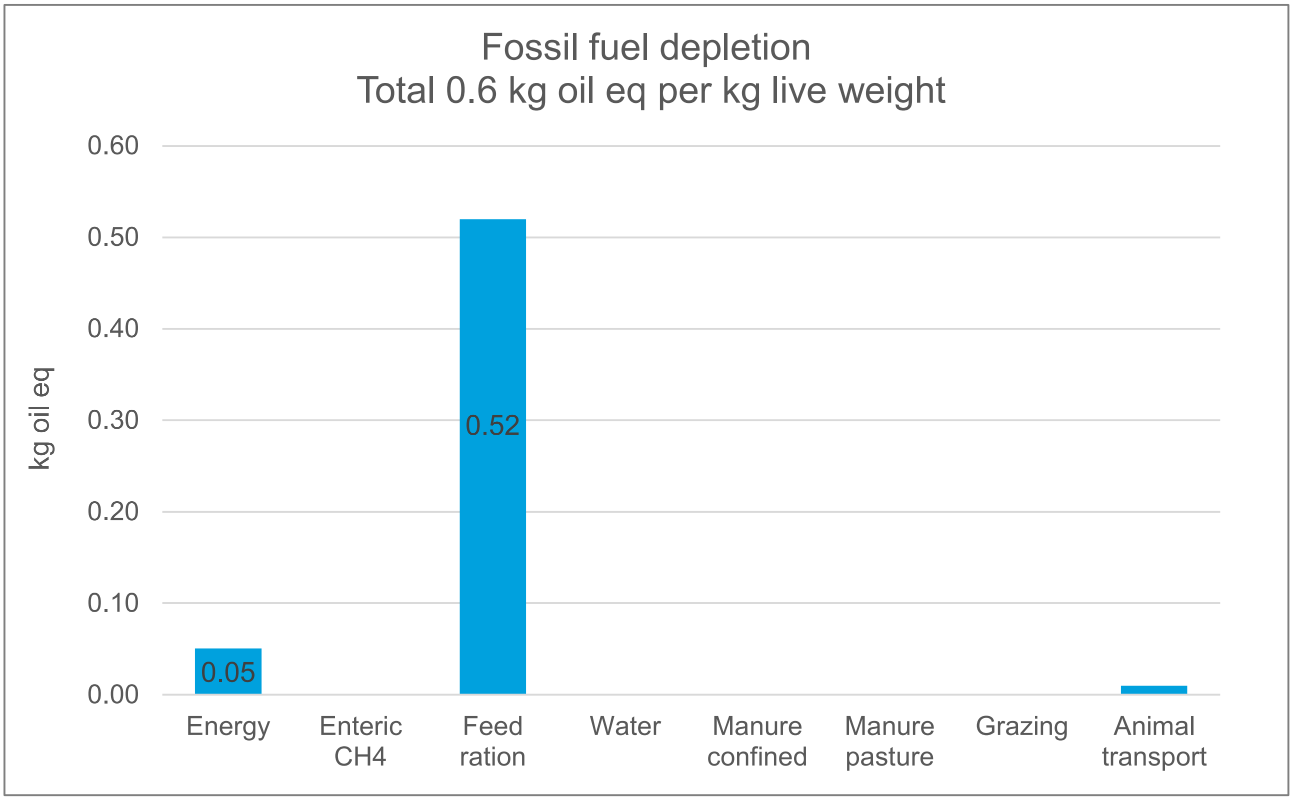

Figure 2-16 Breakdown of contributors depending on their impacts on fossil fuel depletion
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

The production of **one (1) kg of live weight at the farm gate** requires the depletion of 0.6 kg of oil equivalents, i.e. 25 MJ.[21] Indirect energy used to grow feed is by far the major contributor to fossil fuel depletion. It represents 87% of the consumed energy.[22] Direct energy use—i.e. on-farm consumption excepting energy to grow crops—is the second contributor with 9% of the impacts.[22] As mentioned for carbon footprint, the energy used to produce feed mainly relates to the use of machines for hay production (e.g. swather and baler) and hay storage.

Hard coal, crude oil and natural gas consumption are the major contributors, representing 37%, 33% and 24% of the total consumed energy respectively.

[21] 1 kg oil eq. = 41,868 MJ. Source:
[22] Percentage here does not consider the environmental benefits of manure surplus export to other crops
.

The obtained results are in the same value range as the literature results.[23] In the study from Pelletier *et al.* (2010), the energy use from beef production in the United States varies from 38.2 MJ/kg live weight for feedlot-finished production to 48.4 MJ/kg live weight for pasture-finished beef production. In Alberta, the non-renewable energy use was estimated to be 242.8 MJ/kg live weight by Alberta Agriculture and Rural Development (2010).

Terrestrial acidification potential

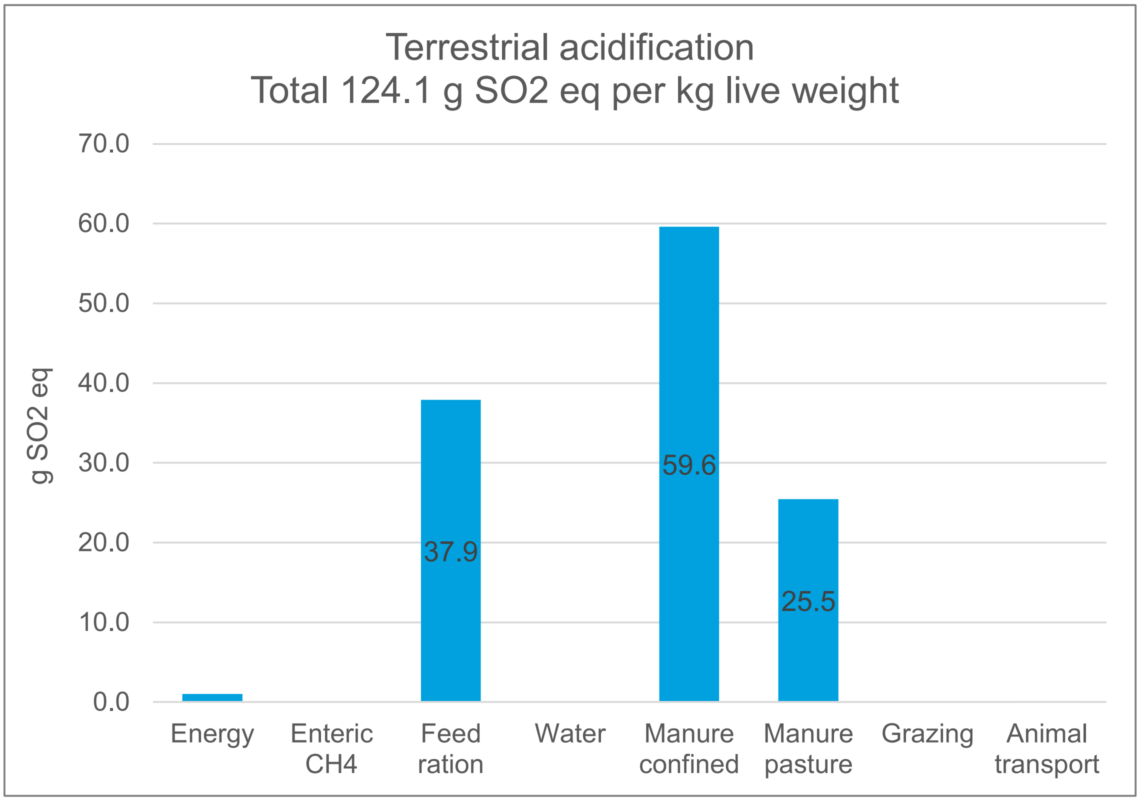

Figure 2-17 Breakdown of contributors depending on their impacts on terrestrial acidification
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

During the production of **one (1) kg of live weight at the farm gate**, 124 g of sulfur dioxide (SO_2) eq. are emitted. Ammonia is by far the largest contributor, representing 89% of the impacts. The other main gases responsible for terrestrial acidification are sulfur dioxide and nitrogen oxides, with 5% of the impacts each. Manure management and feed production are the major sources of impacts, totaling 99% of the impacts.

Manure storage is the main contributor with 48% of the potential terrestrial acidification, while manure excreted in pasture represents 21% of the impacts. Ammonia emissions in confinement are higher than emissions in pasture. This comes from the higher emissions factor, i.e. the quantity of N excreted in urine that is transformed into NH_3 when manure is excreted on pasture or stored. For instance, 10% of the N excreted by a cow in pasture is transformed into NH_3, while the share of N transformed into NH_3 during storage is 21% for deep bedding and 35% for solid storage in piles. Ammonia emissions occur in aerobic conditions. Thus, ammonia emissions are higher when manure is well aerated, which means composting produces higher NH_3 emissions than other types of storage such as deep bedding or solid storage in piles (70% of N lost as NH_3). However, as mentioned for the carbon footprint, composting also produces positive effects. In particular, it significantly reduces the number of pathogens and decreases the risk of nitrogen losses when manure is applied on field. Since only few farmers practice composting in the survey sample, likely due to the associated fuel, equipment and labour costs, its contribution on the global potential impacts of terrestrial acidification is limited.

Production of feed ration represents 31% of terrestrial acidification impacts.

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[23] Comparisons have to be treated with caution as characterization methods vary from one study to another
.

The obtained results are similar to the values found in literature. In the study of Rivera, A. et al (2014), the impacts of beef production in Veracruz (Mexico) varies between 130 g eq. SO_2/kg live weight for intensive systems to 70 g eq. SO_2/kg live weight for extensive systems.

Freshwater eutrophication potential

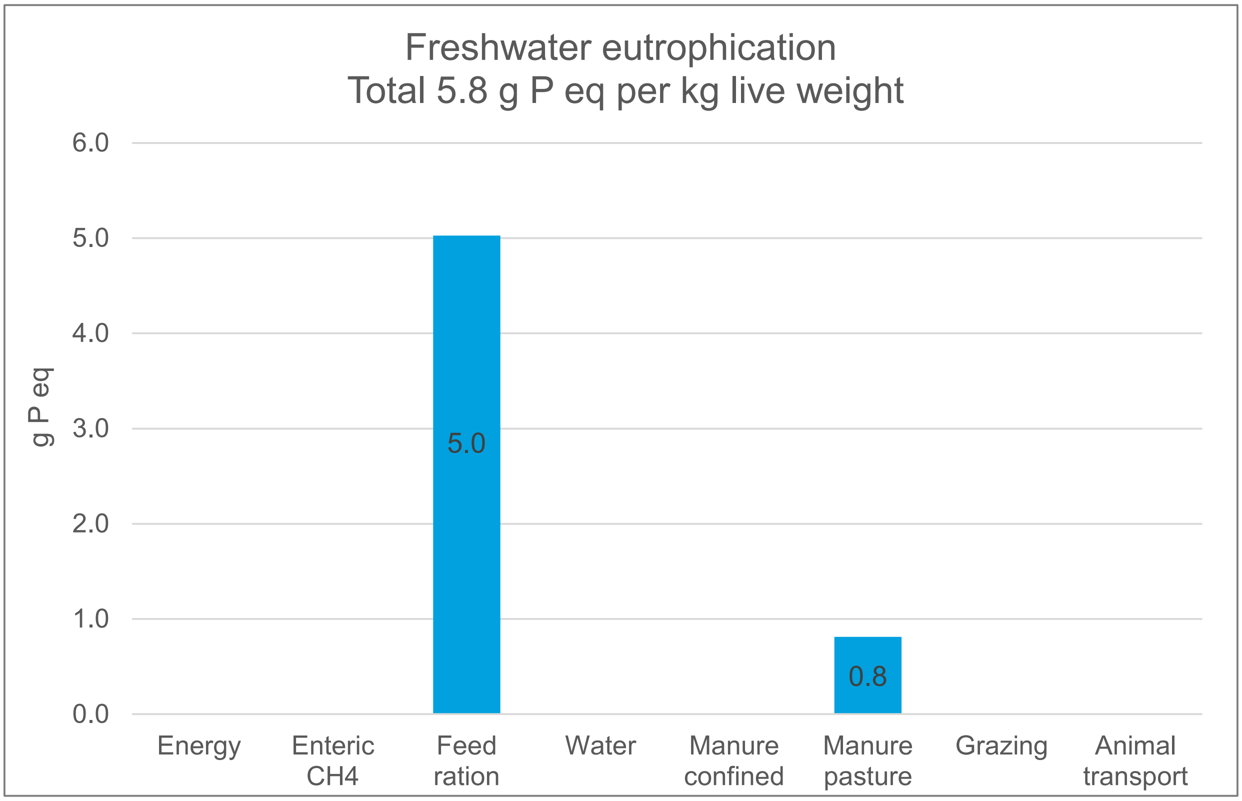

Figure 2-18 Breakdown of contributors depending on their impacts on freshwater eutrophication
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

The production of **1 kg of live weight at the farm gate** results in the loss of nearly six g of P eq. that have a potential impact on freshwater eutrophication. Phosphorus, and in particular phosphate, is often the limiting nutrient to algae proliferation in freshwater. That is why this indicator focuses on the quantification of the potential impacts associated with phosphorus emissions. Thus, in the calculation model, only phosphorus is taken into account, while it does not consider nitrogen effects.

Feed production is the major contributor for this indicator and represents 87% of total impacts. Manure excreted in pasture is the second contributor of freshwater eutrophication with 14% of total impacts. The contribution of crop production and grazing to P losses depends on the quantity and quality of P chemical and organic fertilizers applied, and on soil management (e.g. tillage, soil cover). In particular, P chemical fertilizer and manure can be applied on fields in excess of crop needs. This may result in a surplus of nutrients. If nutrients are not assimilated by plants, they may leach or run-off to water. In the case of phosphorus, erosion is also a possible source of P losses since P is mostly bound to soil particles, which can be eroded by wind, water or ice. It should be noted that manure management in confinement does not have an impact on freshwater eutrophication because the calculation model only takes into account the phosphorus losses and it is assumed that phosphorus losses only occur in pasture.

P losses to freshwater in field are often higher than in pasture. Indeed, first, the amounts of fertilizers applied are often higher on cropland than on pasture. In addition, soil coverage plays an important role in the control of nutrient loss as it helps to maintain soil particles and soil structure, catch nutrients and slow down run-off. While grassland soils are always covered, fields may be occasionally bared between two crops, which increases the risk of nutrient

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losses during certain seasons (e.g. rainy period or during snowmelt). Indeed, since phosphorus particles are highly bounded to soil particles, the risk of phosphorus losses is higher during frequent and/or intense rainfall events.

Results related to P losses in pasture are likely to be overestimated.[24] Indeed, the phosphorus content of manure obtained from Statistics Canada seems to be proportional to the animal weight, based on the P content of manure of finishers. As such, the value appears quite high for grazing animals, especially cows, calves and bulls. In addition, the calculation of the average Canadian P losses by erosion was quite rough. However, the impacts of the manure excreted by cows, bulls and calves that spend time in pasture only represent 7.8% of the impacts on the global freshwater eutrophication potential. In addition, among the causes of P losses (erosion, run-off and leaching), the P content of manure only influences P losses by run-off, which represented 45% of total P losses. Thus, should the P content of manure be reduced, the freshwater eutrophication impacts would only decrease by less than 5%.

Regarding feed production, as mentioned for the carbon footprint, LCIs built in other Canadian projects were used for most of the feeds. It was beyond the scope of this project to model the crop management practices of cattle breeders that rely on crop-livestock farming systems. Given the high contribution of feed production to potential freshwater eutrophication, best management practices to be communicated to farmers should also cover this issue.

These results are in the lower range of the values found in literature. Alberta Agriculture and Rural Development (2010) shows that the total aquatic eutrophication effects for calf-fed and yearling-fed systems are about 1.2 g P eq. per kg of beef live weight; but in other available studies, values of beef production's potential impacts on eutrophication are higher. In the study from Pelletier *et al.* (2010), the energy use from beef production in the United States varies from 33.2 g eq. P/kg live weight for feedlot-finished production to 45.4 g eq. P/kg live weight for pasture-finished production. Finally, according to Zonderland-Thomassen, M.A. *et al.* (2014), the average eutrophication potential is 16.3 g P/kg live weight of beef in New Zealand (pasture-based system, including for the finishing stage). However, no sufficient information was available in these studies to understand the origin of the gaps.

[24] In this study, direct excretion to river was not assessed, as this is a prohibited practice
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Marine eutrophication potential

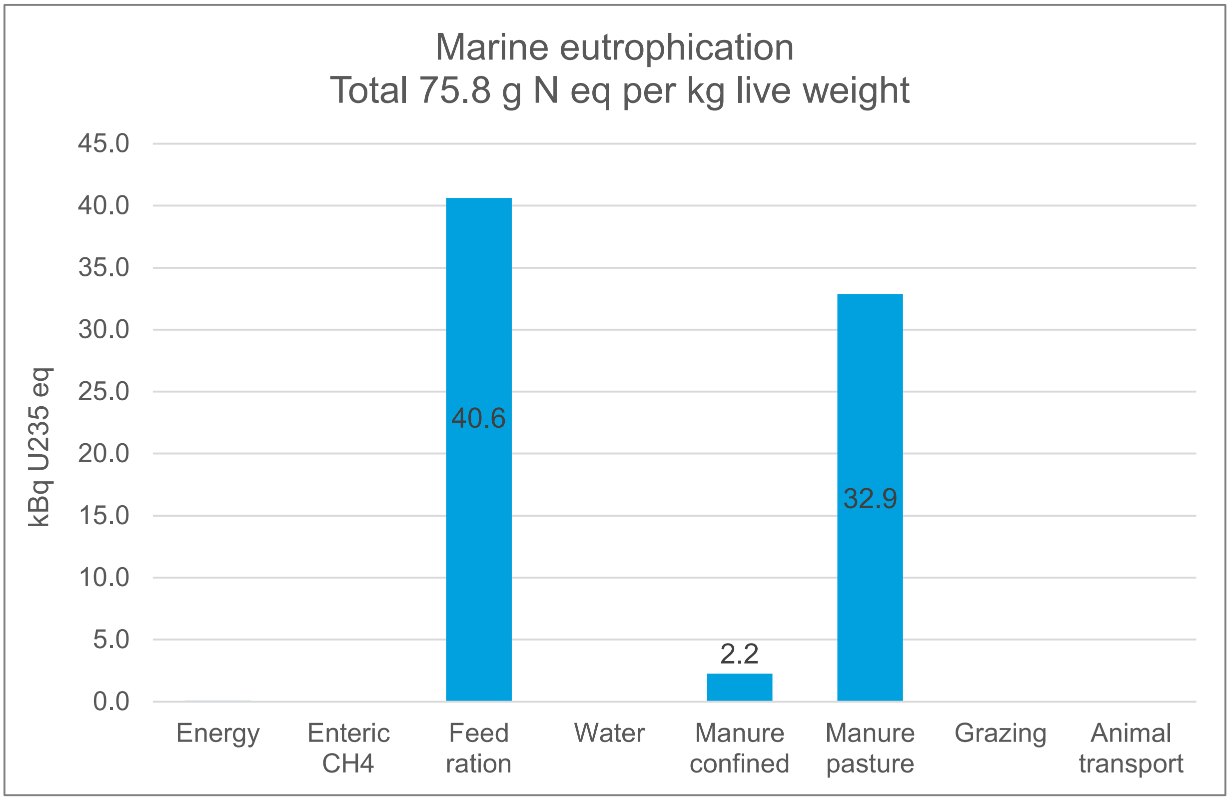

Figure 2-19 Breakdown of contributors depending on their impacts on marine eutrophication
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

A complementary indicator to freshwater eutrophication, the marine eutrophication impact indicator only covers the impacts of nitrogenous compounds on eutrophication, as the latter are often the nutrients that limit algae proliferation in marine water.[25] As such, to produce **one (1) kg of live weight at farm gate**, 75.8 g of N eq. are released and have potential impacts on marine eutrophication.

Nitrate is by far the largest contributor, with 94% of the impacts, mainly emitted during the production of feeding rations (55% of nitrate emissions) and from the manure spread on pasture (45% of nitrate emissions). Ammonia, coming from stored manure (54% of ammonia emissions), feed production (23% of ammonia emissions) and the manure deposited on pasture (23% of ammonia emissions) is the second main contributor, with 5% of the impacts. Finally, nitrogen oxide emissions represent 1% of impacts on marine eutrophication, with 86% of nitrogen oxide emissions coming from the production of feed rations.

The production of feed ration and manure excretion in pasture are the major contributors and represent 54% and 43% of total impacts respectively. The contribution of crop production and grazing to N losses depends on the quantity and the quality of N chemical and organic fertilizers applied, the application methods and the soil management (e.g. tillage, soil cover). In particular, excessive N inputs may lead to nutrient losses by run-off and leaching. For the same reasons set out for P, potential N losses occurring in field are often higher than in pasture.

When it comes to feed production, application of fertilizers (organic or mineral) on feed crops generates high nitrogen emissions and losses. As these result in a high contribution of feed production to potential marine eutrophication, best management practices to be communicated to farmers should also cover this issue.

[25] Here, the indicator marine eutrophication is to be understood as eutrophication caused by nitrogen compounds. The indicator assesses a potential impact, and does not aim to quantify the actual effect of beef production on seas surrounding Canada.
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For lack of available data, these results could not be compared to literature.

Photochemical oxidant formation potential

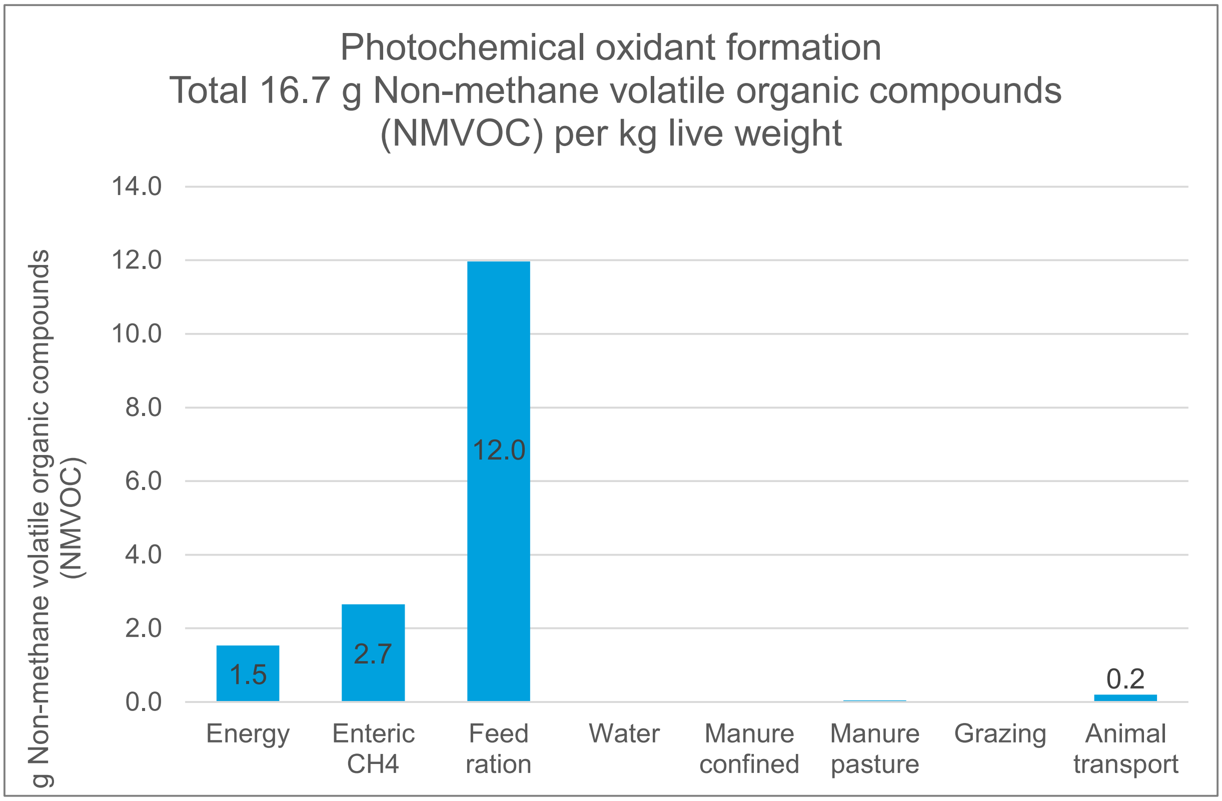

Figure 2-20 Breakdown of contributors depending on their impacts on photochemical oxidant formation
(Note: Due to rounding, percentages may not always appear to add up to 100%.)

To produce **one (1) kg of live weight at the farm gate**, 16.7 g of NMVOC (non-methane volatile organic compounds) equivalents are emitted during beef production. Nitrogen oxides are the largest contributor, representing 70% of the impacts. The other main gases responsible for photochemical oxidant formation are methane, NMVOC and sulfur dioxide with 17%, 7% and 3% of the impacts respectively.

Feed ration is the largest contributor to photochemical oxidant formation and represents 72% of the total. The main sources of the impacts are the emissions of N_2O during barley production and, to a lesser extent, during hay production. Enteric CH_4 and on-farm energy use are also large contributors to this indicator and represent 16% and 9% of total impacts respectively.

For lack of available data, these results could not be compared to literature outcomes.

2.5.2 Results for the functional unit of “one (1) kg of carcass”

To enable comparison of the outcomes with some publications, the results were also expressed per kilogram of carcass weight, i.e. considering animal shrinkage and fuel consumption during transportation to the packing plant, as well as the dressing rate. Animal production accounts for most of the environmental impact indicators, with fossil fuel consumed during transportation to packers representing less than 5.5%.

The table below presents the potential environmental impacts generated by **producing one (1) kg of carcass.**

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Table 2.27 Results by analysis indicators (FU: “one (1) kg of carcass”)

Potential impacts indicators	FU: producing one (1) kg of carcass at packers end gate	Units	Total
Climate change	Global warming potential	kg CO_2 eq.	18.7
Resource consumption	Fossil fuel depletion	kg oil eq.	1.0
	Water depletion	Liters	382.4
Air pollution	Terrestrial acidification	g SO_2 eq.	202.4
	Photochemical oxidant formation	g NMVOC eq.	27.9
Water pollution	Marine eutrophication	g N eq.	123.4
	Freshwater eutrophication	g P eq.	9.5
Land use	Agricultural land occupation[26]	m^2	151.5

[26] Agricultural land occupation is normally expressed in “annual square metres” (m^2a). However, in this study, m^2a can be interpreted as square metres (m^2). As such, the results are displayed in m^2 to facilitate understanding by non-expert readers.
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2.5.3 Results for the functional unit of "one (1) kg of packed bone-free meat at packers' end gate"

2.5.3.1 Overall results

The table below sets out the potential environmental impacts generated by **producing one (1) kg of bone-free meat at packers' end gate.**

The overall results are presented first, followed by the detailed results for the contributing stages broken down by broad indicator type.

Table 2.28 Results by analysis indicators (FU: "one (1) kg of packed bone-free meat at packers' end gate")

Potential impacts indicators	FU: producing one (1) kg of bone-free meat at packers end gate	Units	Total
Climate change	Global warming potential	kg CO_2 eq.	24.5
Resource consumption	Fossil fuel depletion	kg oil eq.	1.4
	Water depletion	Liters	508.3
Air pollution	Terrestrial acidification	g SO_2 eq.	264.3
	Photochemical oxidant formation	g NMVOC eq.	37.2
Water pollution	Marine eutrophication	g N eq.	160.7
	Freshwater eutrophication	g P eq.	12.5
Land use	Agricultural land occupation[27]	m^2	196.4

2.5.3.2 Breakdown of indicators by life cycle stage

Breakdown of impact indicators during farming, transport and packing is presented in Figure 2-21.

The farming stage is by far the main contributor to all studied indicators. As previously noted, the environmental impacts of farming result mostly from direct and indirect animal impacts (enteric methane emission, manure production and management, grazing, surfaces and fertilization of feed crops, etc.). Environmental impacts of this stage are detailed in the analysis for the sub-functional unit "one (1) kg of "live weight" at the farm gate" (see above). Environmental impacts at the packing stage result mainly from water consumption (98% of packing's impacts on water depletion), energy consumption (more than 87% of impacts of packing in terms of GHG emissions, terrestrial acidification and fossil fuel depletion) and the use of corrugated cardboard, which represents 87% of packaging's impacts on agricultural land use due to the fibre used.

[27] Agricultural land occupation is normally expressed in "annual square metres" (m^2a). However, in this study, m^2a can be interpreted as square metres (m^2). As such, the results are displayed in m^2 to facilitate understanding by non-expert readers.

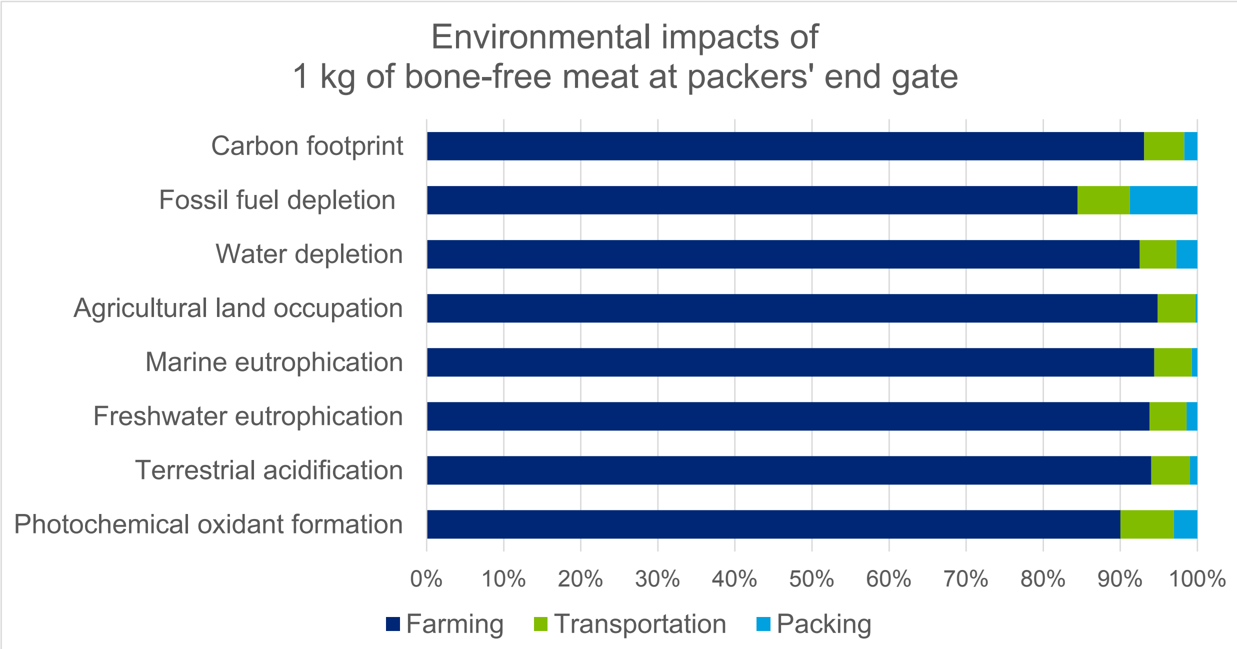

Figure 2-21 Breakdown of impact indicators per kilogram of bone-free meat at packers' end gate

2.5.4 Results for the functional unit "one (1) kg of packed boneless beef which is then delivered and consumed"

2.5.4.1 Overall results

The table below sets out the potential environmental impacts generated by **producing one (1) kg of packed boneless beef which is then packaged, delivered and consumed.**

The overall results are presented first, followed by the detailed results for the contributing stages broken down by broad indicator type.

Table 2.29 Results by analysis indicators (FU: "one (1) kg of packed boneless beef which is then delivered and consumed")

Indicators	FU: producing one (1) kg of packed boneless beef which is then packaged, delivered and consumed	Units	Total
Climate change	Global warming potential	kg CO_2 eq.	30.8
Resources consumption	Fossil fuel depletion	kg oil eq.	2.0
	Water depletion	Litres	631.4
Air pollution	Terrestrial acidification	g SO_2 eq.	327.2
	Photochemical oxidant formation	g NMVOC eq.	47.6
Water pollution	Marine eutrophication	g N eq.	197.6
	Freshwater eutrophication	g P eq.	15.3

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Indicators	FU: producing one (1) kg of packed boneless beef which is then packaged, delivered and consumed	Units	Total
Land use	Agricultural land occupation [28]	m^2	240.9

2.5.4.2 Breakdown of indicators by life cycle stage

Figure 2-22 presents environmental impacts generated by **producing and consuming one (1) kg of packed boneless beef which is then delivered and consumed.**

All indicators have roughly the same profile, with the preponderance of environmental impacts traced back to farming. Consumption and processing are also major contributors in terms of environmental impacts, whereas retail and packing are less significant.

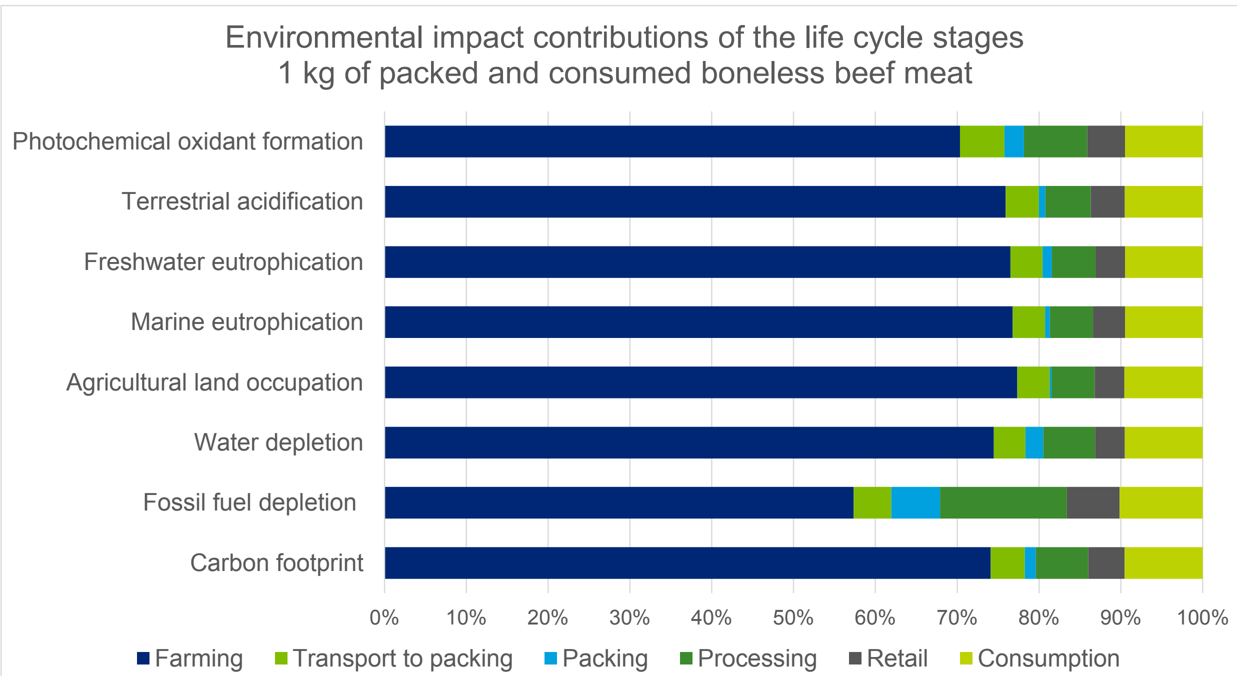

Figure 2-22 Environmental impact contributions of the life cycle stage for producing1 kg of raw boneless beef which is then packaged, delivered and consumed

Farming stage

Farming includes the raising of animals and crop feed production. The farming stage is the main contributor to all indicators: this results mostly from direct and indirect animal impacts (enteric methane emission, manure production and management, grazing surfaces, surfaces and fertilization of feed crops, etc.). The environmental impacts of this stage are detailed in the analysis for the sub-functional unit “one (1) kg of live weight at the farm gate” above.

Packing

Packing mainly contributes to water depletion, fossil fuel depletion and photochemical oxidant formation. This result can be explained by the water, energy and material consumption—such as chemicals, corrugated cardboard, PE film, wood, etc.—that occurs during packaging production.

0.01 kg of meat is wasted during packing. This meat loss arises mainly from animals that die during transportation or are condemned at the processor, and represents 0.2% of the meat before slaughter. Although the impact of meat

[28] Agricultural land occupation is normally expressed in “annual square metres” (m^2a). However, in this study, m^2a can be interpreted as square metres (m^2). As such, the results are displayed in m^2 to facilitate understanding by non-expert readers.
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waste occurring during packing remains limited for most indicators (i.e. contribution below 20%), it is meaningful for terrestrial acidification potential, marine eutrophication potential and agricultural land occupation, which are respectively responsible for 27%, 36% and 95% of the overall impact of packing.

Secondary processing

The contribution of processing on the studied impacts is similar for all indicators (between 5% and 6%), except for fossil fuel depletion (16%). During secondary processing, 0.06 kg of meat is wasted. This loss refers to trimming spillage and represents 5% of processed bone-free meat. This meat loss is by far the main contributor to secondary processing impacts (from 62% to 100% of processing impacts) for all indicators, except for fossil fuel depletion, for which packaging represents 75% of secondary processing impacts.

Retail

Retail represents 4% to 7% of the impacts for all indicators. 0.05 kg of packaged meat is wasted at retail, which represents 4% of the processed bone-free meat. This packaged meat waste represents from 71% to 100% of impacts of retail on all indicators except for fossil fuel depletion, for which it contributes to 42% of impacts. For the latter, energy consumed during retail is a significant contributor, with 31% of the impacts coming from electricity consumption and 7% from natural gas.

Bone-free meat losses and waste are considered in the market system in wholesale, supermarkets, retailers and wet markets. Indeed, food safety and quality standards can induce the removal from the supply chain of food that is still safe for human consumption. It could be, for instance, products which have expired or which are about to expire.

Consumption

Consumption is the second largest contributor for all indicators except fossil fuel depletion. This stage represents 9% to 10% of the total impacts of packed and consumed beef meat. Environmental impacts associated with this stage are related to the waste of packaged bone-free meat. Indeed, 0.12 kg of meat is wasted at the consumer level, which represents 11% of meat bought by the consumer. This loss of packaged meat represents more than 99% of retail's impacts for each indicator. At the consumer level, inadequate planning of purchases and failure to use food before its expiry date also lead to avoidable food waste (Food and Agriculture Organization of the United Nations (FAO), 2011).

2.5.5 Scenarios analyses

The scenarios chosen for the Canadian Beef Sustainability Assessment are intended to be representative of production practices (from birth to processing). However, it is recognized that there is a wide variety of production practices across Canada. Consequently, the sample was defined to encompass a wide range of the most relevant Canadian production systems.

Specifically, three scenario analyses have been performed:

- Beef production systems of Eastern Canada vs beef production systems of Western Canada
- Calf-fed systems vs yearling-fed systems (see description in chapter 1)
- Beef production systems with vs without hormones

2.5.5.1 Comparing two scenarios: considering the uncertainties

When we compare the environmental performance of two systems, within the framework of a comparative LCA analysis, the difference between the impact results of the two systems is, just like the impact results of each system individually, subject to uncertainty.

To evaluate this uncertainty, an uncertainty calculation should be conducted on the difference between the two systems of each scenario analysis in order to take into account the correlation between the parameters of the two systems being compared.[29] The method chosen to evaluate whether impact differences are significant is the following:

[29] For instance, calf-fed and yearling-fed scenario calculations rely on the same electricity production process, or on the same rations for cows and bulls. Data associated with this approach have a certain degree of uncertainty causing an uncertainty on each
.

1. First, we estimate the uncertainty characterizing each impact result by system (e.g. West vs East production system). Generally, LCA results are characterized by two sources of uncertainty:
    - Uncertainty of data used for the life cycle inventory (LCI) calculation.[30] Within the scope of this study, uncertainty level is estimated based on Deloitte's experience, taking the commonly-observed values for each indicator.
    - Uncertainty of characterization models. These are the models used to assess the environmental impact indicators from LCIs. Currently, there is no method or quantified data that can be used operationally to calculate uncertainty linked to a characterization model. For this study, to cover the second source of uncertainty, we rely on each indicator's robustness level as described in the ILCD handbook, in an attempt to upper bound uncertainty linked to input data (European Commission, Joint Research Centre, Institute for Environment and Sustainability, 2012).

    The table below shows the uncertainty level, considering the usual uncertainty on activity data, the inventory flows and the uncertainty of the characterization models ultimately chosen for each indicator.

Table 2.30 Uncertainty associated to each impact result by system (Deloitte expertise)[31]

Impact category	Uncertainty level
Climate change	20%
Fossil fuel depletion	20%
Water depletion	20%
Terrestrial acidification	20%
Photochemical oxidant formation	50%
Marine eutrophication	50%
Freshwater eutrophication	50%
Agricultural land occupation	20%

2. Then, by assimilating the probability distributions of impact results with log-normal distributions, and considering that the uncertainty presented above corresponds to the difference between the maximum of these distributions' 95% confidence interval[32] and the mean value, and finally by adopting a 75%[33]

system's impact results, but do not produce uncertainty on the difference between the impacts of the two systems. In fact, if some of these data are lower or higher than the value chosen for the model, the same impact will take place on the two systems, with no influence on the values of the differences between impacts.

[30] Uncertainty on the LCI parameters is established by the creators of the LCI (ecoinvent, Agri-footprint). In most cases it follows a log-normal distribution and standard deviation is calculated according to the pedigree matrix (https://www.pre-sustainability.com/improved-pedigree-matrix-approach-for-ecoinvent).

[31] Uncertainty levels observed by Deloitte, running Monte Carlo analysis of multiple LCIs.

[32] There is a 95% chance of having an impact result between the minimum and maximum of this 95% confidence interval, a 2.5% chance of having a value smaller than the interval's minimum and a 2.5% chance of having a value greater than its maximum.

[33] The rationale for considering 75% confidence intervals was the following: with system A having an impact illustrated by the red curve and system B having an impact illustrated by the blue curve, the deterministic calculation yields to the impact of A being lower than the impact of B. If we assume that the maximum of the 75% confidence interval of A is equal to the minimum of the 75% confidence interval of B, a sufficient condition for the impact of B being lower than the impact of A corresponds to the impact of A being greater than the maximum of the 75% confidence interval of A and the impact of B being lower than the minimum of the 75% confidence interval of B at the same time. The probability of this occurring is 12.5%*12.5% <1.6%. If we had considered the 95% confidence intervals for each system, this probability would have been lower than 0.07%. As such, taking 75% confidence intervals was considered sufficiently "strict" to ensure that differences in impacts are significant.

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confidence interval[34] associated with each probability distribution for the uncertainty of the difference between the two systems (see table below), we consider that the difference between the impact of two solutions for a given indicator is significant if the maximum of the 75% confidence interval for the solution with the lowest mean impact value is smaller than the minimum of the 75% confidence interval for the solution with the highest mean impact value. The figure below illustrates this case.

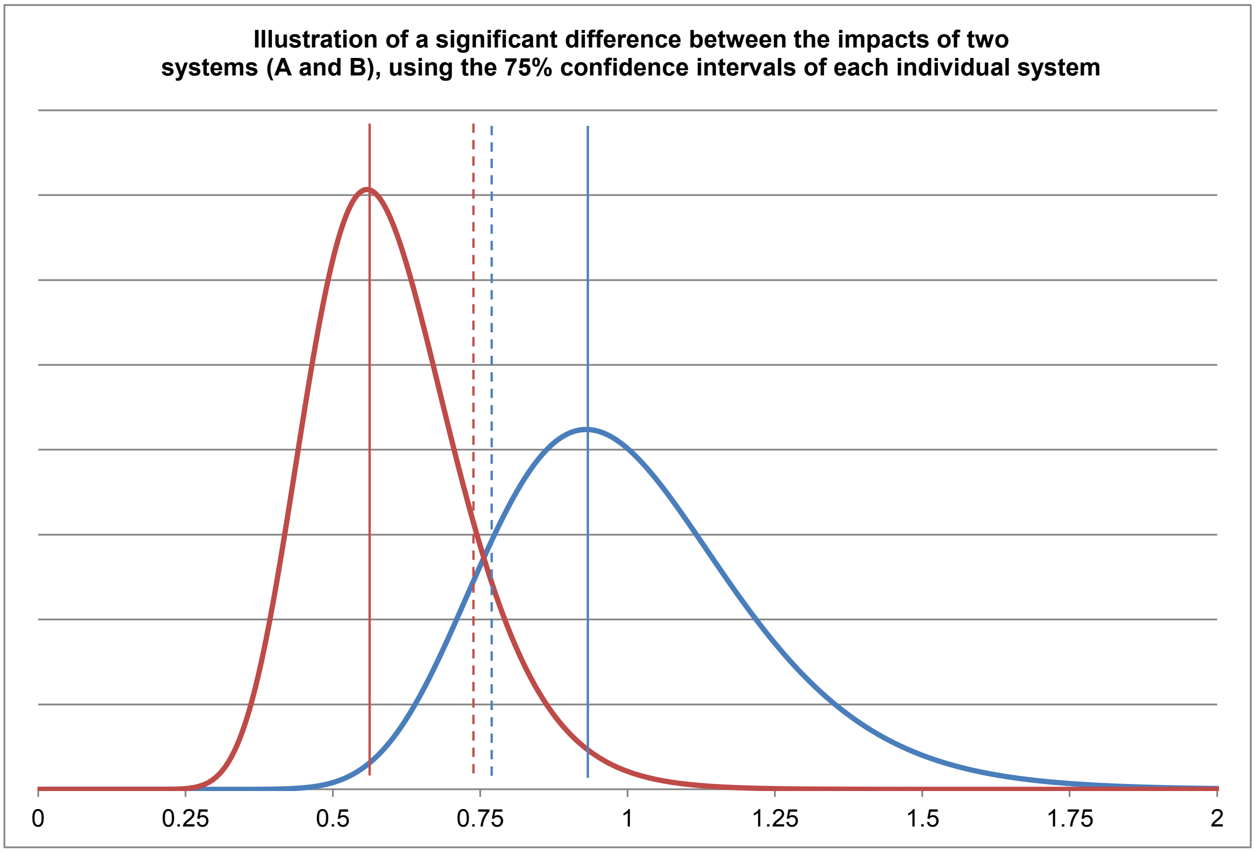

Figure 2-23 Illustration of a significant difference between the impacts of two systems

Alternatively, we consider that the difference between the two systems' impacts is too small to be significant.

The table below shows the correspondence between the 95% and 75% confidence intervals for a log-normal distribution.

Impact category	Uncertainty level	max CI95%	min CI75%	max CI75%
Climate change	20%	120%	88%	112%
Fossil fuel depletion	20%	120%	88%	112%
Water depletion	20%	120%	88%	112%
Terrestrial acidification	20%	120%	88%	112%
Photochemical oxidant formation	50%	150%	77%	125%
Marine eutrophication	50%	150%	77%	125%
Freshwater eutrophication	50%	150%	77%	125%

[34] There is a 75% chance of having an impact result between the minimum and maximum of this 75% confidence interval, a 12.5% chance of having a value smaller than the interval's minimum and a 12.5% chance of having a value greater than its maximum.
.

Agricultural land occupation	20%	120%	88%	112%

We can readily note that this approach's main limitation is that it does not take into account the correlation between the parameters of the systems being compared. This is currently a research topic which is not sufficiently operational to be used by LCA practitioners.

2.5.5.2 Comparison of East and West production

Regional differences are substantial and therefore both East and West scenarios are considered, as well as a number of data and process variations, particularly around feeding and manure management.

Canada's beef cow herd is located primarily in the West (87%), while the dairy herd is located in Eastern Canada (77%). Dairy cattle have been excluded from this study, as explained in the goal and scope chapter. They represent approximately 17% of Canadian beef production annually.

West tends to have larger herds. Average herd size in Alberta is 232 head according to Statistics Canada, compared to 68 head in Ontario.[35] While the "average" regional-sized herd does have economies of scale implications that impact fuel and labour per cow, the environmental impact from this is assumed to be small, with focus placed on the specific production practices that have a greater environmental impact, such as winter feeding and manure handling practices.

To define the two scenarios, farms have been accounted for in the West or East scenarios depending on their location. Farms located in:

- British Columbia, Alberta, Saskatchewan and Manitoba are accounted for in the Western scenario
- Ontario, Québec and Atlantic Canada are accounted for in the Eastern scenario

The West scenario includes 69 farms, from cow/calf to finishers. In contrast, the East scenario includes eight farms, from cow/calf to backgrounding and yearling grazing only. Given that there is no farm which finishes calves and yearlings in the Eastern farms' sample, generic data from a study from Québec were used to model the finishing operations, and the corresponding rations in particular (CECPA, 2012) (see 2.2 Data used in the ELCA). The full description of the data used to model East and West production is set out in 6.6 ELCA—Comparison of activity data with literature—Comparison of East and West production.

The following analysis focuses on the differences in environmental impacts of the two scenarios. **Although results differ, the numerical gaps cannot be considered statistically significant considering the uncertainties, except for agricultural land occupation.** Given that there is no tangible difference between Eastern and Western production systems, research on feed optimization to reduce GHG emissions could be performed at a national level through the creation of a National Feed Research Program for instance.
Although result gaps are not significant, variations by indicator are detailed below, and illustrated in Figure 2-24.

Carbon footprint

The production of one (1) kg of live weight at the farm gate has **similar impacts on the carbon footprint** in Western Canada (11.4 kg of CO_2 eq.) as in Eastern Canada (10.4 kg of CO_2 eq.). For both scenarios, enteric methane and feed production are the major contributors to GHG emissions, followed by manure-related emissions, occurring mostly on pasture for the Western scenario and during storage for the Eastern scenario. Since cattle spend more time in confinement in Eastern Canada (57% of their time vs 33% in the West), a higher amount of manure is collected and stored, resulting in higher emissions during storage. Conversely, in the West, animals spend more time on pasture, resulting in higher emissions from manure applied on grazing lands. Although grazing practices in the

[35] "Average" herd size includes all animals on an operation, not just beef cows. Typical herd sizes for beef operations that rely on beef cattle for income is assumed by industry participants to be larger than the statistics shown here, with partnerships and other reporting issues reducing the reported number.
.

West imply higher overall manure-related emissions, this output is offset by less time spent on feed (42% vs 57% in the East), which reduces the Western system's impacts associated with feed production as compared to the Eastern system.
In addition, enteric emissions per kg of live weight are numerically higher in the West scenario than they are in the East scenario. This is mostly due to the lower finishing weights of Western animals (1,350 lb vs 1,550 lb in the East).

Water depletion

To produce one (1) kg of live weight at the farm gate, 235 litres of water are needed for Western farms and 233 litres of water for Eastern farms, which is an **equivalent footprint considering the uncertainties**. For both scenarios, water consumed to grow crop is by far the main contributor, and water consumption by animals is the second one. The main difference between the scenarios is that the impact from irrigation is numerically higher in Eastern Canada, since animals need higher amounts of feed.[36] Water consumption per kg of live weight is higher in Western Canada due to the lower finishing weights of animals.

Agricultural land occupation

Western farms are larger, with a total agricultural surface area of 93 m2 used to produce one (1) kg of live weight at the farm gate compared to the 36 m2 of agricultural land of Eastern farms. This **significant difference** is explained by grazing practices (cattle spend more time on pasture in Western Canada), the forage yield (pastures in the East are likely more productive than in some drier regions of the West) and the larger farms in the West (74 m2 of land is used for grazing in Western farms, compared to 15 m2 in Eastern farms). Land surface areas used to grow crops to produce feed are slightly larger in Western farms.

Fossil fuel depletion

To produce one (1) kg of live weight at the farm gate, 0.6 kg of oil eq. is needed for Western farms and 0.5 kg of oil eq. for Eastern farms, which is a **similar impact** (see Figure 2-24). Main contributors to fossil fuel depletion have the same consecutive order in both scenarios: the impact indicator being driven by feed production and on-farm energy use. The slight difference between the scenarios is the quantity of energy consumed during feed production. As mentioned above, more feed needs to be produced and cropped to feed animals in Eastern Canada. As a consequence, more fuel is consumed as additional technical interventions—such as tillage, fertilizer and pesticide application or harvesting—are required to obtain higher yields or to grow crops and forage on a greater surface area, and these additional impacts are not offset by the heavier weights of the animals. These results do not show that Eastern animals are less feed efficient, as the amounts of grass ingested are not taken into account in "feed production". However, they highlight the fact that the heavier finishing weight of Eastern animals does not compensate for the additional burdens associated with higher amounts of cropped feed consumed.

Terrestrial acidification

With regards to terrestrial acidification, the **impact is equivalent for both systems**: the production of one (1) kg of live weight at the farm gate generates emissions of 124 g SO_2 eq. in Western farms and 111 g SO_2 in Eastern farms (see Figure 2-24). The share of each contributor is similar for both scenarios, with manure storage, feed production and manure excreted on pasture being the major contributors. The difference comes from the emissions from feed production. Here again, grain-based Eastern production generates more impacts, which are not offset by the heavier weights of the finishers.

Freshwater eutrophication

To produce one (1) kg of live weight at the farm gate, 5.8 g of P eq. are emitted in Western farms and 3.8 of P eq. for Eastern farms (see Figure 2-24). However, **this gap is not significant considering the uncertainties**. For both scenarios, feed production is by far the main contributor to potential freshwater eutrophication. Yet, although the Eastern system relies more on feed than the Western one, Eastern animal diet is, besides hay, dominated by corn, while barley is the major energy supplement in the West. According to the feed LCI used in this study, the corn P fertilization rate is significantly lower than barley's rate, which explains the lower P losses from feed production in the East than in the West.

[36] In our model, used crop LCIs were built to be representative of the whole country; they were not adjusted to consider the different irrigation practices between East and West.
.

Further, P losses in pasture are higher in Western Canada considering the longer time spent in pasture and the larger surfaces used.

Marine eutrophication

To produce one (1) kg of live weight at the farm gate, 76 g of N eq. is emitted during the process in Western farms and 80 kg of N eq. are emitted during the process in Eastern farms (see Figure 2-24). **Here again the gap cannot be considered significant**. Feed production and manure excreted in pasture are the main contributors. The impacts of all stages are higher for the East scenario than for the West scenario. With regard to feed production, higher amounts of feed needed for the Eastern scenario explain the difference. For manure excreted in pasture, the difference is largely due to the fraction of nitrogen leached that was estimated to be much higher in Eastern Canada (39% vs 21% in Western Canada), and partly due to the higher N content of manure of concentrate-fed animals and the heavier precipitation.

Photochemical oxidant formation

To produce one (1) kg of live weight at the farm gate a **similar amount** of NMVOC eq. (17g) is emitted during the process both in Western and Eastern farms (see Figure 2-24). Feed production is by far the main contributor to this indicator for both scenarios. Here again, considering the feed LCIs used in this study, barley has a greater potential to emit NMVOC than corn, which explains the higher contribution of feed in the West scenario. This higher contribution is offset by higher on-farm energy consumption in the East.

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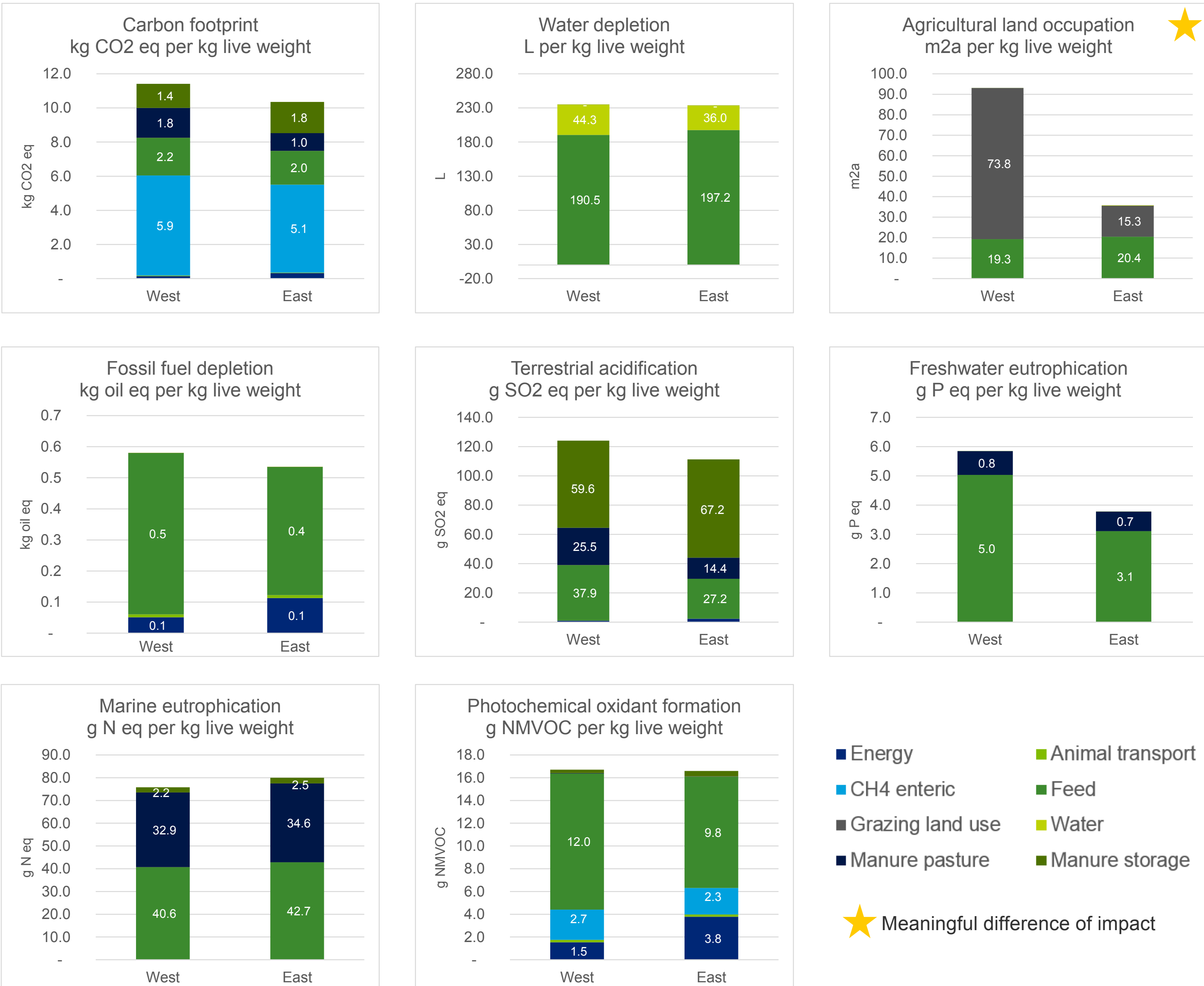

Figure 2-24 Comparisons of environmental impacts of West and East scenarios

2.5.5.3 Comparison of calf-fed and yearling-fed systems

The environmental impacts of the calf-fed and yearling-fed systems scenarios are compared below, for average Canadian production (i.e. from Eastern and Western provinces). The calf-fed systems scenario includes farms which send calves directly for finishing, while yearling-fed animals are backgrounded and grassed before being sent to finishing (see systems description in 1.3.4 System boundaries).

Some farms raise both calves that are directly send to finishing (calf-fed system) and calves that are send to grass as yearling before being sent to finishing (yearling-fed system). Consequently, data for these farms have been weighted by the number of animals in each scenario per farm.

Although the life cycle of calf-fed animals is shorter, the longer finishing period, and thus the higher amounts of feed required, counterbalances this advantage. Result gaps are not significant for any of the indicators. Although result gaps are not significant, the origins of the slight variations by indicator are detailed below, and illustrated in Figure 2-25.

Carbon footprint

Considering the uncertainties the production of one (1) kg of live weight at the farm gate has **a similar potential impact on carbon footprint** (see Figure 2-25) in the yearling-fed scenario (12.5 kg of CO_2 eq.) as in the calf-fed scenario (10.8 kg of CO_2 eq.).

Several factors contribute to the small variation between the two systems. First, the life span in the yearling-fed system is longer than in the calf-fed system. Consequently, methane enteric emissions are higher. Moreover, cattle in the yearling-fed systems scenario spend more days in pasture (additional grazing period after backgrounding). This explains the higher GHG emissions during grazing, since more manure is excreted in pasture.

In addition, the time spent in confinement is higher for yearling-fed systems than for calf-fed systems: the reduced finishing time is offset by additional time spent in confinement during backgrounding. For yearling-fed systems, the animals spend about 260 days confined: 107 days confined as a backgrounder and 152 days as finishers. For calf-fed systems, the animals spend about 220 days confined as finishers.

The difference of 15% between calf-fed and yearling-fed GHG emissions we observe here is higher than the 6.3%-7.5% difference observed by Basarab *et al.* in their work on *Calf- and yearling-fed beef production systems, with and without the use of Growth Promotants* (Basarab, 2012).

Water depletion

To produce one (1) kg of live weight at the farm gate, 255 litres of water are needed for the yearling-fed scenario and 233 litres of water for the calf-fed scenario (see Figure 2-25), which is a **non-significant difference**. The share of each contributor is similar for both scenarios, with water used to grow crops being the main contributor.

In proportion, the contribution to water depletion of crop and forage production is higher for the calf-fed scenarios. The finishing stage lasts longer in the calf-fed system and the quantity of feed provided per day is higher during the finishing stage than during other stages such as backgrounding. Consequently, the average quantity of concentrate and forage provided to calves per day is higher for the calf-fed system than the yearling-fed system. This means more resources—such as fertilizers, water or fuel—are used to obtain higher yields or to grow crops and forage on a greater surface area.

In contrast, direct water consumption (i.e. water drunk by animals) is higher for the yearling-fed system. This is due to the longer animal life-span.

Agricultural land occupation

The yearling-fed system requires more land, at 103 m^2 per kg of LW, than the calf-fed system, which requires 77 m^2 per kg of LW to produce one (1) kg of live weight at the farm gate (see Figure 2-25). This **non-significant difference** results directly from the longer grazing period of the yearling-fed system.

Fossil fuel depletion

The potential impacts of one (1) kg of live weight at the farm gate for the calf-fed system and the yearling-fed system on fossil fuel depletion of production are **similar**: 0.7 kg of oil eq. for the yearling-fed system and 0.6 kg of oil eq. for the calf-fed system (see Figure 2-25). Feed production is the major contributor to both scenarios.

Terrestrial acidification

With regard to terrestrial acidification, the **impact is equivalent for both systems**: the production of one (1) kg of live weight at the farm gate generates 131 g SO_2 eq. in the yearling-fed scenario and 124 g SO_2 eq. in the calf-fed one (see Figure 2-25). Emissions released by higher amounts of manure excreted in confinement in the calf-fed system offset the lower emission of manure excreted in pasture compared to the yearling-fed system.

Freshwater eutrophication

To produce one (1) kg of live weight at the farm gate, 6.2 g of P eq. is emitted during the process in yearling-fed systems and 5.9 g of P eq. for calf-fed systems (see Figure 2-25), which again is a **non-significant difference**.

Marine eutrophication

To produce one (1) kg of live weight at the farm gate, 87 g of N eq. is emitted during the process in the yearling-fed systems scenario and 75 of N eq. for the calf-fed one (see Figure 2-25). **Here again the gap cannot be considered significant**. The difference is mainly due to the longer duration of time spent in pasture by yearling-fed animals that results in more manure excretion and thus more N emissions.

Photochemical oxidant formation

To produce one (1) kg of live weight at the farm gate, 19 g of NMVOC is emitted during farming operations in the yearling-fed scenario and 16 g of NMVOC in the calf-fed one (see Figure 2-25). This **negligible difference** can be explained by the larger amounts of manure excreted on pasture, and corresponding ammonia emissions, by yearling-fed animals.

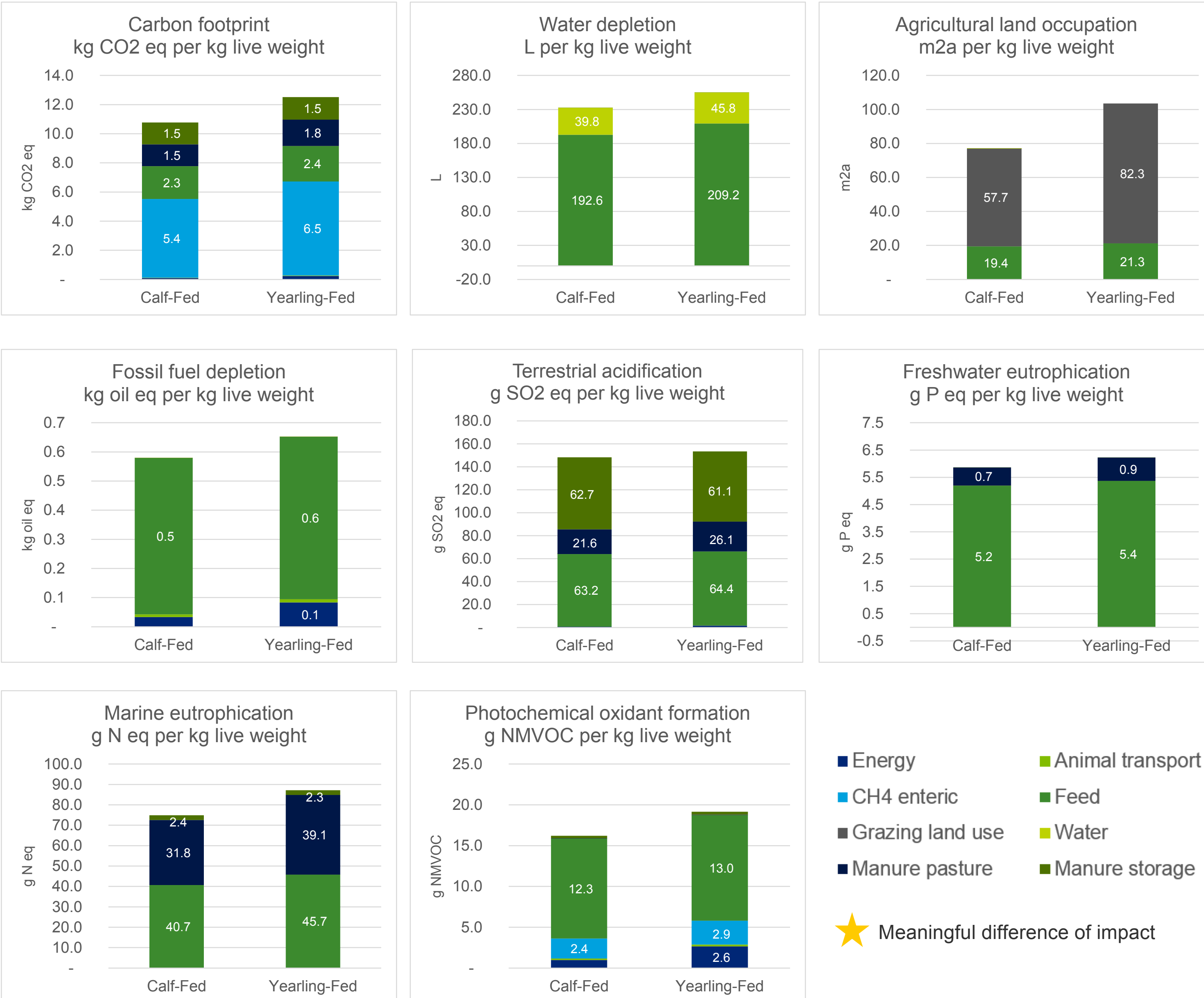

Figure 2-25 Comparisons of environmental impacts of calf-fed and yearling-fed scenarios

2.5.5.4 Comparison of beef production with or without the use of hormones

Hormones are used to improve feed utilization efficiency and daily weight gain. The proportion of implanted beef cattle is set out in Figure 2-26.

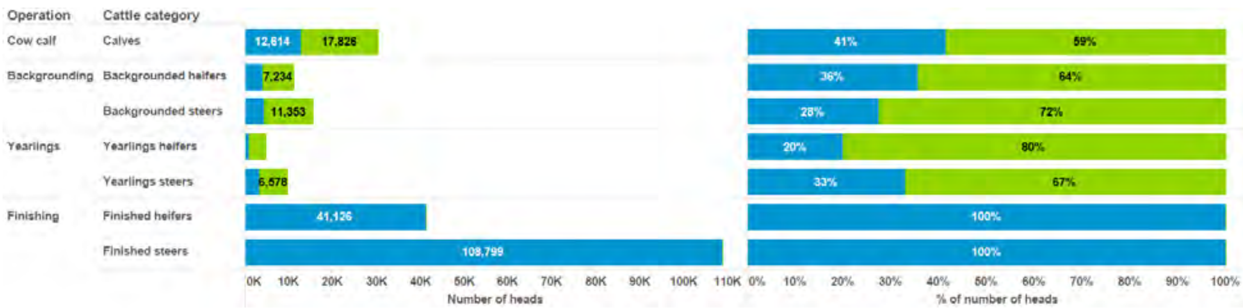

Figure 2-26 Distribution of hormone use in the sample per animal category (in blue: implanted beef cattle; in green: not implanted beef cattle)

Our sample was not designed to follow one given animal from birth to processing, but more to provide an industry picture, and it did not cover the different feed efficiencies between animals. Further, farms frequently simultaneously raise implanted and non-implanted animals. Consequently, data related to both kinds of animals could not be directly distinguished. To assess the influence of hormones, we thus used literature data to estimate the environmental footprint of an industry not using hormones: what would be the environmental impacts if all animals receiving hormones had not been implanted?

Basarab *et al.* (2012) studied the impacts of the use of growth promotants on calf-fed and yearling-fed animals. Although their calculation is likely based on a different life cycle for a similar end-weight,[37] data included in the study are provided the other way around, with similar life-span but different average daily gains resulting in heavier implanted animals than their hormone-free counterparts. From this, we assumed that only weight will vary between implanted and hormone-free animals, all other things being equal,[38] and deduced from Basarab's study the overall weight difference of finishers whether they are implanted or not, calf-fed or yearling-fed (see Table 2.31).

Table 2.31 Weight reduction of hormone-free finishing animals compared to their implanted counterparts

Feeding scenario	Weight reduction of non-implanted finishers compared to implanted animals (Basarab, 2012)	Weight reduction of finishers if no animal of the sample had been implanted
Calf-fed	- 8.0%	- 7.9%
Yearling-fed	- 8.4%	- 6.3%
Sample average	- 8.3%	**- 6.9%**

The average finishing weight used in the baseline scenario was thus lowered by 6.9% to assess the influence of hormones on the performance of the industry. The weights used in the fictional "no-hormone" scenario to express results per kilogram of meat are presented in Table 2.32.

Table 2.32 Finishing and culled animals' weights used in the baseline and the "no-hormone" scenario

Animals	Weight at farm gate (lb)	
	West (baseline)	West (no hormone)

[37] Feedlots are more likely to finish to a similar end-weight in practice

[38] It is recognized that this fails to consider any differences in feed efficiency, which could be larger than changes in average daily gain. Therefore these estimates in differences are very conservative.

Animals	Weight at farm gate (lb)	
	West (baseline)	West (no hormone)
Culled cows	1,381	1,381
Finishers	1,350	1,257

This approach results in an additional environmental burden of the no-hormone scenario of 7% for all indicators, as displayed in the following charts. Given that variables of the baseline and the no-hormone scenario are fully correlated (i.e. relying on the same input data), this difference is meaningful. We acknowledge this is a first rough approach and, while the outcomes would certainly be different if we had considered a similar end-weight for distinct animal life-spans, this crude analysis shows that the approach implemented here is likely conservative. It thus provides insight on the benefits from the use of hormones, although a refined analysis would be necessary to provide more accurate figures.

Figure 2-27 Comparisons of environmental impacts of baseline and no-hormone scenarios

2.5.6 Sensitivity analyses

2.5.6.1 Meat: by-products allocation rule

As previously mentioned, the sensitivity of our model to the meat: by-product allocation rule was tested. In our baseline, an economic allocation is performed, and is here compared to a mass allocation. Rates to distribute the impacts between meat and by-products are displayed in Table 2.16.

Comparative results are displayed in Figure 2-28 Sensitivity analysis on the allocation rules—results at the packers' gate (carcass weight)

As expected, our results are very sensitive to the allocation rule distributing the impact between meat and by-products. Using mass allocation, meat is attributed the same impacts per kilogram as by-products, while with the economic allocation it is attributed the largest part of the impacts.

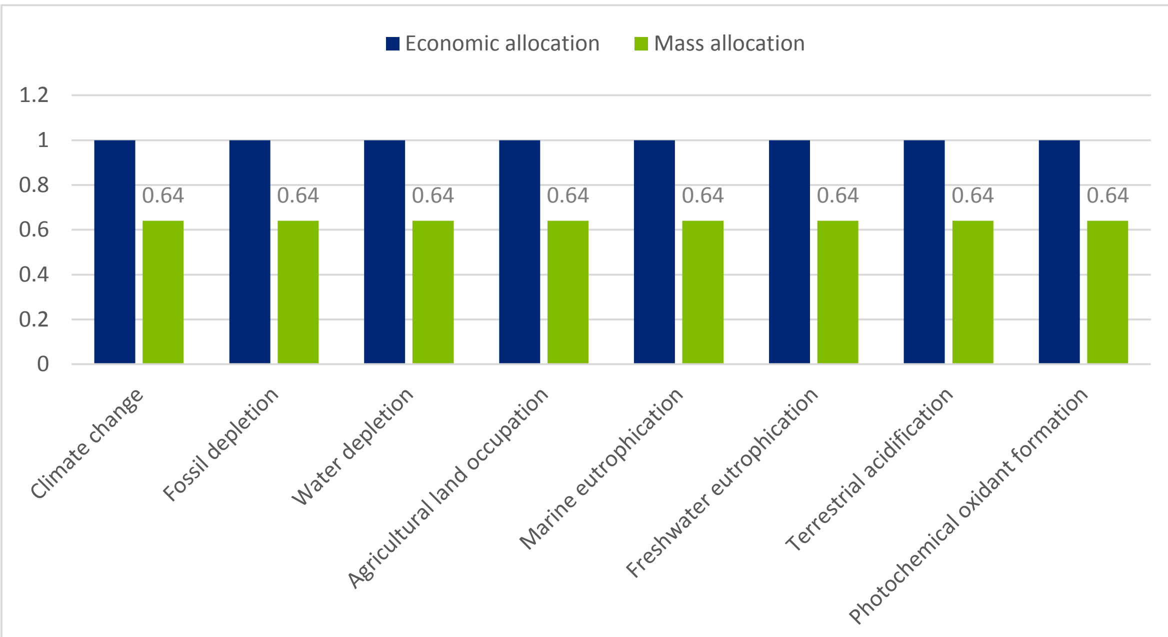

Figure 2-28 Sensitivity analysis on the allocation rules—results at the packers' gate (carcass weight)

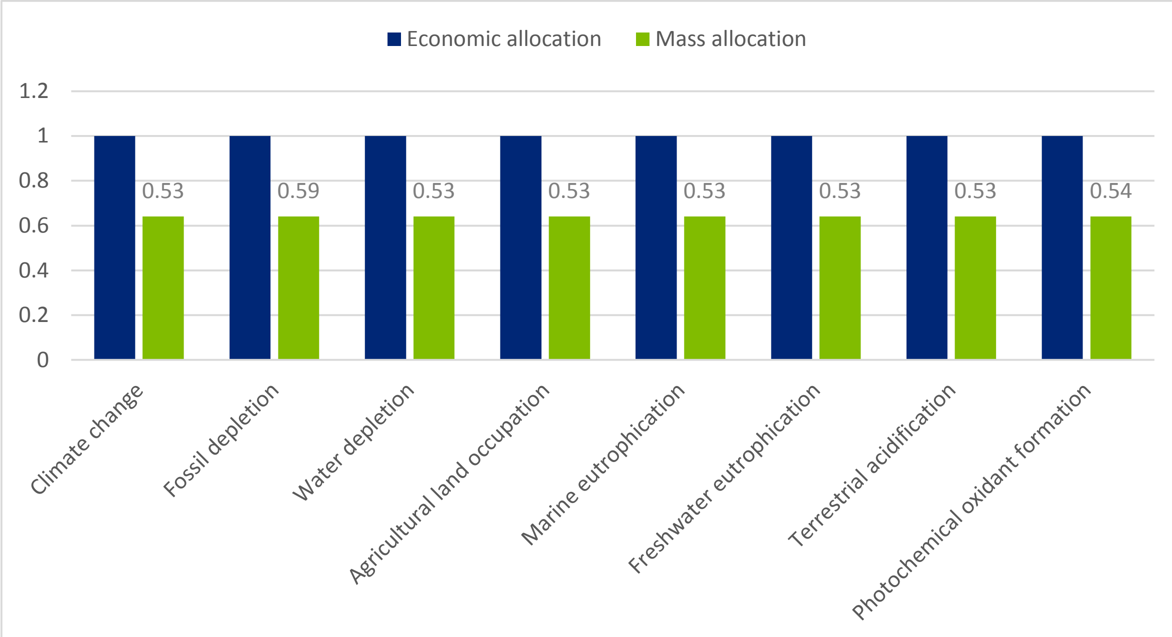

Figure 2-29 Sensitivity analysis on the allocation rules—results at consumer level (bone-free weight)

2.5.6.2 Nitrogen leaching fraction

Our model was also tested against stored manure nitrogen leaching rates. In our baseline, no leaching was assumed; a test on a 20% nitrogen leaching fraction is proposed below.

Marine eutrophication potential, assessing the effects of nitrogen release into water, is very sensitive to the N leaching fraction. Indeed, in our baseline, results are affected by N leaching on pasture, and N leaching due to crop fertilization, but the impact of N leaching during storage was not considered as explained previously (see 2.3.2.3). The effect on climate change is rated low (<1%), as leaching only affects indirect dinitrogen oxide emissions. Considering the lack of data on actual N leaching potential in manure storage facilities, and considering the sensitivity of the marine eutrophication potential to this effect, further research on this topic would be useful to refine the results.

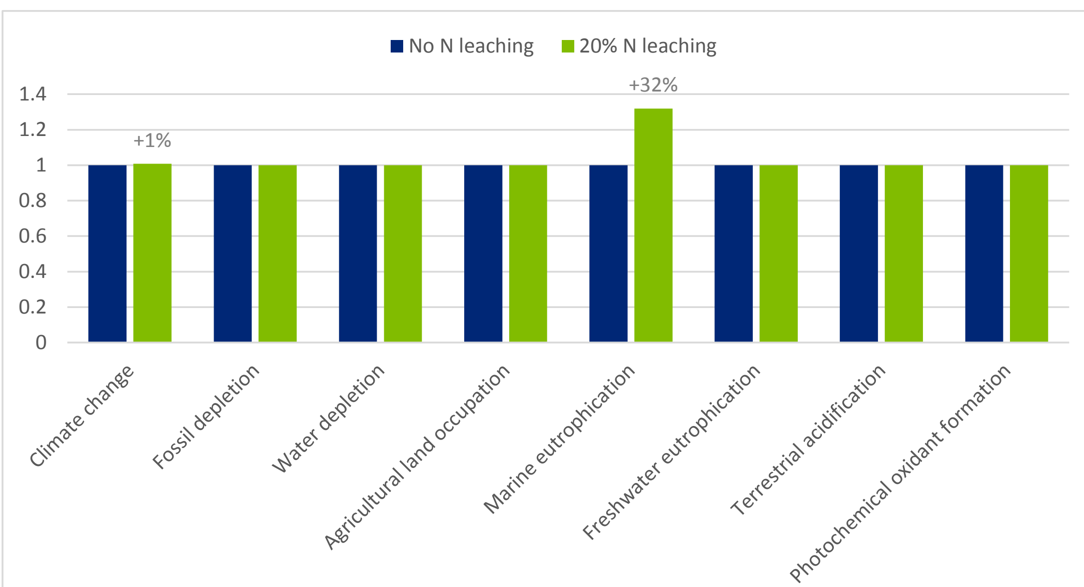

Figure 2-30 Sensitivity analysis on the stored manure nitrogen leaching rate—results at the farm gate

3 Land use assessment

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3.1 General approach

3.1.1 Introduction

While the environmental LCA approach provides an indication of how much land is required on average to produce one (1) kilogram of beef meat, it does not provide a clear indication as to what this footprint means in terms of land use impacts at the Canadian level. This section aims to overcome this limitation and focus on Canadian beef land use impacts related to three important themes: biodiversity, water risk and carbon soil sequestration. Land use impacts are usually looked at through different spatial and geographic levels depending on the topic under discussion (e.g. a hydrogeological basin for irrigation, an ecozone for biodiversity) and are hard to describe in quantitative ways (e.g. natural pasture land health, biodiversity value). This section addresses some of these challenges by combining datasets from various geographical and spatial resolutions to create a Canadian- or provincial-level view that allows interpretation from an overall industry perspective. However, this section is not intended to provide guidance for local decision making, as it would require a consistent and finer resolution of a specific area or location.

3.1.2 Overall methodology

Our methodology is built around three steps, with the first one common to all three themes (biodiversity, water and carbon soil sequestration (CSS)):

1. The first step is to build a clear and detailed view of the beef land cover footprint, in terms of overall area (similar to the information provided by the ELCA land use indicator) but also in terms of the different land cover types leveraged by the Canadian beef industry.
2. The second step is specific to each of biodiversity, water and CSS and is based on literature review and expert interviews. It sets the stage in terms of current research areas under each theme and their potential applicability to beef. The findings are presented at the beginning of each theme to help the reader appreciate the underlying assumptions, limitations and trade-offs that may need to be considered when discussing the theme.
3. The third step is also specific to each theme and aims to perform some quantitative assessments of beef land use impact, based on available thematic data and the detailed beef land cover footprint described in step 1.

The combination of data sources leveraged is presented in (Figure 3-1). Details on data sources used to produce the beef land cover footprint (first step for the three themes of analysis) are provided in the next section, while details on thematic data per land cover type are provided in their respective sections.

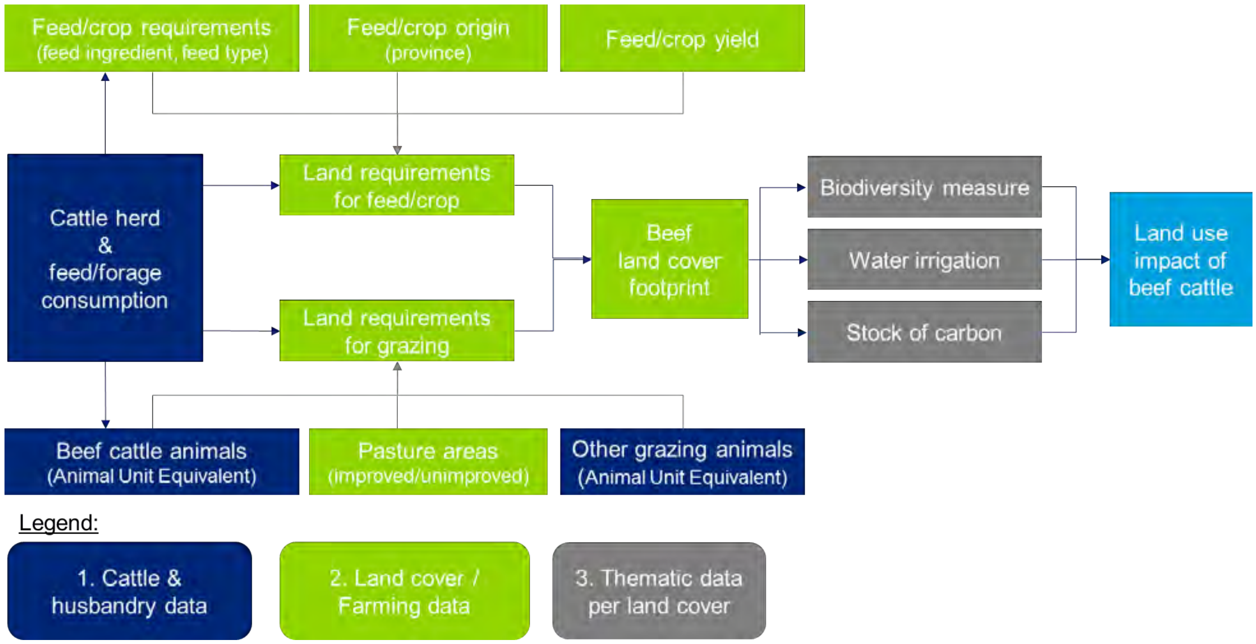


Figure 3-1 A simplified representation of the information flow in assessing land use impact of beef

3.2 Beef land cover footprint

3.2.1 Canadian landscapes and beef production sector

Canadian beef production operates within the broader Canadian agricultural and forest landscapes.

Agricultural areas in Canada often contain cropland, pastures, grasslands, forests, wetlands and other water bodies, including many undisturbed natural areas, each supporting a diverse set of species. The capacity of those agricultural lands to support the habitat needs of species is prone to decline over time due to agricultural intensification on existing farmland and increased risk of nutrient depletion. Improving biodiversity on agricultural lands is key to sustaining natural systems, maintaining water quality and quantity, supporting pollinators, improving wildlife habitat and connectivity, and enabling agro-ecosystems to better recover from and adapt to environmental stresses such as drought. The varied habitats associated with agricultural land provide some or all of the requirements of many wildlife species across Canada. Not all habitat types are equal, however, in their capacity to support wildlife. Wetlands, woodlots, riparian areas and natural pasture are some of the most important habitat elements for wildlife in the agricultural landscape.

Canada's boreal forest is the largest contiguous forest ecosystem on earth, covering a quarter of Canada's land area (Federal Provincial and Territorial Governments of Canada, 2010). It forms a broad greenbelt across the centre of the country from Newfoundland to the Yukon, bounded by prairie and temperate forests to the south. Over 40% of boreal forests are under industrial forest management, including forestry and oil and gas development, while the remaining areas are typically in the North and both less productive and less biodiversity-rich. Threats to boreal forests include habitat loss, conversion of forest types, alteration of forest stands' age-class distribution and structural diversity, and increased isolation of old forest fragments, leading to varying impacts on biodiversity (Venier, et al., 2014). While most of the boreal forest is not suited for agriculture, livestock operations are found on the Southern edges where it meets the prairie grasslands, and about five million ha are cultivated for crops, mostly in Alberta and Saskatchewan (Willms & Dormaar, 1993).

The Canadian beef production sector has been described in detail in other streams of this study. Its main characteristics are recalled briefly, along with some specificities of the Canadian agricultural landscape, especially in terms of biodiversity.

The beef cattle industry is a major source of income for the Canadian agriculture industry, ranking first or a close second behind canola. Beef cattle are raised throughout Canada, and the industry comprises operations with less than 100 animals through to large intensively-managed operations selling more than 100,000 animals per year (Sheppard & Bittman, 2012). A regionalization of beef production is noticeable, with a higher concentration of beef cattle in the Western Prairie provinces than in the Eastern provinces. Alberta, with its vast rangelands and feed supplies, dominates Canada's beef production. Cow/calf operations in Western Canada are characterized by low-input, extensive areas, high climatic risks and winter feed needs (Sheppard, et al., 2015)), while they are typically more intensive in Eastern Canada largely as a result of the harsher winter climate. Accordingly, while 31% of total farmland is pasture (native and cultivated) in Western Canada, only 9% of farmland is pasture in Eastern Canada (Sheppard, et al., 2015). Grazing on native pastures and harvested cropland (grazing crop residues) is also more frequent in the Western provinces (Sheppard, et al., 2015). In addition, feed grains in Western Canada are mostly barley, whereas corn is prevalent in the East. Overall, the land base for beef production can be very diverse, including high-productivity crop and pasture land as well as large areas of low-productivity/marginal and non-arable land. The biodiversity impacts of the Canadian beef industry are thus widespread and variable, due to the diversity of landscapes used, although prairie is the prevalent habitat used for raising livestock.

Much of Canada’s terrestrial biodiversity is supported by two main native habitats, native prairie and boreal forest. Perennial grasslands or native prairie cover about 5% of the Canadian land base and most of the cattle grazing occurs in this region (Horton, 1994). It stretches south of a large arc extending from the lowlands of Southeastern Manitoba, through Saskatchewan and Alberta and into the foothills of the Rocky Mountains. The native prairie has co-evolved with grazers (e.g. bison, ground squirrels, grasshoppers) over thousands of years and comprises three main grassland types: mixed prairie, tallgrass prairie and shortgrass or fescue prairie. More than half of the remaining native grassland in Canadian prairies is mixed. The mixed prairie region in Canada is part of the dry interior plains that extends from the foothills of the Rocky Mountains along the border with the US to the vicinity of the Saskatchewan-Manitoba boundary. Most of the true, tallgrass prairie has been converted to cropland. What remains occurs to the east of the mixed prairie, while shortgrass or fescue prairie occurs in more moist regions occupying the northern extent of the prairies in Alberta and Central West Saskatchewan (Coupland, 1950). Over 80% of Canadian native grasslands have been extensively converted for grain production over the last 100 years (McCartney, 2011) and the remaining areas are subject to ongoing fragmentation and human development (Roch & Jaeger, 2014). Thus, cattle may play a valuable role in the sustainable use of land by contributing to the preservation of wildlife habitat and biodiversity depending on the ecosystem and how cattle are managed (Federal Provincial and Territorial Governments of Canada, 2010).

3.2.2 Data sources and inputs

Land cover data

Canada has developed a national spatial ecological framework which includes a hierarchy of spatial units that share similar geomorphological, soil, vegetation and climate features. The framework comprises three levels of spatial details: ecodistricts, ecoregions and ecozones. Ecodistricts are further broken down by superimposing mapping units called polygons, from Soil Landscapes of Canada (SLC) maps (SLC version 3.0 used in our analysis). The SLC is a national soil map and accompanying database of environmental information for all of Canada at 1:1 million scale that covers the major agricultural areas of Canada (about 2,000,000 km2). It is produced and maintained by the Canadian Soil Information Service (CanSIS), which is a part of Agriculture and Agri-Food Canada, using the Canadian System of Soil Classification and forms the lowest level of the National Ecological Framework for Canada.

We used Soil Landscape of Canada polygons as the geographical unit for some aspects of this analysis since specific sources of our selected data (land cover types, biodiversity measure) could be projected at this geographical unit. The SLC level data were then aggregated with the cattle herd and feed requirement data at the provincial level to provide results that would be meaningful to the Canadian beef industry.

Land cover in each SLC polygon is provided with the Annual Crop Type Inventory (ACI) by the AAFC Earth Observation Division on a yearly basis at a 30 metre resolution, for all agricultural and surrounding land in Canada (Figure 3-2). Sixty-three different land cover types are identified in the ACI (see 6.10 Land use/biodiversity—Land covers available in the Annual Crop Type Inventory (ACI).

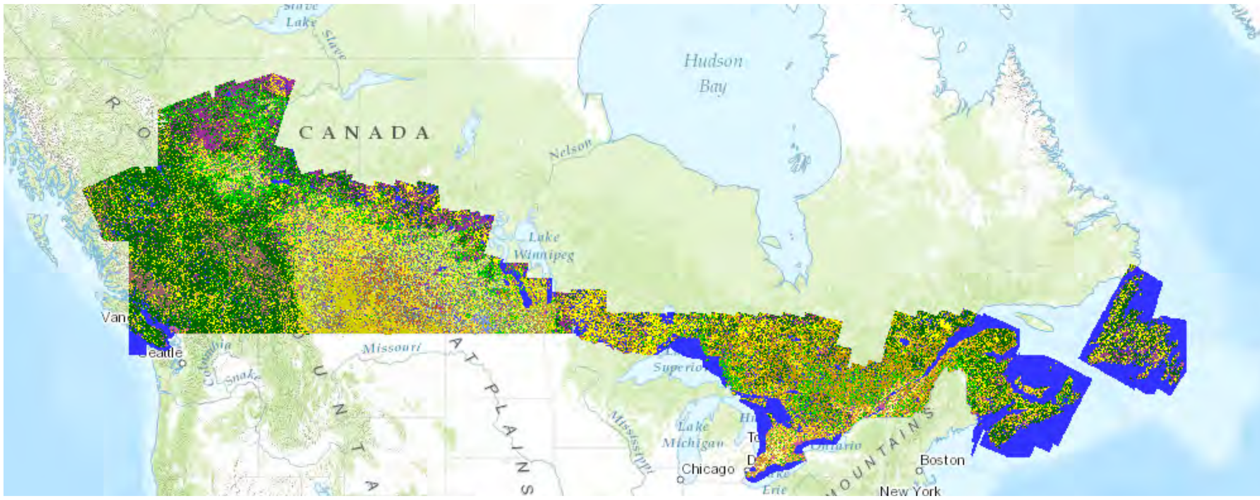


Figure 3-2 AAFC Annual Crop Inventory coverage of the Canadian territory

Agricultural production data
High-level agricultural production data were provided by the Census of Agriculture (Statistics Canada, 2013), through two main tables:

- Table 004-0002 gives the total area of farms and use of farmland in Canada and in provinces. The farmland areas per province are broken down into five categories: all other land (without natural land for pasture), land in crops, natural land for pasture, summerfallow land and tame or seeded pasture).
- Table 004-0213 gives data on hay and field crops areas per province broken down into 27 different categories, including main crops such as barley, wheat, corn, etc.

Beef cattle production data
We used the cattle herd data from the Interpolated Census of Agriculture (2011), which leverages data from Statistics Canada. These data are available at the consolidated census subdivision level.

Land area needs for grazing
The area needed for grazing can be directly approximated by the total area of pastures, including unimproved natural pastures (not seeded in the past 20 years, *sensu* Sheppard 2014), tame or improved seeded pastures (pastures which were seeded less than 20 years ago, *sensu* Sheppard 2014), as well as irrigated hay and permanent grass cover. These data are made available by the Interpolated Census of Agriculture data for 2006 and 2011, at the consolidated census subdivision level. We then used animal units equivalent (AUE) conversion to determine the share of total area that should be allocated to beef cattle, in comparison to other competing grazing animals (i.e. dairy cattle and calves, sheep and lambs, horses or ponies, and bison), with wildlife (e.g. deer, elk) excluded.

Land area needs for feed
The land area needed to grow cattle feed can be evaluated via the diet and amount fed to cattle, as well as local yields for the production of each of the feed ingredients. The amount, type and quality of feed differ per life phase and use of the animal. Different feed ingredients are used to feed cattle, ranging from whole crops (e.g. oats, barley, corn, annual legumes) to by-products from processed food crops, e.g. pellets (Sheppard, et al., 2015). The feed composition used in this study is based on the ELCA survey results as well as expert consultation, both used to develop an average feed composition for each stage of production (cow/calf, backgrounding, feedlot operations), type of animal (cow, bull, calves, heifer and steers), and by region (East or West, as defined in Feed rations—see 2.2.2.1 Farm activity data used, and summarized in Figure 3-3). The regional distinction reflects the difference in feed composition depending on the crops cultivated in the East (where corn is often used) versus West (where barley is often used). In this study, we also assume that all feed consumed in Canada is produced in Canada, and further that the feed is produced locally to feed the cattle, that is, the feed needed for growing the cattle in a given province is produced in that same province—an assumption confirmed by the operations surveyed in this study and by AAFC statistics on domestic production vs imports, over the last 15 years.[39] Barley imports over the last 15 years have

[39] Canada: Outlook for Principal Field Crops, Agriculture and Agri-Food Canada.

averaged 68,000 tonnes. The 15-year (2000-15) average for corn imports is two million tonnes—half to Western Canada and half to Eastern Canada—and is being used for beef but also for other livestock.

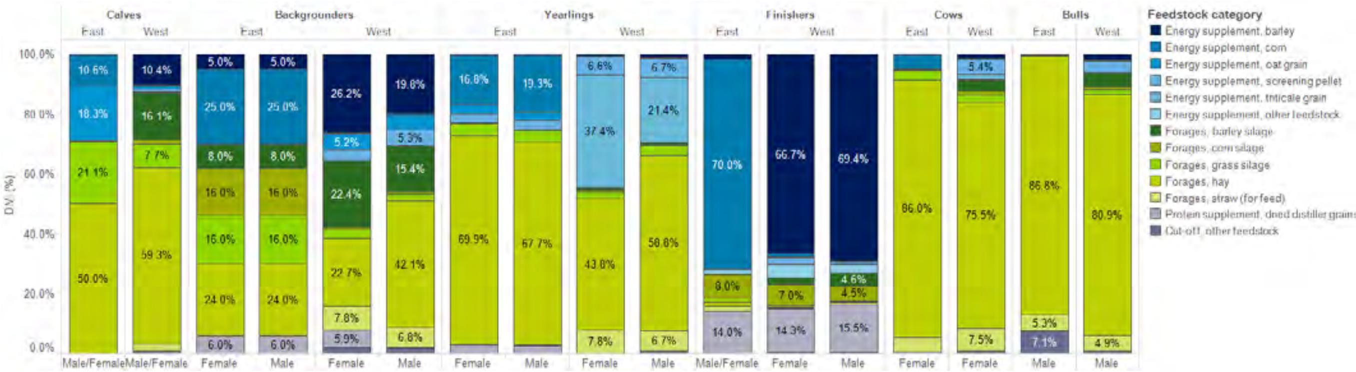


Figure 3-3 Detailed average rations used in this analysis (dry matter intake %)

Feed ingredients used in rations have different land requirements due to different yields per ha. Yield differences among feed ingredients are due to several factors, as reviewed by (Elferink & Nonhebel, 2007). First, feed ingredients originate from different crops which have different yields, e.g. on average, corn yields more than barley per ha. Second, yields of the same crop differ due to regional, local and specific growth circumstances, e.g. different climatic conditions, soil qualities and management practices. Third, the yields of feed ingredients may also differ because sometimes only a part of the harvested material (grain or stock) is used as a feed ingredient (See 6.11 Land use/biodiversity—Yield references for the yields used in this analysis). This study consequently made a distinction in the type of feed ingredient. We distinguished whole feed crops from by-products and "waste streams". Whole feed crops are cultivated solely for use as a feed ingredient. By-products originate from processing food crops in food products, and waste streams are the left-overs of food products or by-products which are not suitable for human consumption.

The following approach is used to determine the average yield of feed ingredients used in Canada. In this study, we use the average yield for each feed ingredient in each Canadian province, based on Statistics Canada Table 001-0010. The average yield during the period 2004 to 2014 is used to prevent errors due to differences in yields between different years. By-products and waste streams were not assigned any land requirement, so no yields were required.

The land requirement for the production of feed used for beef cattle in Canada is calculated as:

$$LR_{herd} = \sum_{i,j,p} \left(N_{i,j,p} \times \sum_{k} Y_{k,p} \times Q_{k,i,j,p} \right)$$

Where:
LR_{herd} = the land requirement for feed for the beef cattle (m^2) in Canada
$N_{i,j,p}$ = the number of animals in the category *i* (e.g. cows, calves, finishing heifers, etc.) in the production system *j* (e.g. calf-fed or yearling grasser) in the province *p* (e.g. Alberta, Saskatchewan, Ontario, etc.)
$Y_{k,p}$ = average yield for the crop *k* in the province *p* (kg/m^2)
$Q_{k,I,j,p}$ = the amount of feed ingredient *k* (kg) consumed by an average head of cattle in the category *i* in the production system *j* in the province *p*

3.2.3 Results

At the national level, Figure 3-4 and Figure 3-5 show the results from those calculations.

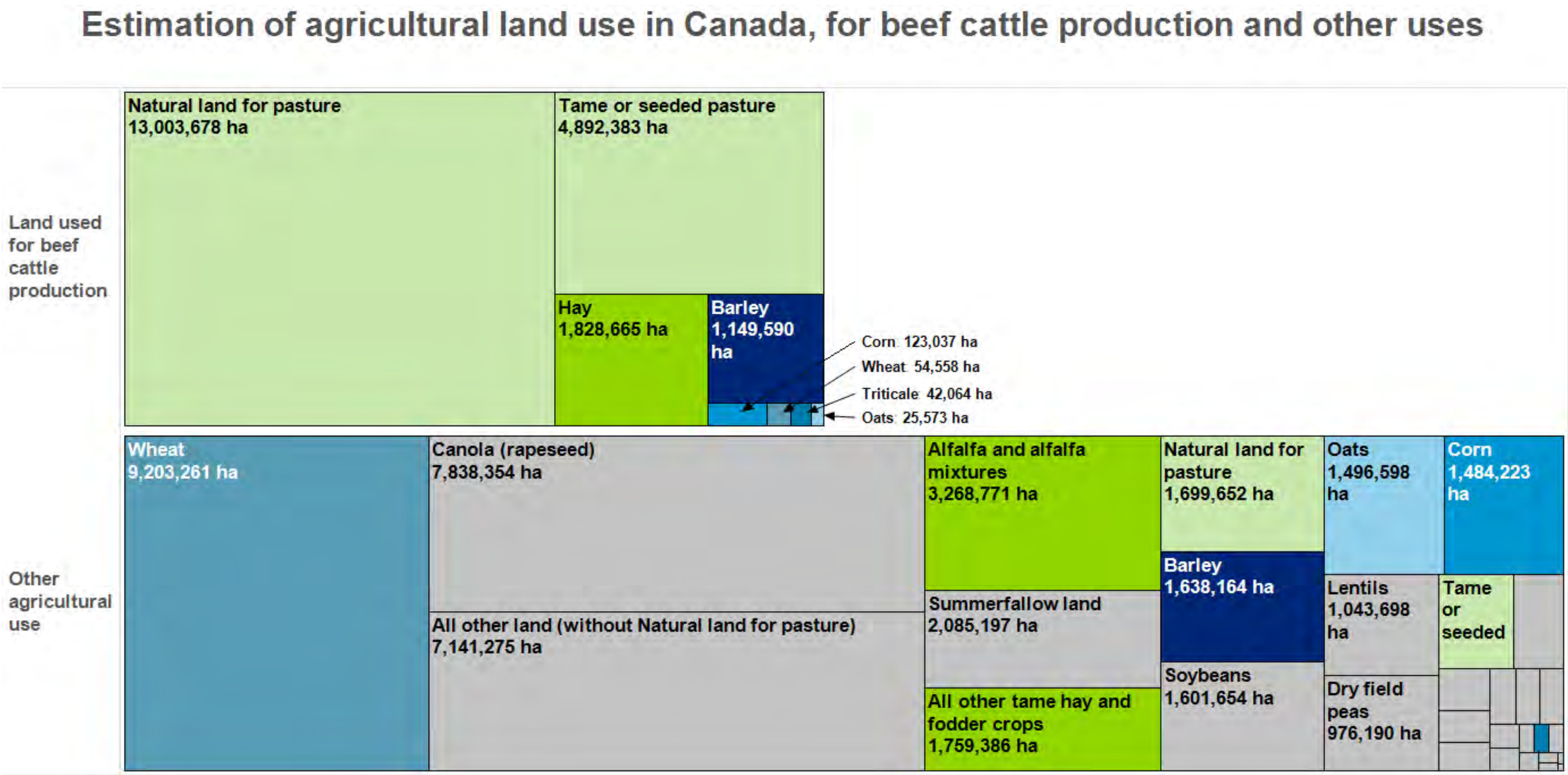


Figure 3-4 Agricultural land use in Canada, for beef cattle production (grazing and feed) and other agricultural land use

Note 1: this view will be modified in the following land use sections to display intensity values specific to biodiversity, water or carbon soil sequestration.

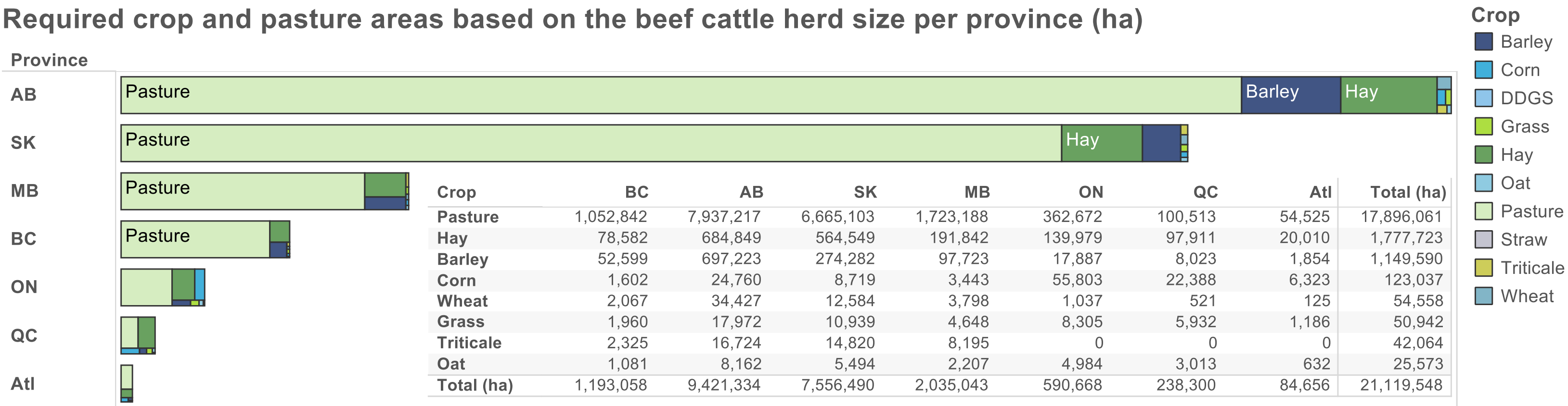
Note 2: DDGS (distillers dried grains with solubles) is a co-product used in beef rations and not included in this land use calculation. Depending on the economic allocation parameters chosen, it would represent between 14,510 and 128,326 ha of wheat.

Note 3: Based on (Adom, et al., 2012)

Note 4: “Other agricultural use” includes some pasture and forage components required for livestock other than beef cattle (e.g. dairy cattle, sheep, horses, bison, etc.).

Estimation of beef cattle land use in Canada, based on required crop and pasture areas

Required crop and pasture areas based on the beef cattle herd size per province (ha)



Crop	BC	AB	SK	MB	ON	QC	Atl	Total (ha)
Pasture	1,052,842	7,937,217	6,665,103	1,723,188	362,672	100,513	54,525	17,896,061
Hay	78,582	684,849	564,549	191,842	139,979	97,911	20,010	1,777,723
Barley	52,599	697,223	274,282	97,723	17,887	8,023	1,854	1,149,590
Corn	1,602	24,760	8,719	3,443	55,803	22,388	6,323	123,037
Wheat	2,067	34,427	12,584	3,798	1,037	521	125	54,558
Grass	1,960	17,972	10,939	4,648	8,305	5,932	1,186	50,942
Triticale	2,325	16,724	14,820	8,195	0	0	0	42,064
Oat	1,081	8,162	5,494	2,207	4,984	3,013	632	25,573
Total (ha)	1,193,058	9,421,334	7,556,490	2,035,043	590,668	238,300	84,656	21,119,548

Required crop areas based on the beef cattle herd size per province (ha)

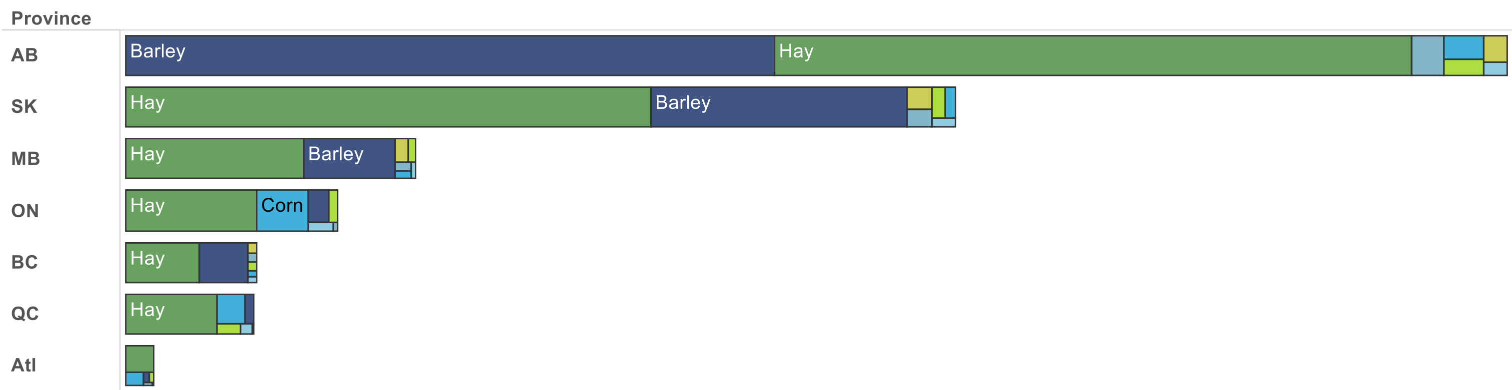


Figure 3-5 Detailed and area needs for grazing and for feed of beef cattle at the Canadian level. Provincial breakdown with and without pasture/grazing area, per major component of the Canadian beef cattle ration component (no allocation for DDGS and straw)

The results allow various breakdown analyses, per province or land cover type. For example, land requirements for hay and grain cattle feed represent roughly 8.6% of total available land in crops and summerfallow land in Canada, which amount to 35,350,000 ha and 2,085,000 ha respectively as per the 2011 Agricultural Census.

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3.3 Biodiversity

The objective of this section is to evaluate the impacts of beef production on biodiversity in Canada. Cattle can modify terrestrial habitats in various ways as a major user of land for pasture and feed crops. Not all habitat types, however, are equal in their capacity to support wildlife, plant varieties and other species. The impacts of beef production on biodiversity are very complex and depend on the habitats used, as well as on the type of production system. Beef production also influences biodiversity beyond these habitat changes, through alterations in carbon sequestration or greenhouse gases emissions for instance, and these aspects are looked at in other sections of this report. Since there is currently no widely-accepted framework for assessing the impacts of beef production on biodiversity in a life cycle context, we use a twofold approach. First, existing evidence of the biodiversity impacts of beef cattle is reviewed to put the Canadian situation in a global context and assess impact mid-points. Second, an approach to quantify these impacts for the whole of Canada is developed, by relating the beef land use area to the wildlife land use, or "habitat capacity", of this land. This analysis paints a broad picture, and recommendations are made to help refine the analyses in the future.

3.3.1 Impacts of livestock on biodiversity

The interdependence of human and ecological systems is now recognized, along with the impacts of production and consumption on those systems. The challenge is how to expand and improve agricultural production to meet rising food demands while ensuring biodiversity and other ecosystem services are preserved. Globally, meat production is increasingly perceived as a primary cause of biodiversity loss, mainly through its large land footprint which could cause substantial habitat change (for example, in tropical rainforests) but also through a suite of more indirect impacts, notably due to nitrogen deposition and altered hydrology: see Figure 3-6 (Steinfeld, et al., 2006) (Westhoek, 2011). Beef production appears to contribute disproportionately to this land footprint, by using almost three orders of magnitude more land than other meat production systems (Eshel et al., 2014). However, beef cattle can also have a valuable role in maintaining or improving the health of native and tame perennial rangeland and thus can improve ecological services and wildlife habitat (LEAP, 2015) (Steinfeld, et al., 2013) (Tilman, et al., 2001).

This contrasting picture illustrates how important it is to quantify the impacts of livestock on biodiversity. Quantification is necessary to understand the extent of the impact of livestock production on biodiversity in a given land base. It can help assess the potential impact of management strategies geared primarily for biodiversity compared to strategies geared towards efficient and competitive livestock production, and identify potential "win-win" situations. Quantifying those impacts can also ensure that the environmental burden is not shifted from one environmental category to another. In some cases, for instance, the biodiversity benefits of livestock production may be offset by its GHG emissions (Teillard, et al., 2014). Grassland systems often involve lower feed digestibility which results in higher CH_4 emissions when eaten, but they can be crucial for maintaining biodiversity-rich habitats (Bignal & McCracken, 2000) (Teillard, et al., 2014). Similarly, the trade-off between increasing the efficiency of livestock production through crop-based feed improvements and the additional pressure this creates for expansion and intensification of croplands needs to be carefully assessed. Particularly, the impact depends upon whether this increase in annual crop feed production occurs in already cultivated areas, which could spare other land for perennial forage land covers (Milchunas & Laurenroth, 1993) (Ewers, et al., 2009) (Phalan, et al., 2011).

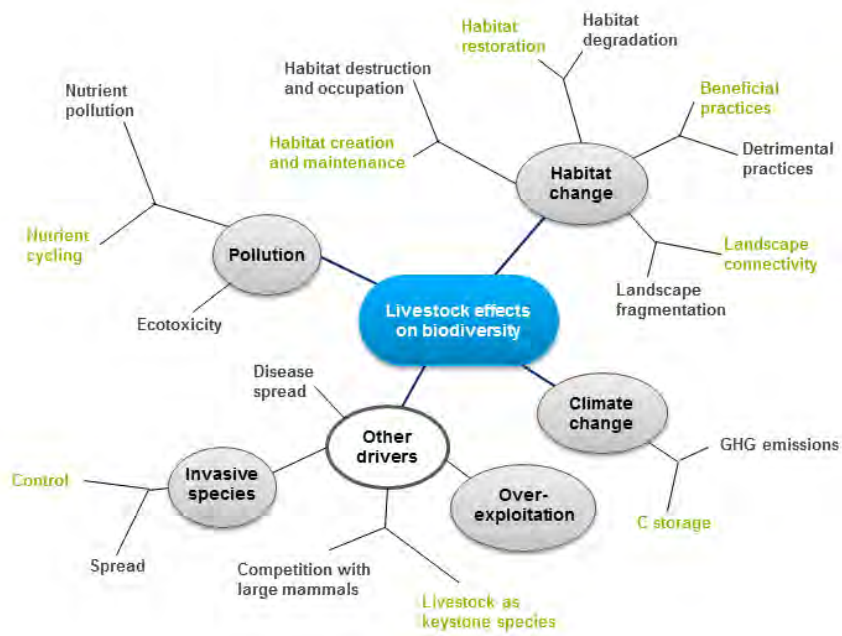

Figure 3-6 Overview of the pressures (brown) or benefits (green) that livestock have on biodiversity. The five main drivers of biodiversity loss recognized in the Millennium Ecosystem Assessment (2005) appear in grey circles (Adapted from (LEAP, 2015))

In the following sections, we briefly review the main potential sources of biodiversity impacts from beef production systems and the way these can be measured. Since beef cattle are the most abundant livestock using land in Canada, and are perceived as a main contributor to livestock impacts on biodiversity, we include impacts from livestock in general in the review. When possible, the impacts of beef cattle or those of the Canadian industry in particular are highlighted.

3.3.1.1 Impacts of livestock on land use change

Impacts of beef production on habitat change would be mainly due to the conversion of natural and semi-natural areas to cropland for the production of forage crops or feed, and to the conversion of native grasslands to improved pastures. (That said, conversion of native or tame perennial rangelands to cropland also occurs for human food production (wheat, canola), not feed crops, as these will have a greater return for the farmer). Beneficial impacts for wildlife can also occur when beef farming enables the maintenance of semi-natural grasslands (Figure 3-6). These habitat changes can be positively or negatively modulated by the cattle management practices that affect grazing intensity.

Habitat loss or maintenance

Land is a limited resource and the continued conversion of natural ecosystems into crop and pastoral land is deemed undesirable for biodiversity and humans alike (Lambin & Meyfroidt, 2011). Conversion of natural or semi-natural land to tame pastures or feed crops often leads to habitat destruction and subsequent loss of biodiversity. Conversion to cropland or tame pastures also contributes to the growing fragmentation of native grasslands, and ensuing species loss, species extinctions or landscape functional simplification (Devictor, et al., 2008). Even intensive minimal land use production systems (e.g. feedlots in the US and Canada) can be an indirect cause of biodiversity degradation, through intensive cultivation of feed crops (LEAP, 2015).

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In North America, large extents of native grasslands and pastures are being managed more intensively or converted to cropland (Gibson, 2009), both for crops used for human use and for feed crops. This is causing important declines in biodiversity, notably for grassland bird species (Askins, et al., 2007) (Coppedge, et al., 2001) (Freemark and Kirk, 2001; Henderson et al., 2004).

In Canada, the expansion and intensification of agriculture has significantly altered the structure and degraded the function of many natural ecosystems in the last century (SCBD, 2004). It is estimated that from 1981 to 2001, Canada's agricultural land lost 5% of its capacity to sustain biodiversity, mostly as a result of agricultural intensification in the Eastern provinces (Javorek, et al., 2007). Overall, increases in production intensity and use of inputs such as those witnessed in Canada in the last decade reduce species richness and the capacity to provide suitable habitats for terrestrial wildlife (Flick, et al., 2012) (Eilers et al., 2010;Freemark and Kirk, 2001). Non-cropland and permanent cover, such as native rangelands and unimproved pasture, provide the highest capacity to sustain biodiversity in agricultural areas, while croplands provide the lowest capacity (Flick, et al., 2012) (Freemark & Kirk, 2001) (Javorek, et al., 2007) (McMaster & Davis, 2001). The main source of concern for biodiversity is not so much the conversion of forests and wetlands, which has slowed down in recent years, but losses of native prairie grasslands which exceed those of other major biomes in Canada. Although the major loss of native prairie grasslands occurred in the first half of the 20th century, conversion of grasslands to cropland has been an ongoing process, such that by 2003, over 97% of tallgrass prairie, 71% of mixed prairie and 48% of shortgrass prairie was lost (Federal Provincial and Territorial Governments of Canada, 2010) resulting in a high level of fragmentation (Roch & Jaeger, 2014). The disappearance of grasslands has led to an overall loss of 44% of the populations of grassland species since the 1970s, with individual species showing significant declines of up to 87% (Downes, et al., 2013). Much of the remaining prairie is used for livestock grazing, so conservation of prairie species actually largely depends on sustainable cattle grazing practices (Ranellucci, et al., 2012).

Conversely, the maintenance of native or extensively managed grasslands can benefit biodiversity. Extensively managed permanent grasslands are among the habitats with the highest biodiversity level (Baldock, et al., 1993) (Cremene, et al., 2005). In many parts of the world, grasslands have been shaped by a long history of agricultural practices, and species have adapted and specialized to these landscapes (Jones-Farrand, et al., 2007) (Poláková, et al., 2011). Native grasslands across the Great Plains of North America, for example, harbour many specialized species as well as threatened or endangered species of all taxa (Jones-Farrand, et al., 2007) (Sieg, et al., 1999). Over the last decade, livestock production has increasingly been recognized as one of the conservation tools to maintain habitats against the contrasting and detrimental pressures to wildlife exerted by conversion to arable land or abandonment (Fuhlendorf & Engle, 2001) (LEAP, 2015). Grasslands are eminently dynamic systems, and without some disturbances, natural grasslands would be lost through the ecological succession of habitats of lower conservation value, with the loss of many specialized species (Fuhlendorf & Engle, 2001) (Henderson & Davis, 2014). In many cases, large-scale abandonment may indeed lead to declines in habitat heterogeneity and species diversity, and result in regional extinctions. In addition, several decades will be needed for these habitats to regain their original biodiversity value, if they do not become dominated by common or invasive species (Henderson and Naeth, 2005) (McLachlan & Knispel, 2005).

Habitat degradation or improvement

Inappropriate grazing management in existing pastures can be responsible for the degradation (as opposed to destruction) of habitats. Grazing is the primary mechanism by which livestock affects biodiversity in seeded pasture or natural rangelands (Rook, et al., 2004). Rangelands include tallgrass, mixed grass and shortgrass prairies, but also other habitat types such as shrublands, wetlands, woodlands or steppes. The dietary preferences of livestock result in selective defoliation, which in turn leads to the creation and enhancement of sward structural heterogeneity, affecting the suite of invertebrates that rely on this vegetation for food, reproduction or shelter, and thus botanical and faunal diversity (Vickery et al., 2001). Livestock may also shift the competitive balance among species in the vegetation community through treading, nutrient cycling and propagule dispersal (Rook, et al., 2004). Treading opens up restoration niches for gap-colonizing species and affects subsequent plant growth in case of soil compaction in particular. In addition, dung and urine patches create hotspots of nutrient enrichment and act as a natural fertilizer facilitating soil bacterial activity (Murray et al 2014). Livestock also acts as a vector for plant seed dispersal.

A recent global meta-analysis suggests that biodiversity changes in rangelands along a gradient of grazing intensities: natural rangelands have the highest biodiversity values, followed by abandoned grasslands or rangelands with moderate stocking rates (Alkemade, et al., 2013). It is clear that overgrazing, when livestock density is beyond

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the carrying capacity of the landscape, can have adverse consequences on biodiversity, both in low-input systems and in improved grasslands (reviewed in (LEAP, 2015)). But even limited intensity increase in grazing systems, whether through the higher use of inputs (pesticides and fertilizers) or the sowing of highly-productive strains of grass, can lead to biodiversity damage (Kleijn, et al., 2009)(Vickery et al., 2001). For instance in Canada, unpublished data from Thorpe (2007) suggest that the species composition of native grasslands used as rangelands was moderately to severely altered by livestock grazing in almost 50% of the plots in the Aspen Parkland and Mixed Grassland regions of Saskatchewan. However, grazing impacts are complex and the way that livestock modify natural habitats depends upon the species under consideration, the grazing regime (i.e. grazing intensity, timing, frequency and the livestock species), climate, and other biotic and abiotic factors, including the type and quality of the land base (Olff & Ritchie, 1998) (Ryan, et al., 2002).

In Canada, large areas of native grasslands are used as rangelands for livestock grazing. In mixed grass prairies, grazing intensity and timing play only a secondary role after climatic factors in controlling trends in plant species composition and production (Biondini, et al., 1998) (Vermeire, et al., 2008). Species diversity and plant heterogeneity appear to peak at intermediate grazing pressures (Collins, et al., 1998) (Virk & Mitchell, 2014). Two long-term grazing exclusion studies in the Northern Great Plains of Alberta show reduced species diversity, although litter biomass increases (Henderson, et al., 2004) (Willms, et al., 2002). Other studies have showed that low to moderate intensity grazing does not significantly reduce soil quality or species distributions (Bai, et al., 2001) (Dormaar, et al., 1997), nor the survival of ground nesting song birds (Lusk & Koper, 2013). Some soil meso-fauna may in fact benefit from grazing protection in both low and high productivity pastures (Miller, et al., 2014). In contrast, heavy grazing has been shown to lead to decline in standing biomass, soil organic matter and plant spatial range (Biondini, et al., 1998) (Virk and Mitchell, 2014). These effects may be mediated by the quality of the land, with upland areas able to sustain species richness and heterogeneity even at high grazing pressures (Milchunas & Laurenroth, 1993) (Warren, et al., 2008) (Bylo, 2014) (Lwiwski, et al., 2015).

Similarly, studies show that grazing generally has a positive effect on biodiversity in tallgrass prairie, with higher plant species richness and diversity at moderate grazing intensities (Hickman, et al., 2004) (Symstad & Jonas, 2011). The re-establishment of grazing in anthropogenically stressed native tallgrass prairie was suggested as a conservation tool to enhance species diversity (Collins, et al., 1998) after the re-establishment of grazing by bison reversed species loss due to frequent burning in tallgrass prairie in Kansas.

In contrast, in shortgrass prairie, one review suggests neutral or negative effect of grazing on biodiversity (Symstad & Jonas, 2011), although a 55-year study in shortgrass rangelands in Colorado shows that plant species diversity and evenness were greatest in lightly and moderately grazed pastures (Hart, 2001). Rough fescue grasslands have little resistance to continuous or heavy grazing (Krzic, et al., 2014) (Willms, et al., 1990), in particular during the growing season (Desserud & Naeth, 2014) and could take more than 75 years to fully recover from the impacts of over-grazing (Krzic, et al., 2014).

The grazing regime can further modulate these impacts. Traditional rangeland management techniques in North America aim for even use of forage, however cattle often favour the most productive, most palatable forage species which can result in homogeneous, species deprived, landscapes (Fuhlendorf & Engle, 2001). But there is growing recognition that spatially or temporally heterogeneous grazing, under a variety of stocking rates, could be an efficient conservation tool (Fuhlendorf & Engle, 2001) (Lwiwski, et al., 2015). For example, (Ranellucci, et al., 2012) showed that spatially heterogeneous but temporally stable areas of livestock use can increase the species richness and diversity of grassland bird communities by creating a diversity of micro-habitats.

3.3.1.2 Other impacts (pollution, climate change and invasive species)

Other parts of this study have quantified climate change, soil and water pollution aspects linked to livestock production, all of which can have cascading adverse effects on biodiversity, which were reviewed in FAO LEAP (2015) (see also Figure 3-6).

In short, pollution can reduce biodiversity in terrestrial and aquatic systems alike. Nutrient leaching and run-off from animal manure and fertilization of feed crops can have direct negative effects on terrestrial wildlife communities (Billeter, et al., 2008) (Vickery, et al., 2001). In aquatic systems, the excess nutrient loads in water can lead to eutrophication and biodiversity loss. Livestock production is also responsible for emissions of nitrogen gases into the atmosphere. The subsequent N deposition is a very important driver of species change (Sala, et al., 2000), favouring

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species adapted to more fertile soils and resulting in net biodiversity loss (McClean, et al., 2011). Use of pesticides, including for crops used for livestock feed, has been associated with decline in bird populations (Fuller, 2000), while veterinary products used for livestock have been known to contaminate other species or ecosystems (Soto, et al., 2004).

Livestock production also stimulates another two important drivers of biodiversity loss: climate change and invasive species. Livestock, and particularly beef cattle, is a significant contributor of GHG emissions and thus of climate change impacts (Havlík, et al., 2014). In Canada, this amounts to approximately 2.4% of Canada's overall GHG emissions (see Figure 3-20). Climate change compels species to shift their geographical range and modifies the selection pressure on them, thereby disrupting entire community structures and possibly leading to biotic homogenization. On the other hand, grazed grasslands can act as substantial carbon sinks (Turbé, et al., 2010). Livestock production is a considerable vector of spread of invasive plant species, along with the forestry and ornamental plants sectors. Indeed, several fast growing grasses have been introduced in feed crop fields, and grazing livestock can also contribute to seed dispersal. Invasive plant species now dominate the landscape in large areas of America for instance (Pimentel, et al., 2005). Semi-natural areas most prone to invasions are the most degraded ones. For instance, in British Columbia (Canada), grasslands are in early stages of succession characterized by many invasive species following grazing by domestic livestock (Federal Provincial and Territorial Governments of Canada, 2010). While cattle can contribute to the spread of invasive species, it may however not be to blame for the initial introduction of these species, which may have originated from gardens or introduced perennial crops.

3.3.1.3 Measuring the impacts of livestock on biodiversity

Although there is much evidence of the global impact of livestock on biodiversity, quantifications are scarce. Measuring biodiversity impacts remains a thorny issue and no consensus has yet been reached about how to do it (Souza, et al., 2015) (Teixeira, 2014). The methodological challenges stem both from the complexity of biodiversity, the many different ways in which it can be impacted (Figure 3-6), as well as from the difficulty in integrating biodiversity impacts in classical LCA methodologies or other impact assessment frameworks. A recent effort from the FAO-LEAP initiative reviewed biodiversity indicators assessment and footprinting methods in the context of livestock production and is currently developing guidelines for the quantitative assessment of biodiversity in livestock (LEAP, 2015).

Biodiversity itself is a complex issue

Biodiversity can be understood as the diversity of life as a whole. It is thus a complex concept, including multiple hierarchical levels (genes, species, communities and ecosystems) and different attributes, such as structure, composition and function (Noss, 1990). The broadness of biodiversity means that many different indicators have been used to measure biodiversity. While some indicators focus on species and emphasize the importance of retaining species richness or abundance at different geographical levels, others focus on the extent or functionality of the original ecosystem. The advantage of these state indicators is that they provide a direct measure of features of biodiversity (e.g. species level), but it is challenging to tease apart the specific impacts of a single sector, such as beef farming, on these trends (LEAP, 2015). Yet other indicators focus on the drivers and pressures causing biodiversity loss because they are usually easier to monitor. Pressure indicators do not provide a direct measure of biodiversity but they are closely linked to management decisions for which a direct link with biodiversity has been evidenced in the literature. For livestock production, pressure indicators could include area of semi-natural grassland, rate of habitat conversion or livestock stocking rates (LEAP, 2015). Finally, response indicators describe management decisions and are often more loosely related to biodiversity itself.

Another issue is that biodiversity impacts are a function of place, not just units of products. The impact on biodiversity of growing beef cattle is not the same in native prairies as in already species-impoverished cropland or minimal land intensive production systems. In addition, the cumulative impact on biodiversity does not scale linearly with the volume of production. This is directly related to the fact that relationship of species diversity to major environmental gradients, such as productivity, changes with spatial scale (Chase & Leibold, 2002). In particular, species richness is exponentially related to area (Drakare, et al., 2006) (Rosenzweig, 1995). Thus, logging 1,000 ha of tropical forest in one continuous area is not the same as logging 100 scattered 10 ha patches. In the latter case, the disturbance is local and may only have a limited impact on regional biodiversity, whereas in the former it can isolate populations and lead to reduced populations or extinctions of local species. The impact of a unit of production is thus a function of the type of production system and its location.

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Therefore, practical decisions need to be made about which level and which aspects of diversity to measure in an impact assessment. This decision needs to be based on data availability as well as which aspects of biodiversity are most relevant for the question at hand. Specifically, the choice of indicators should be guided by the need to address both the positive and negative impacts of livestock on biodiversity and by its ability to reflect the mechanisms which are the main source of biodiversity impact. Unfortunately, all mechanisms cannot easily be captured in a single analysis, although some composite biodiversity indexes can be developed (Willis, et al., 2012).

Impact assessment of livestock production

There is also no consensus regarding the best framework to measure impacts on biodiversity. Proposals on how to quantify the biodiversity value of livestock production and how to determine the contrasting or reference situation are manifold. So far, most efforts including biodiversity impacts have focused on its link with land use (Souza, et al., 2015) and can be classified into three broad approaches (described in the following paragraphs). These approaches, however, differ in the way they account for biodiversity change, from a simple assessment of the baseline (current beef farming production system) to a full comparison against a reference situation or different policy situation.

The first approach is simply using the Drivers-Pressures-State-Impact-Response (DPSIR) analytical framework. This framework characterizes the causality chain leading to impacts and can be used to prioritize the biodiversity indicators used for further analysis in different policy contexts or at broad spatial scales (EEA , 2007). In this framework, livestock production is a pressure affecting the state of biodiversity and impacting the ecosystem functions. Livestock production is linked to drivers such as population growth and demand for meat products. The indicators chosen to reflect this causal chain can then be used in integrated assessment models of global environmental change to support scenario analysis, such as with Globio3 (Alkemade et al., 2009). Alternatively one or several indicators can be used within a bounded spatial area to allow more detailed assessment methods, for instance, to differentiate the effect of different practices (LEAP, 2015). However, although the didactic clarity is appealing, the apparent simplicity can be misleading. The relations between the DPSIR categories may in reality be more complex and are usually not fully understood (Maxim, et al., 2009).

The second approach is a top-down analysis of national production statistics (Elferink & Nonhebel, 2007) (Eshel, et al., 2014). It estimates the land requirements of livestock production of each feed category (e.g. pasture, feed) for each animal type. This partition is based on relatively solid data about the number of animals raised, characteristic feed rations and crop production data, accounting for off-farm production impacts if needed. The environmental burden is then attributed to each animal category per unit of calorie or mass output. The key challenge with this approach is obtaining the data for all the parameters needed in the calculations, such as feed rations and fraction of pasture in beef diets (Eshel, et al., 2014) and getting at the required resolution. This approach has so far only been used to measure the land use footprint of livestock production, and links with measures of biodiversity have not been considered.

LCA, on the other hand, is a bottom-up approach and the prevailing option for rigorously quantifying impacts along the production value chain. It is a very useful tool to conduct broad assessment of impacts on biodiversity and to find hotspots of impact along the supply chain or among spatial entities (LEAP, 2015). It focuses on the links between the different categories of impact. But assumptions used for integrating land use into LCA lead to an oversimplification, and the large amounts of biological diversity data needed to make accurate models means LCA approaches accounting for biodiversity are not easily nationally scalable (Eshel, et al., 2014). A review of LCA studies of livestock production systems (de Vries & de Boer, 2010) shows that quantification of biodiversity impacts in LCAs is still an emerging area of work. Impacts on biodiversity are mainly addressed indirectly, as a result of land surface occupied, but there are also some attempts at specifically assessing loss of biodiversity. A framework (Koellner et al., 2013) (Mila i Canals, et al., 2014) and several characterization factors (reviewed in (Curran, et al., 2011) have recently been proposed to compute biodiversity impacts through land use in LCAs (Teillard, et al., 2014).

Characterization factors are the values that translate life cycle inventory data into their damage impacts. Characterization factors for biodiversity have been developed in terms of species richness—notably plant diversity (de Baan, Alkemade, & Koellner, 2012) (Mueller, et al., 2014), net primary productivity, biodiversity damage potential (de Baan, Alkemade, & Koellner, 2012), mean species abundance (Alkemade, et al., 2009), habitat suitability models (de Baan et al., 2015) (Geyer, et al., 2010) and species threat (de Baan, et al., 2015). The UNEP/SETAC life cycle initiative is attempting to drive global consensus on characterization factors and impact indicators for biodiversity in

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the context of LCA (Jolliet, et al., 2014). The availability of meaningful characterization factors and the level of biogeographical differentiation in land use data are what constrain the level of analysis of the LCA. Initially the characterization factors were based on global biodiversity assessments (Lindeijer, 2000) (Weidema & Lindeijer, 2001) and thus had limited empirical basis. Later attempts have thus been largely restricted to selected geographical regions where good datasets can be available to determine the value of both reference and used land (Geyer, et al., 2010) (Guerci, et al., 2013) (Koellner & Scholz, 2008) (Michelsen, 2008). The more recent attempts have used a regionalized global approach to compute impacts of livestock on biodiversity through land use, accounting for off-farm impacts (de Baan et al., 2015) (Mueller, et al., 2014).

Choice of reference or contrasting situations

The basic idea of assessing land use impacts of livestock production is to quantify the change in biodiversity due to the transformation and occupation of the land by livestock. Biodiversity is indeed changing over time due to evolutionary dynamics and other anthropogenic pressures, so the effect of livestock production on biodiversity needs to be isolated. In other words, this means comparing the current situation with livestock production to a reference situation in the absence of livestock production, or under different intensity of livestock production. This comparison should be able to reflect positive or negative biodiversity impacts. For instance, a decline in biodiversity is expected following the removal of extensive grazing on species-rich grasslands, whereas an increase in biodiversity is expected following the removal of intensive grazing on grass monocultures (LEAP, 2015).

The choice of the reference situation is a value choice that determines whether the biodiversity impacts will be positive or negative (LEAP, 2015) (Mila i Canals, et al., 2014). The reference situation for biodiversity can lie either in the past, present or future. The reference can be the potential natural vegetation, i.e. the future state of vegetation that would develop in the absence of human intervention. It can also be measured relative to the quasi-natural land covers that remain in each biome/region (e.g. natural forest, wetlands and natural grasslands). This choice implies that current land use impacts are similar to those that occurred a long time ago. Alternatively, the reference can be defined as the current or a recent mix of land uses, based on the assumption that recent land use processes have higher impact than older ones (LEAP, 2015). However, the current mix of land uses is a moving yardstick and it is thus recommended to use quasi-natural land cover (Koellner et al., 2013). Several reference scenarios can be developed to reflect past (quasi-natural land cover) versus future risks (future agricultural use) (de Baan et al., 2015).

Alternatively, a contrasting policy scenario can be developed to assess the impacts of changes in livestock production on biodiversity. For instance, Westhoek (2011) modelled how substitution of red meat or reduction of consumption of livestock products by 10%, 20% and 50% would impact biodiversity. Such scenarios need not always reflect current preferences but are helpful in identifying the contribution of meat production.

3.3.2 Development of a methodology to assess the impacts of beef cattle on biodiversity

This is a pioneering attempt to develop robust quantitative indicators to monitor the biodiversity footprint of an industry sector at the national level. The approach aims to be inclusive, accounting for both the grazing and feed requirements of cattle, and consistent with ongoing methodological advances and LCA methodology such that it can be easily integrated in further analyses at a later stage. The limited scope of this study and data availability somewhat constrained the level of analysis, but the future directions (section 3.3.5) highlights some steps that could be taken to improve this approach in the future.

3.3.2.1 Scope and data sources

In the LCA approach, the total land use impact is calculated as the sum of occupation and transformation impacts. Occupation impacts quantify how much biodiversity is lost during the land use phase, while transformation impacts account for the reduction in biodiversity after a (hypothetical) future land abandonment and time lag before biodiversity recovers to a level comparable to the pre-transformation state (de Baan et al., 2015).

In this study, we consider only occupational impacts since data on restoration times of different ecosystems are limited. We thus focus on the land use impacts of beef on biodiversity, which are a function of the area of land needed to raise beef cattle and how the quality of this land affects biodiversity (Figure 3-1). The biodiversity value of this land needs to be estimated, based on land cover and biodiversity data. Land use impacts related to off-farm feed

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cultivation outside of Canada are not considered given that rations calculations in the ELCA section show that most beef feed requirements can be met by Canadian crop productions.

Biodiversity data

Given the complexity of measuring biodiversity impacts, we screened potential data sources based on the following criteria:

- **Sound**: based on scientifically sound principles, such as defined protocol for measuring biodiversity state, pressure or response; use of systematic sampling grids
- **Meaningful**: can be linked relatively easily to beef production systems (without data-intensive manipulations beyond the scope of this study)
- **Relevant**: provide national coverage for both public and private land; adequate spatial grain; recent data, measured at regular time intervals and updatable in the future
- **Available**: the data could be readily accessed and/or a contact person for support was readily available

None of the three widely-used and globally available datasets appeared well-suited to reflect the impacts of beef production systems in Canada (Table 3.1). Biodiversity indicators based on the red list are a useful tool for targeting conservation actions (Butchart, et al., 2004) (Butchart, et al., 2005). The IUCN red list is a widely-recognized system classifying species according to their risk of extinction and the causes for these threats. However, the red list is not meaningful for measuring the impacts of beef production in Canada, since only 18 species in a critically endangered, endangered or vulnerable status in Canada could be partly impacted by livestock farming and ranching.[40] The Mean Species Abundance (MSA) index is increasingly used as an indicator of biodiversity loss in different policy situations (Maes, et al., 2012) (Pereira, et al., 2010) and has been applied in the context of global livestock production (Brink, et al., 2010) (Westhoek, 2011). The MSA represents the mean abundance of current species relative to their abundance in undisturbed ecosystems (Alkemade, et al., 2009). A major limitation of this index is that currently MSA values of each land use and intensity class are measured at the global level and do not account for regional differences (Teillard, et al., 2014). In the context of livestock production, the biodiversity value of grazing lands of varying intensity is very likely to differ between Canada and Amazonia, for instance, but this is not currently captured, and there is not always sufficient data to develop MSA values at finer scales, although there is ongoing work in this direction (de Baan, et al., 2012) (Koellner, et al., 2013). Another prevailing approach consists of capturing the change in ecosystem services provision by changing landscapes, such as ecosystems under pressure from livestock production. InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a tool that was developed to provide such information. It can model habitat quality and rarity as proxy for biodiversity, ultimately estimating the extent of habitat across the landscape and its state of degradation. However, running these models for Canadian beef production requires primary data on threats from beef production and a map reflecting the sensitivity of the different habitats to these threats. The ecological value of landscape could also be estimated with the Local Ecological Footprinting Tool (Willis, et al., 2012). This recently-developed method uses existing globally available web databases to provide a score reflecting five ecological features (the biodiversity, vulnerability, connectivity, fragmentation and resilience) of the landscape for every 300 m parcel, but the tool was not yet fully operational at the time of this study.

At the Canadian level, three main data sources were identified that could be tailored to assess the impacts of beef production on biodiversity (Table 3.1). The first is the data from the Breeding Bird Survey, which could be used to measure indicators of the state of biodiversity throughout Canada (e.g. species richness, abundance, community composition or functional diversity). Birds are an established indicator for farmland ecosystems (Gregory, et al., 2005) (Butler, et al., 2007), however tailoring these data to measure the impacts of beef production was beyond the scope of this study. The second data source identified, the Coverage of Protected Areas, is a frequently used response indicator of the effectiveness of conservation. Several indicators can be used, such as looking at the extent of protected areas found in pastures. But such indicators are rather descriptive, and of limited value for understanding the impacts of beef production, as cause and effect are difficult to disentangle. The third data source, habitat suitability models, is becoming more frequently used to identify conservation priority areas. These models combine species geographical ranges, habitat preferences and environmental data to identify unsuitable habitat within the species ranges (Rondinini, et al., 2011). Such an approach was recently used in an LCA to assess the land use impacts of crop production on mammal species (de Baan et al., 2015). In the same way, Agriculture and Agri-Food Canada (AAFC) has developed a Wildlife Habitat Capacity of Farmland Indicator (WHAFI), which provides a multi-

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[40] As of January 2016, using the following filters: Assessment: critically endangered, endangered and vulnerable species; Systems: terrestrial; Location: Canada; Threats: livestock farming and ranching (Source: http://www.iucnredlist.org/search)

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species assessment of broad-scale trends in the potential ability of Canadian agricultural landscape to provide suitable habitat for populations of terrestrial vertebrates (Eilers, et al., 2010). The indicator relates the various habitats used by birds, mammals, reptiles and amphibians to five broad land cover categories making a significant contribution to biodiversity. It shows that wetlands, woodlots, riparian areas and natural pasture are the most important habitat elements for wildlife in the agricultural landscape. The indicator, by associating land area, land use and wildlife use (habitat capacity), improves our understanding of how sector, market and policy issues can affect the availability of wildlife habitat on agricultural lands. This indicator was just recently updated to leverage yearly earth observation data from the Annual Crop Inventory at a 30 m pixels resolution (ISO 19131 AAFC Annual Crop Inventory—Data Product Specifications), to address some of its initial limitations and cover a broader range of agricultural land covers, including neighbouring natural and semi-natural land covers. This indicator fulfills all the criteria (Table 3.1), being scientifically sound, meaningful, relevant and made available for this study with the kind support of Steve Javorek and Matt Grant of AAFC.

The province of Alberta is leading the way in terms of environmental monitoring, and particularly biodiversity monitoring in Canada (through the Alberta Biodiversity Monitoring Institute (ABMI)). Several biodiversity or livestock relevant datasets were thus available in Alberta that were not available for the whole of Canada (Table 3.1). Because of their limited spatial coverage, these datasets were not considered relevant, although they could be used to validate or refine some broader findings at the national level in future analyses.

As a result of this screening process, the Wildlife Habitat Availability on Farmland indicator was retained as the basis for this study.

Table 3.1 Evaluation of the potential data sources available for measuring the biodiversity impacts of beef cattle production in Canada

Coverage	Dataset	Data owner	Sound	Meaningful	Relevant	Available
Global	Red List data	IUCN	Yes	Moderate	Yes	Yes
	Mean Species Abundance	Globio	Yes	Moderate	Yes	Limited
	Local Ecological Footprinting Tool	University of Oxford	Yes	Moderate	Yes	No
	InVEST	University of Stanford	Yes	Moderate	Yes	Yes
National	Breeding Bird Survey	Bird Studies Canada	Yes	Moderate	Yes	Limited
	Extent of Protected Areas	Environment Canada	Yes	Moderate	Yes	Yes
	Wildlife Habitat Availability on Farmland Indicator (and Habitat Capacity Index)	Agriculture Canada	Yes	Yes	Yes	Yes
Alberta	Grassland Vegetation Inventory	ABMI	Yes	Moderate	Limited	Yes
	Wildlife Sensitivity Maps	ABMI	Yes	Yes	Limited	Yes
	Rangelands assessments	ABMI	Moderate	Yes	Limited	Potentially
	Rangelands stocking rates	ABMI	Moderate	Moderate	Limited	Potentially

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3.3.2.2 Proposed methodology

Our approach is based on a customization of the Wildlife Habitat Availability on Farmland Indicator (WHAFI) approach at the provincial level. Based on provincial feedstock requirements for beef cattle (grazing, crops) converted into land cover uses, specific averaged habitat capacities (MCVs, see below) were applied to agricultural areas in order to obtain a high-level habitat capacity indicator, for beef cattle related and non-related agricultural lands.

Habitat suitability models

Our method is based on habitat suitability models (HSM), which assess the capacity of a given land use to provide suitable habitat for a particular species. This approach allows modelling which species might be affected by habitat conversion and has been used extensively to predict the potential effects of habitat alteration. The output from the model aids in the evaluation of land management alternatives through the quantification and visual representation of habitat quality across a landscape.

We used HSM that were developed by Agriculture and Agri-Food Canada (Javorek et al., 2011, 2007) and recently updated for 587 species of wild terrestrial vertebrates in Canada in four different taxonomic groups (137 mammals, 370 birds, 42 amphibians and 38 reptiles). Javorek et al. (2007) compiled the species lists using information from authoritative wildlife guidebooks,[41] and habitat use information was gathered from a literature review and expert opinion (Javorek, et al., 2007). For each species, each 30 m grid cell (Earth Observation Data)/Soil Landscapes Unit polygon (SLC version 3.0) containing agricultural land cover was classified as primary habitat (without this habitat the species cannot use the area), secondary habitat (species will use several habitat types for the same purpose), tertiary habitat (habitat not required, but species occasionally observed in it) or unsuitable habitat. A habitat capacity matrix was then constructed for each terrestrial vertebrate species known to use agricultural land and adjacent habitats in Canada for one or more specific habitat requirements (breeding, feeding, loafing, cover, staging and wintering). Effects of landscape configuration or neighbourhood effects were not considered as this would require additional species-specific information on landscape requirements (e.g. dispersal distance, distance of secondary to primary habitat to allow species survival, etc.) (de Baan et al., 2015).

The WHAFI (as described in section 3.3.2.1) has mainly been applied to assess the impact of relative changes in land cover types on the wildlife habitat capacity of agricultural land in Canada at the SLC polygon level. To better reflect the impact of beef cattle production at a broader scale, we customized the WHAFI for agricultural land at the provincial level. The approach used for the development of the index was as follows:

- The average habitat use values for breeding and feeding (matrix combined values, MCVs) of each land cover at the SLC polygon level were obtained. The average MCV of each land cover in each ecozone was then derived, since there was little variability among these values. These average MCVs represent habitat capacity intensity values (capacity to provide habitat to various species per unit of surface) calculated through the WHAFI methodology (See Figure 3-7 below).
- A specific **habitat capacity index** was then computed at the provincial level in a similar way the WHAFI index is calculated at the SLC polygon level. The average habitat use values for breeding and feeding (MCVs) of each land cover at the provincial level were proportionally related to the relative area of that land cover within the land used for agriculture in that province:

$$Index_p = 10^{-3} \times \sum_i MCV_{i,p} \times Area_{i,p}$$

Where:
$Index_p$ = habitat capacity index of the province *p*
$MCV_{i,p}$ = average MCV for the land cover *i* in the province *p*
$Area_{i,p}$ = area grown/observed of the land cover *i* in the province *p* (m2)

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[41] The species list was compiled using information from authoritative wildlife guidebooks (Godfrey 1966; Behler and King 1996; Whitaker 1996)
The *Wild Species 2000, General Status of Species in Canada* Report (Environment Canada 2001) was used to generate provincial species lists
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Figure 3-7 provides the breeding and feeding habitat capacity values (MCVs) of the 20 largest land covers areas in this study. The value of a particular land cover type was based on the number of species it supported in a given ecozone and its habitat value to them (i.e. whether it is primary, secondary, tertiary or not used), following Javorek (2011). The importance of these land covers for wildlife varied greatly among ecozones.

Consistent with previous studies and expectations, natural and semi-natural habitat land covers show the highest MCVs. Wetlands and riparian areas ranked highest, followed by grasslands and woodlands (mixed wood, conifers and broadleaves), with MCVs associated to these land covers ranging from 130 to 280. Pastures, including tame or seeded pasture and hay, ranked closely behind, with MCVs ranging from 60 to 110. Wheat, barley, oats and other cereals ranked next, with a marked decline in biodiversity value for breeding and feeding (MCVs range: 30 to 65). In contrast, all the other cultivated lands, including corn, had low value for biodiversity, across all ecozones (range: 0 to 40). It should be noted that these are the potential habitat use values based on SLC level data, but the actual biodiversity value depends on the mix of land covers present in a given ecozone. For example, the Prairies ecozone is dominated by agriculture land uses, in particular cultivated land, and offers little wildlife habitat. In contrast, in the Atlantic Maritime ecozone, the influence of agriculture on habitat is much less, offering considerable wildlife habitat options. Wetlands have not been categorized as a land cover related to cattle as it was difficult to assess the total area of wetland actually located on beef-related pasture land. Given their very high MCVs, this is conservative limitation which could be lifted in the future with better and more accurate wetland inventory on beef pasture land.

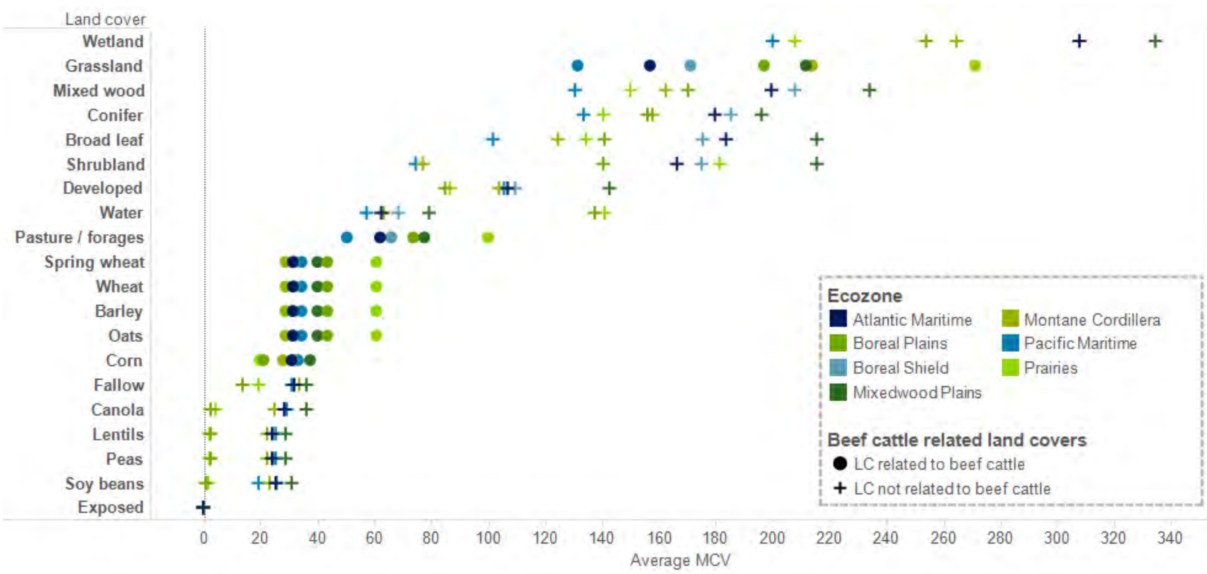

Figure 3-7 Matrix combined values (MCV) per land cover and ecozone (top 20 land covers with the largest areas represented)

Scenarios

The impacts of beef production systems on biodiversity in Canada were assessed by considering changes in production scenarios. Scenarios that are representative of the historical trends in the past ten years were chosen, with either a 10% increase or decrease in beef production compared to the current situation. The drivers for these changes could be shifts in consumption patterns as well as in meat, feedstock or crop prices, at national or global levels. For example, a 10% decrease in beef production could be caused by changed consumption patterns, with Canadians reducing their consumption of red meat. A 10% increase could reflect the response of the industry to a higher global demand for proteins, driven by population and income growth in developing countries.

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The two contrasting scenarios were modelled in a very simple way, to capture the main changes in land use that would be likely to occur (Table 3.2). A 10% change in beef production is considered too small to lead to a change in the area of natural pasture used for beef grazing (discussions with Brenna Grant, Canfax, 2015). However, a change in the number of cattle will result in a proportional change in demand for feedstock. Wheat is taken as the substitute for all feedstock crops and tame or seeded pasture, as it is the most prevalent cereal grown in Canada (Statistics Canada, 2013) – based on hay and field crops areas. A reduction in beef production is thus assumed to lead to the conversion of pastures and land used to grow feedstock to more intensive agricultural uses or cash crops for human use (i.e. malt barley, canola, soy, etc.); the option of land abandonment or regeneration is not considered. While we based our scenario on historical data showing a positive correlation between tame pasture areas and beef cow herd throughout historical cattle cycles (discussions with Brenna Grant, Canfax, 2015) and also on anecdotal evidence of increased grassland losses in recent years with higher corn and soy prices relative to beef in Dakota (Wright & Wimberly, 2013) (Reitsma, et al., 2015), we do recognize the limitations of those scenarios. They are inherently limited by two factors: first, it is very hard to provide a scientific empirical basis to one or another scenario as you never have fully controlled comparison situations, and second, our modelization capacities are limited to simple scenarios. This is an area that calls for future research to develop more robust and complementary scenarios and modelling.

Table 3.2 Description of the scenarios analyzed in the biodiversity and carbon soil sequestration sections

Scenarios	Impact on forage			Impact on field crops (corn and barley only)
	Summer pasture		Winter feed (hay)	
	Natural pasture	Tame/seeded pasture		
+10% in Canadian beef herd	No change	+10% obtained through land conversion from annual cropland to pasture land (spring wheat to tame pasture)	+10% obtained through land conversion from annual cropland to forage crops (spring wheat to tame hay)	**Barley**: +10% obtained through land conversion from spring wheat to barley **Corn:** +10% obtained through land conversion from winter wheat to corn
-10% in Canadian beef herd	No change	-10% obtained through land conversion from pasture land to annual cropland (tame pasture to spring wheat)	-10% obtained through land conversion from forage crops to annual cropland (tame hay to spring wheat)	**Barley**: -10% obtained through land conversion from barley to spring wheat **Corn:** -10% obtained through land conversion from corn to winter wheat

3.3.3 Results and discussion

3.3.3.1 Results

Figure 3-8 sets out a high-level results summary of the biodiversity impact of cattle farming, from a land use and habitat capacity perspective, both at the provincial and national levels. A provincial break-down of the aggregated agricultural land used for beef cattle production versus other agricultural uses is depicted on the left side, and their respective habitat capacity contributions are depicted on the right side. The habitat capacity contribution is based on the contribution of each agricultural land cover referenced in the Census of Agriculture 2011, with their associated average MCV, split by their use for beef cattle production or other agricultural uses.

The analysis demonstrates that beef cattle production represents 68% of its habitat potential in terms of species breeding and feeding across Canada, while using only 33% of the agricultural land occupied, highlighting the

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important role that extensive beef production systems play in maintaining native rangelands and their associated biodiversity.

Canadian beef cattle use 21.1 million ha for feed crops and pasture land, equivalent to 33% of all Canadian agricultural land. The land footprint of cattle peaks in the Western provinces (Alberta, British Columbia) where 46% of all agricultural land is used for beef production (see Figure 3-8). This footprint wanes eastward, representing 28% of all agricultural land in Manitoba, and less than 12% in the more intensive beef production systems in the Eastern provinces. Over two-thirds of the wildlife habitat capacity in agricultural lands in Saskatchewan, Alberta and Manitoba is found within the land used for raising beef cattle, and 60% in British Columbia (Figure 3-8). In contrast, in the Eastern provinces less than 25% of the wildlife habitat capacity in agricultural landscapes is present in the land used by beef cattle (Figure 3-8). This result is mainly due to the high proportion of grassland (native pasture) and seeded pastures used by beef cattle in Western Canada (Figure 3-5 for the area of pasture and Figure 3-7 for MCVs of grassland (native pasture) and pasture (tame or seeded pasture)). Moreover, the importance of corn in the Eastern beef cattle rations also plays a role, since corn has a significantly lower contribution to habitat capacity than other cereals such as barley or wheat (Figure 3-5 and Figure 3-7).

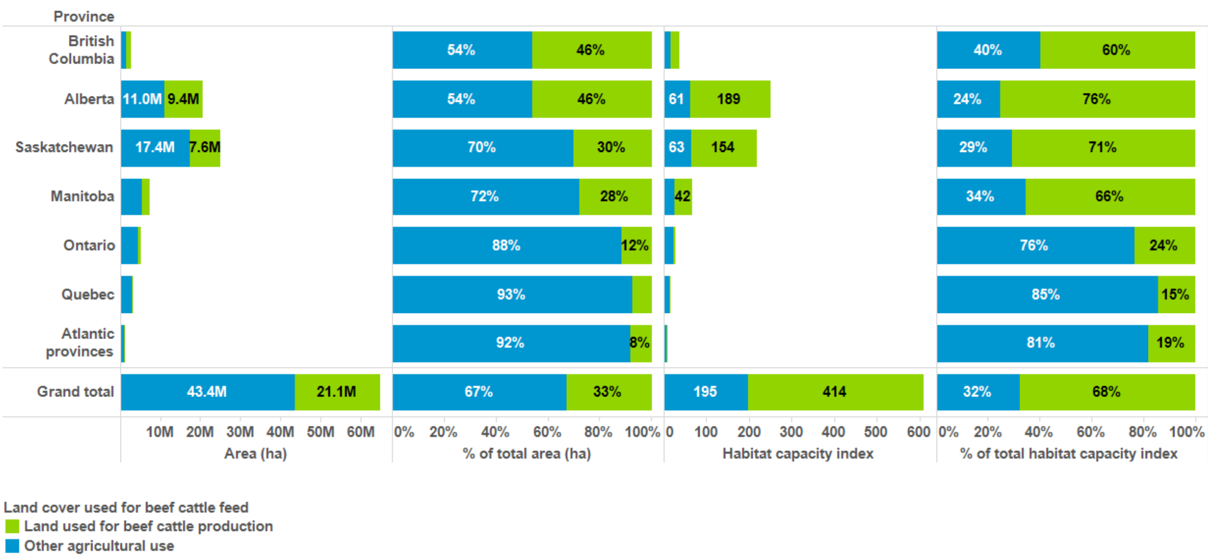

Figure 3-8 Habitat capacity index values in Canada, for land used for beef cattle production and other agricultural areas

Figure 3.9 provides a more detailed snapshot of the current land covers referenced in the Census of Agriculture 2011, with their associated average MCV, split by their use for beef cattle production or other agricultural uses. In Figure 3-9 the increase in the MCV is represented by the rising intensity of the green colour, where the natural land for pasture with highest MCVs are represented by the darkest green colour.

Scenarios analysis

Reflecting the scenarios described in 3.3.2.2 and in Table 3.2, a 10% change in the number of cattle in Canada impacts croplands and tame or seeded pastures. This represents only 38% of the area used for beef cattle production, as natural pasture is not affected. Moreover, switching barley to wheat does not impact the biodiversity value of the area required (based on the average MCV presented in Figure 3-7), while switching tamed pasture to wheat decreases the MCV and switching corn to wheat increases the MCV. The main conclusion of the scenario modelling is that, with a 10% variation of the beef cattle herd size, the overall impact on the total habitat capacity index presented in Figure 3-8 would be limited to a variation of one or two percentage points.

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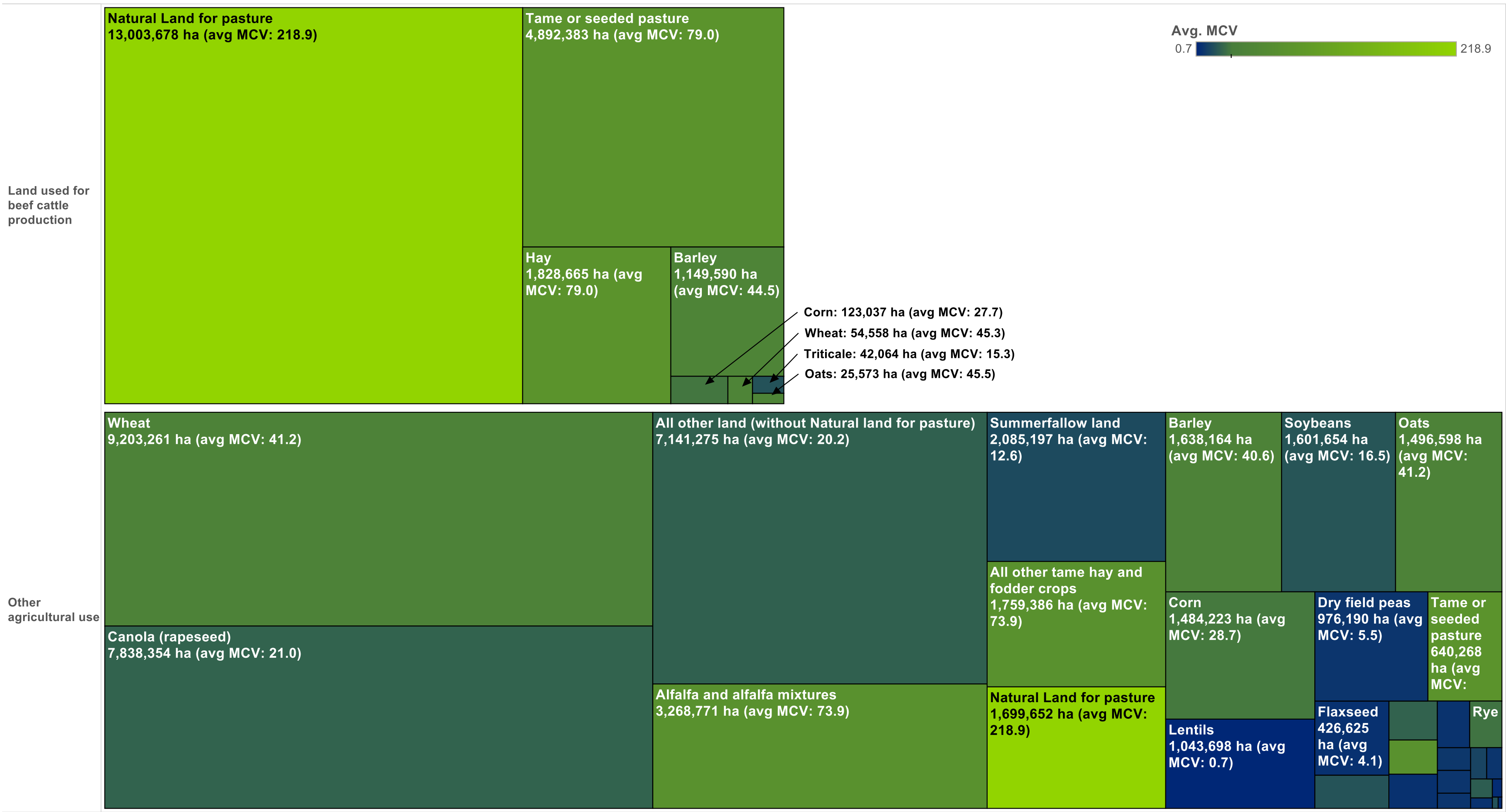

Figure 3-9 Land used for beef cattle production and other agricultural areas, alongside MCV intensity

Note: Greener colour = higher matrix combined value (MCV) = higher habitat capacity potential

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3.3.3.2 The beef industry as a steward for biodiversity conservation

The smaller land footprint of intensive beef production would be expected to lead to smaller biodiversity impacts than in extensive production systems. However, this is without accounting for the fact that extensive production systems are able to maintain a much higher share of biodiversity in the agricultural landscape. As a steward for the maintenance of large areas of grasslands, and other associated rangelands that support cattle grazing, the Canadian beef industry thus has the potential to assist conservation objectives. But this depends on maintaining native and tame pastures and using sustainable management practices, in particular for grazing.

While native prairies and tame pastures can be a rich source of biodiversity, tame pastures, in particular, may contain exotic, sometimes invasive species which can have environmental costs. The conversion of prairie to tame pasture species usually simplifies the landscape (Henderson & Naeth, 2005) (Sutter & Brigham, 1998), typically resulting in reduced species richness (LaRade, et al., 2012) (Willms, et al., 2011), although not always for all taxonomic groups (Sutter & Brigham, 1998). The introduction of exotic plants over large areas of native prairie also modifies ecosystem processes in the long term, by potentially leading to reductions in soil quality, soil organic matter and water holding capacity for instance. Moreover, the unintentional introduction of some invasive species (e.g. spotted knapweed, *Centaurea maculosa*; leafy spurge, *Euphorbia esula*) has caused the degradation of millions of hectares of native prairie. For instance, leafy spurge reduces grazing productivity and diminishes habitat quality for wildlife, resulting in economic losses up to 70% for farmers. Crested wheat grass (*Agropyron cristatum*) was introduced from Russia to Canada in 1911 to stabilize erosion and to improve forage production for livestock grazing. It has escaped and successfully out-competed native grassland vegetation with its rapid establishment and high seed production, severely reducing species richness and diversity (Henderson & Naeth, 2005) (Willms, et al., 2011). In British Columbia, spotted knapweed is established in over 40,000 hectares, reducing forage potential by up to 90%, resulting in over $400,000 in annual losses in hay production (Ministry of Agriculture, British Columbia, 2001). If it spreads to its ecological limits, it could infest up to 10 million hectares in Western Canada. Some exotic species, such as Kentucky bluegrass (*Poa pratensis*), tolerate grazing and can proliferate after heavy grazing (Gifford & Otfinowski, 2013), while cattle grazing can be used to restrict the invasive potential of other exotic grasses while maintaining native plant communities (Beck, et al., 2014). It may also be in the interest of farmers to maintain native prairie pastures since they have been shown to yield higher weight gains for yearling steers (Hofmann, et al., 1993).

While not currently demonstrated with the habitat capacity index, maintained or improved biodiversity outcomes can be achieved through proper grazing management by the beef industry. In areas that evolved with a historic disturbance regime dominated by large herbivores, current range science views proper grazing as a natural process and tool for perpetuating rangeland ecosystems (Morgan, 1980) (Dormaar, et al., 1997) (Willms, et al., 2002). Although beef production has been traditionally viewed as a primary economic benefit from rangelands, current range management recognizes a much broader scope of ecological goods and services that can be achieved from well managed rangelands (Holechek, et al., 2011).

By occupying the land base with an economically viable land use strategy, beef production acts as a mechanism to preserve native rangelands and promote these emergent ecological goods and services in the face of increasingly intensive human use and pressures for land conversion to other uses. As such, properly managed ranches that contain native lands have served to protect much of the remaining native rangelands, home to a vast array of flora and fauna (fish and wildlife).

Grasslands comprise the bulk of grazing lands used for cattle production in Canada and are an important forage and habitat resource for a variety of wildlife. They provide essential forage resources for wild ungulates and habitat for a number of species at risk—animals whose habitat demands were shaped by a historical disturbance regime dominated by bison grazing and fire disturbance (Morgan, 1980).

Today, range management consists of incorporating sustainable grazing practices along with natural disturbances such as fire, and other disturbances stemming from human activity. Proper stewardship of the range resource is

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about balancing human needs and demands from rangelands without reducing the ability to maintain ecosystem integrity, provide wildlife habitat, support healthy watersheds, maintain biodiversity, prevent soil erosion and provide carbon sinks (Holechek, et al., 2011).

The effective application of range management principles can maintain or foster healthy productive rangelands, including biodiversity values. The principles include:

1. Balancing livestock demands with the available forage supply
2. Promoting even livestock distribution by using tools like fencing, salt placement and water development to spread the grazing over the landscape
3. Avoiding grazing rangeland during vulnerable periods; early spring grazing can stress range plants when energy reserves are depleted as new growth is initiated
4. Providing effective rest periods after grazing to allow range plants to recover from the stresses of grazing

These principles can be adhered to by altering the intensity, timing and frequency of grazing. Tailoring grazing management strategies through the application of range management principles to suit the range resource and its current health and function allows the full potential of the forage resource to be reached for livestock production purposes, while effectively stewarding the range resource by sustaining ecosystem health and productivity.

These factors are key to the sustainable management of grasslands, since grazing by large herbivores has been shown to condition the grassland quality for subsequent herbivory, providing benefits to wildlife (Bork, et al., 2012) (Bork et al., 2012). A well-planned and balanced cycle of forage harvest and renewal can protect the range resource and sustain the many benefits that rangelands provide.

3.3.4 Strengths and limitations

3.3.4.1 Compatibility with other biodiversity impact assessment approaches

The approach used in this study meets most of the key principles recommended by the recent efforts of LEAP (2015) and offers the flexibility to be refined and incorporated into other approaches. The habitat capacity index as it is calculated here, per unit of production, could be used as a characterization factor in LCA. The habitat suitability maps could also be included in broader modelling frameworks such as InVEST, which would allow modelling of the impacts under future land use change scenarios for instance. In addition, the habitat capacity index could be refined to include impacts on a subset of species of conservation importance, such as rare and threatened species. It could also be disaggregated to consider only the impacts on certain taxonomic groups, or even the subset of species within a taxonomic group for which good knowledge is available. Species-specific modelling could also be considered, similar to de Baan et al. (2015).

Furthermore, in contrast to previous attempts to model the land use impacts of biodiversity, our approach does not unduly over-emphasize the role of productivity (Teillard, et al., 2014). Biodiversity scores are not simply attributed to a land use category, but are also a function of their location in the landscape. They are a function of the known species ranges at a given place, which means that pastures in intensive production areas are likely to get lower biodiversity scores than those in more natural settings (typically extensive pastures). As such, extensive pastures, which require a large area to generate one unit of product, can yield better biodiversity outcomes than more intensive ones.

3.3.4.2 Limitations of the methodology

The approach that was developed has a number of limitations, largely due to data availability.

- **The biodiversity analysis focuses on the habitat change driver of biodiversity loss** (Figure 3-6**), and within this driver on a single component, the state of land use**. We focus on the impact of beef production on land use since beef cattle is a major user of land resources and this impact is relatively easy to quantify and can be used for LCA analysis (LEAP, 2015). Other components of the habitat change driver, such as habitat configuration (e.g. connectivity, fragmentation or resilience of the

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landscapes) and management practices (e.g. intensification of the land use) were not assessed. Nevertheless, the distinction between the primary and secondary habitats of species is one way to factor in an aspect of the spatial configuration of the landscape in the index. The index is also unable to capture differences in management practices, and cannot reflect the use of rotational or complementary grazing systems, for instance. As a result, our study underestimates the total biodiversity impacts of habitat change.

Other drivers of biodiversity loss such as pollution or climate change were not considered here since the impacts of beef production on carbon storage, GHG emissions, ecotoxicity and water use are quantified in other streams of this study and can be used to infer further biodiversity impacts of the Canadian beef production system. The impact of invasive species, namely the introduction of invasive forage grasses, is discussed.

- **Land use impacts related to off-farm feed cultivation outside of Canada are not considered** and could potentially be very important for biodiversity. Indeed, the supply chain of feed items is often not precisely known. This assumption seems reasonable, however, given that the majority of feed sources for Canadian beef are sourced within Canada (rations calculations in the ELCA section show that most beef feed requirements can be met by Canadian crop production). The main sources of feed imports are from the US (in particular corn distiller's grains used in Alberta might be imported from the US) and it is reasonable to assume that the biodiversity values of the crops grown there are similar to those in Canada.
- **The study accounts for the impacts of land occupation, not the impacts of land transformation**. In a LCA, the land use impact framework considers the temporal dimension of biodiversity change by distinguishing the impacts of land occupation (land use) from those of land transformation (land use change) (Souza, et al., 2015). Occupation impacts quantify how much biodiversity is lost as a result of the land use phase. In other words, land occupation is simply defined as the postponement of recovery of land to its potential natural vegetation state (or other chosen reference value) and is proportional to the area of the land occupied. This is consistent with the way land use impacts are accounted for in this study. Transformation impacts, on the other hand, account for the change in biodiversity after hypothetical land abandonment and are a function of the biodiversity regeneration time. Since reliable data on regeneration success and time were not available, we excluded the temporal dynamics from this study and assigned a constant biodiversity score (the habitat capacity index) to each land use.
- **The habitat capacity index does not relate the change in habitat capacity to an actual response by wildlife populations**. The main drawback of using the habitat capacity index to measure biodiversity is that the index may be affected by the variable and potentially biased knowledge of the species-habitat relationships, and may not have the same level of accuracy for all the species included (Rondinini, et al., 2011). Furthermore, habitat capacity implicitly assumes that a species is present throughout its potential habitat, whereas in reality, it may only occur in some areas. The loss of suitable habitat also does not necessarily imply biodiversity loss or population decline. The habitat capacity index consequently overestimates the biodiversity impacts of land use.
- **The land requirements of feedstocks may be overestimated, since some feedstocks may not be grown solely for beef cattle**. Beef cattle often eat only feed grains rather than the whole crop, and may consume by-products from other agricultural productions, such as from oil production. This is probably a limited source of bias since most of the biodiversity impacts come from grazing land.
- **The study focused exclusively on agricultural land** covered in the Annual Cropland Inventory (see Figure 3-2) and as a result it did not include land covers from northern, usually more natural, ecosystems. This means the habitat capacity index may not adequately cover the full range of natural land covers.
- **The pasture category encompassed different types of land covers.** The Annual Cropland Inventory (ACI) does not distinguish native pasture from tame pasture. To distinguish the two land covers, we used data from the 2011 Agricultural Census which might have biased the results.
- **Land covers with high habitat capacity index could have been underestimated.** Some natural land covers, such as wetlands or shrublands, may be included within grazed land connected to beef (e.g. within natural land for pasture) but not reported as pasture land within the ACI dataset. This could lead to an underestimation of the habitat capacity index of land connected to beef.

3.3.5 Conclusion and future directions

3.3.5.1 Conclusion

The literature review shows the importance of beef production on land use and its contrasting potential impacts on biodiversity. It highlights the potential of the Canadian beef industry to be an important steward for Canadian biodiversity. Extensive production systems, relying on large areas of natural and semi-natural pastures, can play an important role in the maintenance of native grasslands. This however depends on grazing management practices. In contrast, beef production systems relying more exclusively on forage crops contribute to wildlife habitat loss and degradation. The quantitative analysis performed in the second part of this chapter confirms these general trends. Canadian beef cattle use 33% of all Canadian agricultural land, and most of this is for pasture. Extensive production systems in the western parts of the country are able to maintain a high share of biodiversity in the agricultural landscape. This is mainly due to the high proportion of native grasslands and tame pastures used by beef cattle in Western Canada. Overall, the wildlife habitat potential of the land used by Canadian beef cattle turns out to be more than twice (68%) that expected by its sheer land use (33%) (Figure 3-8). These results are relatively unchanged with limited changes in cattle numbers (10% increase or decrease), given our hypothesis that such changes would not affect the area of pastures. Improved data availability on management practices and pasture types would be needed to provide more practical recommendations to the industry.

3.3.5.2 Future direction

The main areas of improvement derived from the limitations highlighted previously are listed below:

- **This study looked at the combined breeding and feeding requirements for wildlife**. A finer level of analysis could be obtained by looking at the contribution of different land covers to either breeding or feeding, thereby highlighting the importance of a heterogeneous landscape. If breeding capacity is the limiting factor for wildlife distribution in Canada, more than feeding, then focusing on breeding habitat only would be warranted. Similarly, considering taxonomic groups separately, and distinguishing the impacts on locally rare or threatened species, could highlight the areas where wildlife is most at risk from certain practices.
- **Differentiating biodiversity impacts between native and tame, improved pastures.** This would allow a quantification of the contribution of beef production to the maintenance of biodiversity important native pastures. The land cover classes in the Earth Observation data that were used in this study only provide a single pasture category. However, more detailed vegetation inventory data are available in the province of Alberta, for instance (Grassland Vegetation Inventory). It could be matched to the biodiversity index at the SLC polygon level to compare the biodiversity values in different types of pastures.
- **Accounting for management intensity**. Sustainable and grazing management practices can yield substantial biodiversity benefits. A first approach could be developed using information on pasture productivity and livestock density. However, monitoring and reporting of management practices would be needed to assess this aspect in further depth.
- **Developing more specific policy scenarios**. This study assessed biodiversity impacts by defining a reference scenario based on natural potential vegetation, which tends to make any impacts of production on biodiversity negative. More realistic scenarios could be developed to support sustainable beef production. Such scenarios could for instance consider an increase in the share of extensive beef production, or how a change in beef rations would affect biodiversity. These developments would require explicit accounting for the feed cultivated off-farm and the indirect impacts of land use change.
- **Broadening the approach**. As discussed, the biodiversity impacts could be integrated in broader types of assessments, such as LCA or models of ecosystem services. Other types of biodiversity measures could also be added. An obvious candidate would be an indicator of habitat connectivity or fragmentation based on the habitat suitability maps and other landscape variables.
- **Filling research gaps.** Monitoring and reporting of management practices used in grasslands and tame/seeded pastures are missing. Wetland and perennial native grassland inventories would also help

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monitor, manage and maintain or restore these biodiversity important areas. Field validation of the habitat capacity indicators would ensure the indexes are robust and useful.

3.4 Water risk

In areas replenished by natural (rainfall) and/or anthropogenic (irrigation) sources of water, the water footprint of beef cattle production has differing blue (consumption of surface/groundwater), green (consumption of rainwater) and grey (pollution of surface/groundwater) water components. The beef cattle water footprint can be direct, i.e. drinking water directly consumed by cattle, or indirect, i.e. the water required to grow feed for cattle.

In Canada, beef production has generally prevailed in dryland areas, in particular in the Western provinces, for a combination of favourable reasons, including: the limited spread of disease due to animal husbandry practices given the dry climate, the minimal amount of nutrient run-off from farms (as surface run-off volumes are minimal due to disparate rainfall patterns) and the economic unviability of producing other agricultural commodities. However insufficient rainfall volumes necessitated the reliance on anthropogenic sources of water (irrigation systems) for watering cattle and ensuring sufficient feed production in surrounding areas. And while most croplands in Canada are not irrigated and mainly reliant on rainfall (see Table 2.8 Irrigation data from 2014 Agricultural Water Survey), irrigation today mostly occurs in those provinces where beef production is dominant, such as Alberta.

Beef producers who are largely dependent on irrigation or other water (non-rainfall) for sustaining their operations and to produce their feed crops face environmental risks they may have little control over. The collection of water from streams, reservoirs and other water features for use in the irrigation of dry agricultural lands, or for watering cattle, is vulnerable to alterations in catchment water balances, changes in social and environmental licenses to operate and increasing competition for water resources. For these producers, knowledge of the direct and indirect blue and green water footprint are critical, as water deficits induced by shortages in rainfall will need to be replaced by other water sources (ground water reserves, piping in from other catch basins, etc.) to prevent significant deleterious impacts on beef production. This also applies to areas where rainfall is currently plentiful and a small blue water footprint prevails as shifting rainfall patterns and alterations in the frequency and magnitude of extreme rainfall events due to climate change will mean that even these areas will require an explicit account of water availability and water use to ensure sustenance. In short, a thorough understanding of beef cattle producers' water footprint is critical for the long-term sustainability of the industry.

The management of intensive (feedlots) and non-intensive (grazing) beef on land can produce water quality impacts that are either negligible, deleterious or positive to local water features. Causes of water quality impairment vary from the mismanagement of localized animal waste at high density beef cattle operations (point source pollution) to excessive nutrient run-off from grazing lands (non-point source pollution). Those beef producers who recognize the role of natural vegetation in retaining nutrients and who maintain vegetation buffers are capturing some of the nutrients produced by their farms or upstream farms. By doing so, they improve water quality by reducing nutrients' contamination of downstream water streams and water bodies. With this, a complete assessment of the water-related impacts of beef cattle production must include both a water quantity and water quality analysis.

3.4.1 Methodology

There is a great deal of spatial and temporal heterogeneity in the biophysical and anthropogenic factors that govern local water resource systems. Given the constraints of this project and knowledge that capturing the blue water footprint is critical for beef cattle producers, we focused our assessment on the use of widely-available global water risk indicators and estimations of irrigated land and irrigated volumes from agricultural surveys and census data. The first stage of the analysis focused on using outputs from Aqueduct's global water risk mapping tool to perform a broad screening of water risk across Canada. From here we extracted data on irrigation across Canada to provide approximations of the blue water footprint and outlined the role of rainfall in altering this

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footprint. Due to data gaps, the intent of this methodology was to provide a high level overview of the beef cattle-related impacts on water resource systems at the provincial level, with a sole focus on the direct/indirect consumption of irrigation water, and recommendations on how rainfall information can be used in this context.

3.4.1.1 Background on Aqueduct

A plethora of water models, ranging from stochastic data-driven approaches to simple conceptual and complex fully-distributed, physically-based models, are available for use in water risk assessments. Each approach holds its own merits and to this day hydrological modellers debate on the applicability, suitability and reliability of the approaches. For example, scientists often prefer physically-based modelling approaches which are built on scientific formulations of catchment dynamics—these scientists question the reliability of data-driven stochastic models that rely only on expansive training datasets and statistical tools with no representation of actual hydrological processes. On the other hand, system engineering-oriented modellers prefer data-driven approaches to physically-based ones as they claim stochastic approaches are far better for use in forecasting and argue there is too much entropy in natural systems that make scientific formulations limited in their representations. However, no matter their stance, the two schools of thought agree that, regardless of type and complexity, water models serve only as approximations of catchment processes and are exposed to varying levels of predictive uncertainty. This lends to the general consensus among water scientists and engineers that there is no single "best" modelling platform. Model selection should be informed by needs and through consultation with stakeholders on the key questions that need to be answered as opposed to one based entirely on scientific and statistical complexity.

In 2013, the World Resources Institute, in partnership with several private sector companies (including General Electric and Goldman Sachs), released a publicly-available online global database of water risk indicators titled the Aqueduct Water Risk Atlas (Aqueduct). Aqueduct is designed to assist decision makers in identifying water risk in three domains: physical risks—quantity; physical risks—quality; and regulatory and reputational risks. The inclusion of these three domains allows Aqueduct to consider socio-economic dynamics, governance and biophysical constraints in a single framework. Specifically, 12 indicators, ranging from baseline water stress to flood occurrence and media coverage, are aggregated to create a single risk score at the watershed level for the globe. The tool allows users to create customized maps of composite water risk scores that can be used to provide insights on localized water-related risks and inform the development of water conservation plans. Aqueduct has been applied globally by a full range of private and public sector organizations as well as research institutes and is commonly referred to as the go-to screening tool for the high level screening of water-related risks.

Through several discussions with the Steering Committee and with consideration for the availability of data and computational resources, a decision to use Aqueduct v2.0 was made. While a large number of models could have been used in place of this model, this approach is reputable and suffices to provide reliable insights into the water quantity-related impacts of beef cattle production.

3.4.1.2 Aqueduct formulation

Aqueduct was created through an exhaustive literature review of publicly-available datasets—the full list of datasets and sources can be found in Gassert, et al. (2014a). The screening tool uses these existing datasets to create 12 indicators and one overall score of water risk for hydrological catchments across the globe. The hydrological catchments are based on the Global Drainage Basin Database published by Masutomi, et al. (2009), comprising a total of 11,476 river basins and 73,074 sub-basins.

Aqueduct creates an overall water risk score by aggregating the values of 12 indicators capturing physical, as well as reputational and regulatory, risk. A description of the methodology used to create each indicator is provided in Gassert, et al. (2014b). A list of the indicators included in Aqueduct is set out in Figure 3-10.

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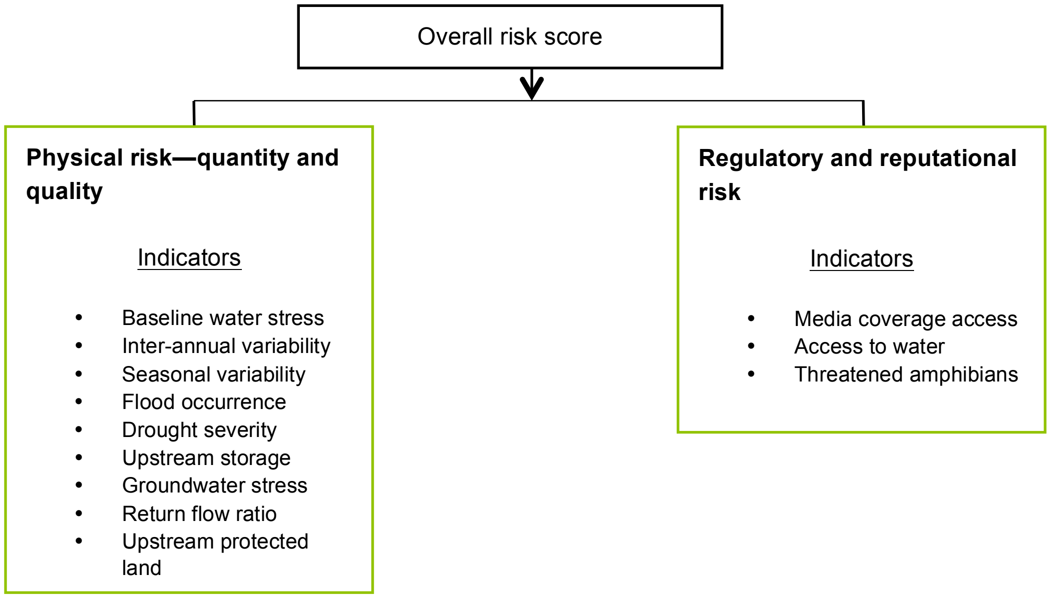

Figure 3-10 Description of Aqueduct indicators (adapted from Gassert et al., 2014a)

Upon review of all 12 indicators, the baseline water stress, inter-annual variability and drought severity indicators were selected to develop a composite water risk score for beef cattle dense areas across Canada. These indicators were selected as they were most relevant for an assessment of the water-related impacts of beef cattle production, in particular for the Canadian Western provinces. We also considered including flood occurrence but, given quality and availability of flood recording data in Canada at the time of the study, it was decided not to include it. This present limitation should however be reconsidered in future revisions of the study given research currently underway to improve flood tracking, especially in Eastern Canada where this indicator is particularly relevant and may be impacted by climate change knock-on effects and impact phosphorous run-off values. A full description of the indicators and methodology used to create them is provided in Gassert et al., 2014b.

Briefly, the *baseline water stress* is a ratio of the total annual water withdrawal to average annual water availability accounting for upstream consumptive uses. Water withdrawal data for agricultural, domestic and industrial uses was extracted from FAO's AQUASTAT database for 2010 or from Gleick et al. (2011) where data were not available. The average annual water availability was estimated using monthly run-off from the Global Land Data Assimilation System Version 2.0 land surface model and a simple flow accumulation approach.

The *inter-annual variability* indicator measures the variation in water supply between years and is calculated as the ratio of the standard deviation of total blue water to the mean of total blue water per catchment. Here the ratio considers variations in water supply that are natural, and all anthropogenic influences are excluded.

Finally, *the drought severity* indicator measures the mean severity of drought events from 1901 to 2008 as modelled by Sheffield & Wood (2008). This dataset was generated by creating a monthly soil moisture hydrograph at a one degree grid resolution for the globe, and defined drought periods as continuous days under which soil moisture falls below the 20th percentile of the monthly hydrograph. The indicator emphasizes those regions where soil moisture deficits are longer, making adaptation difficult.

By design, Aqueduct does not contain a set of water quality indicators specific to cattle production. The tool instead relies on estimations of wastewater discharge and the amount of water originating from protected ecosystems to provide an aggregate score of water quality risk. These indicators, while useful, are not sufficient in capturing estimations of changes in nutrient contributions to water features due to cattle production. As this information cannot be gleaned from the indicators provided by Aqueduct, an assessment of water quality using Aqueduct was not performed.

3.4.1.3 Data sources

Aqueduct, by design has all the necessary datasets required to create a composite risk score built directly into its web-based tool. Aqueduct outputs were extracted from the online platform in their native form; no additional processing or procurement of data were required. The entire Aqueduct model output was collected in GIS format and an overlay analysis of key indicators was performed to develop a composite risk score.

For data on cattle numbers, agricultural and irrigation areas across Canada, the 2011 Census of Agriculture from Statistics Canada was consulted. Specifically, data were extracted from:

- Table 004-0221: cattle and calves on census day, every five years
- Table 004-0002: total area of farms and use of farmland, Canada and provinces, every five years
- Table 004-0210: irrigation in the year prior to the census, every five years
- Table 004-0213: hay and field crops, every five years

3.4.1.4 Limitations

Water risk assessments conducted from an overlay of indicators derived from global datasets are often exposed to large amounts of uncertainty as they are unable to properly account for very specific localized heterogeneities. By design, these assessments are meant to serve as approximations for use only in risk screening and while Aqueduct is a very well-reputed water risk tool, we are aware of its limitations. To deal with some of these limitations, we decided to:

- focus on indicators based on native datasets that have undergone minimal processing;
- assign equal weights for each indicator in determination of the composite risk score to prevent bias; and
- focus on larger watersheds as we understand Aqueduct is built on native datasets of coarse spatial resolution.

While localized modelling of catchment dynamics is a good way to explore the uncertainty inherent in large scale water risk assessments, these assessments demand the procurement of datasets which, in this case, were not readily available. Instead, focus here was placed on scaling the analysis to the provincial level to smooth out all variability and uncertainty. This proved sufficient, as without specific information on where the feed for beef cattle is sourced, a finer resolution blue water footprint could not be developed. By scaling to the provincial level, a broad assumption was made that all beef cattle in one province were reliant only on the direct and indirect consumption of blue and green water from within that same province.

Another limitation to this work stems from the source of irrigation data. Irrigation data were extracted from the 2011 Agricultural Census, which is limited by the number and location of survey respondents. We were unable to identify or take into account any bias that exists in the Agricultural Census, however a fact check exercise was performed to compare the findings against other publications on water use in Canada.

The findings revealed that data from the 2011 Census were representative of the general distribution, type and volume of water use across Canada. While the resolution of this comparison was quite coarse for most provinces, in Alberta and Ontario (where cattle density is among the highest), local water authorities provide explicit account of water use, which was beneficial to this analysis. Furthermore, high resolution multispectral satellite data (Landsat 8) were used to explore the spatial extent of irrigated areas and in the estimation of actual evapotranspiration rates from irrigated areas across Canada.

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3.4.2 Analysis

In this section, we present the results of the water risk assessment—starting first with the development of the composite water risk score using Aqueduct. From here, using information on cattle density, ration requirements and irrigated area, we approximated the blue water footprint at the provincial level

3.4.2.1 Water risk assessment

As mentioned earlier, the Aqueduct indicators for baseline water stress, inter-annual variability and drought severity were used to create a composite water risk score. Figure 3-11, Figure 3-12 and Figure 3-13 present each of the indicators, while Figure 3-14 shows a map of the composite risk score. Each of the three Aqueduct indicators is mapped over a spatial distribution of cattle density (the number of cattle per 10 square kilometres) to constrain our analysis to only those areas that have cattle. A quick scan of the three indicators reveals that there is generally a medium to extremely high water risk score for areas with the largest number of cattle. The southern part of Alberta (near Lethbridge) has the highest density of cattle across all of Canada (200-400 animals per 10 square kilometres) and has the highest water risk scores for each of the three indicators. In fact, for the baseline water stress indicator, there is only one watershed in all of Canada with an extremely high water stress score—this watershed lies in the middle of the most cattle dense area in Canada. It is important to note here that a cause and effect relationship between beef cattle production and water risk is not so easily defined. In fact, while highly cattle dense areas seem to coincide with high water risk areas, it is not immediately evident if beef cattle production is causing this water stress. For one, the correlation may simply be a function of the fact that beef cattle producers have, in the first instance, sought out dry land areas for production to minimize manure run-off or muddy feeding pens—here the water stress is not a function of beef production, but rather beef production is a function of the water stress. In these cases, as expected, reliance on irrigation water or on feed shipped in from less dry areas is necessary as the renewable supply of water is less than the amount consumed, which explains the findings from Aqueduct.

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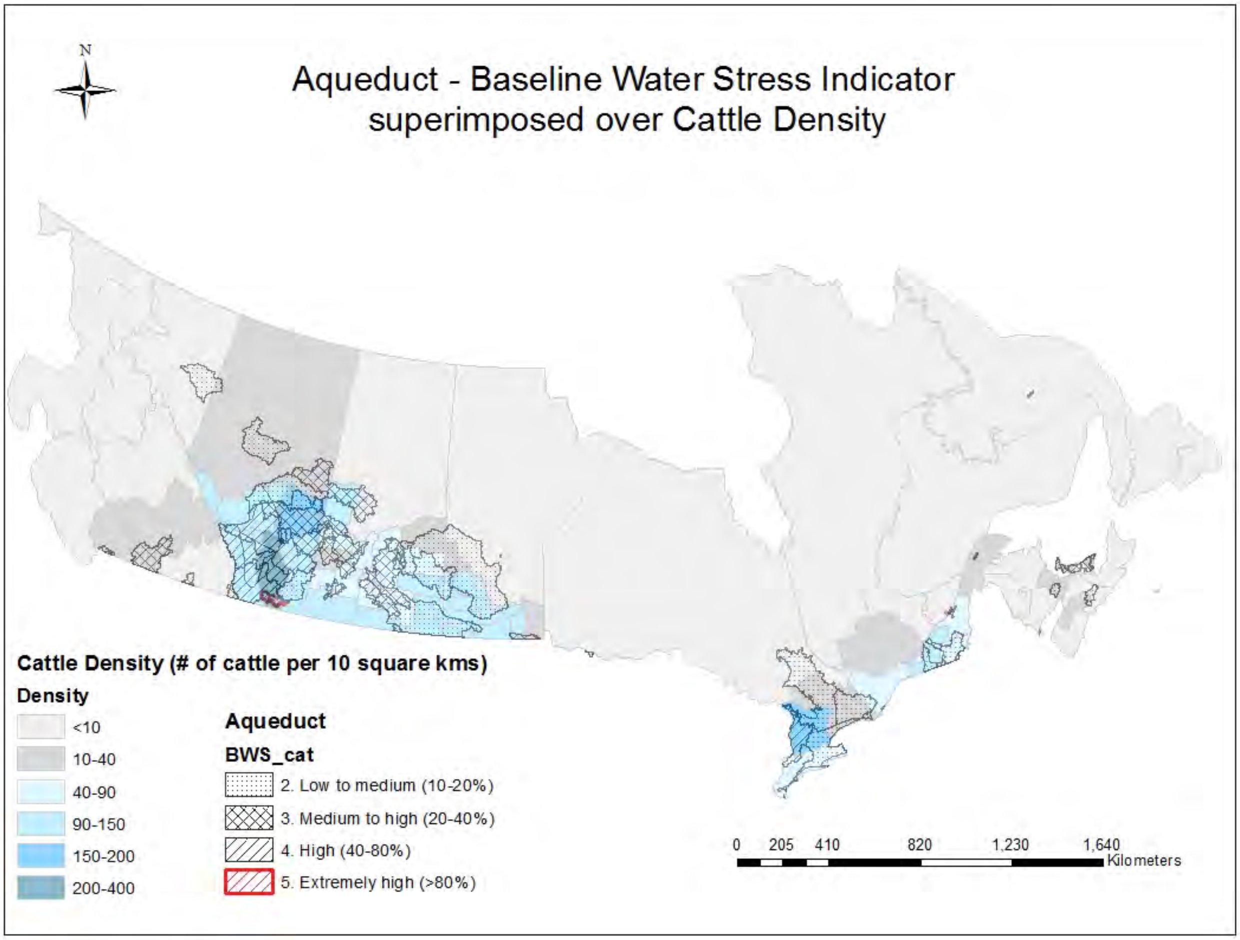

Figure 3-11 Aqueduct—baseline water stress indicator

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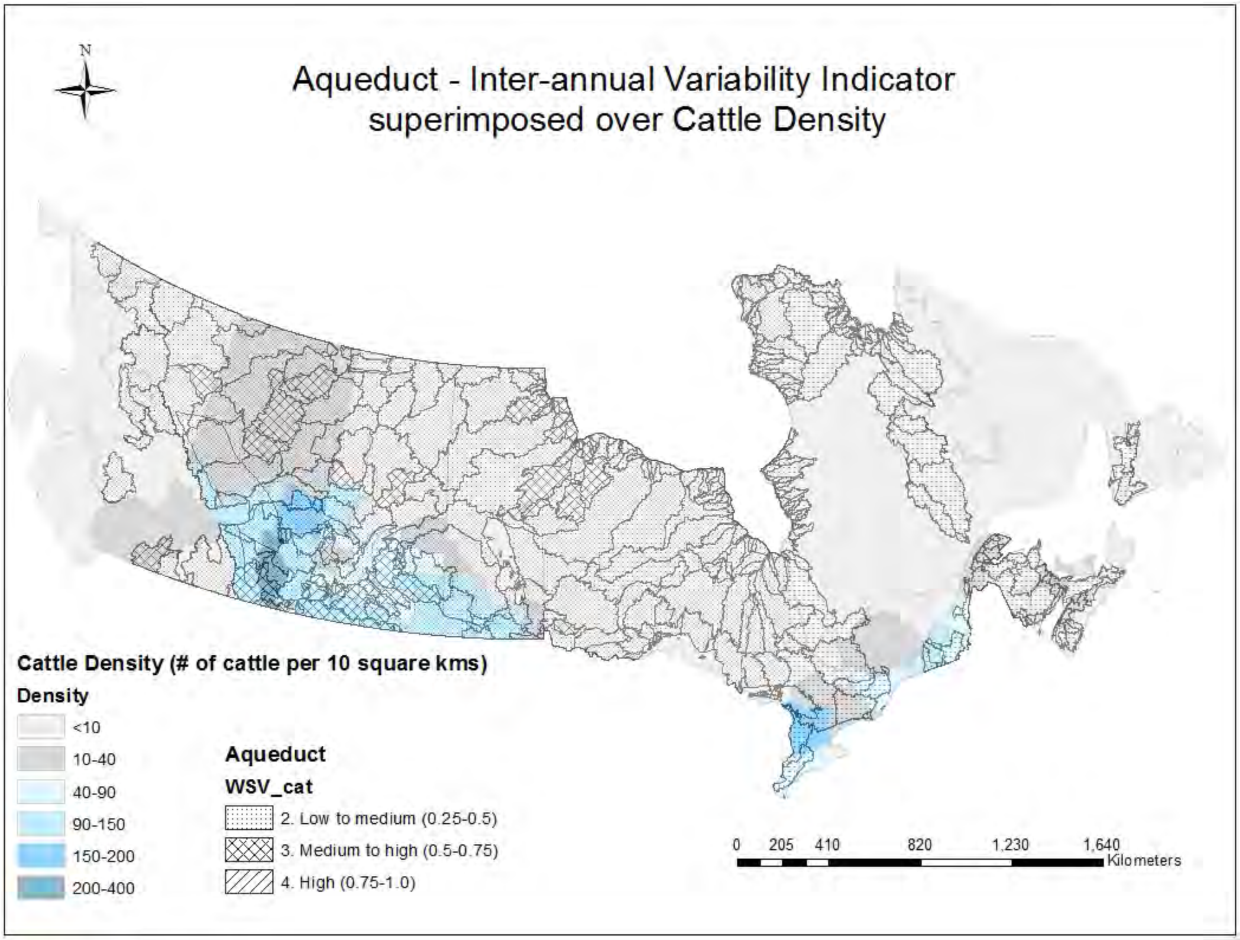

Figure 3-12 Aqueduct—inter-annual variability indicator

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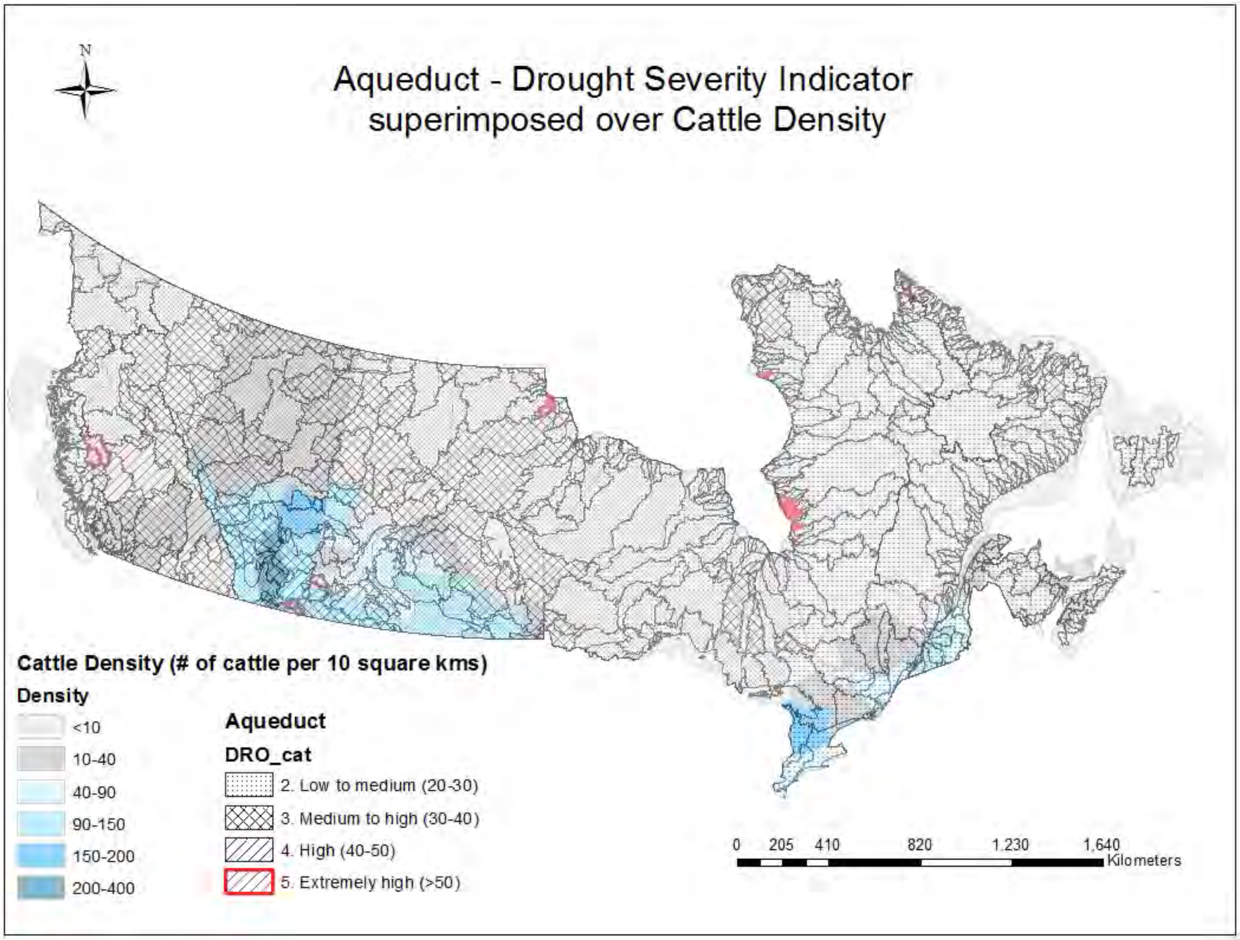

Figure 3-13 Aqueduct—drought severity indicator

Figure 3-14 shows the composite risk score which was created using an additive function of all three Aqueduct indicators—no weights were used to scale the relative importance of one indicator over another. The composite risk score is discretized into four risk categories: low to medium; medium to high; high; and extremely high. The results indicate that there is some level of correlation between water risk and cattle density, however, as explained earlier, a causal relationship is not necessarily apparent. There are high cattle dense areas with a high/extremely high composite risk score as well as a low composite risk score. This may be explained by the case that, while some beef cattle producers have preferentially selected dry land areas for production, a portion of these producers may be implementing effective water efficiency measures that are reducing their impact on the catchment water balance of the watersheds in which they operate. Yet, it can also be argued that these low water risk areas are simply a result of higher rainfall volumes in these areas with everything else being held constant. Table 3.3 shows that 35% of all the cattle in Canada are in medium to high risk areas, while 39% are in high risk areas and only 10% are in extremely high risk areas. It is evident that in order to properly understand the impacts of beef cattle production on the state of water resources, fine scale assessments of water use, supply and management practices over time and space are necessary, as well as information on the changes in rainfall and changes in water use.

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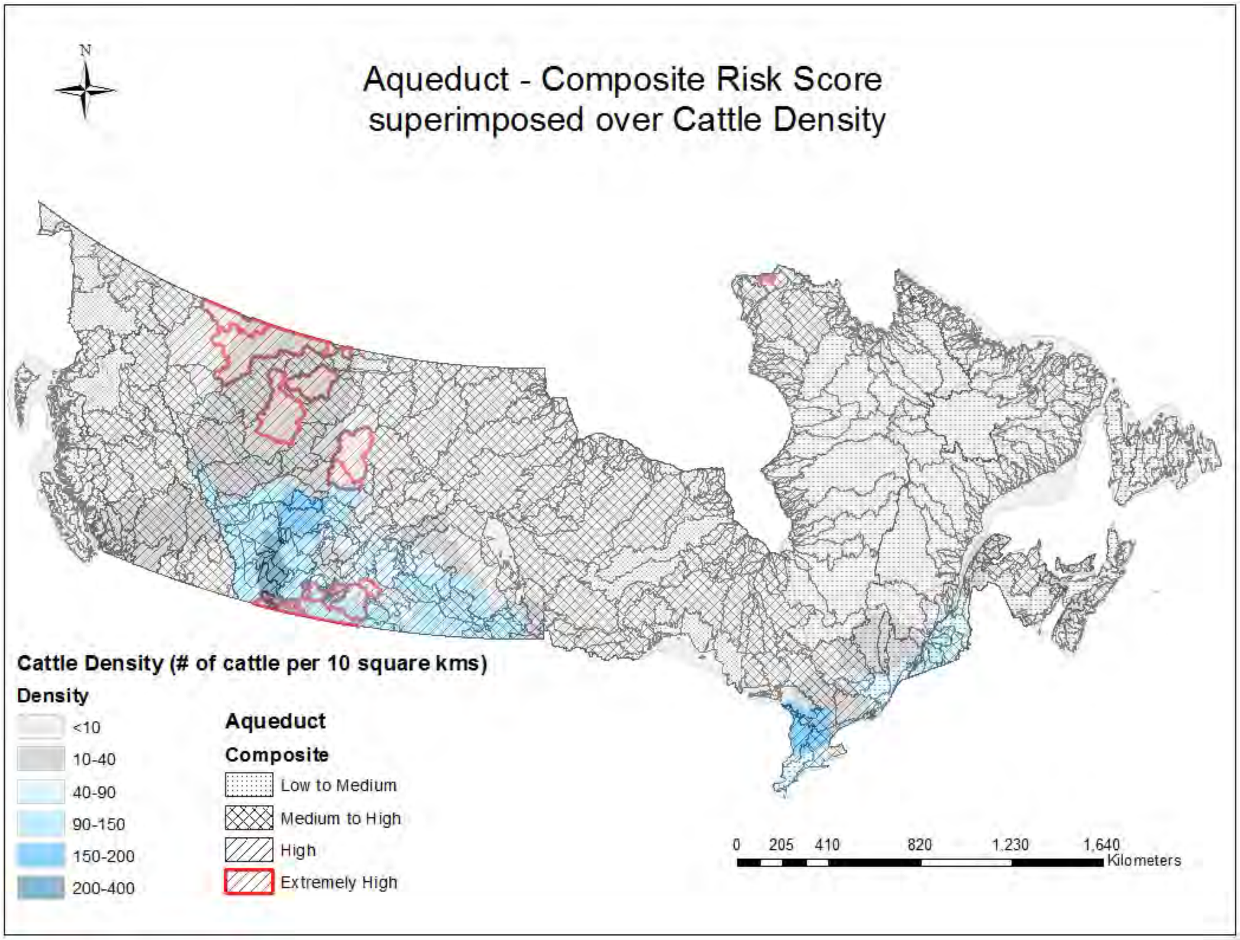

Figure 3-14 Aqueduct—composite water risk score

Table 3.3 Distribution of composite water risk score by number of cattle

Composite risk score	% of total beef cattle
Low to medium	15.5%
Medium to high	35.0%
High	38.8%
Extremely high	10.3%

3.4.2.2 Blue water footprint

The 2011 Agricultural Census revealed that broadly across Canada most irrigation occurs in British Columbia, Alberta and Saskatchewan, with these areas accounting for over 90% of the total irrigation in Canada. Table 3.4 shows the ratio (as a percentage) of irrigated field crops and irrigated forage crops to their non-irrigated counterparts. Here, the field crops category includes all annual field crops and tame forages, including barley and potatoes, while the forage crops category includes hay and improved pasture. Simply, the results in this table indicate that, for example in BC, approximately 7% of field crops are irrigated and 18% of forage crops are irrigated. In 2011, BC had the highest irrigation of field and forage crops of all the provinces.

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Table 3.4 Ratio (as %) of irrigated to non-irrigated field and forage crops by province

Land use	BC	AB	SK	MB	ON	QC	NS	PEI	NB	NL	CAN
Field crops	7.1	4.8	0.3	0.7	0.6	0.5	0.9	1.1	0.1	0.0	1.7
Hay & alfalfa	18.2	6.0	1.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.19

The challenge now was to determine if this information on irrigated field and forage crops could be used to make an approximation on how much of these irrigated areas were used for irrigating the feed for beef cattle. Since we are limited by the inability to properly identify the source of where beef rations, an upper and lower bound of potential irrigated beef rations was created. For the lower bound, we assumed that 50% of the ratio derived from the census data on irrigated and non-irrigated areas could identify the area of beef rations that were irrigated. For the upper bound, we assumed 200% of this ratio would set a proper upper limit to the beef rations that were irrigated. In other words, from Table 3.4, in the case of BC, the census revealed a 7% ratio of irrigated to non-irrigated field crops. The lower bound would assume that only 3.5% of the beef field crops ration areas in BC were irrigated, while the upper bound would assume that 14% of the beef field crops ration areas in BC were irrigated. Table 3.5 outlines the potential irrigated beef rations, as well how much volume of water these areas would require. As shown in Figure 3-15, Alberta has the highest blue water requirement of all the provinces with a total of 39,887 ha—159,546 ha of irrigated beef rations requiring between 118.9 Mm^3-475.8 Mm^3 volumes of water. In addition, the results reveal that forage crops are irrigated more than field crops in the West, but in the Eastern provinces, the opposite is prevalent.

While it can be argued that, in fact, a much higher or even lower percentage of the total beef ration areas are irrigated, we are limited by the inability to account for many externalities. For one, irrigation demand is a function of rainfall patterns and irrigation practices, among other factors. Standardized values of crop water demand can provide us with information on how much water is needed to grow a crop, but without information on water deficits induced by shortages in rainfall or the type of irrigation practice employed (i.e. sprinkler vs border dyke) we cannot properly differentiate between rain-fed and irrigated crops.

Furthermore, the data provided by the Agricultural census report findings in broad categories of field and forage crops. Field crops include a broad range of crop types, everything from soybeans to chickpeas, canola and barley—only a few of these are actual crops used for beef cattle (cf. the rations presented in the Environmental LCA and Land use sections). Indeed, irrigated field crop areas seem to be dominated by three crop types (canola, soybean and corn or barley), of which only barley/corn constitute a potential feed stock for beef. As such, there may be an overestimation of the land used to irrigate beef feed, but we feel the value will lie somewhere between the upper and lower bounds presented in Table 3.5 and Figure 3-15.

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Table 3.5 Irrigated area approximations of land use for beef cattle feed

Land use	Data		BC	AB	SK	MB	ON	QC	NS/PEI /NB/NL	CAN
Forage crops	Irrigated area required for beef cattle feed production (ha)	Min.	7,337	21,023	3,107	112	64	19	-	29,124
		Max.	29,350	84,094	12,429	449	258	75	-	126,65 3
	Water volume required for beef cattle feed production (Mm^3)	Min.	23.0	66.0	9.7	0.4	0.2	0.1	-	99
		Max.	92.1	263.8	39.0	1.4	0.8	0.2	-	397
Field crops	Irrigated area required for beef cattle feed production (ha)	Min.	2,123	18,863	466	419	239	82	261	22,453
		Max.	8,492	75,452	1,866	1,674	955	327	1,003	89,769
	Water volume required for beef cattle feed production (Mm^3) [3,4]	Min.	6.0	53.0	1.3	1.2	0.7	0.2	0.7	63.1
		Max.	23.9	211.9	5.2	4.7	2.7	0.9	2.8	252.2

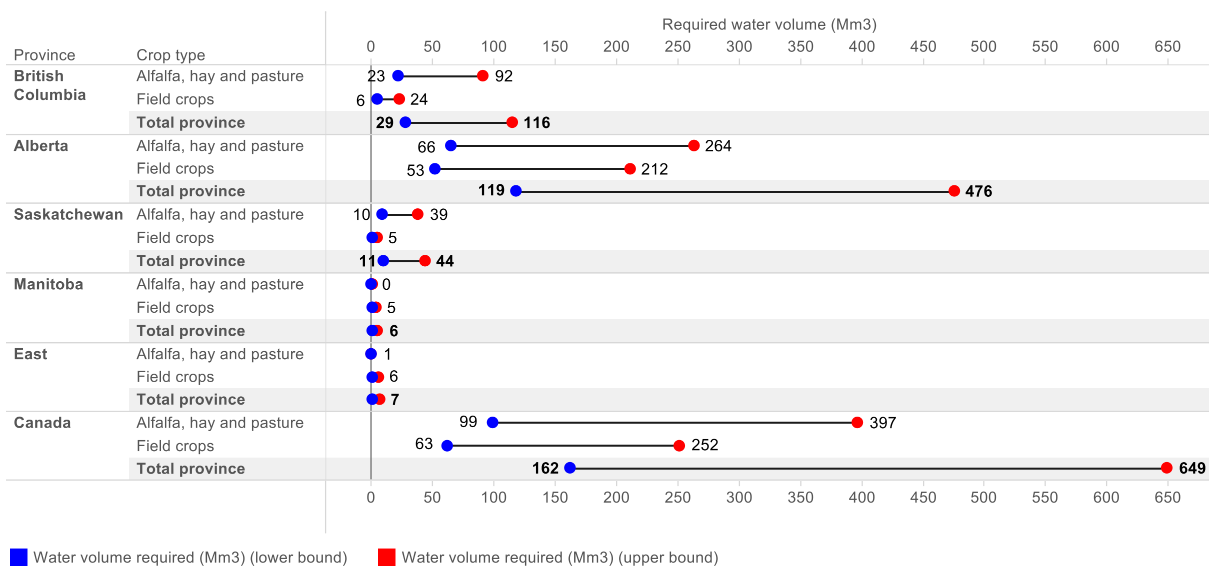

Figure 3-15 Water volume required by beef cattle-related crops

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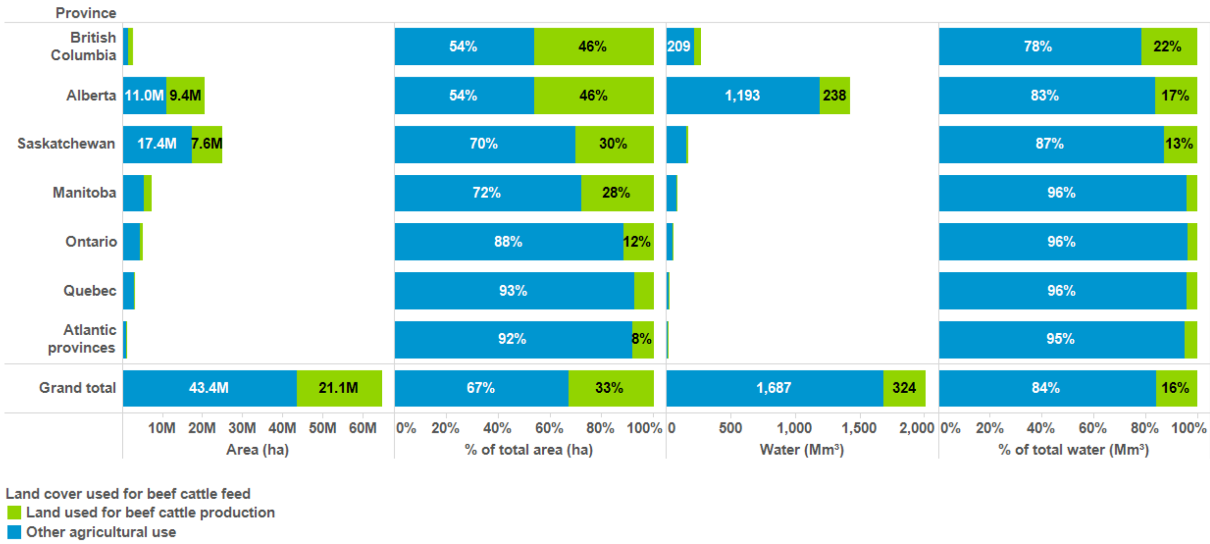

Figure 3-16: Water volume required for irrigation in Canada, for land used for beef cattle production and other agricultural areas

Figure 3-16 provides mid-range estimates of water volumes required for irrigation of beef-related land use, both at the provincial and national levels, using the ratio on irrigated vs non-irrigated areas from the Table 3.4 census data. A provincial breakdown of the aggregated agricultural land used for beef cattle production versus other agricultural uses is depicted on the left side (similar to biodiversity, Figure 3-8), and their respective water volume contributions are set out on the right side. The water volume contribution is based on the contribution of each agricultural land cover referenced in the Census of Agriculture 2011, with their associated average water irrigation intensity value based on data from the Agricultural Water Survey from 2012 and 2014, split by their use for beef cattle production or other agricultural uses. Overall, beef production in Canada requires an estimated 324 Mm^3 per year for the irrigation of its various feed crops. The analysis demonstrates that beef cattle production represents only 16% of total water volumes leveraged for agriculture across Canada, even if it uses 33% of the agricultural land, highlighting the fact that natural range land and almost all tame pasture are not irrigated. This result is mainly due to the high proportion of grassland (native pasture) used by beef cattle in Western Canada.

To provide a more comprehensive picture of the beef cattle production blue water footprint, direct water consumption by the animals should also be taken into account, even if it represents a small portion of the total blue water footprint of beef cattle production. According to the ELCA results (Figure 2-13), 44 L of water are required for animal consumption to produce one kg of live weight at the farm gate. Considering the total number of animals slaughtered, the direct consumption of water by animals would equal 62.0 Mm^3 per year.

To fine tune the estimations of the blue water requirement for beef cattle, information is required on precipitation patterns, the locations of feed grown for beef rations, sources of irrigation water and specifics on irrigation practices. Most of this information can be derived from permits to take water, i.e. the majority of farmers across Canada will operate in a watershed governed by a local water authority, which will set allocation limits on the water resources in their watershed. As part of assigning these allocation limits, the water authority will keep track of how the water is being used, how much is being applied and when. The majority of farmers will irrigate their farms using some proxy for soil moisture deficit. To elaborate, the crops grown on each farm have a biophysical need for water to survive. The plants extract water from the root zone in the soil profile; once a soil moisture deficit arises in the root zone, the farmer will irrigate the crops to remove the deficit if there isn't enough rainfall to satisfy the deficit naturally. The green and blue water impacts are therefore intrinsically linked, as the unavailability of rain water will necessitate the need for irrigation water. Given the limitations faced in this assessment, one approach that could be used to fine tune estimations of the blue water impact would rely on simply using information on rainfall patterns, cattle density and ration requirements at a basin level.

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Since we do not know where the beef rations are located, we can make a broad assumption that the feed should be sourced somewhere within a given km radius from a beef cattle farm. Using information on land use in this area, and the number of cattle in this area, an approximation of the beef feed grown in these areas can be made. For example, the FAO has established a standardized methodology for use in irrigation timing which is based on crop coefficients and potential evaporation (FAO, 1998). The crop coefficient methodology can provide estimations of how much water is required to grow each ration.

As an illustrative example, consider the case where are there are 144,741 beef cattle that occupy a 250 km buffer, 30% of which are calves under one year, 22% steers one year and over, 13% heifers and 32% a mix of beef cows (bulls, lactating cows, dry cows etc.). The feed required to sustain these cattle, the water required to grow their feed and the water required for direct consumption is presented in Table 3.6 and Table 3.7.

Table 3.6 Number of cattle and direct water consumption by these cattle

Number of Cattle	Direct water consumption (L/day)
144,741	5.28E6

Table 3.7 Area required for beef cattle feed and the associated crop water demand

Ration type	Required feed coverage area (ha)	Water intensity (m3/ha/year)	Crop (blue or green) water requirement (m3/year)
Barley	19,576	582	1.14E7
Corn	1,813	520	9.43E5
Hay + pasture	235,551	390	1.01E8
Oat	141	585	8.25E4
Wheat	1,119	580	6.49E5

If we overlay a map of sub-basins for Canada and information on rainfall, we can approximate if rainfall will be sufficient to satisfy the amount of water required to grow this feed and for use as drinking water for the cattle. The Canadian Climate data repository maintained by Environment Canada provides a good repository of rainfall records. Using this information, along with a conventional soil-moisture threshold as a proxy in the estimation of likely rain-fed crops and the green water impact, the lower bound of the blue water footprint can be established with better confidence. To fine tune the upper bound of the blue water footprint, several other sources of information on irrigation would need to be procured. Future research will need to be conducted to fine tune the estimation of the green and blue water impact of beef cattle production.

Along with the green and blue water footprint, beef cattle production will have a grey water footprint as well. Cattle that are free to graze contribute significant amounts of non-point source pollution, as their excrement and urine can mix with rain water and flow into streams, degrading the quality of the water resources in a catchment. The management of pollution caused by these cattle is really a function of how well the excrement and urine are contained on site or the ability of downstream vegetation to retain and buffer some of these contaminants from impacted water bodies. Simply, the same number of grazing cattle operating in two different physiographic environments can have varying grey water impacts. The existence of downstream buffers, the distance to major streams, even the shape and curvature of the stream can impact the rate of water quality impairment. As such, water quality assessments require a localized understanding of catchment water balances and physiographic parameters—a very dry watershed is less likely to suffer from water quality issues from cattle grazing, whereas a

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wet watershed with large flashy rainfall events is likely to move nutrients into streams more quickly and suffer more from water quality issues. While the ELCA does provide a good starting point for the assessment of freshwater pollution potential impact, it doesn't account for those localized management practices. Future research will need to be conducted to better understand these nuances and establish the grey water footprint for beef cattle at specific catchment areas.

3.4.3 Conclusions

This chapter highlights the results of the analysis that was conducted to capture the impacts of beef cattle production on water resources. The first stage of the analysis focused on using data provided by the Aqueduct water risk tool to broadly estimate the state of water risk for land that supports beef cattle across Canada. Three indicators from Aqueduct—baseline water stress, inter-annual variability and drought severity—were used to create a composite water risk score and superimpose it with cattle dense areas across Canada. The findings revealed that although some watersheds in Alberta and Saskatchewan present high or extremely high water risk scores alongside cattle dense areas, the causal relationship between cattle density and water risk is not easily established. Almost 50% of Canadian herd are to be found in low to medium and medium to high water risk score areas and only 10% are located in extremely high water risk score areas. In addition, it was noted that some beef cattle producers have preferentially selected dry land areas for production, so it is expected that instances of high cattle density and high water risk would coincide. Furthermore, we were unable to properly identify those cattle producers who are implementing water efficiency measures in water stressed watersheds versus those who are less efficient but operate in water rich watersheds.

The blue water impact was the focus of this assessment and information from the 2011 Agricultural census was used to develop an approximation of the area that is irrigated to grow the feed for cattle. It was estimated that between British Columbia, Alberta and Saskatchewan approximately 106,000 ha are irrigated for beef feed. Water for irrigation of feed required by beef production can be estimated at about 324 million cubic metres, accounting for about 16% of total water volumes required for irrigation in Canada. Of all provinces, beef grown in Alberta has the highest blue water impact. A number of limitations in the approximation of the blue water footprint were established and it was noted that capturing the green water footprint is critical to fine tune the estimation of the blue water footprint. Future areas of research were outlined as it is critical to understand the coping capacity of local water systems to promote sustain beef production in those areas.

3.5 Carbon soil sequestration

The objective of this chapter is to evaluate carbon emissions or storage due to land management change (LMC) and land use change (LUC) associated with Canadian beef production. Carbon soil content varies across the world depending on soil cover (forest, crop, grassland, peatland, etc.), soil type (mostly based on clay, sand and lime contents) and climate (rainfall and temperature). For a given land use, management practices can result in an increase or a decrease of soil carbon content, and thus store or release organic carbon. Carbon is exchanged with the atmosphere, and atmospheric carbon is in the form of carbon dioxide (CO_2). Further, a change in land use (for instance forest to cropland) induces variation in soil carbon stock, resulting in either CO_2 emissions or removal from the atmosphere, depending on the change.

3.5.1 Definition

The world's soils are the largest terrestrial reservoir of carbon (FAO, 2002). However, a significant part of the release of GHGs into the atmosphere today comes from soil carbon release (converted in atmospheric carbon dioxide, CO_2) due to soil carbon stock changes over time, resulting from land use or management.

IPCC defines six land use categories: forest land, cropland, grassland, wetlands, settlements and other lands, plus a seventh category of perennial crops (IPCC, 2006). Soil carbon stock change can occur either on land remaining in a land use category, due to change in management practices—i.e. land management change (LMC), or on land converted to a new land use—i.e. land use change (LUC). Emissions from land use change can be

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either direct—i.e. occurring at the location of the studied production, or indirect—i.e. consequent to the studied production practice but which is not taking place at the location of the activities that cause the change (ISO 14067:2013).

Staying within one land use category, organic matter will accumulate or decline in ground depending on the land use category and management practices used on that land. For example, organic carbon can accumulate (until reaching a stable level) in sustainably-managed grassland while a decrease in soil organic carbon can occur in arable crop farming. Organic carbon accumulation or release depends on the age of the land cover, the level of nutrient inputs, management practices (e.g. harvest, tillage, grazing), and local soil and climatic conditions (soil type, current organic matter content, temperature, precipitations).

In the case of beef production, which includes feed, land use change may include:

- Change of forest land to grassland, arable land or perennial land[42]
- Change of grassland to arable land or perennial land
- Change of arable land to grassland or perennial land
- Change of perennial land to arable land or grassland (FAO, 2014)

It should also be noted that land management and land use change also result in non-CO_2 emissions such as methane (CH_4) or nitrous oxide (N_2O). Modelling these emissions is included in the analysis.

3.5.2 Assessing emissions from land use and land use change—state-of-the-art

3.5.2.1 International standards

IPCC (2006) proposes equations and default values to be used if no specific data are available to model changes in soil carbon stock and related emissions from land.

Several international standards and reference documents provide recommendations on the modelling of emissions from land use and land use change:

- BSI (2011) PAS 2050:2011 *Specification for the assessment of the life cycle greenhouse gas emissions of goods and services* and BSI (2012). PAS 2050-1:2012 *Assessment of life cycle greenhouse gas emissions from horticultural products*
- ISO 14067:2013 *Carbon footprint of products—Requirements and guidelines for quantification and communication*
- European Food Sustainable Consumption & Production Round Table (2013) *Envifood protocol—Environmental Assessment of Food and Drink Protocol*
- FAO-LEAP (2014) *Environmental Performance of Animal Feeds Supply Chains—Guidelines For Quantification*. Draft for Public Review. Livestock Environmental Assessment and Performance Partnership

Regarding land use carbon emissions/removal modelling, there is lack of a consensual and uniform approach. Consequently, neither ISO 14067 nor PAS 2050 recommend their calculations. However, given the potential importance of land use carbon emissions/removal, the FAO-LEAP guidelines (2014) recommend their inclusion in the assessment. Land use carbon emissions/removals should however be reported separately from the general carbon footprint assessment (see Figure 2-12 Breakdown of contributors depending on their impacts on climate change). Land use carbon emissions/removal assessments should be based on specific soil organic carbon stock change whenever possible. In the case where such primary information is lacking, generic models can be used, such as the one detailed by IPCC (2006) Vol. 2 chapter two. If generic models are used, they should be acknowledged by the scientific community (scientific paper peer review, good acceptance).

[42] "Grassland" stands for "native grassland", while "perennial land" stands for "tame perennial land"

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In all cases, only land use change that occurred in the last 20 years or during a single harvest period (whichever is longer) should be considered, and emissions/removals should be linearly amortized during a period of 20 years (20 years is the default time period for transition between equilibria of soil organic carbon contents). Both impacts from direct and indirect land use change are taken into account.

3.5.2.2 Canada-specific data sources

Canada has ratified the United Nations Framework Convention on Climate Change, and is thus required to report GHG sources and sinks annually, which includes emissions (or removals) resulting from the land use, land use change and forestry (LULUCF) sectors. The latter includes the change of soil carbon stock due to LMC and LUC.

In this context, McConkey *et al.* (2014) have established a methodology to estimate GHG sources and sinks for the LULUCF sector[43] for the following categories:

- Cropland Remaining Cropland (CL-CL): includes CO_2 emissions from mineral soil, liming, cultivated Histosols and wood biomass; cropland converted to tame pasture is included in this category, as tame pasture being cultivated; corresponding areas are grouped with cropland and not with grassland (i.e. native grasslands)
- Land Converted to Cropland (L-CL): includes CO_2 and N_2O emissions from Forestland Converted to Cropland (FL-CL) and Grassland Converted to Cropland (GL-CL)
- Grassland Remaining Grassland (GL-GL): includes CO_2 emissions from native grassland soils remaining as native grasslands (McConkey, et al., 2014)[44]

McConkey's team has established associated soil carbon stock changes and N_2O emissions across Canada. No CH_4 emissions are accounted for because most CH_4 emissions come from peat lands (permafrost, muskeg, wetlands, etc.). Reporting CH_4 emissions from draining peat is not mandatory and no recent conversion of peatland to cropland has been identified.[45]

3.5.3 Proposed methodology

In the publication *Change in carbon footprint of canola production in the Canadian Prairie from 1986 to 2006*, which follows McConkey *et al.'s* methodology, Shrestha, *et al.* calculated the inventory of GHG emissions associated with canola production in the major Prairies provinces of Canada (i.e. Manitoba, Saskatchewan and Alberta), including emissions and removals from LMC and LUC (Shrestha, et al., 2014). These three provinces and Ontario are also the main beef producing regions in Canada (Statistics Canada, 2011).

According to McConkey,[46] current data do not enable the distinction between commodity-specific impacts of LMC and LUC of different agricultural land. As such, agricultural land—including land to grow canola and other annual crops (including summerfallow), perennial crops (i.e. forages), improved pasture and natural rangeland—can be considered to have similar environmental impacts/benefits in terms of emissions and removals issuing from LMC and LUC (i.e. these are net responses to overall economic effects from production of all commodities, including feed for beef). Given this, GHG emissions and removals resulting from LMC and LUC associated with canola production were used here to model the impacts and benefits of LMC and LUC of crops, forages and grass from improved pasture fed to Canadian beef cattle. Impacts and benefits from non-improved pastures were excluded given these grasslands were established long ago and there is no estimated C emission nor removal for grassland remaining grassland.

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[43] Note that in this methodology, a timer period longer than the 20 years recommended by IPCC is considered. The exact period varies for different LMC and LUC and by region. The values from the Shrestha *et al.* (2014) paper reflect those periods.
[44] Although, for the moment, the authors have reported these emissions as not estimated and are moving to reporting as zero or a small sink (direct communications with the author in July and August 2015)
[45] Direct communications with the author in July and August 2015
[46] Direct communications with the author in July and August 2015—Brian McConkey being a co-author of the article from Shrestha, *et al.* (2014)

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We acknowledge that modelling C sequestration based on canola only is a strong limitation, as canola is very specific in growth form, phenology, chemical composition (and therefore decomposability), root:shoot ratio, and many other factors. However, this assessment provides a first estimation of the effects of land use management and change on Canadian beef production.

The latest data calculated by Shrestha, *et al.* (2014) date from 2006. However, according to McConkey,[47] LMC and LUC GHG inventory per hectare associated with crop and improved pasture production in 2006 can still be considered representative of today's situation.

LUC emissions assessed by the authors only encompass the effects of direct LUC, which is consistent with Canadian feed sourcing practices, since it can be assumed that Canadian cattlemen source feed locally at a provincial level (e.g. cattlemen from Western Canada get their feed within Canadian Western provinces), and that foreign importation of feed is negligible[48] (see section 3.2 Beef land cover footprint).

Given the geographic coverage of Shrestha, *et al.'s* (2014) study, the model described below to assess the environmental impacts and benefits of LMC and LUC was built to be representative of Western Canada beef production, which aligns with our baseline scenario modelling Western Canada beef production systems.

Table 3.8 presents the average GHG emissions and removals issuing from LMC and LUC of canola for the years 1986 and 2006, relying on data used to model the impacts and benefits of LMC and LUC for crops, forages and grass from improved pasture for the years 1986 and 2006.

Table 3.8 Average GHG emissions and removals issuing from LMC and LUC of crops, forages and grass from improved pasture for the years 1986 and 2006 (Kg CO_2 equivalents / ha)

Year	LMC[49]	LUC[50]
1986	-32	342
2006	-399	99

Finally, to put the LUC and LMC influence back into perspective, associated emissions and removals were compared to current organic carbon stocks. To do so, Brian McConkey provided carbon stock value to a 30 cm depth.[51] The corresponding values per type of crops are displayed in Table 3.9.

Table 3.9 Average current organic carbon stock in Canadian soils to a 30 cm depth (2015)

Land cover	Carbon stock (tonnes per ha)
Cropland	75.9
Tame pasture	71.2
Native pasture	74.5

The combination of carbon stock values and beef land cover footprint are presented in Figure 3-17.

[47] Direct communications with the author in July and August 2015—Brian McConkey being a co-author of the article from Shrestha, *et al.* (2014)
[48] Discussion with Brenna Grant from CanFax, confirmed with the survey
[49] Removals due to land management change
[50] Emissions due to land use change
[51] Direct communications with the author in November 2015—Brian McConkey being a co-author of the article from Shrestha, *et al.* (2014)
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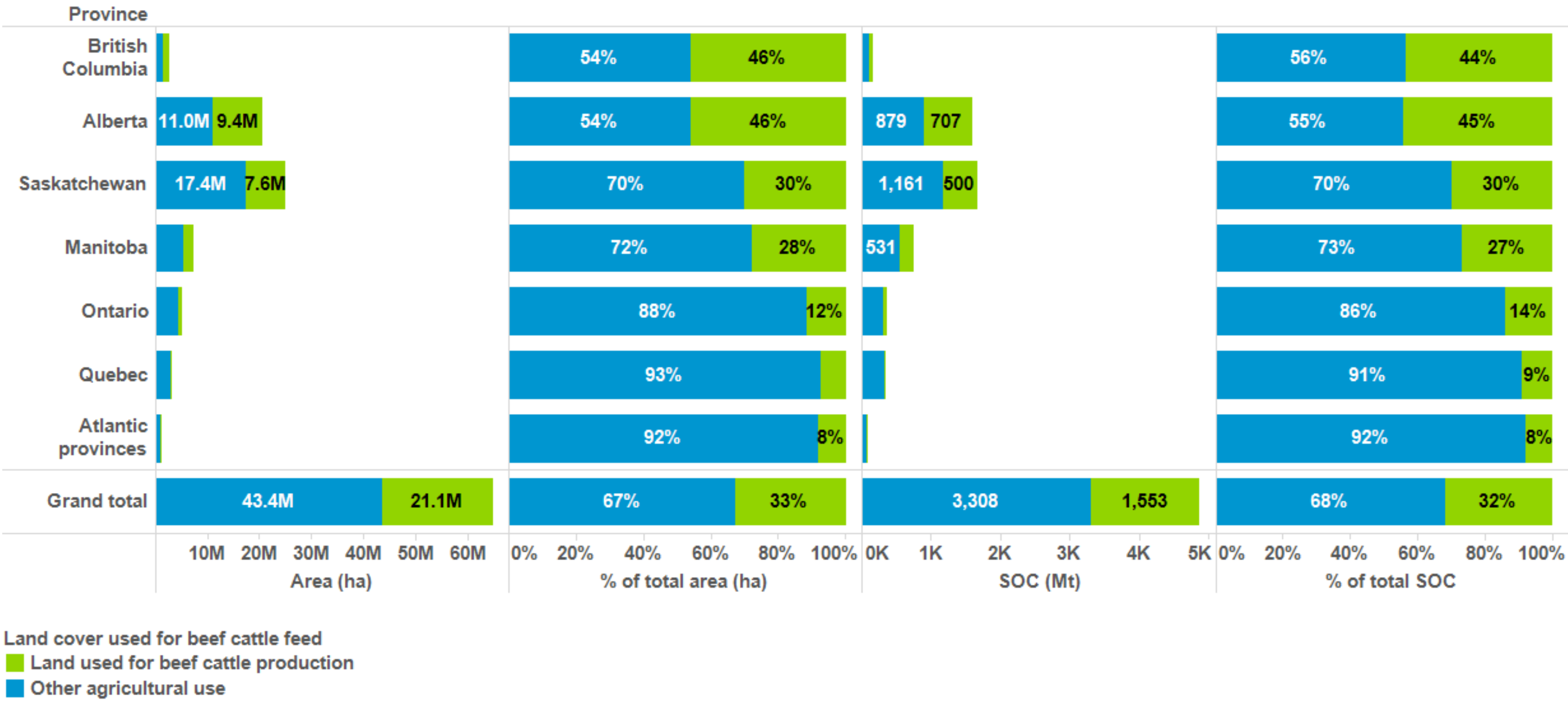

Figure 3-17 Stock of carbon (SOC) values in Canada, for land used for beef cattle production and other agricultural areas

Figure 3-17 provides high-level results of the carbon stock impact of cattle farming, from a land use perspective, both at the provincial and national levels. A provincial breakdown of the aggregated agricultural land used for beef cattle production versus other agricultural uses is depicted on the left side (similar to the biodiversity and water assessment, see Figure 3-8 and Figure 3-16), and their respective stock of carbon contributions are provided on the right side. The stock of carbon contribution is based on the contribution of each agricultural land cover referenced in the Census of Agriculture 2011, with their associated average stock of carbon intensity value, split by their use for beef cattle production or other agricultural uses.

The analysis demonstrates that beef cattle production represents 32% of the agricultural land stock of carbon across Canada, while using 33% of the agricultural land occupied, highlighting the fact that the average carbon stock intensity is relatively similar in croplands and pastures (see Figure 3-17 and Figure 3-18).

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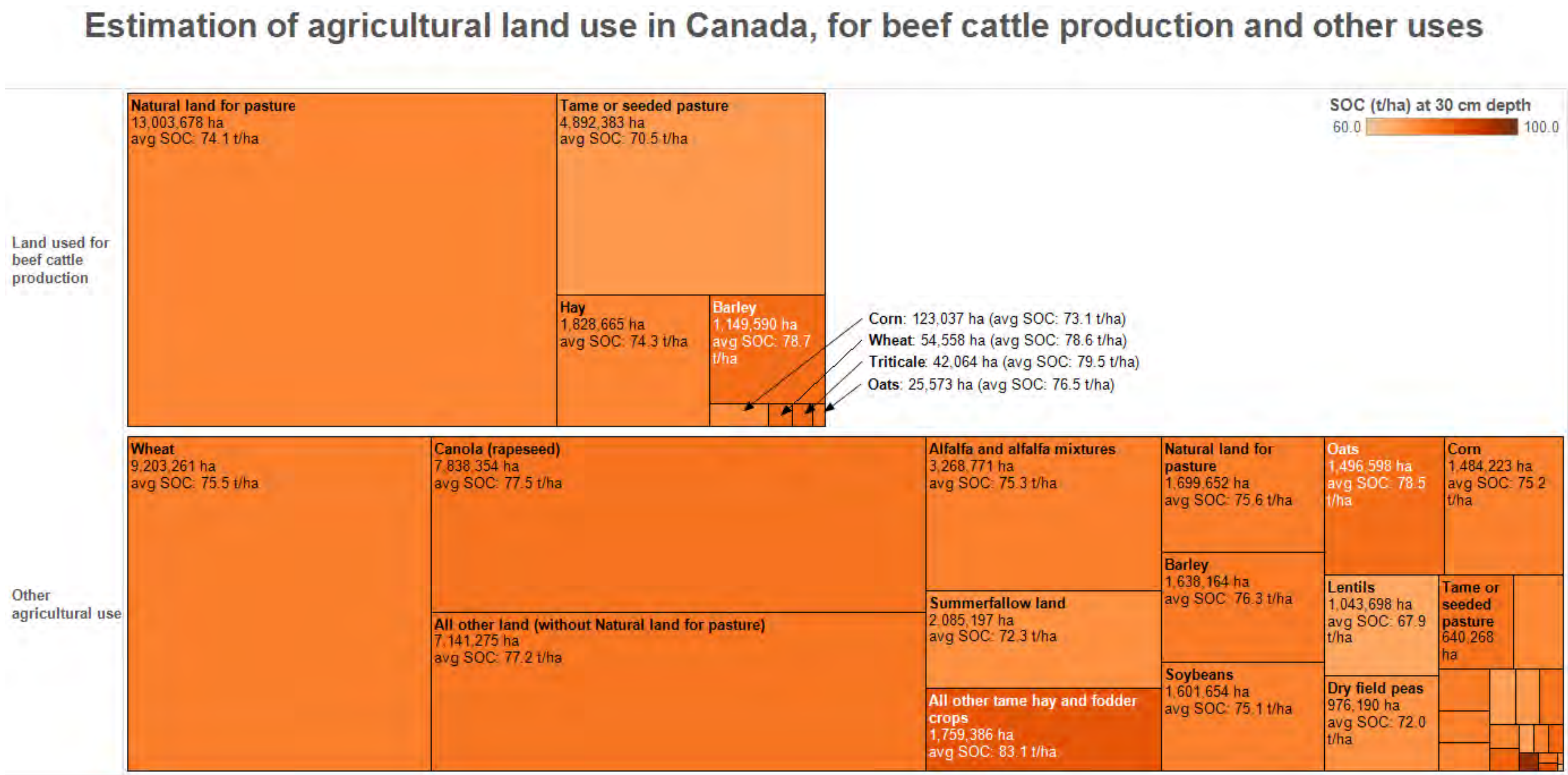

Figure 3-18 Land used for beef cattle production and other agricultural areas, alongside stock of carbon (SOC) intensity

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3.5.4 Result

3.5.4.1 Influence of LUC and LMC on the carbon footprint (per kg of live weight)

Values presented in Table 3.9 were applied to the rations fed to cattle and to the pasture areas. Correspondin removals and emissions associated with LMC and LUC are presented in Table 3.10.

Table 3.10 Average GHG emissions and removals issuing from LMC and LUC associated with Western Canada beef meat production (Kg CO_2 equivalents/kg of live weight)

Land cover	LMC[52]	LUC[53]
Feeds and forages	-0.76	0.19
Tame grassland	-0.51	0.13
Native grassland	-	-

In Western Canada, the GHG emissions associated with beef meat production, excluding the effects of land us land management change, amount to 11.4 kg CO_2 equivalents/kg of live weight. When considering the remova emissions associated with LMC and LUC, the net carbon footprint of Western Canada beef production is reduc 10.5 kg CO_2 equivalents/kg of live weight.

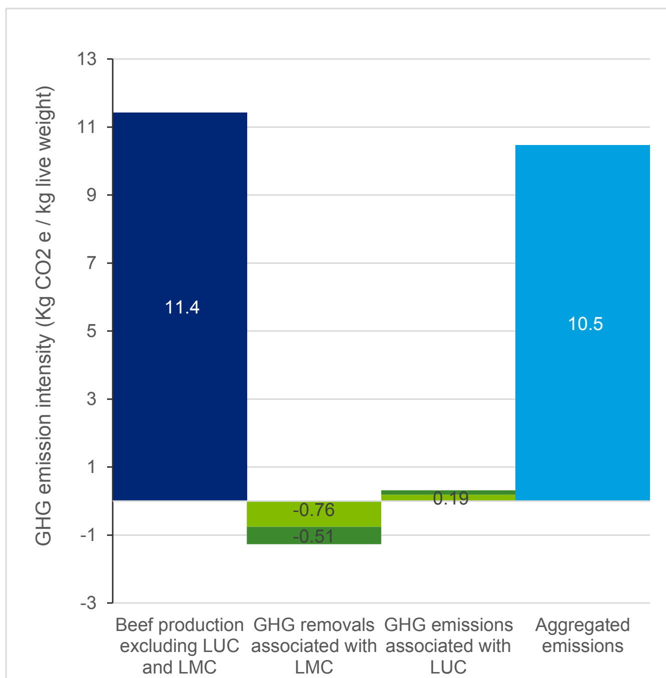

Figure 3-19 Greenhouse gas emissions and removals associated with Western Canadian beef meat production per kg of live weight. In light green: emissions and removals associated with cropped feed and forages). In dark green: emissions and removals associated with tame grass.

Compared to the other sources of GHG emissions (CH_4 from enteric fermentation and manure, N_2O emissions manure and crop fertilization, etc.), LUC have a relatively minor impact on GHG emissions, given that forest la conversion has decreased, while improved land management practices—mostly reduction or cessation of tillag enable the reduction of GHG emissions through soil absorption of atmospheric CO_2. Indeed, if we compare LU

[52] Removals due to land management change
[53] Emissions due to land use change

LMC-induced emissions and removals between 1986 and 2006, we can see that LMC removals have multiplied 13 times, while LUC emissions have increased but by only 70% (Shrestha, et al., 2014).

Comparing the effects of LUC and LMC to current carbon stocks

Provided the figures of organic carbon stocks per hectare in Canadian soils (see Table 3.9) are realistic, and considering the crop, native and tame pasture areas required to produce one kilogram of live weight of beef, the carbon sequestered by cattle per kilogram of live weight amounts to 672 kg C to a 30 cm depth. Given molar mass ratio between C and CO_2, this stock of C represents an equivalent of nearly 2.5 tons of CO_2 per kg live weight (illustrative figure, as soil carbon will never be fully released in the atmosphere). Given current Canadian land use and land management practices, this carbon stock is not at risk, but needs to be preserved and enriched. Overall, the soil organic carbon stock in Canadian agricultural lands can be estimated to about 4,861 million tons of organic C to 30 cm, while land occupied for beef production represents 1,553 million tons (Figure 3-17).

Scenario analysis

To understand the effect on emissions and removals associated with LUC and LMC in case of a variation of the total Canadian herd size, a scenario analysis was performed similar to the biodiversity scenario analysis. The impacts in terms of land use of a 10% increase or a 10% decrease of herd size are described in the chapter dedicated to biodiversity (see Table 3.2). As most land conversion would only occur between croplands and/or tame pasture, assuming conversion of native rangeland is minimal today and provided the similar values for GHG emissions/removals associated with LUC and LMC for croplands and tame pasture, a 10% increase or decrease in herd size would not result in significant changes in LUC and LMC, so changes in emissions, either stored or released, would be minimal. It would only affect the current cropland and tame pasture areas dedicated to beef meat production. All other things being equal (in terms of cattle management, rations composition, etc.), a 10% increase or decrease in cattle herd size would not affect the current GHG removals and emissions associated with LUC and LMC per kg of live weight.

Greenhouse gas emissions from beef meat production

To provide some comparison points in absolute GHG emissions, we assessed how Canadian beef-related emissions compared to agriculture emissions calculated in the *National Inventory Report 1990-2013: Greenhouse Gas Sources and Sinks in Canada*. Given finishers and culled cows sent to processors in Canada in 2011, as well as the GHG emissions intensity of 11.4 kg CO_2 eq./kg of live weight meat for Western Canada (excluding the effects of land use and land management change), we estimated the absolute emissions related to beef meat production at 17.1 Mt CO_2 eq. Those emissions were accounted for in the Agriculture category of the economic sector allocation (see Figure 3-20) in 2013. As Canada's total GHG emissions in 2013 were estimated at 726 Mt CO_2 eq., beef meat production accounts for about 2.4% of Canada's overall GHG emissions.

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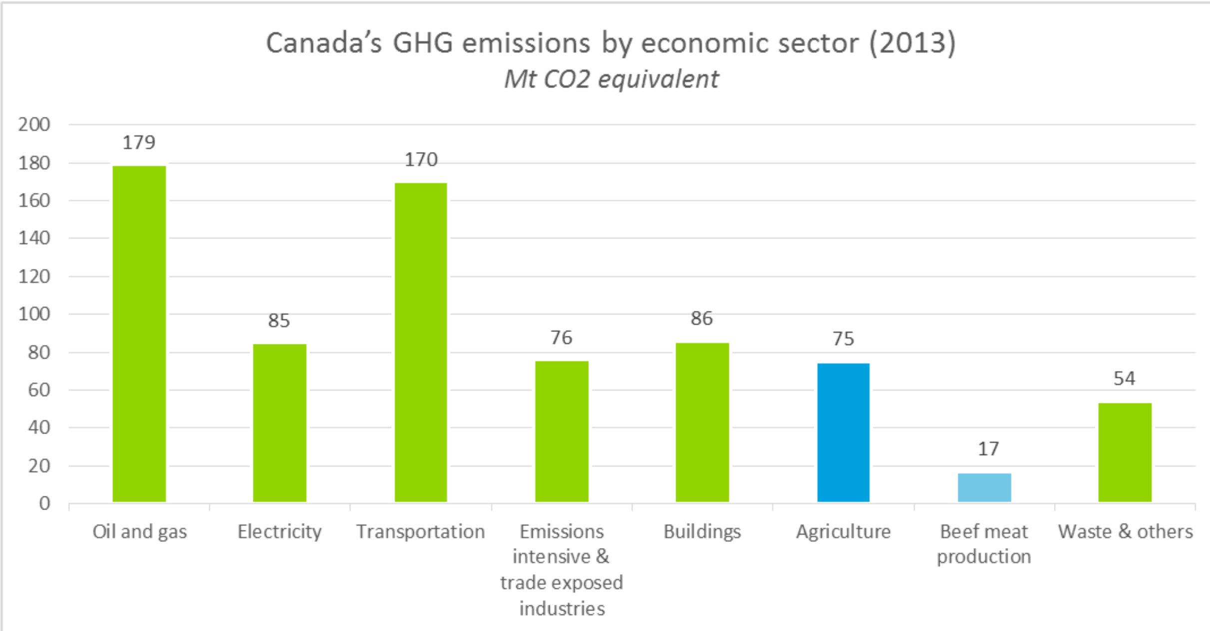

Figure 3-20 Canada's GHG emissions by economic sector in 2013

3.5.5 Discussion

This assessment demonstrates the significance of native grassland in terms of carbon storage in Canada. Beef production is a compatible use for native grasslands that provides economic benefits to the land manager while still providing important environmental benefits, including the preservation of native rangelands from conversion to other land uses such as cropping or tame pasture. Cropping and tame pasture are significantly less effective at storing carbon than native rangelands. In fact, cultivation of native grasslands can release 30-50% of the carbon present (Burke, et al., 1995) (Lal, 2002). By merit of occupying the land base as an economically viable practice, beef production acts as a mechanism to preserve native grasslands and their carbon storage values in the face of increasingly intensive human use and the risk of further loss and/or degradation to other uses (Pitt & Hooper, 1994).

Often regarded as an area of low productivity, native grassland should rather be considered an area of high priority for conservation considering the services it provides in terms of carbon storage as well as biodiversity (see next chapter). Grasslands sequester significant amounts of carbon and provide a stable carbon sink that is compatible with sustainable grazing. Indeed, as previously shown, native grasslands contain over 40% more carbon at 30 cm depth than cropland and tame pastures, and this carbon is stored in its most stable form (below ground) relative to the less stable forms of carbon stored in cultivated land in particular. This presents an opportunity for the beef industry to play an active role in preservation of existing native grasslands. Although restoration of native grassland is a difficult, costly and slow process, it may increase carbon storage (to a point of equilibrium with the natural capture and release cycle) relative to other land uses in the long term (Bork, 2015).[54]

[54] Thanks to Dr. Edward Bork (University of Alberta) for his overall vision of the land carbon storage issue across Canada

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4 Social life cycle assessment

Table of contents

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4.1 Abstract

The social life cycle assessment (SLCA) is a "technique that aims to assess the social and socioeconomic aspects of products and their potential positive and negative impacts along their life cycle" (UNEP/SETAC, 2009). This chapter describes the process and results of the life cycle assessment conducted for Canadian beef according to the goal and scope previously presented in Chapter 1. The SLCA is divided into five distinct sections. The first section covers the methodological choices and assumptions used to conduct the SLCA based on a literature review of existing methods and SLCAs of other products. The second section is the life cycle inventory analysis or, more specifically, the identification and categorization of data collected to perform the SLCA. The third section presents the results by life cycle stage. In this section, the scope of each life cycle stage, as well as the limits of the assessment, is presented. The fourth section summarizes the results and interpretations of the SLCA. Finally, the fifth section presents the SLCA limitations and challenges.

The results of this SLCA are based on both specific data—collected through surveys of beef producers, processors and the industry's associations—and generic data based on secondary research for the assessment of downstream (distributors) and upstream (suppliers) value chain actors, as well as the national legal and regulatory environment.

Overall, the SLCA results indicate mostly low and very low risks for the indicators assessed. It should be noted that there may be some biases in the results due to the stakeholders consulted for the study. Complementary secondary research was conducted to balance these biases, but due to time and budget limitations, indicators may not portray other stakeholder perspectives. Indicators showing high risks include: national regulations regarding indigenous population and migrant workers, workers' income at the distributors' level, workload at cattle operations and injuries at the suppliers' level.

Lastly, we also observed that there seems to be a perception gap between internal stakeholders of the industry (based on specific data) and observed trends (based on generic data) on the following topics: health and safety, environmental management, hourly wages and migrant employee working conditions. This gap highlights the need for direction in subsequent phases of the project and for consideration in developing the industry's sustainability strategy.

4.2 SLCA methodological choices and assumptions

SLCA is a relatively new field with differing methods of assessment (Fan, et al., 2015). However, as of 2015, "no globally shared application tools have yet been developed" (Arcese, et al., 2015). Depending on the objectives (internal vs external communication, eco design, product comparison), object (product or service) and scope (company or industry) of the study, some SLCA methodologies are more relevant and applicable than others. SLCAs are categorized into two main types of impact assessments, namely: Type 1—using ordinal scales to describe a risk, a performance or a level of control, therefore relying on semi-quantitative data; and Type 2—seeking to represent the impact pathways, as in ELCA and requiring quantitative data (UNEP, 2013).

For different reasons presented in the goal and scope, the methodological choice for this SLCA pertains to the Type 1 SLCA. Consequently, a crucial question to answer was: "What are data assessed against?" Again, this is determined through a characterization process that can be done by following several methodologies. The reference points can rely on several sources, such as international norms and standards, experts' or stakeholders' judgement, and average or comparative performance (Russo Garrido, et al., 2015). However, more research is still needed to reach a consensus on the characterization of indicators to enable comparison (Vinyes, et al., 2013).

We should also note the existence of the Social Hotspot Database which provides social supply chain impacts globally. However, because the activities and supplies covered by the SLCA scope mainly occur in Canada, it was decided not to use the Social Hotspot Database (SHDB), which enables an assessment at the country level. With targeted indicators, we aimed to provide a more customized approach for the industry by reviewing practices of major companies active in the different fields, in both upstream and downstream beef production (see 4.4.3 for more details).

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One study proposes a multi-criteria indicator-assessing model that can be applied to all social impacts (Dreyer, et al., 2010). The assessment is based on three steps: 1) identification of the impact category, 2) scoring the managerial effort on the protection of human dignity and well-being and 3) conversion from the managerial effort score to the company risk score. The company risk score is similar to the credit score system in the financial sector and evaluates the efforts that a company puts into preventing the violation of human dignity and well-being of each stakeholder involved in a product's life cycle stages. It can then describe the level of the risk or the probability that this violation will happen. This approach is similar to the approach used for the SLCA of the dairy sector in Canada (Dairy Farmers of Canada, 2012) and relies on both specific data for a socioeconomic performance analysis and generic data for a potential hotspot analysis. Although the approach is similar in terms of methodology, the references and content are adapted to the beef cattle industry by taking into account specific practices and stakeholders.

Because our sample for specific data is limited—i.e. data collected from surveys distributed to beef producers and major processors—our analysis approach was similar for both specific and generic data, and was based on a potential hotspot analysis. Although the potential hotspot analysis is usually used for generic data analysis, the approach was retained for the specific data analysis as well in our study. Instead of providing an assessment of stakeholders' performance, which would require a representative and therefore larger sample, the approach provides a risk assessment of potential impacts. For the cattle operators, our sample could not be used to represent the industry in its entirety. While lower scores enable the identification of potential risks, higher scores represent potential opportunities or good practices across the industry. The "comments" section of the indicators provides contextual information to help further understand the results through complementary data, survey details, national statistics or other external references.

Our methodology combines two approaches (multi-criteria analysis and potential hotspot analysis) to provide risk evaluation scales based on both specific and generic data. Collected and compiled data are aggregated into indicators and compared against assessment factors based either on documented references when available, or on experts' judgement. This flexibility is in line with the UNEP/SETAC (2009) guidelines which states that "impact assessment methodologies are under development and SLCA is an open field for future research."

It is important to note that consultation and discussions with industry experts or subject matter specialists (such as animal welfare specialists) were key steps in the development and review of indicators and their respective comments. This approach contributed to developing a baseline of indicators relevant to the industry, and as much as possible in line with the reality of stakeholders, while following current social life cycle assessment standards in a balanced way.

The assessment of a product involving a nation-wide industry adds a level of complexity to the assessment and limitations in data collection due to a broad geography and reduced accessibility—there are more than 68,500 beef cattle farms and ranches in Canada, including many small family-owned operations (Anon., 2008). This is one of the reasons why questionnaires were sent to operator/owners and processor managers, rather than to workers and employees. This approach was used in another social LCA of chemical and food products in the Czech Republic. The results from the study in the Czech Republic relied on semi-structured interviews with 35 companies' top managers (Vavra, et al., 2015).

With the help of the Canadian Roundtable for Sustainable Beef, the main beef producing provinces were represented in our sample. However, the scope of the study, representative of a full life cycle assessment, should contain more than a single element of the value chain. Figure 4-1 shows the scope of the assessment, covering several stages of the Canadian beef industry value chain.

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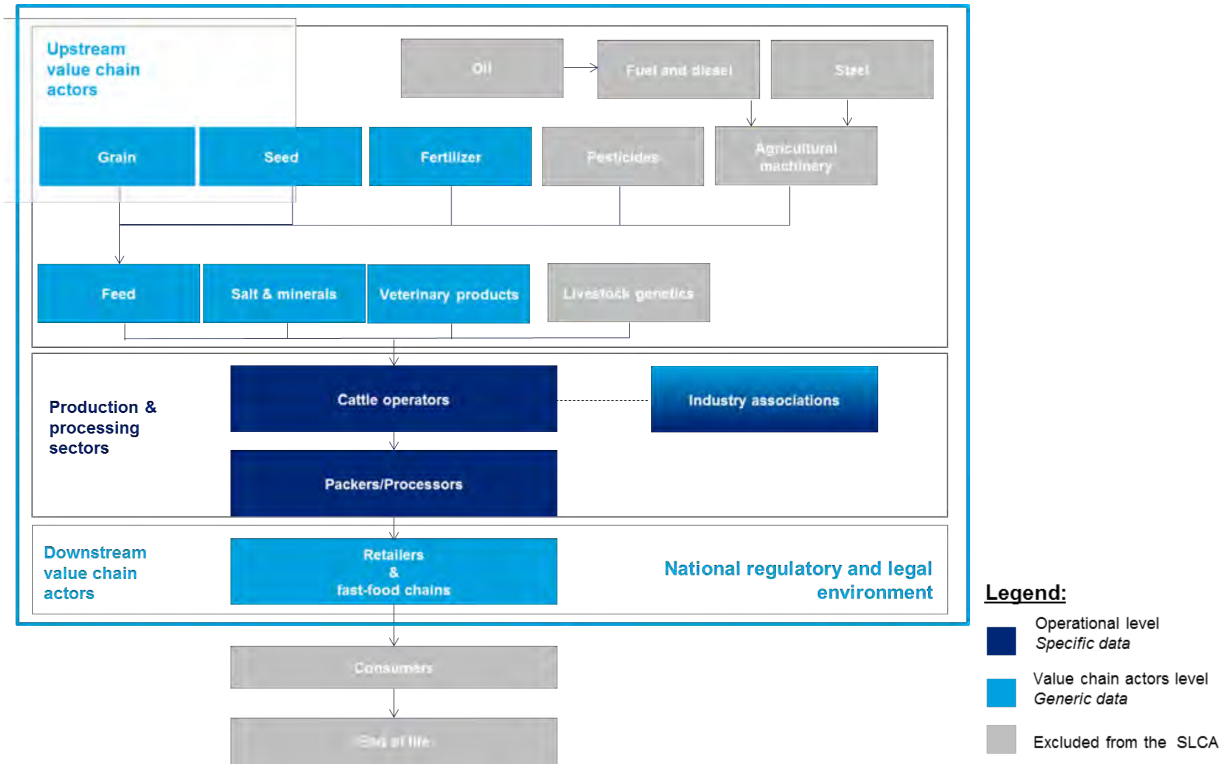

Figure 4-1 SLCA scope—Stages covered by the assessment

For industry associations, both specific and generic data were collected—represented by different shades of blue in Figure 4.1. Data in the LCA are specific to a certain site and generally collected for the purposes of this study, whereas generic data were collected from various sources, including web research, in order to provide proxies when specific data were not available or could be collected. Sources of data will be further explained in the main methodological choices section for each life cycle stage.

Three types of data were collected for this LCA: quantitative, semi-quantitative and qualitative data. All data used for the risk evaluation were compiled into semi-quantitative data. Some data were also kept “as is” in order to provide additional context information to better analyze and interpret the results at a later stage.

Finally, it is important to remember that the objective of this SLCA is to conduct a **baseline** assessment to be leveraged during the next phase of the project, which will be an analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT) to build a sustainability strategy for the Canadian beef industry. An important take-away of this baseline assessment will be to identify—based on the hotspots and limitations identified—key performance indicators that will enable the industry’s actors, including the Canadian Roundtable for Sustainable Beef, to monitor and improve practices (Arcese, et al., 2015).

4.2.1 Main methodological steps

Keeping in mind that the SLCA aims to assess social risks across the value chain and identify the main “hotspots”, several steps were taken to obtain a big picture view of the industry and its social impacts, both positive and negative. These steps are presented in Figure 4-2.

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Figure 4-2 SLCA methodological steps

The **specific methodological choices** at each life cycle stage—presented alongside the SLCA results by life cycle stage section—follow the template set out in Figure 4-3:

- Scope of assessment and sources of data
- Average risk score calculation methodology
- Limitations [of the assessment observed at each specific life cycle stage]
- Interpretation of the evaluation scale
- Characterization table of indicators and risk scores—see template below:

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[Stakeholder group *affected by practices occurring at each life cycle stage]*		
[Subcategory of impact *based on the social profile defined in the goal and scope section]*		
[Indicator]	**Description** XXX	
Assessment factor	*Element of risk assessment*	
Rating scale	High risk = 1 point	
	Moderate risk = 2 points	
	Low risk = 3 points	
	Very low risk = 4 points	
Risk assessment	**Results breakdown** (i.e. % of respondents by level) *(for cattle operations only)*	**Average score**
Comments	XXX	

Figure 4-3 Template of indicator characterization

The risk assessment of each indicator is based on a scale from one to four, according to the distribution presented in Figure 4-3. The points attributed to each level, depending on the evaluation of the surveys' answers or data collected online, were used to define the average score following Table 4.1.

Table 4.1 Scoring table by number of levels used to assess indicators

Colour	4-level	3-level (A)	3-level (B)	3-level (C)	3-level (D)	2-level (A)	2-level (B)
Red	1-1.75	---	1.00-2.00	1.00-2.00	1.00-1.66	---	1.00-2.50
Orange	1.76-2.50	2.00-2.66	---	2.01-3.00	1.67-2.33	2.00-3.00	---
Yellow	2.51-3.25	2.67-3.33	2.01-3.00	---	2.34-3.00	---	---
Green	3.26-4.00	3.34-4.00	3.01-4.00	3.01-4.00	---	3.01-4.00	2.51-4.00

- Depending on the indicator, only three- or two-levels were considered. For instance, the red level does not always exist as it is considered a "risky" behaviour, which does not necessarily apply in all situations, whereas some questions imply binary answers (yes or no) and have only two levels of evaluation.
- The scoring system presented above is considered unbiased and equally distributed between the colour codes. This "distribution" approach, aimed at obtaining brackets of points equal for each level, has also been used by Quantis Canada, AGECO and CIRAIG (2012) in their socioeconomic assessment of the Canadian milk industry, and will more easily allow the comparison between these two important sectors of the industry. An example of the impact of using this approach is that, for indicators with a predominance of answers falling in the orange and green categories, for instance, the average results will appear as yellow, even if there is a small percentage of respondents falling in the yellow category. It is one of the limitations of this approach, but does not impact the credibility of the results, as it is the result of an average calculation.

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- Each bracket of points per level should be equivalent, while respecting the minimum and maximum number of points possible depending on the number of levels for each indicator. As presented in the table above, several scenarios were therefore used to determine the average score of each indicator.

See the specific methodological choices for more details regarding the calculation of the average risk score by life cycle stage in section 4.4 SLCA results by life cycle stage.

Because the assessment of each life cycle stage did not rely on the same sources of data (see figure below), these specific methodological choices were necessary to apply and to present in this report.

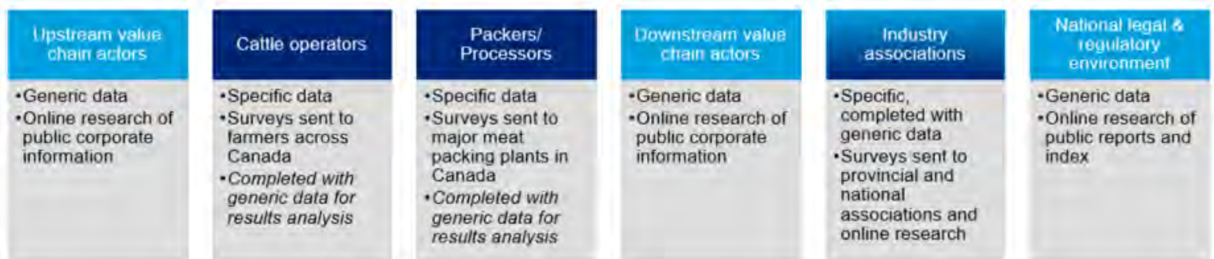

Figure 4-4 Overview of data sources used for each life cycle stage assessment

Note: Although the positions of upstream and downstream value chain actors differ in the life cycle, the approach used for their assessment is the same. Their specific methodology is therefore presented together in the SLCA results by life cycle stage section.

Figure 4-5 provides an overview of our study's data sources and coverage at each life cycle stage:

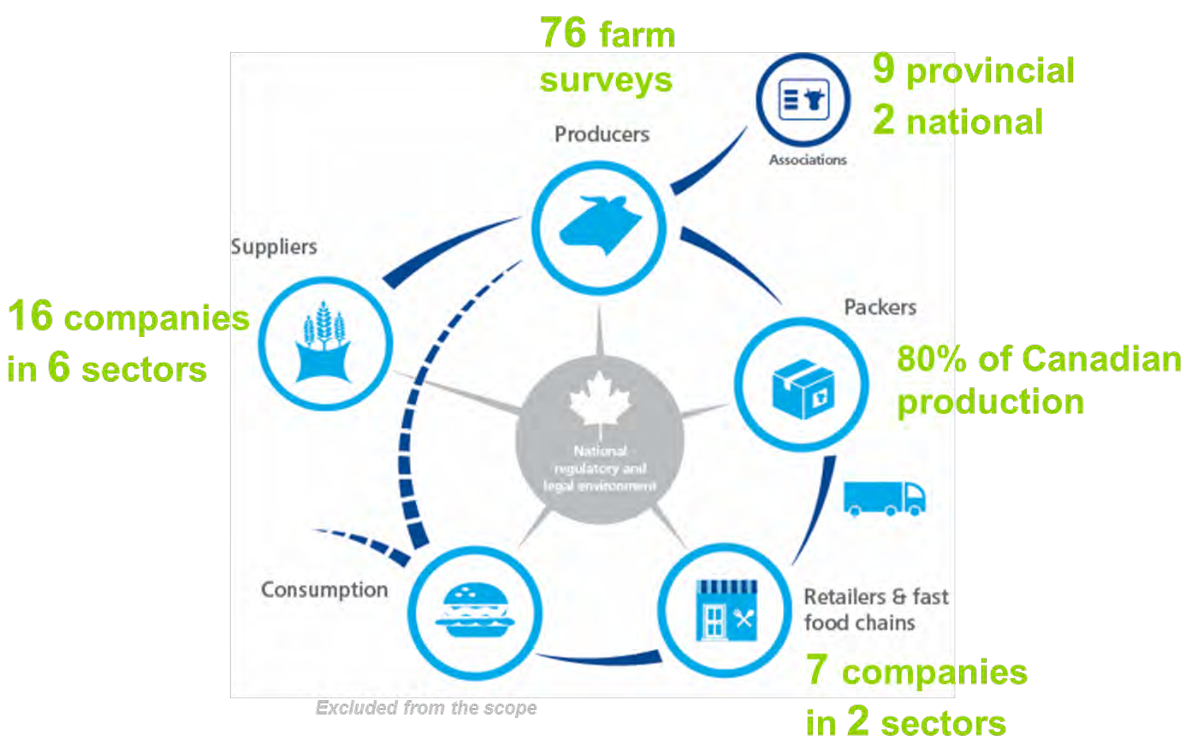

Figure 4-5 SLCA in numbers

4.2.2 Data quality

Table 4.2 presents the confidence level of data at each life cycle stage and, when applicable, the mitigation measures taken to enhance data quality.

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Table 4.2 Review of SLCA data quality

Life cycle stage	Type of data	Source of data	Data confidence level pre-mitigation	Mitigation measures	Data confidence level post-mitigation
Producers	Specific	Survey of farm owners	Low due to non-statistical representativeness and focus on farm owners only	Results compared with generic data from secondary research (national trends and statistics, reports)	Medium—secondary research information taken into account in results' analysis but not used to change the indicators' assessment
Packers	Specific	Survey of managers	Medium—focus on managers only	Results compared with generic data from secondary research (national trends and statistics, reports)	Medium—secondary research information taken into account in results' analysis but not used to change the indicators' assessment
Value chain (i.e. suppliers, retailers and fast-food chains)	Generic and specific	Secondary research	Medium—possible gap between what is communicated and what is done in reality	CRSB members asked to review the information found online about their companies	High—indicators' results were reviewed based on received feedback
Associations	Generic and specific	Secondary research	Medium—possible gap between what is communicated and what is done in reality	Associations' representatives asked to review the information found online about their associations	High—indicators' results were reviewed based on received feedback
Legal & regulatory environment	Generic	Secondary research	Medium—data compiled from diverse sources (vs from existing database)	n/a—no mitigation measures were taken for this life cycle stage as this confidence level is inherent to the source of data	n/a

4.3 SLCA life cycle inventory analysis

4.3.1 Flow inventory

The product system and flows are tied to the system boundaries presented in the goal and scope section. The product system has inputs such as: human resources, financial resources, business practices, and laws and regulations. The application of these inputs to the product system leads to social impacts, analyzed in our assessment as potential positive and negative hotspots for the beef industry. To determine hotspots, inputs are tested in our assessment at the different life cycle stages of beef production, presented in blue in Figure 4.6 below, based on different sources of data—including surveys for specific data and secondary review for generic data.

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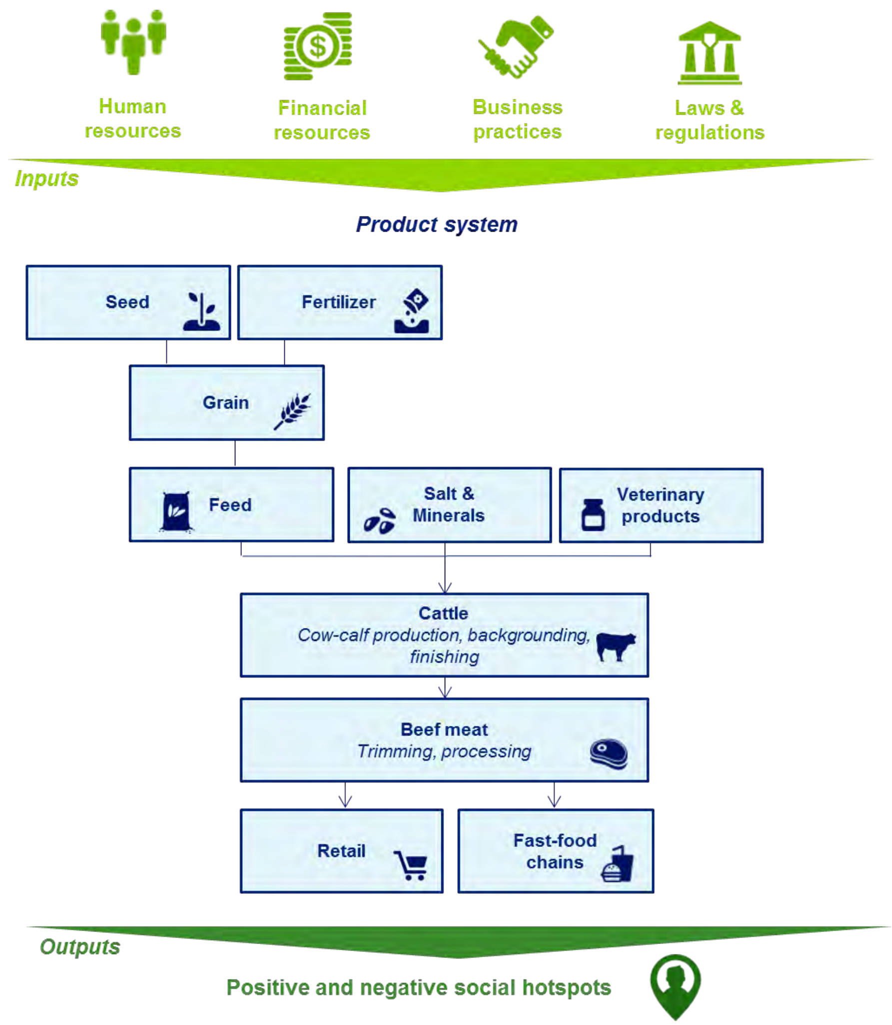

Figure 4-6 SLCA product system and flows

4.3.2 Selection of stakeholder groups and subcategories of impact

According to the UNEP/SETAC guidelines, the classification of social impacts can be made based on two schemes that are complementary and not contradictory, i.e. the stakeholder groups and the impact categories. In order to identify the indicators that will determine the social hotspots studied in our LCA, stakeholder categories and their associated subcategories of impact were selected according to the UNEP/SETAC guidelines.

The UNEP/SETAC guidelines identify five main categories of stakeholders: workers, local communities, society, value chain actors and consumers.

Table 4.3 Definition of stakeholder groups by life cycle stage

Life cycle stage	Workers	Local communities	Value chain actors	Society	Consumers

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<table>
<tr><th>Life cycle stage</th><th>Workers</th><th>Local communities</th><th>Value chain actors</th><th>Society</th><th>Consumers</th></tr>
<tr><td>Cattle operations</td><td>Cattlemen and farm workers</td><td>Local communities where cattle farms are located</td><td>Partners and suppliers of cattle raising activities such as feed producers, veterinary products companies, etc.</td><td rowspan="6">Canadian society</td><td rowspan="6">Consumers of Canadian beef</td></tr>
<tr><td>Processors</td><td>Processing plants' workers</td><td>Local communities where processors are located</td><td>Processors' partners and suppliers</td></tr>
<tr><td>Upstream value chain (VC)</td><td>Suppliers' workers</td><td>Local communities where suppliers' operations are located</td><td>Suppliers of seed, grain, fertilizer, feed, salt and minerals, veterinary products</td></tr>
<tr><td>Downstream value chain (VC)</td><td>Workers in the retail sector and fast-food chains</td><td>Local communities where retailers and fast-food chains are located</td><td>Retailers and fast-food chains</td></tr>
<tr><td>Associations [of beef producers and processors]</td><td>Workers of the sectors represented by beef producers and processors associations</td><td>Local communities in which the associations operate</td><td>Value chain actors of the sectors represented by beef producers and processors associations</td></tr>
<tr><td>National [legal and regulatory environment]</td><td>Workers in Canada</td><td>Local communities in Canada</td><td>Value chain actors located in Canada</td></tr>
</table>

Note: the consumers category refers to the end-consumers of the product studied in this life cycle assessment. They do not represent the consumers of each life cycle stage (e.g. the consumers of the upstream value chain would be the cattle operations, the consumers of cattle operations would be the processors, etc.).

These categories of stakeholders are linked to subcategories of impact presented in the UNEP/SETAC guidelines and are based on international agreements, defined for instance by the International Labour Organization or other organizations developing conventions and agreements to ensure the application of minimal compliance in different social areas. When necessary, additional relevant impact subcategories were added, such as animal welfare.

The "value chain actors" category identified in the UNEP/SETAC guidelines has been divided into two subcategories to represent both upstream and downstream value chain actors. The sectors analyzed in each of these categories were selected based on discussions with the project's Steering Committee and experts' judgement. Please refer to 4.4 SLCA results by life cycle stage.

For the purpose of our study and the objectives described in the goal and scope, the table below presents the definition of each selected impact subcategory. These subcategories can also be linked to a broader impact category, i.e. human rights (HR), working conditions (WC), health and safety (HS), cultural heritage (CH), governance (G) and socio-economic repercussions (SER), identified in the table below for each subcategory. The last columns of the

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table present the different life cycle stages for which each impact subcategory has been assessed in our study (i.e. life cycle stage column marked with an “x”). This does not mean the impact subcategory is not applicable or not relevant if the life cycle stage is not marked with an “x”, but rather reflects the scope of our study based on available, collected information and the limitations of our process.

For subcategories included in the UNEP/SETAC guidelines that were not used in this study, a rationale is provided in Table 4.5. Most subcategories are relevant to the Canadian context.

Table 4.4 List of subcategories included in the SLCA of Canadian beef production and their definitions (adapted from UNEP/SETAC methodological sheets)

Stakeholder categories	Impact subcategories	Life cycle stage assessed >>> Definition	Cattle operations	Processors	Upstream VC	Downstream VC	Associations	National
Workers	Freedom of association and collective bargaining (HR)	All workers and employers have the right to establish and join organizations of their choice, without prior authorization, to promote and defend their respective interests and to negotiate collectively with other parties.		x				x
Workers	Fair salary (WC)	Fair wage means a wage fairly and reasonably commensurate with the value of the particular services rendered in this study.	x	x	x	x		
Workers	Working hours (WC)	The hours of work comply with applicable laws and industry standards. Workers are not on a regular basis required to work in excess of 48 hours per week. Hours of work are considered in function of different time arrangements (from part time to full time) and work places (e.g. from home workers to field workers and manufacture).	x	x				
Workers	Equal opportunities/ discrimination (WC)	Everybody has the right to be treated fairly and to have access to equal opportunities irrespective of sex, race, age, family status and responsibilities, pregnancy, religious or political beliefs and sexual orientation.					x	x
Workers	(occupational) Health and safety (HS)	All workers have the right to a safe (free of serious recognized hazards) and healthy (including absence of	x	x	x	x	x	

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Stakeholder categories	Impact subcategories	Life cycle stage assessed >>> Definition	Cattle operations	Processors	Upstream VC	Downstream VC	Associations	National
		disease or infirmity) workplace.						
Workers	Social benefits/social security (WC)	Social benefits refer to non-monetary employment compensation. Social benefits are typically offered to full-time workers, but may not be provided to other classes of workers (e.g. part time, home workers, contractual).	x	x				
Workers	Full-time seasonal and migrant workers (WC)	*[not included in the UNEP/SETAC guidelines]* Seasonal and migrant workers should be entitled to the same working conditions as full-time workers.	x	x				x
Consumers	(consumer) Health and safety (HS)	Consumer health and safety refers to the consumers' rights to be protected against products and services that may be hazardous to health or life.	x	x			x	
Consumers	Feedback mechanisms (G)	Feedback mechanisms are paths by which consumers communicate with organizations to help reveal consumer satisfaction related to the consumption and use of the product or service.		x		x		
Consumers	Transparency (G)	Organizational transparency enables an informed choice for the consumer without intent to mislead or conceal. While strategies may be used to communicate with consumers, others simplify the communication between organization and consumer.		x		x	x	
Consumers	End-of-life responsibility (SEC)	In a product life cycle, end-of-life refers to product and/or its packaging disposal, reuse or recycling.		x				
Local communities	Secure living conditions (HS)	Organizations with weak security oversight may contribute to insecure living conditions or community tensions.'		x	x			

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Stakeholder categories	Impact subcategories	Life cycle stage assessed >>> Definition	Cattle operations	Processors	Upstream VC	Downstream VC	Associations	National
Local communities	Respect of indigenous rights (HR)	Respect of indigenous rights includes the right to lands, resources, cultural integrity, self-determination and self-government.						x
Local communities	Community engagement (SEC)	Organizations can foster community engagement through direct involvement in community initiatives and/or through financial support of community projects.	x	x			x	
Local communities	Local employment (SEC)	Local hiring preferences provide important income and training opportunities to community members. Organizations that develop relationships with locally-based suppliers will further encourage local employment and development.	x	x	x	x		
Local communities	Delocalization and migration	Movement of population from other countries as a result of industry's workforce needs.						x
Local communities	Cohabitation (SEC)	*[not included in the UNEP/SETAC guidelines]* The nature of cattle and processors' operations may lead to proximity issues related to nuisance such as odour, noise or dust.	x	x				
Society	Public commitments to sustainability issues (SEC)	Commitments relate to the contribution of organizations to the sustainable development of the community or society as the reduction of impacts from their activities.	x				x	
Society	Contribution to economic development (SEC)	Organizations can foster economic development in many ways. They generate revenue, create jobs, provide education and training, make investments or forward research.	x	x	x		x	
Society	Technology development	The development and transfer of technology is an umbrella concept in which the different key elements					x	

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Stakeholder categories	Impact subcategories	Life cycle stage assessed >>> Definition	Cattle operations	Processors	Upstream VC	Downstream VC	Associations	National
	(SEC)	(technology needs, technology information, enabling environments, capacity building, financial and institutional mechanisms) play an important role.						
Society	Corruption (G)	Corruption is the misuse of power for personal advantages.		x				x
Society	Animal welfare (G)	*[not included in the UNEP/SETAC guidelines]* For the sake of this study, animal welfare is assessed against the Code of Practice for the Care and Handling of Beef Cattle (including sound management and welfare practices for housing, care, transportation and other animal husbandry practices) complemented by animal welfare experts' judgement.	x	x			x	
Other value chain actors	Fair competition (G)	Anti-competitive behaviour and anti-trust and monopoly practices are against fair competition.		x	x	x		x
Other value chain actors	Respect of intellectual property rights (G)	Intellectual property rights refer to the general term for the assignment of property rights through patents, copyrights and trademarks.			x	x		x
Other value chain actors	Promoting social responsibility (SEC)	Social responsibility is an organization's obligation to consider the interests of their stakeholders as customers, employees, shareholders or communities. By integrating it into core business processes and stakeholder management, organizations can achieve the ultimate goal of creating both social value and corporate value.	x	x	x	x		
Other value chain actors	Supplier relationships (SEC)	Organizations should consider the potential impacts or unintended consequences of their procurement and purchasing decisions on other organizations, and take due care to	x	x	x	x	x	

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Stakeholder categories	Impact subcategories	Life cycle stage assessed >>> Definition	Cattle operations	Processors	Upstream VC	Downstream VC	Associations	National
		avoid or minimize any negative impacts.						

Table 4.5 List of UNEP-SETAC guidelines' subcategories excluded from the study

Stakeholder categories	Impact subcategories	Justification for exclusion
Workers	Child labour	Child labour is not considered a concern in Canada where it is regulated by provincial and federal governments (Anon., n.d.). Canada has also ratified the Convention on the Rights of the Child and one of the two optional protocols to it while signing the other (Anon., n.d.).
	Forced labour	Forced labour is not considered a concern in Canada where the Canadian Charter of Rights and Freedoms and other applicable provincial standards protect workers (Anon., 2004).
Consumers	Consumers' privacy	Beef products' purchase and/or consumption do not pose risks to consumers' privacy.
Local communities	Access to material resources	Natural material resources such as water, land and other environmental resources and services are already covered by another subcategory: public commitment to sustainability issues.
	Access to immaterial resources	Immaterial resources such as community services and intellectual property rights (defined by UNEP/SETAC) are already covered by other subcategories—respectively Local community support and Respect of intellectual property rights.
	Cultural heritage	Beef production is not considered a threat to cultural heritage in Canada. On the contrary, it can be considered part of Canada's cultural heritage, as beef has been produced in the country for more than 100 years (Canadian Beef Breeds Council, 2015).
Society	Prevention and mitigation of armed conflicts	Armed conflicts are not considered an issue in Canada and beef production is not considered an industry potentially supporting countries with armed conflicts.

Finally, for each subcategory of impact, one or several indicators were identified to assess the social impacts of the industry on stakeholder groups—see 4.4 SLCA results by life cycle stage.

The large number of indicators selected for this assessment reflects complex and multifaceted types of impacts that can occur throughout the Canadian beef life cycle—from agricultural goods suppliers to consumers. This assessment

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aims to provide a baseline for the industry that enables it to identify the hotspots across a large spectrum of potential issues or concerns, as well as opportunities and good practices. The comprehensive set of indicators selected means there is a reduced risk associated with excluding subcategories that may have been important.

This large pool of indicators also enables each stakeholder group to make a selection of relevant indicators for making improvements in potential hotspots or highlighting positive impacts and practices.

4.4 SLCA results by life cycle stage

4.4.1 Cattle operations

4.4.1.1 Scope of assessment and source of data

The cattle operations life stage assessment is based on specific data, i.e. site-specific data collected especially for this study at the farm level across Canada. Surveys were sent via the provincial beef producer associations and contacts working in the industry to obtain a sample as representative as possible of the Canadian beef production profile as presented in Table 4.6. However, the sample is not statistically representative due to time and budget restrictions, the difficulty of accessing beef production community members and the diversity, geographic expanse, and size of operations, from single family operated farms to operations with hundreds of employees.

Despite these challenges, the sample includes farms with cow/calf, backgrounding and finishing operations. Efforts were made to match the beef cows' geographic breakdown with the sample geographic breakdown, as presented in Table 4.6 (Statistics Canada, 2013).

This sample differs from the ELCA, as about half of the farm owners/operators responded to both surveys (environmental and social), while the other half responded to only one or the other.

Table 4.6 Breakdown of beef cow inventories and survey sample by province

Province	Beef cows	Sample breakdown by province
BC	5%	11%
AB	40%	45%
SK	30%	22%
MB	13%	13%
ON	7%	8%
QC	4%	n/a
Atlantic	1%	1%

This was one of the first surveys conducted across such a large geographic scale while also covering such a large spectrum of topics at both the social and environmental levels. Although there are some limitations, the study will inform future decision making and strategy development processes for the industry, while providing a comprehensive risk assessment of the current situation. It will also provide the industry with direction for future research; for example, where hotspots or gaps are identified.

As illustrated in Table 4.6**,** the breakdown of respondents by province for the cattle operators' survey is generally aligned with provincial production ratios.

The sample used for this assessment is composed of 76 surveys which are geographically distributed as presented in Figure 4-7.

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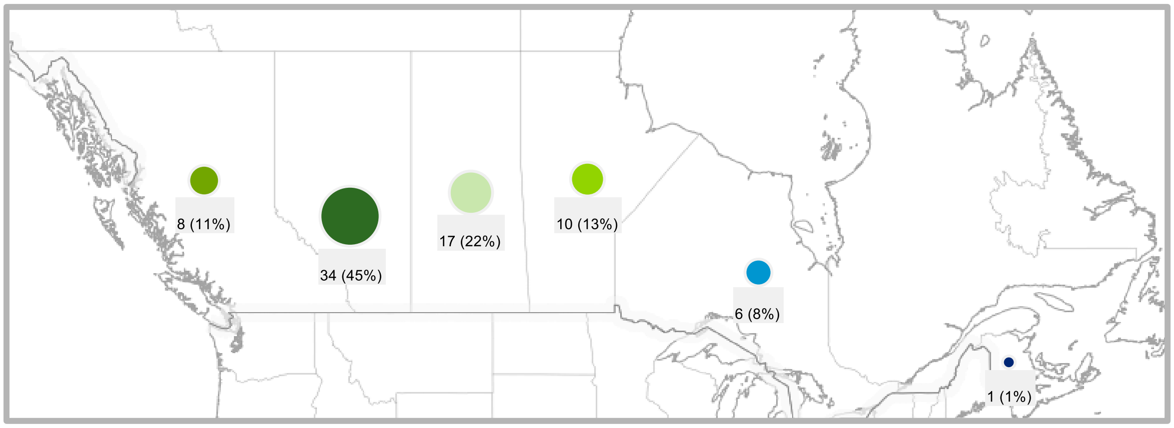

Figure 4-7 Survey sample geographic distribution

This sample is not large enough to be considered statistically representative of this sector, as there are approximately 68,500 farms with cattle in Canada. Our approach was therefore not to provide an assessment of the actual performance of this life cycle stage, but rather a risk assessment based on practices derived from a small sample of the sector that puts these risk indicators into perspective by relying on other references relevant for Canadian cattle operations—e.g. surveys on specific aspects, national statistics and other reports addressing the topics covered by the subcategories of impact assessed in this SLCA.

In terms of farm size as it relates to number of workers and farm annual revenues, our sample is represented as presented in Figure 4-8. Please note, however, that when comparing the profile of surveyed farms with the 2011 Agricultural Census data, we find that we have a skewed sample in this study, as it primarily represents larger operations with high gross revenue in comparison to the industry average (Statistics Canada, 2013).

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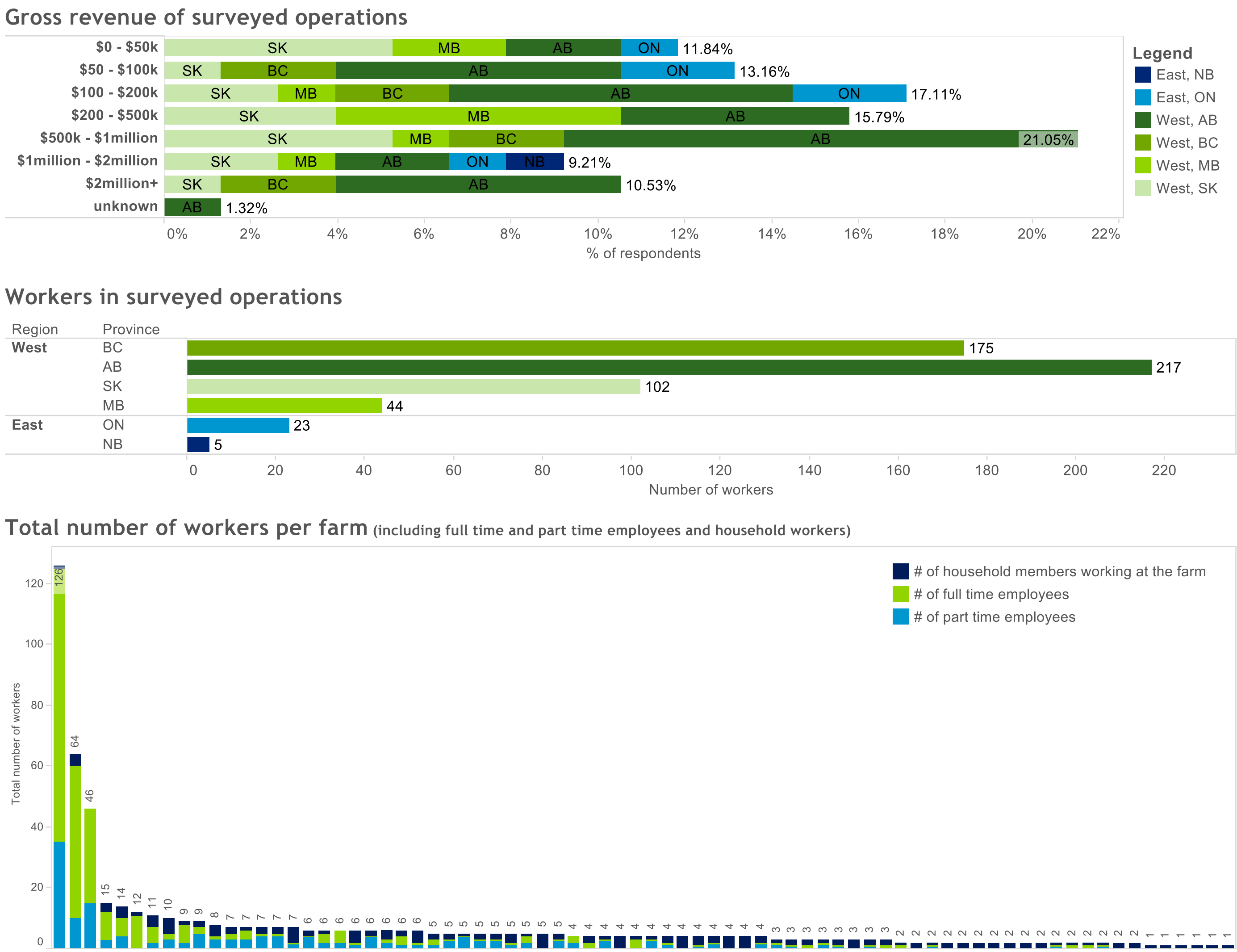

Figure 4-8 Surveyed farms profile.

The distribution of workers per operation may depend on their type of activities (i.e. cow/calf, backgrounding, finishing). Although information was not provided by all respondents, feedlots (finishing) generally have more workers than cow/calf operations. The graph above shows that most operations have less than five workers, while a few operations show higher numbers of workers (from 15 to 126 workers—including part-time and full-time employees and household members working at the farm). The difference in the number of employees has an impact on some indicators ("Workers" category) which have been weighted by number of employees, and are identified in the characterization table with an asterisk (*).

4.4.1.2 Average risk score calculation methodology

The average score for each indicator was calculated in four steps: 1) assignment of the number of respondents by rating level for each indicator identified in the characterization table; 2) calculation of the sum of points by indicator; 3) calculation of average score; and 4) translation of the average score into colour code, defining the level of risk from high (red) to low (green). Figure 4-9 illustrates the process using an example with fictitious numbers:

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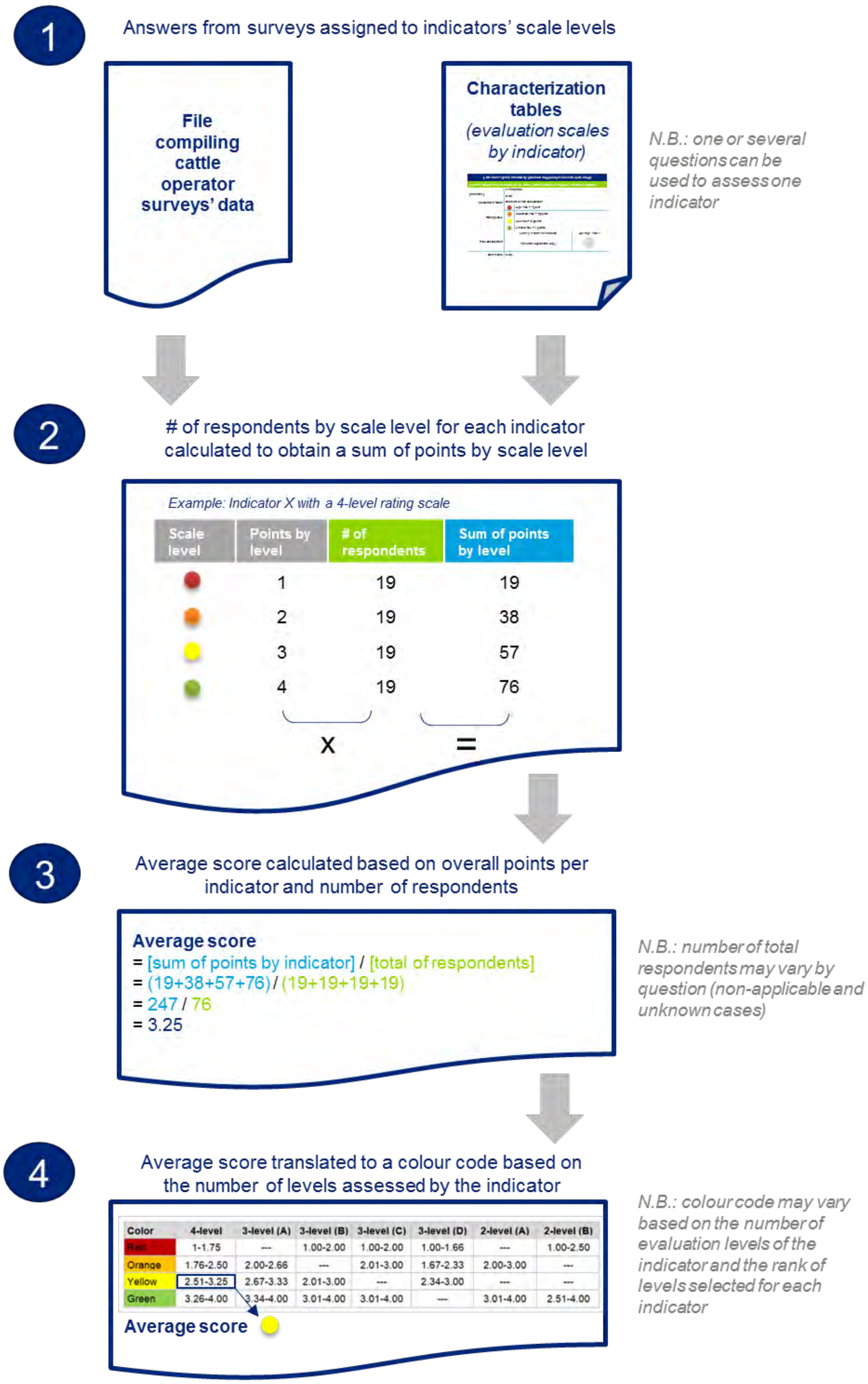

Figure 4-9 Average risk score calculation methodology steps (cattle operations)

Notes:

- For certain indicators of the "Workers" stakeholder group (identified with an *), results were calculated based on the number of farm workers (full time and/or part time) declared by the respondents rather than on the number of respondents (i.e. farm owner who has responded to the questionnaires) to reflect the different operations' sizes in terms of workforce.
- For cattle operators, indicators also include a "Survey results breakdown" box. It represents the breakdown of respondents' answers to the survey for each rating level of indicators.

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4.4.1.3 Limitations

- As already mentioned, the size of our sample does not allow us to have statistically representative data. The risk assessment methodological approach was adapted to address that limitation. As such, the sample population was not weighted (all operations were considered to have the same importance, as were all workers for indicators based on the number of farm workers).
- Our survey was distributed to a limited number of farms in Québec due to the language barrier. As a result, no Québec cattle operations (4% of total production in Canada) are represented in our sample.
- Other Eastern provinces are also less well represented than Western provinces, where most of the production is concentrated. Some practices may vary from East to West due to climate conditions and other specificities, so these regional differences may not be entirely reflected in our risk assessment.
- Although several indicators can be framed around common federal laws and regulations, some provincial specificities exist, which can provide a certain bias in the results for farms located in provinces with different regulatory or legal requirements and obligations.
- The types of operations run by respondents include cow/calf, backgrounding and feedlot, which may imply different realities for certain indicators due to the type of workers/employees, infrastructures and specific requirements. Our results only provide an average of practices for these operations, and distinctions are not always possible to make.
- The number of respondents by indicator may vary due to:
  - the topic covered, which may not always be applicable to all farms for different reasons; and
  - blanks in the completed surveys with information not provided by respondents, because information was not available, confidential or omitted. Active follow-ups were made to make questionnaires as complete and clear as possible.
- The impacts associated with growth enhancing technologies (GET) were not covered by the SLCA indicators. From a beef quality point of view, the effects of hormones highly depend on the strategy adopted and the proper use and timing of implants to mitigate or even avoid potential adverse effects. Impacts and risks can therefore greatly differ. From a human health perspective, there are conflicting positions at the international scale that are too divergent for a baseline risk assessment. Finally, our literature review showed positive economic impacts though reduced costs for beef producers. However, strictly economic aspects were not covered by the SLCA. For more details on GETs, please refer to 6.13 SLCA—Rationale for hormones exclusion.

4.4.1.4 Interpretation of the evaluation scale

The scale presented in Table 4.7 was used to assess potential risks at the farm level.

Table 4.7 Risk scale levels

Colour	Risk scale level	Definition
(red)	**High**	High risk of negative social impact
(orange)	**Moderate**	Moderate risk of negative social impact
(yellow)	**Low**	Low risk of negative social impact
(green)	**Very low**	Very low risk of negative social impact / potential positive impact

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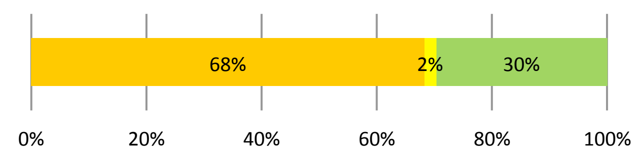
4.4.1.5 SLCA indicators and risk scores

WORKERS		
Fair salary		
Overtime pay*	**Description**	
	Even if they are not legally obligated, employers can pay workers for overtime as well as offer them a premium (Federal labour standards[55] (Anon., 2013))	
Assessment factor	Farm employers paying for overtime work.	
Rating scale		---
		Employers do not pay overtime (e.g. employees receive fixed salary)
		Employers pay overtime without an overtime premium
		Employers pay overtime with an overtime premium
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The score is a weighted average by number of employees. However, it presents several limitations depending on the employment and contractual situations of employees, e.g. workers paid by the hour would not be paid overtime and employees with a fixed salary that would be "smoothed" over the year would likely not be paid overtime either.	
Average hourly wage*	**Description**	
	Assessment of average hourly wage of workers (both full time and part time) against the legal minimum hourly wage and the average hourly wage of the province they are located in.[56] (Government of Canada, 2015)	
Assessment factor	Comparison between 1) the average hourly wage of farm workers, and 2) the provincial hourly wage.	
Rating scale		Average hourly wage of farm workers < the provincial legal minimum hourly wage
		Average hourly wage of farm workers = the provincial legal minimum hourly wage
		Average hourly wage of farm workers > the provincial legal minimum hourly wage but ≤ the provincial average wage
		Average hourly wage of farm workers > the provincial legal minimum hourly wage and ≥ the provincial average wage

[55] Federal labour standard: Hours of work "Overtime pay at a rate of a minimum of 1.5 times the regular hourly wage for those hours would apply, with the following exceptions: Managers and professionals, such as doctors, lawyers, dentists, architects and engineers, are exempt from overtime." : http://www.labour.gc.ca/eng/standards_equity/st/hours.shtml

[56] Minimum wage rate per province: AB = $10.20; SK = $10.20, MB = $10.70, ON = $11.00, BC = $10.25, QC = $10.55, NB = $10.30, NS = $10.60, PEI = $10.50, NL = $10.25. Data from the Canadian Labour program: Average hourly wage per province, Statistics Canada

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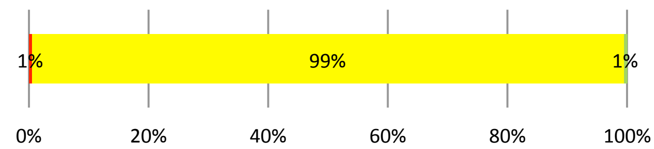
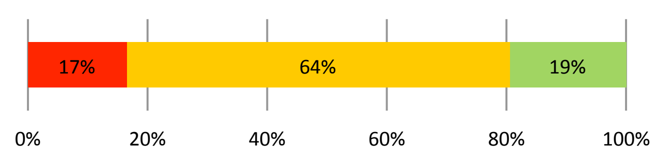
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Nearly all farm workers of the operations participating to the survey are paid above the provincial legal minimum wage but below the provincial average wage.	
Working hours		
Workweek length*	Description	
	The average work week length (hours/week) per year of regular workers during peak season in comparison to the ILO standard of 48 hours/week.	
Assessment factor	The average number of hours worked per week for regular workers should not exceed 48H (ILO convention).	
Rating scale		The average number of hours worked per week for regular workers exceeds 48H per week during both peak and low season
		The average number of hours worked per week for regular workers exceeds 48H per week only during peak season
		---
		The average number of hours worked per week for regular workers does not exceed 48H per week
Risk assessment	**Results breakdown**	**Average score**
		
Comments	A study published in 2010 shows "owner-operators reported a median of 60 to 70 hours of farm work per week during warm weather months, with declines in hours over the winter" (Marlenga, 2010). Given that the results presented above include owner-operators, the average score is in line with what is typically observed in the industry (Marlenga, 2010). Canadian business owners (other industries) work "an average of 51 hours a week" and "one in five business owners work 60 hours or more per week" (Bank of Montreal, 2013).	
Workload*	**Description**	
	Comparison of workers' practices with the ILO standard (48 hours/week) over a three month period, which was considered to be the length of a peak season for this study and which was used in the Canadian dairy study (Dairy Farmers of Canada, 2012).	
Assessment factor	Number of weeks per year during which workers worked more than 48 hours per week.	
Rating scale		Exceed 13 weeks
		One to 13 weeks
		---
		0 weeks
Risk assessment	**Results breakdown**	**Average score**

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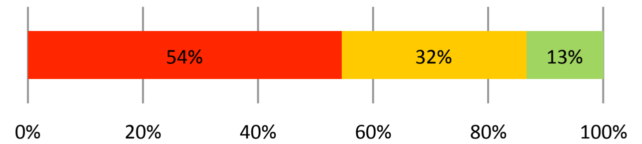
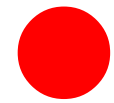
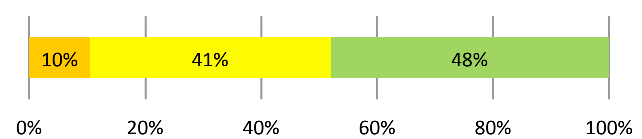
		
Comments	Beef production is a cyclical and seasonal industry which requires more work during certain periods of time to address the needs at each life cycle stage. “Peak season” (e.g. calving, harvest of feed) will therefore be busier for agricultural workers than “low season”. This indicator echoes the work week length indicator and is reflective of cattle operations’ business size and associated constraints. It also reflects the motivation of owners and workers of the industry to properly take care of animals or harvest feed in a timely manner, for example. Although this is an expected hotspot, it should not be ignored, as scientific literature shows a link between overtime/long working hours and occupational injuries and illnesses (Dembe, et al., 2005).	
Social benefits		
Scope of benefits*	**Description** ILO minimum standards (C-102 Social Security) (International Labour Organization, 1952) include nine social benefits: medical care, sickness benefit, unemployment benefit, old-age benefit, employment injury benefit, family benefit, maternity/paternity benefit, invalidity benefit, survivor's benefit.	
Assessment factor	Number of social benefits provided to employees.	
Rating scale	(red)	---
	(orange)	None of the benefits listed by the ILO is provided to employees
	(yellow)	One to four benefits listed by the ILO are provided to employees
	(green)	At least five benefits listed by the ILO are provided to employees
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The three most common benefits offered by employers are: unemployment benefits, employment injury benefit and old-age benefit. The least offered benefit is maternity/paternity benefit. Note: the red level is not included in this indicator as the ILO minimum standards are not Canadian minimum legal requirements.	
Health and safety		
Farm health and safety management*	**Description** The employer shall, in order to address identified and assessed hazards, take preventive measures to address the assessed hazard (Canada Occupational Health and Safety Regulations). (Government of Canada, 2015)	
Assessment factor	Health and safety initiatives tested were: formal health and safety policy, prevention measures to avoid accident and emergency protocol in case of accident including through verbal communication, training/simulation or information display.	
Rating scale	(red)	---

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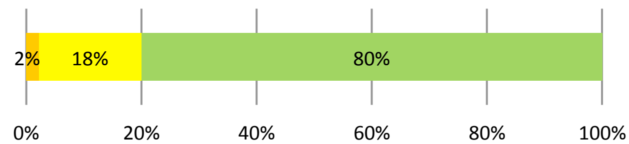
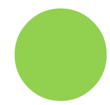
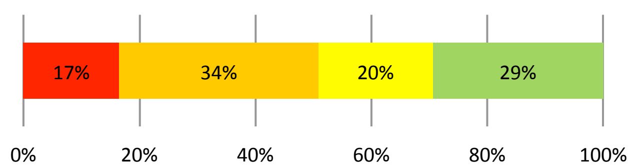
		None of the listed health and safety prevention initiatives is in place
		One of the listed health and safety prevention initiatives is in place
		At least two of the listed health and safety prevention initiatives are in place
Risk assessment	**Survey results breakdown** 	**Average score** 
Comments	The majority of respondents have implemented at least two of the listed health and safety prevention initiatives. The Canadian Agricultural Safety Association (CASA) however notes that "although the majority of Canadian producers (85%) believe safety is a priority on their farm, less than one in 10 (9%) currently have a written agricultural safety plan on their farm or ranch" (CASA, 2011).	
Health and safety training*	**Description** Farm workers are covered by federal occupational health and safety legislation, although there are some provincial exceptions. Employers must ensure that employees have the necessary information, training and supervision to perform their work safely. (Canada Labour Code, Part II) (Government of Canada, 2015)	
Assessment factor	Percentage of employees who received health and safety training.	
Rating scale		0% of employees received health and safety training
		Between 1% and 25% of employees received health and safety training
		Between 26% and 75% of employees received health and safety training
		More than 75% of employees received health and safety training
Risk assessment	**Survey results breakdown** 	**Average score**
Comments	A limitation of this indicator is the provincial exceptions regarding health and safety regulation for farm workers (Barneston, 2009). It has been noted by the Steering Committee that the question might have been interpreted differently by certain participants due to the wording used in the question. Indeed, "training" might have been interpreted as a formal session, while important health and safety information might have been communicated in a less formal way. Recommendation as to how to improve the question for a next assessment to avoid biased results is included in 6.14.	
Seasonal workers		
Seasonal worker hourly wage*	**Description** There should be no significant and unfair discrepancies between hourly wage of seasonal worker and the provincial minimum wage.	

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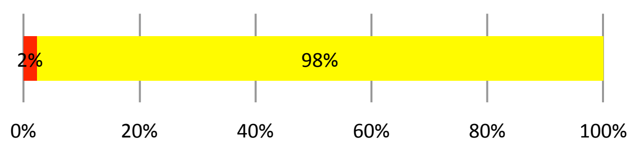
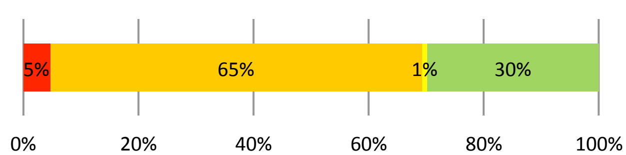
<table>
<tr><td>Assessment factor</td><td colspan="2">Comparison between 1) the average hourly wage of seasonal workers, and 2) the provincial hourly wage.</td></tr>
<tr><td rowspan="4">Rating scale</td><td></td><td>Average hourly wage of seasonal workers < the provincial legal minimum hourly wage</td></tr>
<tr><td></td><td>Average hourly wage of seasonal workers = the provincial legal minimum hourly wage</td></tr>
<tr><td></td><td>Average hourly wage of seasonal workers > the provincial legal minimum hourly wage but ≤ to the provincial average wage rate</td></tr>
<tr><td></td><td>Average hourly wage of seasonal workers > the provincial legal minimum hourly wage and > the provincial average wage rate</td></tr>
<tr><td rowspan="2">Risk assessment</td><td>Survey results breakdown</td><td>Average score</td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>Comments</td><td colspan="2">Because seasonal workers include youth workers, some eligible workers may be paid the student minimum wage, which is lower than the general legal minimum wage. The level of details of our survey did not enable us to determine if the cases of workers paid under the minimum wage were youth.</td></tr>
<tr><td rowspan="2">Seasonal worker services/benefits*</td><td colspan="2">Description</td></tr>
<tr><td colspan="2">Seasonal workers should be entitled to the same services and benefits that full-time employees receive. (Government of Canada, 2015)</td></tr>
<tr><td>Assessment factor</td><td colspan="2">Best practices expected: services provided to seasonal workers (transportation, work permit, meals, housing, protective clothes and health insurance).</td></tr>
<tr><td rowspan="4">Rating scale</td><td></td><td>No services/benefits are provided to seasonal workers</td></tr>
<tr><td></td><td>Services/benefits are provided and all costs are transferred to seasonal workers</td></tr>
<tr><td></td><td>Services/benefits are provided and some costs are transferred to seasonal workers</td></tr>
<tr><td></td><td>Services/benefits are provided and no costs are transferred to seasonal workers</td></tr>
<tr><td rowspan="2">Risk assessment</td><td>Survey results breakdown</td><td>Average score</td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>Comments</td><td colspan="2">Although the average score is marked “yellow” for this indicator as a result of the methodology used for calculation, the reality is generally more binary with employers either covering all (green) or none (orange) of the costs related to services/benefits.</td></tr>
<tr><td rowspan="2">Health and safety training for seasonal workers</td><td colspan="2">Description</td></tr>
<tr><td colspan="2">Seasonal farm workers are also covered by federal occupational health and safety legislation.[57] However, there are some provincial exceptions.</td></tr>
<tr><td>Assessment factor</td><td colspan="2">Percentage of employers who provide health and safety training for seasonal workers.</td></tr>
</table>

[57] Pesticides and chemical use requirements/Seasonal agriculture workers/Government of Canada.

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Rating scale		---
		Employers do not provide health and safety training for seasonal workers
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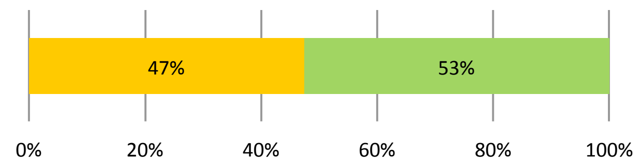
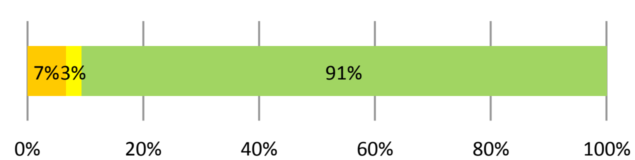
		Employers provide health and safety training for seasonal workers
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	A limitation of this indicator is the provincial exceptions regarding health and safety regulation for farm workers (Barneston, 2009). It has been noted by the Steering Committee that the question might have been interpreted differently by certain participants due to the wording used in the question. Recommendation as to how to improve the question for a next assessment to avoid biased results is included in 6.14.	
LOCAL COMMUNITY		
Community engagement		
Local community support	**Description**	
	Assessment of farmers' engagement based on local community involvement practices: visits, volunteering, donations and local purchase (recommended in the BMP Environmental Manual for Cow/Calf Producers "*building community partnerships"* (Agriculture and Forestry , 2006))	
Assessment factor	Evidence of local community engagement.	
Rating scale		----
		None of the listed community engagement practices is in place
		One of the listed community engagement practices is in place
		At least two of the listed community engagement practices are in place
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The majority of farms surveyed support their local community. The two most common forms of support are local purchase and volunteering.	
Local employment		
Local suppliers	**Description**	
	Assessment of farmers' local purchase choice (including animal purchase) based on suppliers' geographic location (Canada or abroad).	

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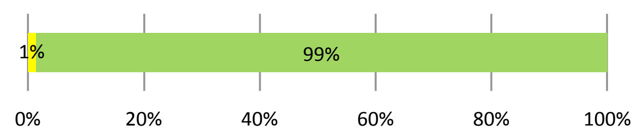
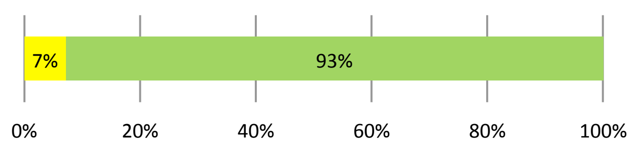
Assessment factor	Regional breakdown of farmers' suppliers by amount of goods and services bought by geographic location breakdown (same province, neighbouring province, rest of Canada, abroad).	
Rating scale	(red)	---
	(orange)	More than 50% of spending with suppliers located abroad
	(yellow)	More than 50% of spending with suppliers located in Canada but not in the same or neighbouring province
	(green)	More than 50% of spending with suppliers located in the same or neighbouring province
Risk assessment	**Survey results breakdown**	**Average score**
		(green)
Comments	Even if farmers' purchasing decisions may be mainly based on economic considerations, the fact that most suppliers are local is positive from an economic standpoint for local/regional communities and from an environmental standpoint—assuming that closer suppliers result in less GHG emissions for transport.	
Suppliers relationship	**Description**	
	Assessment of respondents' relationship practices with their supplier base (respectful communication, sufficient lead time, appropriate order size, availability of products and timely payments). (UNEP, 2013)	
Assessment factor	Evidence of good relationships with suppliers.	
Rating scale	(red)	---
	(orange)	None of the listed good relationship indicators is identified
	(yellow)	One of the listed good relationship indicators is identified
	(green)	At least two of the listed good relationship indicators are identified
Risk assessment	**Survey results breakdown**	**Average score**
		(green)
Comments	The majority of respondents have good relationships with their suppliers.	
Cohabitation		
Collaboration with neighbours	**Description**	
	Assessment of neighbourhood collaboration based on the following practices: purchase of grains, land sharing, equipment sharing and labour sharing.	
Assessment factor	Evidence of neighbourhood collaboration.	
Rating scale	(red)	----

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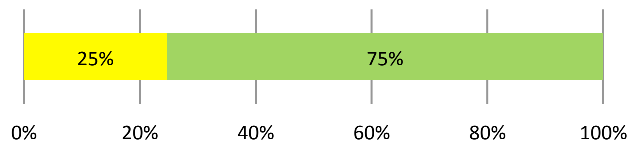
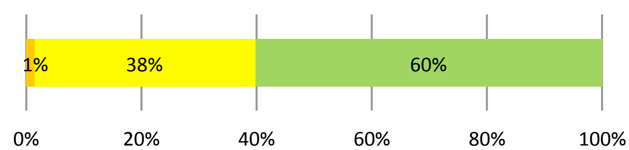
		None of the listed neighbourhood collaboration practices is identified
		One of the listed neighbourhood collaboration practices is identified
		At least two of the listed neighbourhood collaboration practices are identified
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The three most common collaboration practices mentioned were: equipment sharing, labour sharing and purchase of grains.	
Nuisance complaints	**Description**	
	Assessment of frequency of nuisance complaints from neighbourhoods related to noise, odour, fence conditions, unsightliness or other identified by respondents.	
Assessment factor	Frequency of neighbourhood complaints for nuisance.	
Rating scale		Complaints often received from neighbours
		Complaints sometimes received from neighbours
		Complaints rarely received from neighbours
		No complaints received from neighbours
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The main subject of complaints received from neighbours and identified by respondents was fence conditions, then, to a lesser extent, odour and noise, as well as various other complaints. Several provincial boards exist across Canada to address complaints due to feeding operations of livestock. For instance, the main categories of complaints received in Ontario include: odour, noise, dust, flies, smoke, light, vibration and municipal by-laws. (Government of Ontario, 2015) In 2011-2012, 206 complaints were received in Ontario (for all categories of livestock). In Alberta, main categories of complaints include: odour/nuisance, water quality and non-compliance. In 2012, 65 beef feedlot operations and 22 cow/calf operations were involved in complaints (Natural Resources Conservation Board, 2012).	
Odour reduction	**Description**	
	Assessment of the following odour reduction practices: practices preventing the release and transport of odours (e.g. cover of manure storage); windbreaks, in-barn condition management or others as identified by respondents. Odour management practices are recommended in the Environmental Manual for livestock producers in Alberta (Government of Alberta, 2010).	
Assessment factor	Evidence of odour reduction practices.	

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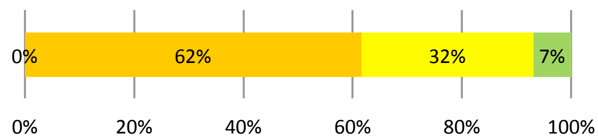
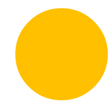
Rating scale		---
		None of the listed odour reduction practices is applied
		At least one of the listed odour reduction practices is applied
		Two or more of the listed odour reduction practices are applied
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Windbreaks was the most common odour reduction practice identified (25% of respondents). As this is a national assessment, some practices (in-barn condition management) are relevant to barn operations only, which are mostly observed in Eastern Canada. Odour is one of the most common areas of complaints registered by the Natural Resources Conservation Board in Alberta. (Natural Resources Conservation Board, 2015), the Ontario Ministry of Agriculture, Food and Rural Affairs (Government of Ontario, 2015) and the Ministry of Agriculture of Saskatchewan.[58] In 2001, 18.4% of beef farms in Canada had some method of odour control (compared to 33.2% of hog farms and 18.3 for dairy farms) (Beaulieu, 2004).	
SOCIETY		
Animal welfare		
Code of practice implementation	**Description** Assessment of farmers and workers' awareness and implementation level of the Code of Practice for the Care and Handling of Beef Cattle published by the National Farm Animal Care Council (NFACC) in 2013. The code of practice is composed of national guidelines for the care and handling of farm animals developed by a recognized organization taking into account the best science available for each species, compiled through an independent peer-reviewed process, along with stakeholder input. (National Farm Animal Care Council, 2013)	
Assessment factor	Code of Practice implementation level.	
Rating scale		Code of practice has not been read
		Code of practice has been read and basic requirements are partially implemented
		Code of practice has been read and basic requirements are fully implemented
		Code of practice has been read and basic requirements are fully implemented and some or all recommended practices are implemented
Risk assessment	**Survey results breakdown**	**Average score**

[58] https://cfo.nrcb.ca/Compliance/Complaints.aspx ; http://www.omafra.gov.on.ca/english/engineer/nfppb/annual-report2011.htm#3 ; Direct request of information for SK.

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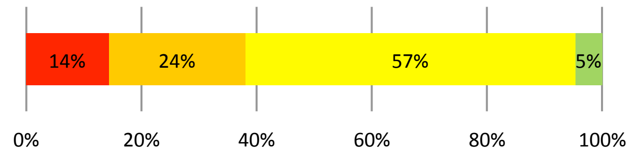
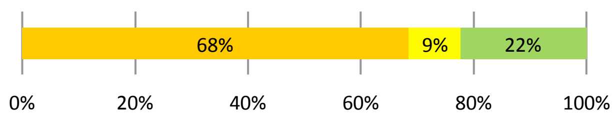
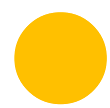
		
Comments	The majority of respondents have read and fully implemented the basic requirements of the code of practice. A small percentage has also implemented recommended practices. However, there is still a significant percentage that has not implemented basic requirements or read the code of practice.	
Branding	**Description** Assessment of farmers’ branding practices and pain control techniques based on animal welfare experts’ judgement consulted for the study.	
Assessment factor	Branding occurrence and pain control use.	
Rating scale	(red)	---
	(orange)	Branding without pain control
	(yellow)	Branding with pain control (anesthetic or analgesic)
	(green)	No branding
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Although pain control is a preferable practice, it is recognized by the Code of Practice that viable options for pain mitigation are still lacking. A limitation of this indicator is that pain controls identified in the survey are probably anesthetics or analgesics used for other purposes as well—for instance during castration, as mentioned by the Western Cow/Calf Survey (Western Beef Development Centre, 2015), and therefore are not specifically designed for branding. In addition, the Code of Practice for the Care and Handling of Beef Cattle mentions that “branding remains a necessary form of permanent identification in some parts of Canada. Brands provide proof of ownership and easy identification of cattle at a distance, and may be required in some situations”[59]—particularly at cow/calf operations. Types of irons used for branding include: single iron (used by 66% of respondents); double iron (used by 22% of respondents); triple iron (used by 7% of respondents).	
Dehorning	**Description** Assessment of farmers’ disbudding and dehorning practices based on the 2013 Beef Code of Practice for the Care and Handling of Beef Cattle. Dehorning/disbudding is performed to avoid injury risks to both workers and animals. The earlier dehorning/disbudding is performed, the less stressful and painful the operation is for animals. Pain mitigation techniques should be explored with veterinarians.	
Assessment factor	Stage of horn attachment (calves’ age) and use of pain control when dehorning/disbudding performed.	
Rating scale	(red)	---

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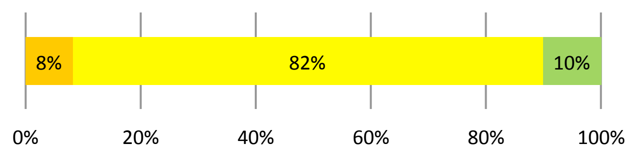
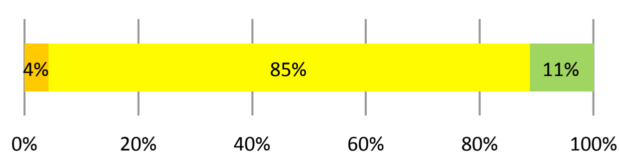
		Calves dehorned without pain control after horn attachment (four months or older)
		Calves dehorned with pain control after horn attachment (four months or older) or calves disbudded without pain control before horn attachment (before four months)
		Calves disbudded with pain control before horn attachment (four months or younger)
Risk assessment	**Survey results breakdown** 	**Average score**
Comments	The four-month threshold represents a conservative approach to the calves' age mentioned in the Code of Practice (i.e. horn bud stage at "typically two to three months"). According to the WCCS survey, 69% of respondents have at least 90% polled calves (born without horns). The Code of Practice mentions that, as of 2016, producers will be required to use pain control for dehorning after horn attachment.	
Castration	**Description** Assessment of farmers' castration practices based on the 2013 Code of Practice for the Care and Handling of Beef Cattle. The earlier castration is performed, the less stressful and painful the operation is for animals. Use of pain control is recommended.	
Assessment factor	Calves' age at which castration is performed and use of pain control.	
Rating scale		Castration performed at 10 months or older without pain control
		Castration performed at 10 months or older with pain control or between six and nine months without pain control
		Castration performed between six and nine months with pain control or before six months without pain control
		Castration before six months with pain control
Risk assessment	**Survey results breakdown** 	**Average results**
Comments	14% of respondents use single or double pain (anesthetic and/or analgesic) control for castration. The Code of Practice mentions that, as of 2016, it will be required to use pain control for castration of bulls older than nine months; and as of 2018, of bulls older than six months.	
Weaning conditions	**Description** Assess farmers' calves weaning practices based on the 2013 Code of Practice for the Care and Handling of Beef Cattle and the animal welfare expert consulted for the study. Low-stress weaning practices exist to minimize animal welfare issues related to weaning. These weaning practices include: two-stage weaning, nose tags, fence line weaning, delayed weaning.	
Assessment factor	Weaning practices.	

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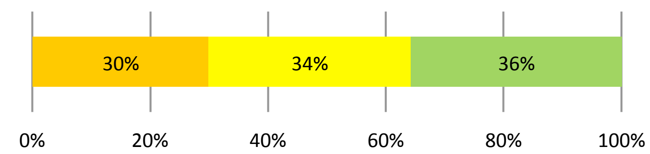
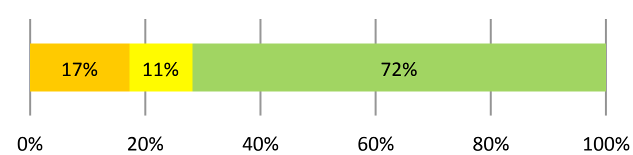
Rating scale	(red)	---
	(orange)	Separation of calves by truck/distance (to auction or feedlot) without pre-conditioning
	(yellow)	Low-stress weaning without pre-conditioning or separation of calves by truck/distance (to auction or feedlot) with pre-conditioning
	(green)	Low-stress weaning with pre-conditioning
Risk assessment	**Survey results breakdown**	**Average score**
		(yellow)
Comments	55% of respondents pre-condition their calves, which includes: castration, dehorning, weaning, parasitic control, vaccination (Clostridial and Infectious Bovine Rhinotracheitis) and bunk-breaking, minimum 45 days prior to sale or shipping.	
Cattle handling training	**Description** Assessment of handling training received by farm employees in one of the following forms: self-training with dedicated references and documentation; training by farm or feedlot worker or already-trained owner; training by external resource; training by a certified trainer (e.g. Canadian Livestock Transport program for cattle producers/farm handlers). (Canadian Livestock Transport , n.d.)	
Assessment factor	Percentage of employees trained for cattle handling.	
Rating scale	(red)	---
	(orange)	Less than 50% of employees trained for cattle handling
	(yellow)	50-75% of employees trained for cattle handling
	(green)	More than 75% of employees trained for cattle handling
Risk assessment	**Survey results breakdown**	**Average score**
		(green)
Comments	56% of respondents have declared that 100% of employees are trained for cattle handling. Limitations of this indicator are the quality of the training, which was not assessed in the survey, as well as the position of employees who have received the training for larger operations (some workers may have limited interaction with/exposure to cattle).	
Handling issues	**Description** Assessment of handling issues (stopping/balking at entrance/exit to or in chute), falling (belly or torso touches ground), slipping (knee contact ground), chute pile up, running/slamming into fence/gates and chute, failing to move through handling facility without excessive force (prod), flipping in chute, animal stuck in chute requiring dismantling of chute sides, choking in head gate) as identified by animal welfare experts consulted for this study.	

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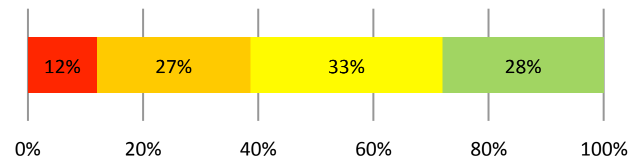
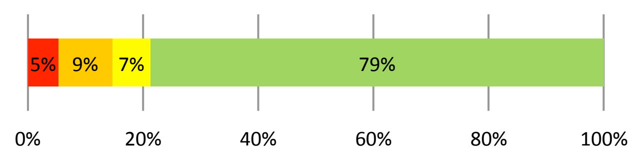
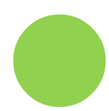
Assessment factor	Frequency of handling issues observed by farmers.	
Rating scale		At least one handling issue mentioned in the list above observed more than 50% of the time
		Handling issues mentioned in the list above observed at most 21-50% of the time
		Handling issues mentioned in the list above observed at most 6-20% of the time
		Handling issues mentioned in the list above observed at most 5% of the time
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	94% of respondents have made changes to facilities to improve handling, such as solid sided chutes, curved chutes and crowed tubs, bud boxes, open sided chutes, grooved floors/installation of non-slip surfaces, hydraulic squeeze chutes.	
Cattle injuries	**Description**	
	Assessment of frequency of handling injuries in 2013: broken leg (handling), broken leg (non-human related), abscesses, lacerations, predator-related as defined by animal welfare experts consulted for this study.	
Assessment factor	Frequency of injuries observed by farmers at the time of handling.	
Rating scale		At least one listed injury observed more than 50% of the time
		Listed injuries observed at most 21-50% of the time
		Listed injuries observed at most 6-20% of the time
		Listed injuries observed at most 5% of the time
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The most often observed injuries are abscesses (70% of respondents observed this type of injury) and the least observed injuries are broken legs due to handling issues (20%) and predator-related (33%). A limitation of this indicator is that the type of cattle is unknown and the temperament of cattle was not taken into account since this can affect injuries. Also, the frequency of cattle handling and their comfort with people can affect the occurrence and frequency of injuries. Note: Percentages of injury occurrence were validated by the animal welfare expert consulted for the study.	
Calving assistance	**Description**	

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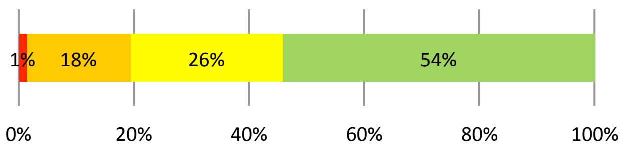
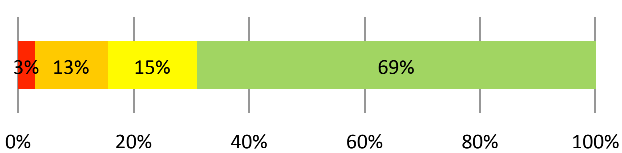
	Assessment of calving assistance situations.	
Assessment factor	Percentage of animals that required assistance during calving.	
Rating scale		More than 20% of heifers and cows required assistance
		10-20% of heifers and cows required assistance
		5-9% of heifers and cows required assistance
		Less than 5% of heifers and cows required assistance
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	On average, respondents declared that they had to perform a C-section or other calving emergency interventions on less than 1% of their heifers and cows. According to the Western Canadian Cow/Calf Survey conducted in 2014, 94% of births were unassisted during calving. In 2006, a survey conducted in British Columbia, Alberta and Saskatchewan showed that 77% of calving situations did not require assistance, whereas 1.7% required a C-section. (Western Interprovincial Scientific Studies Association (WISSA), 2006)	
Breeding season injuries	**Description**	
	Assess proportion of injured bulls during the breeding season as validated by animal welfare experts consulted for this study.	
Assessment factor	Average percentage of bulls injured during the breeding season.	
Rating scale		More than 20% of bulls injured during the breeding season
		10-20% of bulls injured during the breeding season
		5-9% of bulls injured during the breeding season
		Less than 5% of bulls injured during the breeding season
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	About 85% of respondents have declared that less than 10% of their bulls were injured during the breeding seasons.	
Housing and feeding	**Description**	
	Assessment of farmers' practices for supporting cattle during extreme weather events (cold and heat) based on practices defined by animal welfare experts consulted for this study.	

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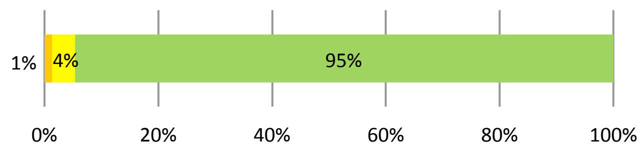
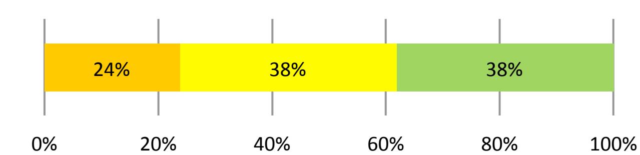
Assessment factor	Practices implemented by farmers to support cattle.	
Rating scale	---	
	No specific support provided during extreme weather events	
	Specific support provided during extreme cold or heat events	
	Specific support provided during both extreme cold and heat events	
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The most common practices identified by respondents to support cattle during extreme cold are: additional feed, wind shelter, bedding and heated water bowls. During extreme heat events, the two main mitigation practices identified are to avoid handling cattle and provide shade. 96% of respondents also implement additional practices during spring thaw (mainly with additional straw/other bedding material and proper drainage), and 96% of respondents had some kind of drought management practices for feed and water (top three being stockpiled grazing/feed, sale of animals and land renting).	
Housing condition	**Description** Assessment of farmers' practices regarding pen cleaning as validated by animal welfare experts consulted for this study.	
Assessment factor	Annual frequency of pen cleaning.	
Rating scale	---	
	Pens cleaned less than once a year	
	Pens cleaned once a year	
	Pens cleaned more than once a year	
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	It must be noted that these results compile practices of different operations (cow/calf, backgrounding and finishing). Also, because of the number of animals, weather conditions or length of time in a pen, the pens may only need to be cleaned once a year.	
Cattle health assessment	**Description** Assessment of animal health in feedlot/dry lot only (excluding pasture) by farmers as defined by an animal welfare expert. This practice recommended by animal welfare experts allows for treatment of any potential health issue in due time.	
Assessment factor	Frequency of health assessment.	

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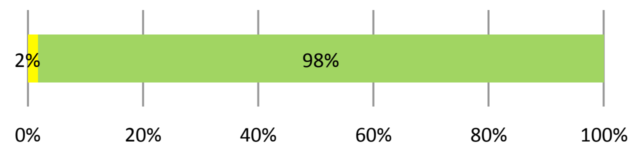
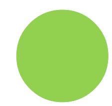
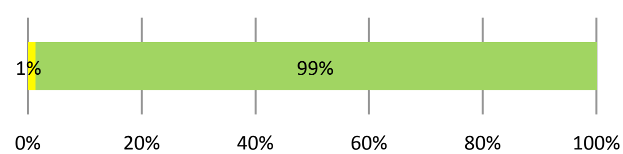
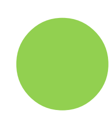
Rating scale		Health problems are not assessed
		Health problems are assessed monthly
		Health problems are assessed weekly
		Health problems are assessed daily or two to three times per week
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Pastured animals are assessed slightly less often for health issues. 22% of respondents declared that pastured cattle were typically assessed for health problems daily, 43% make an assessment two to three times per week, 30% weekly and 5% twice per month. Health will also be determined by bedding, pen cleanliness or other housing factors.	
Health prevention	**Description**	
	Assessment of animal health prevention practices: Veterinarian/Client/Patient Relationship (VCPR), herd health management program, disease prevention strategy (to manage risk of bovine respiratory disease for newly-arrived cattle), provision of different levels of care for fragile herd individuals, as identified in the 2013 Beef Code of Practice for the Care and Handling of Beef Cattle.	
Assessment factor	Evidence of cattle health prevention strategies.	
Rating scale		None of the listed prevention strategies is in place
		One of the listed prevention strategies is in place
		Two of the listed prevention strategies are in place
		Three or all of the listed prevention strategies are in place
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Of the four practices mentioned in the description, the least implemented is the "disease prevention strategy" with a non-selection rate of 10% (i.e. 90% of respondents identified this strategy as being implemented).	
Post-euthanasia practice	**Description**	
	Assessment of confirmation of insensibility and death post-application of euthanasia methods.	
Assessment factor	Confirmation of insensibility and death.	
Rating scale		---
		No confirmation of insensibility and death

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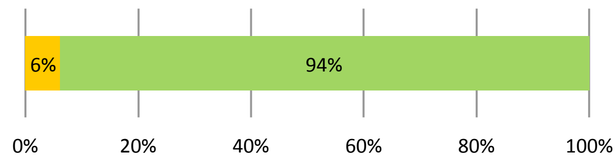
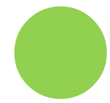
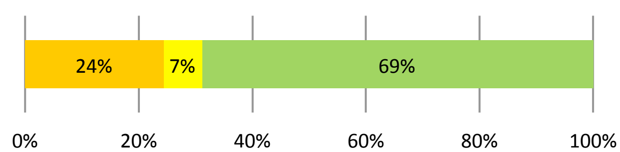
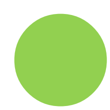
		Confirmation of insensibility and death
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Other practices assessed regarding euthanasia include how often chronic animals are checked and how animals are euthanized. 76% of respondents say they assess chronic animals' need for euthanasia at least once per day (including 15% hourly), 8% assess two to three times per week, 1% less often than weekly. The majority of respondents (75%) use gunshot to euthanize animals. However, the appropriate use of gunshot (depending on the animal's weight and type of firearm used) was not assessed.	
Transporters' certification	**Description**	
	Assessment of the ratio of use of transporters certified by the Canadian Livestock Transport (CLT).[60] (Canadian Livestock Transport, n.d.)	
Assessment factor	Percentage of transporters certified by the CLT.	
Rating scale		---
		Less than 25% of farmers' transporters have CLT certification
		26-50% of farmers' transporters have CLT certification
		More than 50% of farmers' transporters have CLT certification
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Key knowledge areas of the certification program include: animal welfare, health, behaviour, laws and regulations, vehicle and handling techniques and emergency response.	
Contribution to economic development		
R&D investment	**Description**	
	Assessment of farmer's R&D investment practices.	
Assessment factor	Percentage of farm revenues invested in R&D projects.	
Rating scale		----

[60] The CLT certification is a program led by an industry initiative to address the need for increased accountability and improved handling practices in livestock transport

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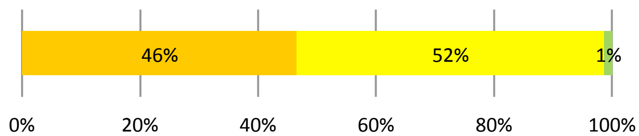
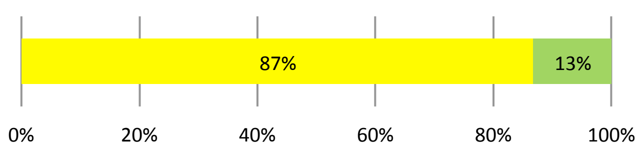
		No R&D investment
		1-10% of farm revenues invested in R&D
		More than 11% of farm revenues invested in R&D
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	Top three categories of R&D projects are environmental management practices, animal well-being practices and feed/nutrition trial. Most projects are run at an individual farm level or as part of a provincial initiative. Some farmers may also implement continuous R&D initiatives that are not registered in specific or formal projects. In addition, beef check-off, paid by producers, funds industry-wide research (Beef Cattle Research Council, 2012).	
Employment succession	**Description**	
	Assessment of the following employment succession measures: trainee/internship program, family member training, partnership with training centres and other measures.	
Assessment factor	Evidence of succession measures.	
Rating scale		---
		None of the listed succession measures is in place
		At least one non-formal succession measure (internship program, family member training) is in place
		Formal succession measure (partnership with training centres) is in place
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The most common succession measure implemented by respondents is family member training.	
Agricultural risk plan	**Description**	
	Assessment of the following economic risks mitigation measures: agricultural insurance subscription and risk management plan (for drought, floods, local market competition, internal market competition and commodities prices). Since 2001, federal government agricultural programming has been aimed at helping Canada's agricultural sector move beyond crisis management by providing tools to manage risk in a proactive way. (Agriculture and Agri-Food Canada, 2012)	
Assessment factor	Evidence of economic risks mitigation strategies.	
Rating scale		---
		None of the listed risk mitigation strategies is adopted

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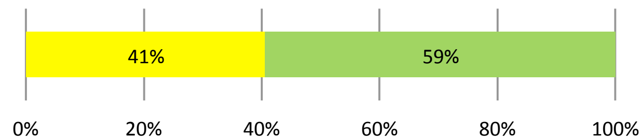
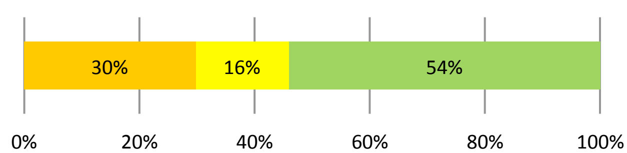
		Either insurance or formal risk management plan is adopted
		Both insurance and formal risk management plans are adopted
Risk assessment	**Survey results breakdown** 	**Average score**
Comments	Most respondents appear to be well prepared to financially and operationally manage agricultural risks. In Alberta, according to the Agriculture Financial Services Corporation, “during 2013-14, LPIP [Livestock Price Insurance Programs] producers purchased coverage on 347,000 fed cattle, 759,000 feeders, 190,000 calves and 6,700 hogs. LPIP provided $1.77 billion in coverage, generating $23.4 million in premiums and paying indemnities of $2.9 million as of March 31, 2014.” (Agriculture Financial Services Corporation, n.d.)	
Public commitment to sustainable issues		
Environmental farm plan	**Description** Assessment of environmental management practices based on the development of an environmental farm plan (voluntary process for farmers to evaluate the environmental risks and strengths of their operations and develop a plan to address those risks and strengths (Environment Canada, 2012).	
Assessment factor	Development of an environmental farm plan.	
Rating scale		---
		No environmental farm plan developed
		Environmental farm plan developed but not reviewed by a third party
		Environmental farm plan developed and reviewed by a third party
Risk assessment	**Survey results breakdown** 	**Average score**
Comments	The Human Activity and the Environment report states that: “environmental farm plan (EFP) programs, which help farmers assess the environmental issues or concerns on farms, began in Ontario in 1993 now operate in all provinces. Although participation is voluntary, 33% of Canadian beef farms had a formal EFP in 2011 representing 39% of total beef production (Statistics Canada, 2014).	
Riparian areas management	**Description** Assessment of grazing management practices around wetlands/riparian areas (free access to wetlands/riparian areas, shoreline fence, remote water stations/tanks, access ramp, stream crossing, grazing control and grazing certain times of the year only) recommended in the BMP. (cow-calf operations and GHGs (Alberta Agriculture and Food, 2007))	
Assessment factor	Evidence of riparian areas management practices to mitigate risks related to grazing on	

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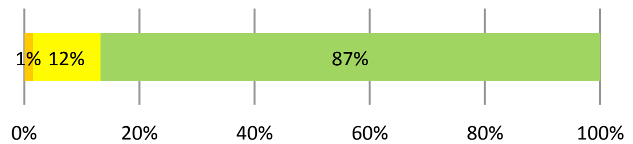
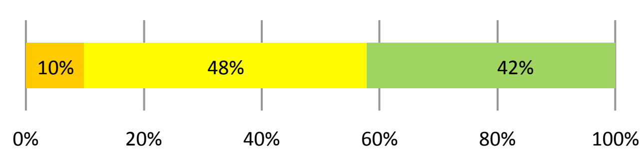
<table>
<tr><td></td><td colspan="3">water quality and wetland ecosystems health.</td></tr>
<tr><td rowspan="4">Rating scale</td><td>Red</td><td colspan="2">---</td></tr>
<tr><td>Orange</td><td colspan="2">None of the listed riparian areas management practices is applied</td></tr>
<tr><td>Yellow</td><td colspan="2">One of the listed riparian areas management practices is applied</td></tr>
<tr><td>Green</td><td colspan="2">At least two of the listed riparian areas management practices are applied</td></tr>
<tr><td rowspan="2">Risk assessment</td><td colspan="2">Survey results breakdown</td><td>Average score</td></tr>
<tr><td colspan="2">
</td><td>Green</td></tr>
<tr><td>Comments</td><td colspan="3">The three most common best management practices are: grazing only certain times of the year, remote water stations/tanks and grazing control (e.g. use of salt blocks to contain cows in certain areas).
According to the Human Activity and the Environment report, “in 2011, 56% of livestock farms had pastures or grazing paddocks adjacent to surface water. This proportion was highest in Saskatchewan (74%) and lowest in Québec (33%). In 2011, 15% of livestock farms allowed no access to surface water, 18% allowed limited access and 35% allowed unlimited access during the grazing season. The proportion of livestock farms allowing no access was highest in Québec (66%) while the proportion allowing unlimited access for the entire grazing season was highest in Manitoba (43%) and Saskatchewan (41%).” (Reminder: These figures are for all types of livestock operations, not only beef cattle.)</td></tr>
<tr><td rowspan="2">Rangelands health</td><td colspan="3">Description</td></tr>
<tr><td colspan="3">Assessment of native rangelands health level (healthy, healthy with problems, unhealthy, unknown) as promoted by the Beef Cattle Research Council (BCRC). (Beef Cattle Research Council, 2013)</td></tr>
<tr><td>Assessment factor</td><td colspan="3">Rangelands health assessment level.</td></tr>
<tr><td rowspan="4">Rating scale</td><td>Red</td><td colspan="2">---</td></tr>
<tr><td>Orange</td><td colspan="2">Rangelands have never been assessed or have been assessed and the score was “unhealthy”</td></tr>
<tr><td>Yellow</td><td colspan="2">Rangelands have been assessed and the score was “healthy with problems”</td></tr>
<tr><td>Green</td><td colspan="2">Rangelands have been assessed and the score was “healthy”</td></tr>
<tr><td rowspan="2">Risk assessment</td><td colspan="2">Survey results breakdown</td><td>Average score</td></tr>
<tr><td colspan="2">
</td><td>Yellow</td></tr>
<tr><td>Comments</td><td colspan="3">Of the respondents, 59% declared that their last rangeland health assessment was made in 2013 or yearly. Of the respondents, 53% declared that they or their employees have taken a range management course (also see “biodiversity practices” indicator)
The Human Activity and the Environment report states that: “in 2011, 39% of livestock farms practiced extended grazing [i.e. keeping livestock in an open field during the late fall and winter period]. This proportion was highest in the Western provinces, particularly</td></tr>
</table>

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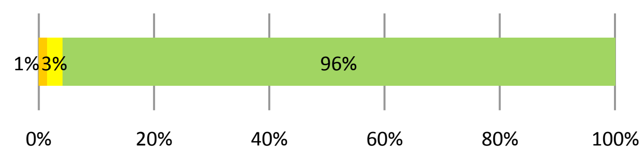
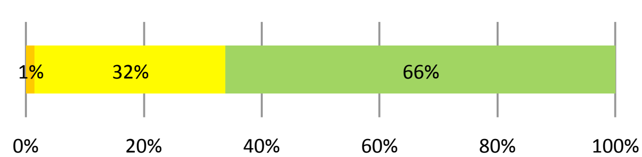
	Saskatchewan (65%) and Alberta (62%), the two largest producers of beef, and lowest in Québec (6%), where dairy operations are more prevalent."	
Beneficial water practices	**Description**	
	Assessment of beneficial water management practices: nutrient management, alternative water sources, appropriate grazing management, sediment and erosion control, water resource management, conservation buffers, fence installation, high intensity areas management, animal mortality management, wellhead protection, prescribed burning, integrated pest management, safe disposal of pharmaceuticals.	
Assessment factor	Evidence of beneficial water impact practices.	
Rating scale	Red	---
	Orange	None of the listed beneficial water impact practices is applied
	Yellow	Up to two of the listed beneficial water impact practices are applied
	Green	At least three of the listed beneficial water impact practices are applied
Risk assessment	**Survey results breakdown**	**Average score**
		Green
Comments	The three most common practices identified by respondents are: appropriate grazing management, safe disposal of pharmaceuticals and fence installation. The least common practices are: prescribed burning, conservation buffers and integrated pest management.	
Water impact mitigation	**Description**	
	Assessment of the following mitigation measures: moving wintering areas away from streams, using ridges and ditches to divert corral run off into lagoons, sloping corrals away from water sources, maintaining buffer zones around water sources.	
Assessment factor	Evidence of water impact mitigation measures.	
Rating scale	Red	---
	Orange	None of the listed water impact mitigation measures are applied
	Yellow	One of the listed water impact mitigation measures is applied
	Green	At least two of the listed water impact mitigation measures are applied
Risk assessment	**Survey results breakdown**	**Average score**
		Green
Comments	Of the four practices mentioned above, the most common are "moving wintering areas away from streams" (30%) and "maintaining buffer zones around water sources" (30%), and the least common is "using ridges and ditches to divert corral run off into lagoons" (14%).	
Biodiversity	**Description**	

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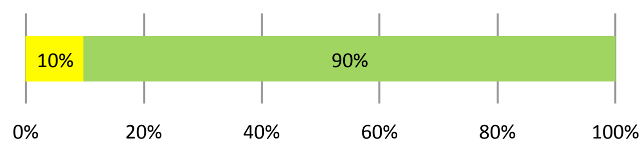
practices	Assessment of practices that have beneficial impacts on biodiversity: land seeded to permanent pasture, rangeland-field boundaries, maintenance of healthy rangelands, nutrient recycling mechanisms (e.g. increased nutrient recycling by fish and/or zoo-plankton), availability of blooming plants for pollinators, reduction/appropriate use of pesticides, reintroduction/inoculation of beneficial soil organisms, integrated pest management, maintain healthy riparian areas, rotational grazing.	
Assessment factor	Evidence of beneficial biodiversity practices.	
Rating scale	---	
	None of the listed beneficial practices for biodiversity is applied	
	Up to two of the listed beneficial practices for biodiversity are applied	
	At least three of the listed beneficial practices for biodiversity are applied	
Risk assessment	**Survey results breakdown**	**Average score**
		
Comments	The three most common practices are: maintenance of healthy rangelands, rotational grazing and reduction/appropriate use of pesticides. The three least common practices are: promotion of on-farm habitats that reduce pests and increase natural enemies, reintroduction/inoculation of soil beneficial organisms, field boundary trees and hedges. Of the respondents, 53% declared that they or their employees have taken a range management course.	
Waste management	**Description**	
	Assessment of management practices for the following waste: battery, building materials, chemical plastic containers, electronics, forage plastic wrap, machinery, machinery oil, paints, silage tarp, tires, treated fence posts, twine, veterinary products. For this assessment, the worst management practices for waste were considered to be burning, then disposal and on-farm storage (due to the risk of soil/water/air pollution depending on the waste category both at the farm and at a landfill site or equivalent). The best practices are considered to be recycling or trade-ins, and return in sharp item container for veterinary products.	
Assessment factor	Waste management practices for different agricultural waste categories.	
Rating scale	Wastes are, on average, burnt	
	Wastes are, on average, stored on-farm or disposed	

	Wastes are, on average, recycled/traded-in or returned in sharp item container for veterinary products	
Risk assessment	**Survey results breakdown**	**Average score**

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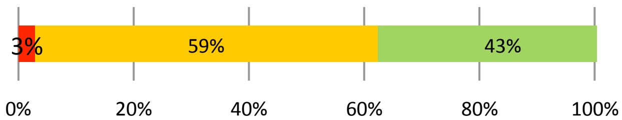
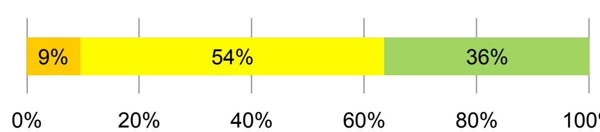
		
Comments	Clean Farms, an organization that focuses on waste management on farms, has a number of reports that further investigate waste management practices on Canadian farms. Pertinent highlights of the reports are summarized below. In BC, plastic bags, paper bags and twine from livestock farms are mainly sent to landfill with limited recycling and take-back programs available; plastic containers are traded-in or re-used, cardboard is usually recycled and animal health waste is usually recycled. For sharp products, they are usually removed from the farms by vets, taken back or sent to landfill. (2cg Waste Management Consulting Services, 2012) In Alberta, "over half (54%) [of growers] burn their twine on farm, and another 20% take it to the landfill. About one in 10 take it to a depot for recycling. Over half (56%) also burn their bale/silage wrap, and one in 10 take it to the landfill. Fourteen percent take it to a depot for recycling." (Blacksheep Strategy, 2012) "In Manitoba, a high portion of farmers are burning seed bags, plastic wrap, cardboard packaging, twine or net wrap, feed bags, plastic silage and bale wrap, Styrofoam packaging. A high portion of farmers are storing the following on their farm: sharps and needles, antifreeze, pesticides, paints and solvents, unwanted tires. A portion of farmers are putting the following in municipal landfill: plastic oil or antifreeze containers, tires, plastic wrap and packaging, paints and solvents, sharps or needles, Styrofoam packaging, animal health products, livestock disinfectant containers." (CleanFARMS Inc., 2011)	

CONSUMERS

Health and safety

Antibiotics use	**Description**	
	The use of antibiotics can be reduced and minimized by a number of best management practices on the operation. Pre-conditioning programs promote calf growth, enhance immune function and minimize stress during weaning thus mitigating the need for antibiotics. Pre-conditioning was defined in the survey to include castration, dehorning, weaning, parasitic, vaccination (Clostridial and Infectious Bovine Rhinotracheitis) and bunk-broke a minimum 45 days prior to sale or shipping. Verified Beef Program training helps ensure appropriate and responsible use of antibiotics, i.e. use of drugs for the shortest time period required.	
Assessment factor	Assessment of pre-conditioning practice and Verified Beef Program uptake.	
Rating scale		---
		Neither pre-conditioning nor Verified Beef Program training in place
		Pre-conditioning of calves OR Verified Beef Program training
		Pre-conditioning of calves AND Verified Beef Program training
Risk assessment	**Survey results breakdown**	**Average score**
		

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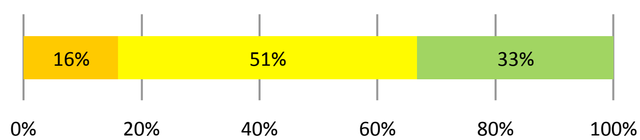
Comments	Canadian regulations seek to ensure that antibiotics and other veterinary drugs are used responsibly so that beef is safe for consumers. If the Canadian Food Inspection Agency's residue screening program detects non-compliant residues, that beef is prohibited for sale. The most recent results of the CFIA's residue testing program for multi-class antibiotics shows a compliance rate of 100% for beef (Canadian Food Inspection Agency, 2014). The use of antibiotics (whether in livestock, companion animal or human medicine) increases the risk that bacteria will develop antimicrobial resistance. Further monitoring is completed by the Public Health Agency of Canada's "Canadian Integrated Program for Antimicrobial Resistance Surveillance" (CIPARS) that monitors antimicrobial susceptibility and resistance in healthy cattle entering packing plants as well as retail beef (CIPARS, 2015). In 2014, Health Canada announced two key measures to mitigate risks linked to antibiotic use: "1) Removal of growth promotion and/or production claims of medically-important antimicrobial drugs; and 2) Development of options to strengthen the veterinary oversight of antimicrobial use in food animals" (Government of Canada, 2014).	
Food safety training	**Description**	
	Assessment of food safety practices based on food safety training under Verified Beef Production (VBP) and other programs.	
Assessment factor	Evidence of food safety training for farm owners and workers.	
Rating scale	Red	---
	Orange	No evidence of farm owner or workers trained on food safety
	Yellow	Farm owners or workers trained on food safety (under the VBP or another program)
	Green	Farm registered under the VBP program (audited farm)
Risk assessment	**Survey results breakdown**	**Average score**
		Yellow
Comments	As of 2015, between 70% and 75% of beef production in Canada comes from a VBP-trained operation (representing 19,636 operations). Of the 19,636 operations that have training, 1,183 operations have taken the next step to become registered (audited); these operations represent 24% of beef production in Canada (VBP, 2015).	

4.4.2 Meat processors

4.4.2.1 Scope of assessment and source of data

The scope of assessment for this life cycle stage includes meat processors in Canada. Meat processors, or packers, constitute the next step of the beef life cycle after farming operations. Packers handle the slaughtering, processing, packaging and distribution of beef meat to downstream value chain actors (mainly, retailers and food service). However, further (secondary) stages of beef meat processing[61] are not included in the scope of our assessment. Specific data were collected from a sample of packers representing 86% of total Canadian beef meat production. For confidentiality reasons, further details of the plants included in this assessment will not be mentioned in this report.

[61] Examples of these secondary stages include patty plants and processed food plants preparing frozen meals or other ready-to-serve dishes

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4.4.2.2 Average risk score calculation methodology

The average score for each indicator was calculated in four steps:

- Compilation of survey results into the characterization tables
- Assignation of scores by site for each indicator
- Calculation of average score, weighted based on percentage of total production by site (e.g. site A produces X ton of meat per year, representing Y% of the total production)
- Translation of average score into colour code, defining the level of risk from high (red) to low (green)

Please note that, for confidentiality reasons, the number of sites and the breakdown of answers by site are not presented in this report.

The diagram below illustrates the process using an example with fictitious numbers:

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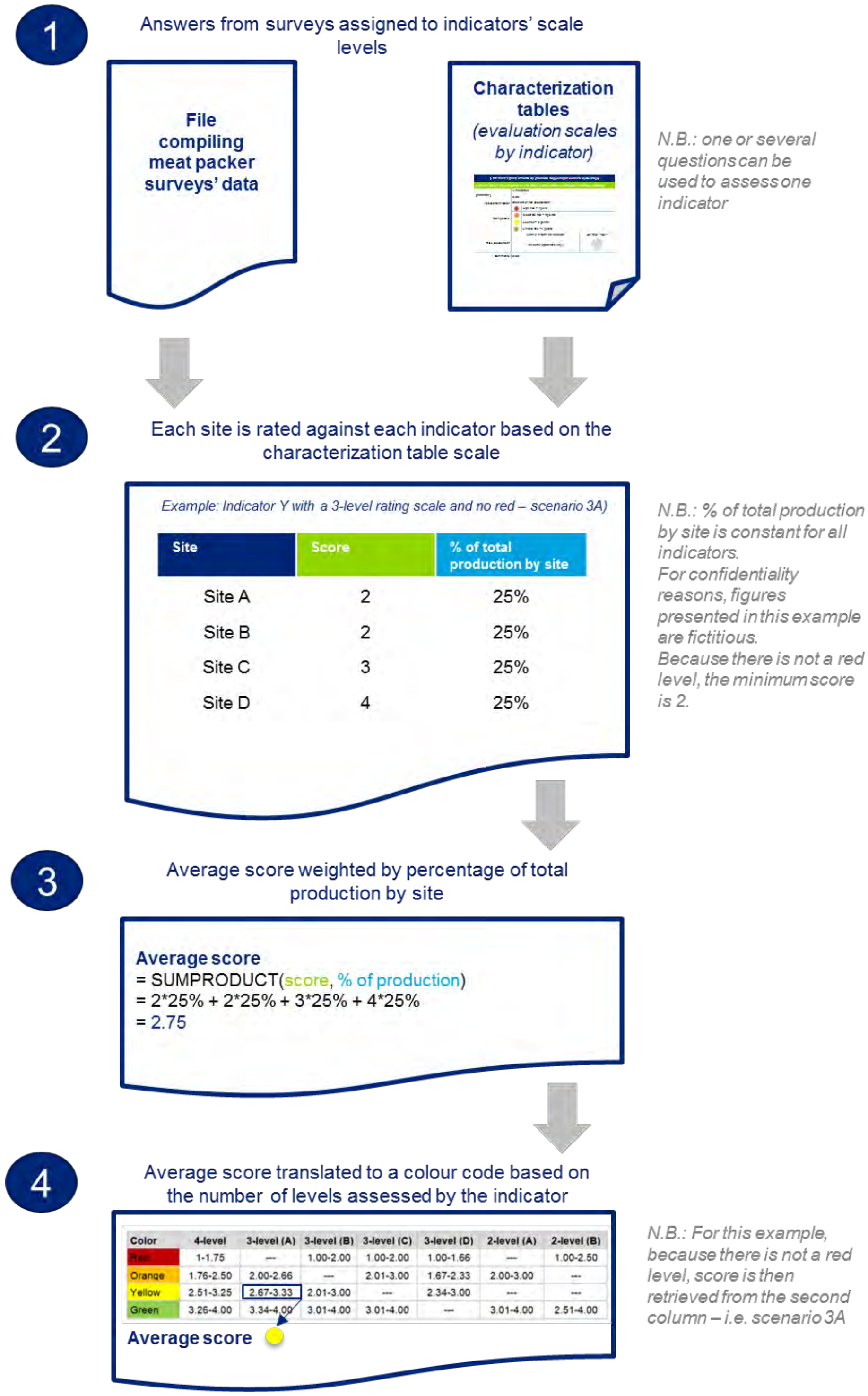

Figure 4-10 Average risk score calculation methodology steps (meat processors)

4.4.2.3 Limitations

The sample does not account for the practices of all beef processors in Canada. Again, the results provide a risk assessment rather than the actual performance of the sector.

4.4.2.4 Interpretation of the evaluation scale

The following scale was used to assess potential risks at the meat packers' level:

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Colour	Risk scale level	Definition
	High	High risk of negative social impact
	Moderate	Moderate risk of negative social impact
	Low	Low risk of negative social impact
	Very low	Very low risk of negative social impact / potential positive impact

4.4.2.5 Characterization table of indicators and risk scores

WORKERS		
Freedom of association		
Unionization	**Description**	
	The ILO convention[62] (International Labour Organization, 1948) sets forth the right for workers and employers to establish and join organizations of their own choosing without previous authorization.	
Assessment factor	Existence of unionized workers and comparison with the union rate for manufacturing sector in Canada.	
Rating scale		----
		No evidence of unionized workers
		Existence of unionized workers and the average union rate of farm workers is under the Canadian manufacturing union rate
		Existence of unionized workers and the average union rate of farm workers is equal to or more than the Canadian manufacturing union rate
Risk assessment	**Average score**	
Comments	The union membership rate in Canada in 2011 was 31.7% and 26.9% for the manufacturing sector (Statistics Canada, 2011) (Statistics Canada). More than 75% of employees at the surveyed sites are unionized.	
Fair salary		
Overtime pay	**Description**	
	Even if they are not legally committed to, employers can pay workers for overtime as well as offer them a premium (Federal labour standards (Government of Canada, 2013).	
Assessment factor	Employers paying for overtime work.	
Rating scale		----
		Employers do not apply overtime pay

[62] Art. 2 of the Freedom of association ILO's convention : "Workers and employers, without distinction whatsoever, shall have the right to establish and, subject only to the rules of the organization concerned, to join organizations of their own choosing without previous authorization" : http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C087
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	🟡	Employers apply overtime pay without an overtime premium
	🟢	Employers apply overtime with an overtime premium
Risk assessment	**Average score** 🟢	
Comments	Employees of the surveyed sites receive a premium when doing overtime work. According to the Canada Labour Code, overtime is "any hours worked in excess of the daily hours of work set out in paragraph (d) [i.e. work schedule defined in contract] and in excess of a weekly average of 40 hours over the work schedule". (Government of Canada, 2015) In Alberta, "overtime hours must be paid at not less than 1.5 times the employee's wage rate". (Jobs, Skills, Training and Labour Alberta, 2014)	
Average hourly wage	**Description** Assessment of average hourly wage of employees against the legal minimum hourly wage and the average hourly wage of the province they are located in.[63] (Government of Canada, 2015), (Statistics Canada, 2015)	
Assessment factor	Comparison between 1) the average hourly wage of farm workers, and 2) the provincial hourly wage.	
Rating scale	🔴	Average hourly wage of employees is below the provincial legal minimum hourly wage
	🟠	Average hourly wage of employees is equal to the provincial legal minimum hourly wage
	🟡	Average hourly wage of employees is above the provincial legal minimum hourly wage but below the provincial average wage rate
	🟢	Average hourly wage of employees is above the provincial legal minimum hourly wage and above the provincial average wage rate
Risk assessment	**Average score** 🟡	
Comments	The average hourly wage in Canada across all industries in 2013 was $22.85/hour – including overtime.	
Working hours		
Workweek length	**Description** The average work week length (hours/week) per year of regular workers in comparison to the ILO's standard of 48 hours/week. (International Labour Organization, 1919)	
Assessment factor	The average number of hours worked per week for regular workers should not exceed 48 hours (ILO convention).	
Rating scale	🔴	The average number of hours worked per week for regular workers exceeds 48 hours per week
	🟠	---
	🟡	---

63 Minimum wage rate per province: AB = $10.20; SK = $10.20, MB = $10.70, ON = $11.00, BC = $10.25, QC = $10.55, NB = $10.30, NS = $10.60, PEI = $10.50, NL = $10.25; Average hourly wage per province, Statistics Canada.

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		The average number of hours worked per week for regular workers does not exceed 48 hours per week
Risk assessment	**Average score**	
Comments	The Canadian Labour Standard states that "the maximum time an employee may work each week is normally 48 hours". (Government of Canada, 2015)	
Workload	**Description**	
	Comparison of workers' practices with the ILO standard (48 hours/week).	
Assessment factor	Number of weeks per year during which workers worked more than 48 hours/week.	
Rating scale		Exceed 13 weeks
		One to 13 weeks.
		---
		0 weeks
Risk assessment	**Average score**	
Comments	All surveyed sites declared that workers—in all departments—never work more than 48 hours/week.	
Social benefits		
Scope of benefits	**Description**	
	Minimum ILO standards (C-102 Social Security) (International Labour Organization, 1952) include nine social benefits: medical care, sickness benefit, unemployment benefit, old-age benefit, employment injury benefit, family benefit, maternity/paternity benefit, invalidity benefit and survivor's benefit.	
Assessment factor	Number of social benefits provided to employees.	
Rating scale		---
		One to three benefits listed by the ILO are provided to employees/workers
		Four to six benefits listed by the ILO are provided to employees/workers
		Seven to nine benefits listed by the ILO are provided to employees/workers
Risk assessment	**Average score**	
Comments	The most common benefits mentioned by sites surveyed are: medical care and employment injury benefit (or equivalent).	

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Equal opportunities		
Visible minorities and aboriginal workforce	**Description**	
	In Canada, employment equity encourages the establishment of working conditions that are free of barriers. The Labour Program of Canada ensures that the "*Employment Equity Act*" and its mandates are applied appropriately to Aboriginal peoples and members of visible minority (persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour). (Government of Canada, 2015)	
Assessment factor	Presence of visible minority and Aboriginal workers in 2013.	
Rating scale		---
		No visible minority and Aboriginal workers
		Presence of visible minority workers OR Aboriginal workers
		Presence of visible minority AND Aboriginal workers
Risk assessment	**Average score** *Data not collected to respect individual privacy*	
Comments	In 2013, 66.9% of Alberta Aboriginal people living off-reserve were employed in the services-producing sector, and 33.1% were employed in the goods-producing sector (including 5.5% for manufacturing). (Government of Alberta, 2015)	

Occupational health and safety		
Health and safety prevention	**Description**	
	The employer shall, in order to address identified and assessed hazards, including ergonomics-related hazards, take preventive measures to address the assessed hazard (Canada Occupational Health and Safety Regulations).[64] (Government of Canada, 2015)	
Assessment factor	Health and safety measures completed by employers: formal policy, preventive measures to avoid accident and an emergency protocol.	
Rating scale		---
		None of the listed health and safety prevention measures are in place
		One of the listed health and safety prevention measures is in place
		At least two of the listed health and safety prevention measures are in place
Risk assessment	**Average score**	

[64] The employer shall take preventive measures to address the assessed hazard in the following order of priority: (1) the elimination of the hazard, including by way of engineering controls which may involve mechanical aids, equipment design or redesign that take into account the physical attributes of the employee; (2) the reduction of the hazard, including isolating it; (3) the provision of personal protective equipment, clothing, devices or materials; and (4) administrative procedures such as the management of hazard exposure and recovery periods and the management of work patterns and methods / Canada Occupational Health and Safety Regulations, Government of Canada

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Comments	All sites surveyed have implemented the three health and safety measures used for the assessment, namely: a formal policy, preventive measures and an emergency protocol.	
Health and safety training	**Description** Workers are covered by provincial occupational health and safety legislation. Employers must ensure that employees have the necessary information, training and supervision to perform their work safely (Canada Labour Code, Part II (Government of Canada, 2015)).	
Assessment factor	Percentage of employees who received health and safety training.	
Rating scale		0% of employees received health and safety training
		1-25% of employees received health and safety training
		26-75% of employees received health and safety training
		More than 75% of employees received health and safety training
Risk assessment	**Average score**	
Comments	100% of employees working at the plants surveyed received health and safety training.	
Temporary foreign workers		
Unionization	**Description** The ILO convention[65] (International Labour Organization, 1948) sets forth the right for workers and employers to establish and join organizations of their own choosing without previous authorization.	
Assessment factor	Existence of unionized workers and comparison with the union rate for manufacturing sector in Canada.	
Rating scale		----
		No evidence of unionized workers
		Existence of unionized workers and the average union rate of farm workers is under the Canadian manufacturing union rate
		Existence of unionized workers and the average union rate of farm workers is equal to or more than the Canadian manufacturing union rate
Risk assessment	**Average score**	
Comments	The union membership rate in Canada in 2011 was 31.7% and 26.9% for the manufacturing sector (Statistics Canada, 2011) (Statistics Canada). The unionization rate of temporary foreign workers at processors surveyed is near 100%.	

[65] Art. 2 of the Freedom of association ILO's convention : "Workers and employers, without distinction whatsoever, shall have the right to establish and, subject only to the rules of the organization concerned, to join organizations of their own choosing without previous authorization" : http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C087
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Average hourly wage	**Description**	
	Assessment of average hourly wage of workers (both full time and part time) against the legal minimum hourly wage and the average hourly wage of the province they are located in.[66] (Government of Canada, 2015) (Statistics Canada, 2015)	
Assessment factor	Comparison between 1) the average hourly wage of farm workers, and 2) the provincial hourly wage.	
Rating scale	🔴	Average hourly wage of workers is lower than the provincial legal minimum hourly wage
	🟠	Average hourly wage of workers is equal to the provincial legal minimum hourly wage
	🟡	Average hourly wage of workers is greater than the provincial legal minimum hourly wage but lower than or equal to the provincial average minimum wage rate
	🟢	Average hourly wage of workers is greater than both the provincial legal minimum hourly wage and the provincial average minimum wage rate
Risk assessment	**Average score** 🟡	
Comments	The average hourly wage in Canada—across all industries—in 2013 was $22.85/hour including overtime.	
Scope of benefits	**Description**	
	Minimum ILO standards (C-102 Social Security) (International Labour Organization, 1952) include nine social benefits: medical care, sickness benefit, unemployment benefit, old-age benefit, employment injury benefit, family benefit, maternity/paternity benefit, invalidity benefit and survivor's benefit.	
Assessment factor	Number of social benefits provided to temporary foreign workers.	
Rating scale	🔴	---
	🟠	One to three benefits listed by the ILO are provided to temporary foreign workers
	🟡	Four to six benefits listed by the ILO are provided to temporary foreign workers
	🟢	Seven to nine benefits listed by the ILO are provided to temporary foreign workers.
Risk assessment	**Average score** 🟡	
Comments	The most common benefits offered by sites surveyed include: medical care and employment injury benefit (or equivalent). Temporary foreign workers must meet the same eligibility requirements as Canadian citizens and permanent residents to obtain benefits. (Government of Canada, n.d.) Processors also provide some services specific to temporary foreign workers, such as English as a second language (ESL) classes and contact with non-profit organizations	

[66] Minimum wage rate per province: AB = $10.20; SK = $10.20, MB = $10.70, ON = $11.00, BC = $10.25, QC = $10.55, NB = $10.30, NS = $10.60, PEI = $10.50, NL = $10.25. Data from Canadian Labour program;
Average hourly wage per province, Statistics Canada.

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	for immigrants or newcomers to Canada.	
Health and safety training	**Description**	
	Workers are covered by provincial occupational health and safety legislation. Employers must ensure that employees have the necessary information, training and supervision to perform their work safely (Canada Labour Code, Part II (Government of Canada, 2015)).	
Assessment factor	Percentage of employees who received health and safety training.	
Rating scale	🔴	0% of workers received health and safety training
	🟠	1-25% of workers received health and safety training
	🟡	26-75% of workers received health and safety training
	🟢	More than 75% of workers received health and safety training
Risk assessment	**Average score** 🟢	
Comments	100% of temporary foreign workers at the sites surveyed received health and safety training.	
LOCAL COMMUNITIES		
Community engagement		
Local community support	**Description**	
	Packers' engagement is assessed regarding their local community involvement practices (e.g. volunteering, donations and sponsorships).	
Assessment factor	Local community support practices.	
Rating scale	🔴	----
	🟠	No local community support
	🟡	Packers have local community support actions without having a formal policy
	🟢	Packers have a formal policy on community support AND local community actions
Risk assessment	**Average score** 🟢	
Comments	All of the processors surveyed have a formal policy for local community support and have various initiatives, including donations and sponsorships.	
Secure living conditions		
Safety prevention	**Description**	

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measures	Assess packers' safety prevention measures in case of incidents or negative effects to local communities through: workers' training to ensure the safe use of chemicals and/or workers' training to ensure the safe disposal of meat production waste.	
Assessment factor	Existence of safety prevention training programs in case of incidents or negative effects to local communities.	
Rating scale	Red	----
	Orange	No safety prevention training
	Yellow	Packers have at least one of the listed training programs
	Green	Packers have both training programs
Risk assessment	**Average score** Green	
Comments	Both training programs are in place at the sites surveyed to minimize risks to local communities due to processors' operations.	
Cohabitation		
Odour reduction	**Description** Assess packers' odour management mechanisms through three odour management mechanisms: site design, process design and management, control technologies.	
Assessment factor	Number of odour management mechanisms adopted.	
Rating scale	Red	Packers do not adopt odour management mechanisms
	Orange	Packers adopt at least one of the listed odour management mechanisms
	Yellow	Packers adopt at least two of the listed odour management mechanisms
	Green	Packers adopt the three listed odour management mechanisms
Risk assessment	**Average score** Green	
Comments	All of the sites surveyed adopt the three odour management mechanisms listed above.	
SOCIETY		
Animal welfare		
Installations for animal welfare	**Description** Assess packers' technologies and installations to improve animal welfare (e.g. non-slip flooring in stunning box; ventilation equipment in rest stop facilities; passageways allow two or more animals to walk side-by-side; non-slip flooring in rest stop facilities and passageways; one-way flow of animals to slaughter; indirect lighting; noise reducers; passageways without sharp angles; ramp inclination < 20 degrees; blinders).	

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Assessment factor	Existence of installation for improving animal welfare.	
Rating scale		---
		Packers do not have any of the listed installations
		Packers apply between one and three of the listed installations
		Packers apply at least four of the listed installations
Risk assessment	**Average score**	
Comments	Overall, at least six of the installations identified are implemented to improve animal welfare by the processors surveyed.	
Internal communication of animal welfare regulation	**Description**	
	Assess packers' practices to communicate with employees regarding the guidelines and procedures for the proper unloading, holding and movement of animals in slaughter facilities defined by the federal Meat Inspection Regulations.	
Assessment factor	Communication practices to ensure employees' awareness of animal welfare regulation.	
Rating scale		No communication in place to ensure employees' awareness of animal welfare regulation
		Packers display information to ensure employees' awareness of animal welfare regulation
		Packers use verbal communication and information display to ensure employees' awareness of animal welfare regulation
		Packers use verbal communication, information display and training to ensure employees' awareness and application of animal welfare regulation
Risk assessment	**Average score**	
Comments	All processors surveyed use verbal communication, information display and training to ensure employees' awareness and application of animal welfare regulation.	
Animal stunning method	**Description**	
	Assessment of animal stunning methods using different levels of efficiency and/or risk impacting animal welfare. The use of gas or gas mixture is not recommended for cattle; non-penetrating bolt and electronarcosis or electrocution present some risks of recovery of consciousness; penetrating captive bolt is the method presenting the least risk to animal welfare. (OIE - Terrestrial Animal Health Code, 2008)	
Assessment factor	Types of stunning method used.	
Rating scale		---
		Stunning method used: exposure to gas or gas mixture
		Stunning method used: non-penetrating captive bolt, electronarcosis or electrocution

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	●	Stunning method used: penetrating captive bolt
Risk assessment	**Average score** ●	
Comments	All sites surveyed used the stunning method that presents the least risks to animal welfare, i.e. penetrating captive bolt.	
Animal killing method	**Description** Assessment of animal slaughter methods; different methods have different levels of efficiency and/or risk impacting animal welfare. Chest sticking or bleeding by cutting of one carotid artery is more risky for animal welfare than by cutting two carotid arteries (OIE - Terrestrial Animal Health Code, 2008).	
Assessment factor	Types of killing method used.	
Rating scale	● (red)	Animals are slaughtered without prior stunning
	● (orange)	Prior stunning and bleeding by cutting one carotid artery or by chest sticking
	● (yellow)	---
	● (green)	Prior stunning and bleeding by cutting two carotid arteries
Risk assessment	**Average score** ●	
Comments	All sites surveyed are using the method considered the best practice for animal slaughtering, i.e. prior stunning and bleeding by cutting two carotid arteries.	
Transporters certification	**Description** Assessment of the ratio of haulers certified by the Canadian Livestock Transport (CLT).[67] (Canadian Livestock Transport, n.d.)	
Assessment factor	Percentage of haulers certified by the CLT for the handling of animals.	
Rating scale	● (red)	---
	● (orange)	Less than 25% of haulers have CLT certification
	● (yellow)	26-50% of haulers have CLT certification
	● (green)	More than 50% of haulers have CLT certification
Risk assessment	**Average score** ●	

[67] The CLT certification is a program led by an industry initiative to address the need for increased accountability and improved handling practices in livestock transport

.

Comments	Unloading crews of plants surveyed are also trained for animal handling, either through in-house training or through CLT certification training.	
Animal welfare audit	**Description**	
	Audits aim to ensure that food business operators comply with relevant animal health and welfare standards.	
Assessment factor	Auditing processes in place implemented by 1) packing plants, and 2) packing plants' clients	
Rating scale		---
		Animal welfare audits are not performed
		Animal welfare audits are performed by either the packing plants themselves or by their clients
		Animal welfare audits are performed by both the packing plants and their clients
Risk assessment	**Average score**	
Comments	Meat packing plants surveyed declared that they audit their operations for animal welfare on a regular basis. Some clients require audits for animal welfare at the plant and sometimes at the farm level as well. Those audits can be led by an external auditor (third-party) or internally by the packing plant staff.	
Corruption		
Anti-corruption practices	**Description**	
	Assessment of packers' measures to prevent corruption (i.e. misuse of power for personal advantages) in their activities.	
Assessment factor	Existence of corruption prevention measures.	
Rating scale		No anti-corruption measure is in place

		Anti-corruption guidelines are in place
		Anti-corruption guidelines and other practical measures (e.g. whistleblowing mechanism, training) are in place
Risk assessment	**Average score**	
Comments	All surveyed processors have a business code of conduct, or equivalent, which includes anti-corruption guidelines. They also implement additional initiatives such as whistleblower hotlines and training.	
VALUE CHAIN ACTORS		
Promoting social responsibility		
Responsible	**Description**	

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procurement promotion	Assess packers' practices for promoting socially and environmentally conscious purchasing (e.g. purchasing tools, guidelines, farmers' awareness campaigns) through formal (i.e. as part of a plan, policy, strategy or other corporate document/program) or informal (i.e. not directly promoted by the company) initiatives.	
Assessment factor	Existence of procurement practices to promote responsible beef production.	
Rating scale	Red	---
	Orange	No social and environmental purchasing initiatives
	Yellow	Existence of non-formal social and environmental purchasing initiatives to promote sustainable procurement
	Green	Existence of a formal social and environmental purchasing initiatives to promote sustainable procurement
Risk assessment	**Average score** Green	
Comments	The companies representing the meat processors surveyed are participants in the Global Roundtable for Sustainable Beef and the Canadian Roundtable for Sustainable Beef. They are also participating in the McDonald's Pilot Project to source verified sustainable beef.	
Fair competition		
Anti-competition prevention measures	**Description** Assessment of packers' initiatives to comply with the Canadian Competition Act, which seeks to prevent anti-competitive practices in the marketplace. (Government of Canada, 2015)	
Assessment factor	Existence of a business code of conduct and other proactive initiatives to prevent anti-competitive behaviour (e.g. membership in alliances that denounce anti-competitive practices; documented statement or procedures to prevent engaging in or being complicit in anti-competitive behaviour; communication to employees/workers of the importance of compliance with competition legislation and fair competition).	
Rating scale	Red	No business code of conduct
	Orange	---
	Yellow	Business code of conduct
	Green	Business code of conduct and other proactive initiatives to prevent anti-competitive behaviour
Risk assessment	**Average score** Green	
Comments	All processors have a business code of conduct, or equivalent, covering anti-competitive behaviour. Other proactive initiatives include: membership in alliances that denounce anti-competitive practices and training of employees on this particular subject.	
Suppliers relationship		
Positive business	**Description**	

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practices with suppliers	Assessment of respondents' relationship practices with their suppliers based on factors identified by the UNEP/SETAC guidelines and that include: respectful communication, sufficient lead time, appropriate order size, availability of products and timely payments. (UNEP, 2013)	
Assessment factor	Evidence of good relationship with suppliers.	
Rating scale		---
		None of the listed good relationship factors are identified
		One of the listed good relationship factors is identified
		At least two of the listed good relationship factors are identified
Risk assessment	**Average score**	
Comments	The most common signs of good relationships identified by processors surveyed are the absence of coercive communication with suppliers and timely payment of suppliers.	
CONSUMERS		
Health and safety products		
Food safety measures	**Description** Assessment of packers' efforts to address consumer health in their production processes. Consumers have the right to be protected against products that may pose a risk to their health and safety. Implementation of a food safety risk management plan and/or employee food safety training are best practices addressing food safety.	
Assessment factor	Evidence of food safety prevention measures.	
Rating scale		---
		No food safety risk management plan or employee training is in place
		Either a food safety risk management plan or employee training is in place
		Both a food safety risk management plan and employee training are in place
Risk assessment	**Average score**	
Comments	All processors surveyed have implemented a food safety risk management plan and provide internal training to their employees. Annual national figures reported through the National Enteric Surveillance Program (NESP) show that between 2007 and 2013 the rates for Major Organism Groups generally decrease, with 2013 showing the lowest rate for the four categories: e-coli, salmonella, listeria and shigella (Public Health Agency of Canada, 2015). Please note however that these numbers are not beef-specific.	
Transparency		

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Product origin	**Description**	
	Assessment of packers' mechanisms, policies, initiatives to track animals' origin.	
Assessment factor	Existence of tracking mechanisms, policies, initiatives regarding animals' origin.	
Rating scale		---
		No tracking mechanism, policy or initiative is in place

		Tracking mechanisms, policies or initiatives are in place
Risk assessment	**Average score**	
Comments	All processors surveyed track the origin of the cattle they receive. This process is facilitated by Canada's mandatory cattle identification system that utilizes radio frequency identification (RFID) ear tags for disease management. Thanks to this internet database, rapid and accurate animal information is available to track animal origin. (Canada Beef Inc., 2012)	
Feedback mechanisms		
Feedback mechanisms	**Description**	
	Feedback mechanisms are paths by which consumers communicate with organizations. These mechanisms help reveal consumer satisfaction related to the consumption and use of the product or service (UNEP).	
Assessment factor	Presence of feedback mechanisms.	
Rating scale		---
		No feedback mechanisms available

		Presence of feedback mechanisms
	Average score	
Comments	The feedback mechanisms mentioned by the processors surveyed include: customer hotline, complaint policy and sales representative contact person.	
End-of-life responsibility		
Packaging reduction and optimization	**Description**	
	Assessment of initiatives aimed at minimizing product disposal impact. For packers, initiatives to reduce or optimize packaging would reduce the environmental impact of the product.	
Assessment factor	Existence of initiatives to reduce or optimize products' packaging.	

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Rating scale	🔴	---
	🟠	No initiatives to reduce or optimize products' packaging
	🟡	Initiatives to reduce or optimize products' packaging
	🟢	Initiatives to both reduce and optimize products' packaging
Risk assessment	**Average score** 🟢	
Comments	All processors surveyed have initiatives to both reduce and optimize products' packaging, reducing the environmental impact of the product.	

4.4.3 Value chain actors

4.4.3.1 Scope of assessment and source of data

In order to include an assessment of value chain actors, both downstream (i.e. beef producers' suppliers) and upstream (i.e. beef distributors), generic data were collected. This process was based on the most relevant subcategories of impact for each of these streams. The four subcategories of impacts specifically identified by the *Methodological Sheets for Subcategories in Social Life Cycle Assessment* (UNEP/SETAC, 2013) for the stakeholder group "value chain actors" were included, as well as additional subcategories of impacts relevant either to the downstream actors or to the upstream actors.

Table 4.8 Alberta cow-calf cost of production

Operating costs	$/cow
Winter feed	$ 159
Grazing	$ 210
Summer mineral	$ 9
Veterinary and medicine	$ 20
Fuel	$ 18
Marketing	$ 10
Repairs	$ 17
Utilities	$ 12
Annual labour	$ 47
Total operating costs	**$ 502**

Portions of the value chain's upstream processes have been selected from the cow/calf operating costs for 2013 in Alberta (see Table 4.8)[68] to identify the sectors to be reviewed in this assessment. However, the following costs were not included in the value chain analysis: fuel, marketing, repairs and utilities due to the multitude of possible suppliers.

These costs were completed based on experts' judgement (see *6.1* ELCA & SLCA—Composition of the study's Steering Committee and critical review panel) to also include suppliers of fertilizer, and more upstream suppliers such as seed and grain to complete the winter feed assessment.
The two sectors selected to assess downstream value chain actors were retail (food distribution stores) and fast-food chains.

Because the assessment mainly relies on information collected at the company level, except for two indicators, major companies representative of these sectors were identified either based on market share when available or on expert judgement based on observed purchasing practices in Canada. Please note that the intermediary level between meat processors and fast-food chains is out of the scope of our analysis due to the complexity of collecting data from the high number of actors involved in this stage.

The selected companies by sector for value chain actors are:

Sector	Company	Comments / rationale for selection

[68] Unpublished data: Canfax Research Services, updated 9/04/2015

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Sector	Company	Comments / rationale for selection
Upstream		
Seed companies	Monsanto	Top companies based on expert assessment
	Pioneer / DuPont	
	Syngenta	
Grain companies	Cargill	Top companies based on expert assessment
	Nutreco/Shur-Gain	
	Viterra	
Fertilizers industry	Agrium Inc.	Top companies based on market share
	Potash Corp.	
	The Mosaic Company	
Feed production	Nutreco	Top companies based on market share
	Ridley	
	ADM	
Salt and mineral	Cargill	Top company based on expert assessment
Veterinary products	Elanco	Top companies based on expert assessment
	Merck	
	Boehringer	
Downstream		
Distribution	Loblaw	Top companies based on market share and expert assessment
	Sobey's	
	Walmart	
	Costco	
Fast-food chains	McDonald's	Top companies based on expert assessment
	Burger King	
	Tim Hortons	
	A&W	

The value chain of a product taken from cradle to grave for a product like beef meat can lead to an extensive network of suppliers and other value chain actors. Examples of sector inputs that have been excluded from the social assessment are: oil and steel extraction, fuel and diesel, agricultural machinery and pesticides. The main reasons for exclusion of these sectors include: a low contribution to overall production costs and a limited influence capacity of the study sponsor on these sectors to induce change and impact decision making processes. However, overall, the scope limits were also set based on the resources available to conduct the study. Data used for this stage of the social life cycle assessment were sourced from online research of publicly available documents and information at time of search, either from:

- companies' websites and reports,
- press articles covering the topics addressed by indicators and/or

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- statistics at the sector level when not available at the companies' level.

4.4.3.2 Average risk score calculation methodology

The average score for each indicator was calculated in four steps:

- Rating level based on number of companies scoring at each level summarized in the characterization table
- Calculation of sum of points by indicator
- Calculation of average score
- Translation of average score into colour code, defining the level of risk from high (red) to low (green)

The diagram below illustrates the process using an example with fictitious numbers:

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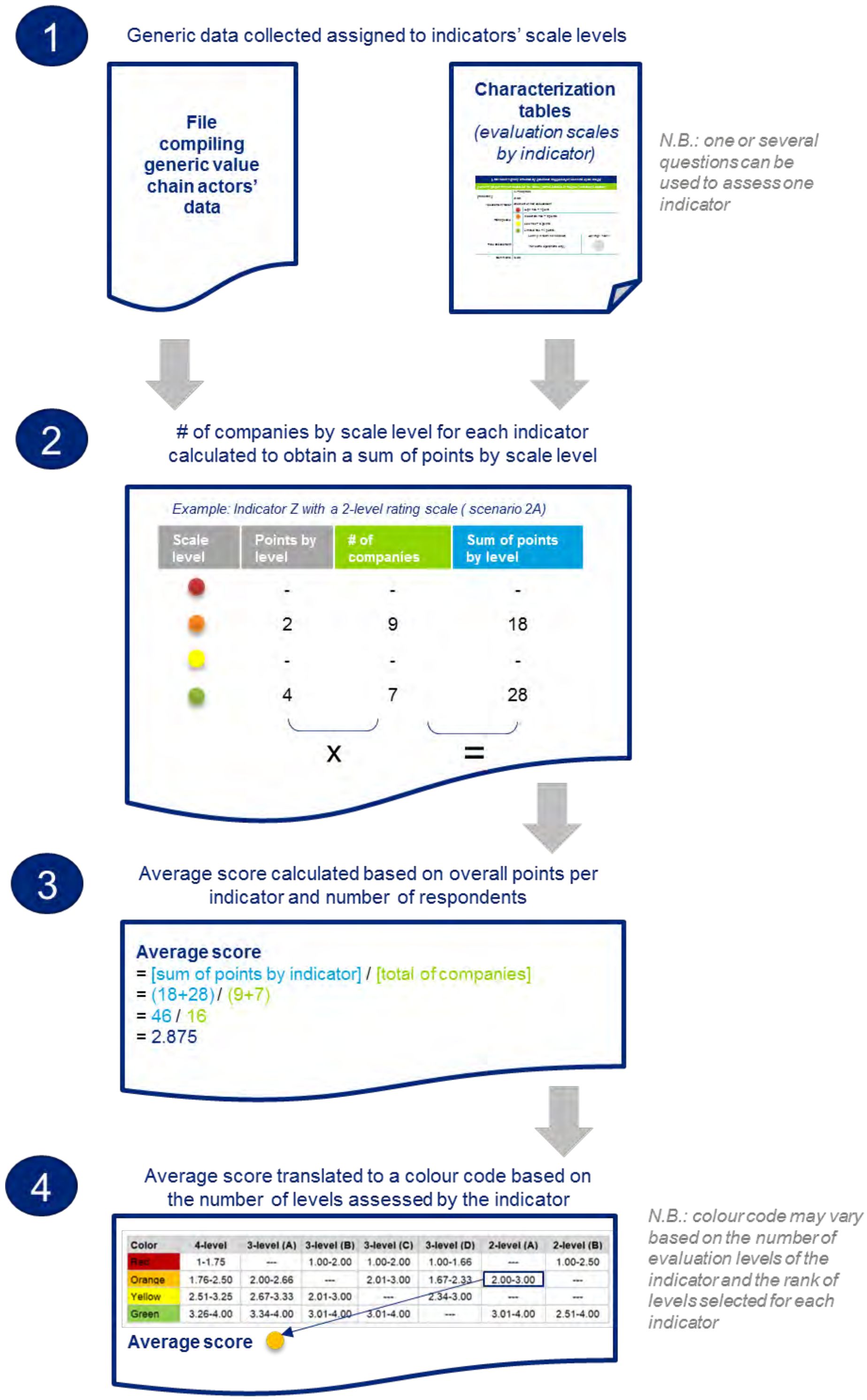

Figure 4-11 Average risk score calculation methodology steps (value chain actors)

The following assumptions and methodological choices were applied for this assessment:

- When serious risks or practices contravening laws or regulations were not identified for indicators, the high risk level was left blank. Some indicators may be binary and only include two levels of assessment. A three-level assessment can also demonstrate the lack of an intermediary situation between levels.
- Assessment is conducted at the "corporate" or "group" level, unless otherwise noted. For instance, some of the companies assessed are involved in several sectors. In these cases, only the sector relevant to our study and

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the practices/events potentially related to the identified sector of activities were taken into consideration (e.g. Monsanto is also active in the pesticide industry, but only practices/events relating to seeding were taken into account, as pesticides are not included in our scope of assessment).

- Two indicators (adequacy of average salary and rates of fatal and non-fatal injuries) were assessed at the sector level rather than at the corporate level due to the lack of public information at the company level.
- Two indicators (adequacy of median income and occupational health and safety) for veterinary product companies were based on generic pharmaceutical sector data, as data for brand name pharmaceutical manufacturing in Canada were not available.
- In the case of rating levels looking at evidence of events/incidents that would indicate a high risk, the period taken into account is 10 years (i.e. between 2003 and 2013) at the time it was recognized by the company, ruled by a court and/or the fine was paid by the company (which can differ from the year the event/incident happened). In case another level would also be applicable, the lowest score (or the "worst case scenario") is kept.

4.4.3.3 Limitations

- This assessment is solely based on generic data, i.e. publicly available information at the time of research. There may be a gap between what companies do, what they communicate about and when they communicate it.

4.4.3.4 Interpretation of the evaluation scale

The following scale was used to assess potential risks at the value chain actors' level:

Colour	Risk scale level	Definition
Red	**High**	High risk of negative social impact
Orange	**Moderate**	Moderate risk of negative social impact
Yellow	**Low**	Low risk of negative social impact
Green	**Very low**	Very low risk of negative social impact / potential positive impact

4.4.3.5 Characterization table of indicators and risk scores

WORKERS		
Fair salary		
Adequacy of median income	**Description**	
	Reminder: this indicator is based on sector average ranking, not on companies' specific data. Income of half the national median is considered inadequate. (Anker et al., 2008) Statistics Canada differentiates income (considered for population of non-employed/self-employed workers) from wages and salaries (considered for population of employed workers). The wages and salaries figures for full-time employment were used in the assessment of this indicator.	
Assessment factor	Comparison between 1) the sector median wages and salaries, and 2) the national median wages and salaries established by Statistics Canada. (Government of Canada, n.d.)	
Rating scale	Red	The sector median wages and salaries are < 50% of the national median wages and salaries
	Orange	The sector median wages and salaries are 51-85% of the national median wages and salaries
	Yellow	The sector median wages and salaries are 86-115% of the national median wages and salaries

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		The sector median wages and salaries are more than 116% above the national median wages and salaries
Risk assessment	**Average score** **Upstream**	**Average score** **Downstream**
Comments	National figures for 2013 were not available, so the most recent (from 2010) were used for both the national average and the sector's average. The national median wages and salaries for 2010, used as the reference point for the assessment, was $48,964. Upstream value chain actors with the highest average wages and salaries score (86-115% of the national median) include the sectors of the following products: fertilizers, salt and mineral, and veterinary products. At the downstream level, fast-food chains show the lowest score (< 50% of the national median).	
Occupational health and safety		
Rate of fatal and non-fatal injuries	**Description** *Reminder: this indicator is based on sector average ranking, not on companies' specific data.* Indicators of safety and health at work provide the framework for assessing the extent to which workers are protected from work-related hazards and risks (ILO).	
Assessment factor	Comparison of 1) the sector rate of injuries[69] (per 100,000 workers employed in 2008), and 2) the country average rate of injury (in 2008), LabourStat indicator—ILO.	
Rating scale		Rate of fatal injuries > country average
		Rate of fatal injuries < country average and rate of non-fatal injuries > country average
		Rates of fatal and non-fatal injuries < country average

Risk assessment	**Average score** **Upstream**	**Average score** **Downstream**
Comments	The sectors of the following products supplied by upstream value chain actors have a fatal injury rate above the country average: seeds, grains, fertilizers, feed, salt and mineral. However, their non-fatal injury rate is below the country average.	

[69] Frequency rates are generally calculated as the number of new cases of injury during the calendar year (as given in Table 8A) divided by the total number of hours worked by workers in the reference group during the year, multiplied by 1,000,000. Incidence rates are calculated as the number of new cases of injury during the calendar year divided by the number of workers in the reference group during the year, multiplied by 1,000,000 (LabourStat, ILO).

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	At the downstream level, the fast-food chains sector has both fatal and non-fatal injury rates below the country average. Sectors of veterinary products and retailers both have a fatal injury rate below the country average, but a non-fatal injury rate above the country average.	
LOCAL COMMUNITIES		
Secure living conditions		
Public health and safety measures	**Description**	
	Assessment of how organizations' sites impact local communities' health and safety through their operations, practices or activities. This indicator assesses the general safety conditions of operations and their potential impacts on public health. Considerations include incidents impacting public health (e.g. air quality or water quality) and risk prevention measures that ensure local communities' health and safety.	
Assessment factor	Evidence of incident and preventative measures regarding: management oversight of buildings and installations, structural integrity, organization efforts to strengthen community health and management effort to minimize use of hazardous substances	
Rating scale		Evidence of public health and safety incident
		No evidence of incident and no evidence of any measures seeking to ensure safe and healthy living conditions
		No evidence of incident and limited evidence of measures seeking to ensure safe and healthy living conditions
		No evidence of incident and clear evidence of measures seeking to ensure safe and healthy living conditions
Risk assessment	**Average score**	
	Upstream	**Downstream**
		n/a
Comments	On average, the assessment of companies in the upstream value chain revealed neither incidents nor specific measures to ensure safe and healthy living conditions of the communities in which they operate. Our research however showed three companies (Monsanto for the grain products sector, Cargill for the salt and mineral sector and Merck for the veterinary products sector) with evidence of incidents. One company (Agrium Inc. for the fertilizers industry) showed clear evidence of measures to ensure safe and healthy conditions of local communities.	
SOCIETY		
Contribution to economic development		
R&D investments	**Description**	
	Assessment of the extent to which organizations contribute to the economic development of the country through R&D initiatives.	
Assessment factor	Evidence of presence of a national R&D centre/dedicated facility or R&D initiatives conducted in Canada.	
Rating scale		---
		No evidence of a national R&D centre/dedicated facility nor R&D initiatives

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		conducted in Canada
	(yellow)	Evidence of R&D initiatives conducted in Canada but with no national R&D centre/dedicated facility
	(green)	Evidence of a national R&D centre/dedicated facility

	Average score	
	Upstream	**Downstream**
Risk assessment	(yellow)	*n/a*
Comments	Results show that 50% of companies assessed have a national R&D centre/dedicated facility. About 30% conduct R&D initiatives in Canada, and about 20% have no R&D initiatives (nor centre) in Canada.	

Local employment		
Promotion of local suppliers and workforce	**Description** Supplier and workforce policies implemented by companies can have socio-economic impacts on the communities in which they operate. Companies with local hiring and procurement preferences encourage sustainable development (UNEP).	
Assessment factor	Existence of 1) local hiring policy, and 2) local procurement policy as local economy contributing factors.	
Rating scale	(red)	---
	(orange)	No evidence of local hiring or procurement policies
	(yellow)	Evidence of a local hiring OR procurement policy
	(green)	Evidence of both local hiring AND procurement policies

	Average score	
	Upstream	**Downstream**
Risk assessment	(amber)	(amber)
Comments	Results show that 70% of both upstream and downstream value chain companies assessed for this study show no evidence of local hiring and procurement policies. Either a local hiring or a local procurement policy exists 30% of the time. As a reminder, these results are based on generic data and publicly available information at the time of research. There may be a gap between actual initiatives and publicly disclosed initiatives.	

CONSUMERS	
Transparency	
Sustainability report	**Description** Assessment of the extent to which organizations communicate in a transparent way on all issues regarding their products' social responsibility (UNEP).
Assessment factor	Publication of a sustainability report or sustainability-related information (e.g. information available on website, short documents covering limited sustainability

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	topics).	
Rating scale		---
		No evidence of publication of a sustainability report or sustainability-related information
		Publication of limited sustainability-related information or non-updated sustainability information/report (2011 or prior year)
		Publication of a sustainability report (for 2013 or 2012 at the latest)
Risk assessment	**Average score**	
	Upstream	**Downstream**
	n/a	
Comments	Downstream value chain companies with recent sustainability reports include: Loblaw and Walmart for the retail sector and McDonald’s for fast-food chains. Research showed that other companies either had limited information or non-updated reports.	
Feedback mechanisms		
Consumer feedback mechanisms	**Description**	
	Assessment of the effectiveness of management measures to support consumer feedback.	
Assessment factor	Evidence of feedback mechanisms to enable consumers to report any issue or comment on their service/consumption experience.	
Rating scale		No evidence of feedback mechanisms

		Evidence of feedback mechanisms
Risk assessment	**Average score**	
	Upstream	**Downstream**
	n/a	
Comments	All companies assessed and representing the downstream value chain showed evidence of feedback mechanisms.	
VALUE CHAIN ACTORS		
Fair competition		
Anti-competitive prevention measures	**Description**	
	Assessment of the extent to which organizations’ competitive activities are conducted in a fair way and in compliance with legislation preventing anti-competitive behaviour (UNEP). In Canada, the Competition Act seeks to prevent anti-competitive practices in the marketplace. (Government of Canada, 2015)	

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Assessment factor	Evidence of documented statement or procedures (policy, strategy, etc.) to prevent engaging or being complicit in anti-competitive behaviour.	
Rating scale		Evidence of anti-competitive behaviour
		No evidence of anti-competitive behaviour and no evidence of documented statement or procedures preventing anti-competitive behaviour
		---
		No evidence of anti-competitive behaviour and evidence of documented statement or procedures preventing anti-competitive behaviour
Risk assessment	**Average score**	
	Upstream	**Downstream**
Comments	The majority of companies assessed at both the upstream and downstream levels showed no evidence of anti-competitive behaviour with evidence of documented statements or procedures preventing anti-competitive behaviour through their business code of conduct, or equivalent document. Research revealed one case of anti-competitive behaviour in the value chain for Merck (veterinary products).	
Respect of intellectual property rights		
Intellectual property protection	**Description**	
	Assessment of the extent to which organizations' actions safeguard and value the creators and other producers of intellectual goods and services. Intellectual property rights refer to the general term for the assignment of property rights through patents, copyrights and trademarks. These property rights allow the holder to exercise a monopoly on the use of the item for a specified period (UNEP).	
Assessment factor	Evidence of organizations' policy and/or practices demonstrating engagement towards the respect of intellectual property rights.	
Rating scale		Evidence of intellectual property right infringement
		No evidence of infringement and no evidence of organizations' policy and/or practices demonstrating engagement towards the respect of intellectual property rights
		No evidence of infringement and evidence of organizations' practices demonstrating engagement towards the respect of intellectual property rights
		No evidence of infringement and evidence of organizations' policy demonstrating engagement towards the respect of intellectual property rights
Risk assessment	**Average score**	
	Upstream	**Downstream**
Comments	Protection of intellectual property (IP) is generally higher at the upstream than the downstream level. We may interpret the general lack of policy/practice towards IP at the downstream level by lower risks/relevance to the sectors concerned. Research showed that about 60% of upstream value chain companies assessed have a	

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	dedicated IP policy, about 20% have some practices in place and 20% have neither policies nor practices dedicated to IP protection. Research revealed no case of intellectual property infringement in the value chain.	
Supplier relationships		
Engagement with suppliers	**Description** Assessment of organizations' engagement with their suppliers to understand their priorities and issues in order to strengthen mutual relationships.	
Assessment factor	Evidence of engagement with suppliers.	
Rating scale		---
		No evidence of engagement with suppliers
		Evidence of informal/unstructured engagement with suppliers
		Evidence of formal/structured engagement with suppliers
Risk assessment	**Average score**	
	Upstream	**Downstream**
Comments	Overall, the average score shows that companies have informal/unstructured processes to engage with their suppliers at both the upstream and downstream levels, but generally companies either scored orange or green, i.e. no supplier engagement vs formal engagement process. At the upstream level, companies with best practices (formal/structured supplier engagement process) include: Cargill for grain products and salt and mineral, Agrium and Mosaic for fertilizers and Merck for veterinary products. At the downstream level, companies with best practices include: Sobey's and Walmart for retailers and McDonald's for fast-food chains.	
Promoting social responsibility		
Responsible procurement practices	**Description** Assessment of the extent to which organizations promote social responsibility among their suppliers and through their own actions. Social responsibility (SR) is the organizations' obligation to consider the interests of their stakeholders as customers, employees, shareholders or communities. By integrating SR into core business processes and stakeholder management, organizations can achieve the ultimate goal of creating both social value and corporate value (shared value) (UNEP).	
Assessment factor	Evidence of responsible procurement through either passive (e.g. supplier code of conduct) or proactive initiatives (e.g. responsible sourcing strategy and engagement with suppliers).	
Rating scale		---
		No evidence of responsible procurement practices
		Evidence of supplier code of conduct or similar document
		Evidence of proactive initiatives by companies to engage in a responsible procurement strategy

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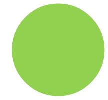
Risk assessment	Average score	
	Upstream	**Downstream**
		
Comments	While the majority of companies assessed at the upstream level showed evidence of a supplier code of conduct or equivalent, while the majority of companies assessed at the downstream level showed proactive initiatives to engage with suppliers as part of a responsible procurement strategy. This good practice was found to be implemented by the following companies at the upstream level: Cargill for grain products and salt and mineral, and Merck for veterinary product; and by the following companies at the downstream level: Loblaw, Sobey's, Walmart and McDonald's. Evidence of responsible procurement practices was not found for the following companies: Pioneer/DuPont (seeds), Viterra (grains), Ridely and ADM (feed), Elanco (veterinary products) and Burger King (fast-food chains).	

4.4.4 Industry associations

4.4.4.1 Scope of assessment and source of data

To complete the picture of Canadian beef production, the activities and practices of beef producers associations were also assessed as influencing actors of the industry.

Please note that some of the topics covered by our assessment are not specifically part of all associations' mandate. Other associations or not-for-profit organizations also work in a complementary space to promote and strengthen the industry's sustainability through research or promotion of beneficial management practices for instance. However, based on the project's resources, only the provincial and national beef industry associations are covered in this assessment.

Both specific and generic data were used for this assessment. A survey was sent to the associations for specific data collection. However, not all the associations answered the survey. For those lacking specific data, a review of their website was made to assess their practices based on publicly available information.

The map below shows the provinces covered by our assessment, with a different colour code for those based on specific or generic data.

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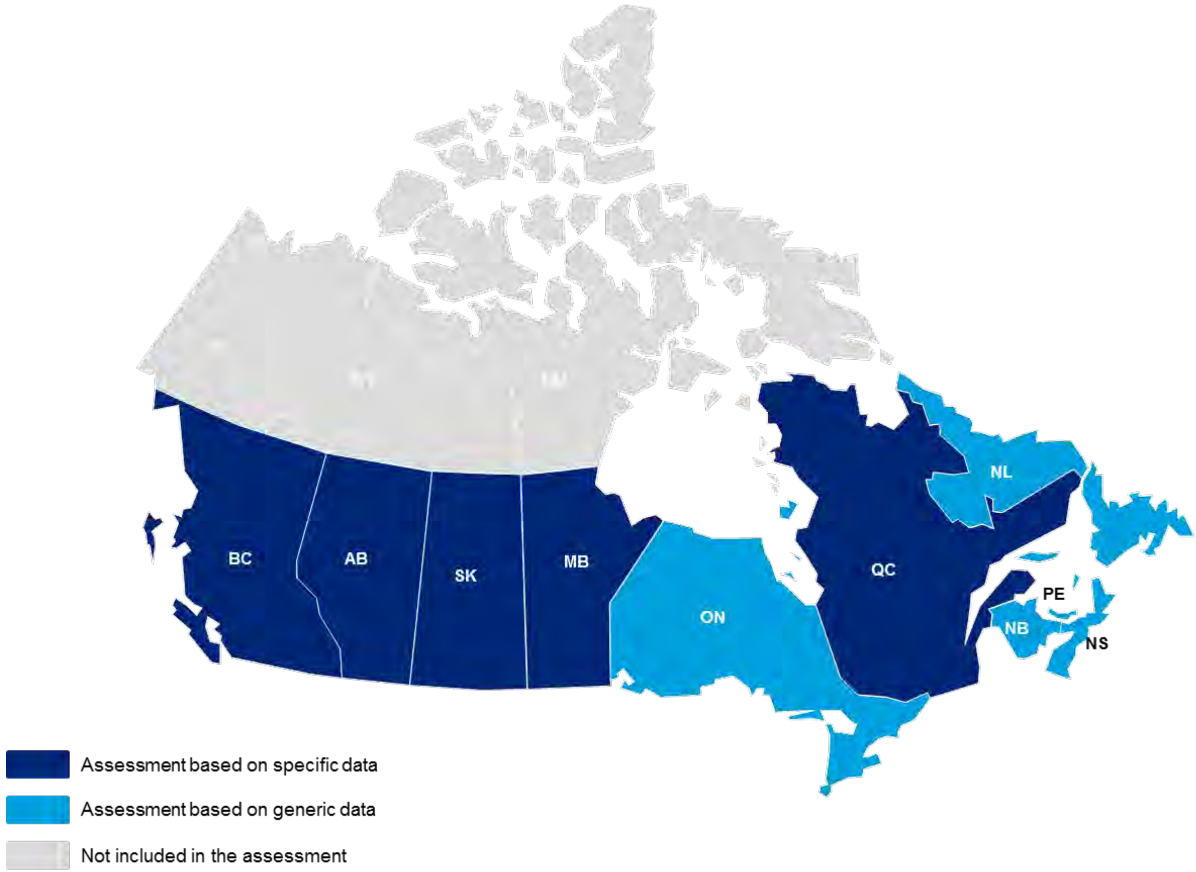

Figure 4-12 Scope of beef producer associations' assessments

In addition to nine provincial associations, two national associations representing the two main actors of the industry were included in the assessment:

- The Canadian Cattlemen's Association, for cattle operations
- The Canadian Meat Council, for processors

4.4.4.2 Average risk score calculation methodology

The average score for each indicator was calculated in four steps:

- Rating level based on number of associations scoring at each level summarized in the characterization table
- Calculation of sum of points by indicator
- Calculation of average score
- Translation of average score into colour code, defining the level of risk from high (red) to low (green)

The diagram below illustrates the process using an example with fictitious numbers:

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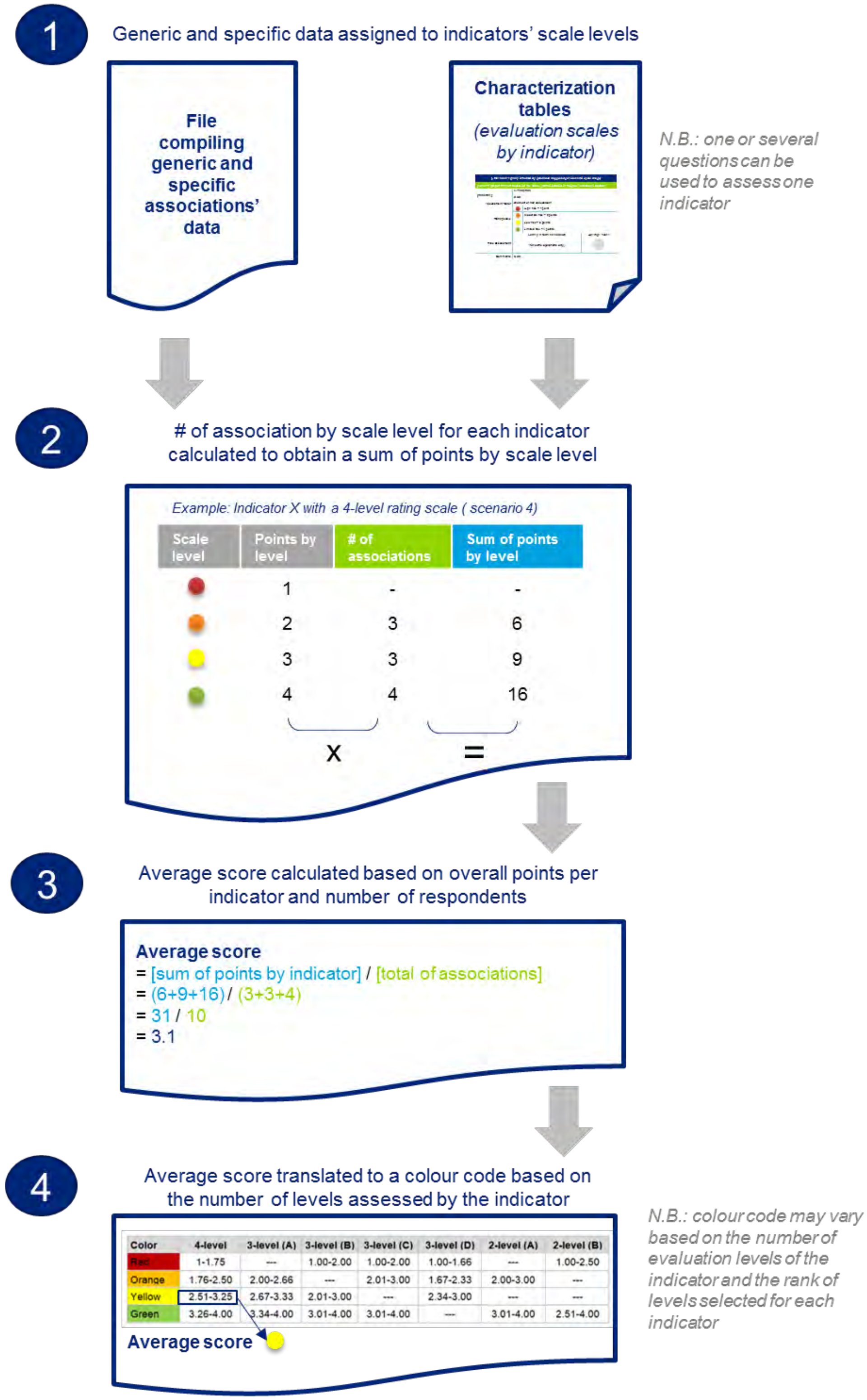

Figure 4-13 Average risk score calculation methodology steps (associations)

4.4.4.3 Limitations

For associations where generic data were collected due to the lack of specific data, it should be noted that some existing initiatives may not be publicly communicated on association website, which can partially skew the results negatively. Indeed, when no information was found, it was marked as non-existent.

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4.4.4.4 Interpretation of the evaluation scale

The following scale was used to assess potential risks at the association level:
A "red" risk level is not included in this scale, as no specific laws or regulations were applicable to the selected indicators.

Colour	Risk scale level	Definition
(red)	**---**	---
(orange)	**Moderate**	Moderate risk of negative impacts (low level of engagement)
(yellow)	**Low**	Low risk of negative impacts (moderate level of engagement)
(green)	**Very low**	Very low risk of negative impacts (high level of engagement)

4.4.4.5 Characterization table of indicators and risk scores

LOCAL COMMUNITIES		
Community engagement		
Local community support	**Description** Assessment of associations' engagement towards local communities (e.g. donations and sponsorships dedicated to specific causes/events).	
Assessment factor	Evidence of support to local communities.	
Rating scale	(red)	----
	(orange)	No local community support
	(yellow)	Existence of local community support but no formal program in place
	(green)	Existence of local community support with formal program in place and/or dedicated budget
Risk assessment	**Average score** (yellow)	
Comments	Although this indicator is marked yellow, the situation is actually binary: associations either have no local community support program or they have a formal program and/or a dedicated budget for it.	
SOCIETY		
Public commitment to sustainable issues		
Promotion of sustainability	**Description** Assessment of associations' practices for promoting sustainability to their members (e.g. sustainability policy, sustainability objectives, sustainability code of practice).	
Assessment factor	Promotion of sustainable development to association members.	
Rating scale	(red)	---
	(orange)	No sustainability promotion practices

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	● (yellow)	Promotion of sustainability and dedicated initiatives without a formal sustainable policy/objectives
	● (green)	Existence of a sustainability program or policy and/or sustainability objectives
Risk assessment	**Average score** ● (yellow)	
Comments	Although not all provincial associations have a formal sustainability policy, the CCA and most provincial associations are members of the CRSB (except Québec and the Maritimes), a multi-stakeholder initiative developed to advance existing and new sustainability efforts within the industry.	
Waste and manure management	**Description**	
	Assessment of associations' initiatives to promote best environmental management practices for **waste and manure management.**	
Assessment factor	Promotion of best environmental management practices for **waste and manure management.**	
Rating scale	● (red)	---
	● (orange)	No promotion of best practices
	● (yellow)	Promotion of best practices
	● (green)	Promotion of best practices and active capacity-building and/or training and/or funding programs to support their implementation
Risk assessment	**Average score** ● (yellow)	
Comments	The majority of associations promote waste and management best practices through communication, but there are generally no proactive initiatives to support the implementation of these practices. However, this is the environmental management topic that is the most widely (80%) covered by the industry's associations. Furthermore, a number of proactive initiatives are being conducted at the provincial level that are working with associations to promote the implementation of practices through policy and regulations, e.g. the Intensive Livestock Working Group (ILWG), Alberta Soil Phosphorus Limits Project and the Agricultural Operation Practices Act (AOPA) review in Alberta.	
Biodiversity and wildlife	**Description**	
	Assessment of associations' initiatives to promote best environmental management practices in the field of **biodiversity and wildlife.**	
Assessment factor	Promotion of best environmental management practices for the protection of **biodiversity and wildlife.**	
Rating scale	● (red)	---
	● (orange)	No promotion of best practices
	● (yellow)	Promotion of best practices

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		Promotion of best practices and active capacity-building and/or training and/or funding programs to support their implementation
Risk assessment	**Average score**	
Comments	The majority of associations promote biodiversity and wildlife best practices through communication, but there are generally few proactive initiatives undertaken by the association to further support implementation of these practices. Provincial associations do support (financially and otherwise) a number of pertinent initiatives; examples include the Alberta Riparian Habitat Management Society (known as “Cows and Fish”) or the British Columbia, Farmland—Riparian Interface Stewardship Program (FRISP). Biodiversity and wildlife are not covered by 40% of associations that were assessed in this study.	
Water resources and riparian areas	**Description**	
	Assessment of associations’ initiatives to promote best environmental management practices in the field of **water resources and riparian areas.**	
Assessment factor	Promotion of best environmental management practices for **water resources and riparian areas management.**	
Rating scale		---
		No promotion of best practices
		Promotion of best practices
		Promotion of best practices and active capacity-building and/or training and/or funding programs to support their implementation
Risk assessment	**Average score**	
Comments	The majority (70%) of associations promote water resources and riparian areas management best practices through communication, but there are generally few proactive initiatives to further encourage the implementation of these practices. Some examples would include: funding of the Farmland—Riparian Interface Stewardship Program (FRISP) by the BC Cattlemen's Association and funding of Cows and Fish by the Alberta Beef Producers. Both are major programs supporting the best management of water resources and riparian areas.	
Grazing management	**Description**	
	Assessment of associations’ initiatives to promote best environmental management practices in the field of **grazing management.**	
Assessment factor	Promotion of best environmental management practices for **grazing management.**	
Rating scale		---
		No promotion of best practices
		Promotion of best practices
		Promotion of best practices and active capacity-building and/or training and/or funding programs to support their implementation
Risk assessment	**Average score**	

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Comments	The majority of associations promote grazing management best practices through communication, but there are generally no proactive initiatives to further encourage the implementation of these practices. This topic is not covered by 40% of associations that were assessed in this study. Educating farmers about best management practices is, however, not a main focus/mandate of these associations.
Animal welfare	
Animal welfare promotion	**Description** Assessment of associations' measures for promoting animal welfare best practices to their members (e.g. animal welfare code of practices awareness).
Assessment factor	Promotion of animal welfare best practices.
Rating scale	---
	No promotion of animal welfare best practices
	Animal welfare best practices are promoted
	Animal welfare best practices are proactively promoted with training and/or informative sessions offered to increase awareness
Risk assessment	**Average score**
Comments	Only one association was identified as not promoting animal welfare practices, and the majority of associations which do promote it also provide training and/or information sessions to raise their members' awareness.
Technology development	
R&D activities	**Description** Assessment of associations' R&D activities (e.g. R&D finance support, involvement in R&D activities).
Performance indicator	Involvement in and level of support for R&D activities.
Rating scale	---
	No R&D support
	Involvement in R&D activities but no dedicated budget
	Involvement in R&D activities with a dedicated budget
Risk assessment	**Average score**

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Comments	The majority (55%) of associations assessed are involved in R&D and have a dedicated budget for these activities. Two associations were identified as being not involved in any R&D activities.
Economic contribution	
Industry economic resilience	**Description** Assessment of associations' practices to support farmers in improving their economic performance (e.g. market price update and trends) and product marketability.
Assessment factor	Evidence of tools/information available to farmers to improve their economic resilience.
Rating scale	---
	No communication of tools/information
	Communication of information on market trends
	Development of tools and training for farmers to improve their products' marketability
Risk assessment	**Average score**
Comments	Associations' practices to support the industry's economic resilience are diverse, but they generally provide information and in some cases tools and training for farmers to improve their products' marketability.
VALUE CHAIN ACTORS	
Value chain actors relationship	
Partnerships with value chain actors	**Description** Assessment of associations' practices related to their relationships (e.g. partnerships, involvement in industry boards/committees) with industry's value chain actors (e.g. upstream suppliers, downstream suppliers, NGOs, industrial associations).
Assessment factor	Existence of value chain partnerships.
Rating scale	---
	No partnership with industry's value chain
	Existence of partnerships with industry's value chain without a formal strategy plan/objectives
	Existence of partnerships with industry's value chain with a formal strategy plan/objectives
Risk assessment	**Average score**
Comments	The majority of associations have implemented partnerships with value chain actors in the industry, some with a formal strategy plan/objectives. Examples of these initiatives include: the National Beef Strategy, the Canadian Roundtable for Sustainable Beef and the Beef Value Chain Roundtable.

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Transparency		
Promotion of transparent practices	**Description**	
	Assessment of associations' efforts (e.g. provincial or national studies) to support transparent communication of members' production processes.	
Assessment factor	Support of transparent communication on members' production processes.	
Rating scale		---
		No communication on production processes
		Transparent communication of members' production processes
		Transparent communication of members' production processes based on active stakeholders' consultation
Risk assessment	**Average score**	
Comments	The majority (64%) of associations do not communicate about their members' production processes. However, two have a transparent and proactive approach involving stakeholder consultation. Farm and Food Care, and Agriculture in the Classroom are examples of not-for-profit organizations acting in this space, offering complementary initiatives to the provincial and national beef industry's associations. Canada Beef and Saskatchewan Cattlemen are also funding partners of Farm and Food Care, and CCA provides editorial support.	
Health and safety		
Promotion of product quality and safety	**Description**	
	Assessment of associations' efforts to ensure food safety and quality beef production at the farm level.	
Assessment factor	Promotion of product quality and food safety.	
Rating scale		---
		No promotion of product quality and food safety best practices
		Promotion of product quality and food safety through dissemination of best practices
		Proactive promotion of product quality and food safety through training and information sessions
Risk assessment	**Average score**	
Comments	Results show that 73% of associations are promoting product quality and safety through either the dissemination of best practices or through a more proactive approach involving training and information sessions. Associations' funding for Verified Beef Production (VBP) also represents an initiative promoting product quality and food safety.	
WORKERS		

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Equal opportunities/Discrimination		
Promotion of diversity and inclusion	**Description**	
	Assessment of associations' engagement to promote diversity and inclusion of the beef producer workforce—including employment of members of Aboriginal communities, gender diversity and non-discrimination against minorities.	
Assessment factor	Existence of initiatives to promote diversity and inclusion.	
Rating scale		---
		No initiatives to promote diversity and inclusion
		Existence of initiatives to promote diversity and inclusion
		Diversity and inclusion as part of a formal policy, plan or strategy
Risk assessment	**Average score**	
Comments	Only two associations have initiatives to promote diversity and inclusion.	
Health and safety		
Occupational health and safety	**Description**	
	Assessment of associations' initiatives to promote the health and safety of beef producers and farm workers.	
Assessment factor	Existence of health and safety initiatives, training and awareness-building activities.	
Rating scale		---
		No promotion of health and safety
		Promotion of health and safety through dissemination of best practices
		Proactive promotion of health and safety through training and information sessions
Risk assessment	**Average score**	
Comments	The majority (64%) of associations do not promote occupational health and safety to their members. The others disseminate best practices, but no occurrence of training, workshops or information sessions has been identified/declared.	

4.4.5 National legal and regulatory environment

4.4.5.1 Scope of assessment and source of data

To strengthen our assessment and refine our analysis, subcategories of impacts were also analyzed at the national level based on generic data collection.

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This section of the assessment is largely based on the World Economic Forum (WEF) Executive Opinion Survey that publishes results annually in the Global Competitiveness Report. To respect the time scope of our assessment, the 2013-2014 version of the report was used.

Additional sources were used to complete the assessment for social topics particularly relevant to the agricultural sector or to Canada but not covered by the WEF report (i.e. respect of indigenous rights and rights of migrant workers).

4.4.5.2 Risk score methodology

Contrary to the other sections of the social life cycle assessment, the risks related to the national laws and regulations in Canada were based on single data points, thus not requiring the calculation of average scores.
For indicators based on the WEF report providing scores by country, the score of Canada was used as the point of reference to define the risk colour code.

For the two other indicators not relying on the WEF report, the same logic was applied referring to the practices of Canada among other countries.

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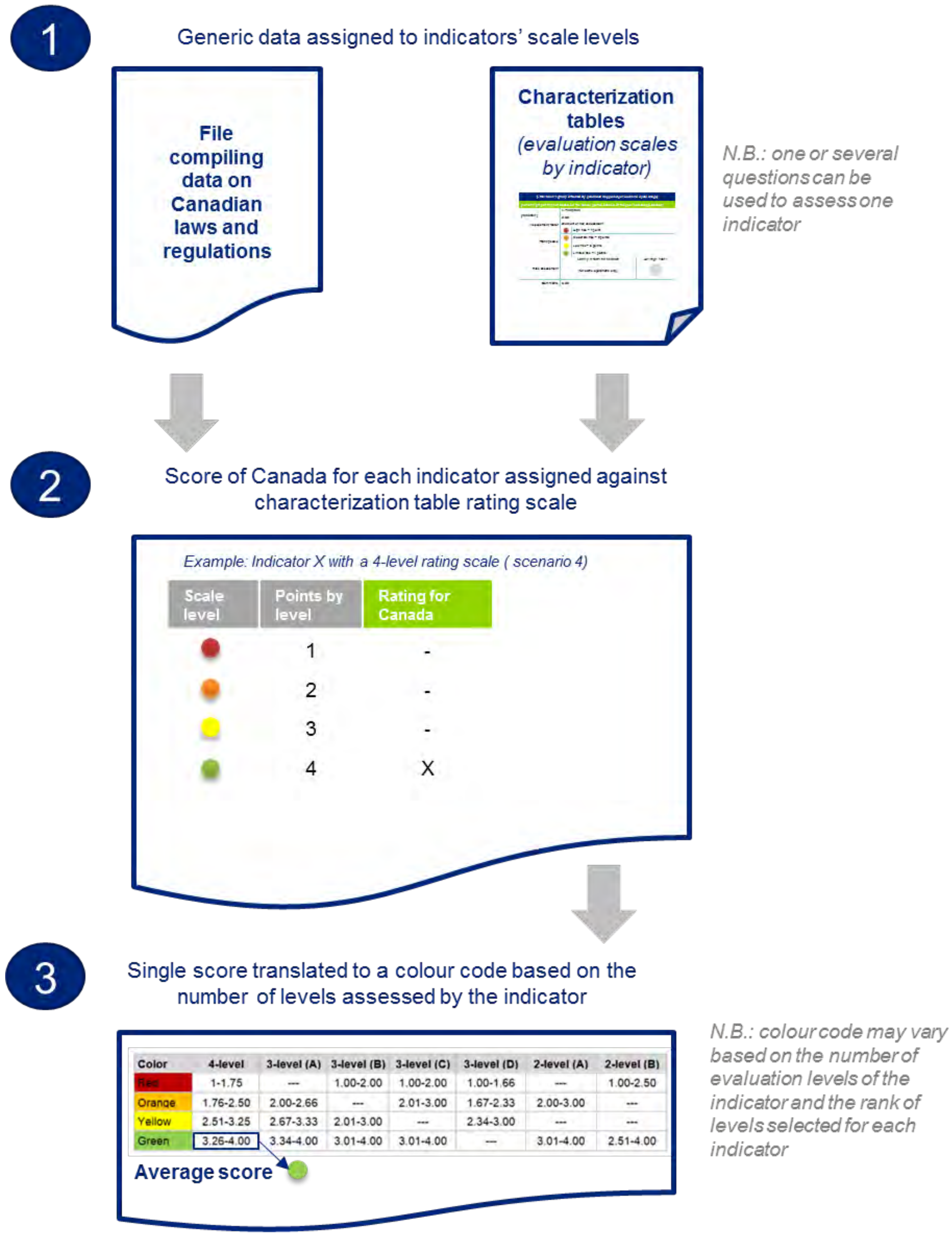

Figure 4-14 Average risk score calculation methodology steps (national assessment)

4.4.5.3 Limitations

The main limitation of this stage of the social life cycle assessment is that the scope is national, therefore not taking into account the industry's specific characteristics and potential other practices, positive or negative.

However, it provides a good overview of the legal and regulatory environment in which the different stakeholders operate.

4.4.5.4 Interpretation of the evaluation scale

The following scale was used to assess potential risks at the national level:

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Colour	Risk scale level	Definition
	High	High risk of negative social impact
	Moderate	Moderate risk of negative social impact
	Low	Low risk of negative social impact
	Very low	Very low risk of negative social impact / potential positive impact

4.4.5.5 Characterization table of indicators and risk scores

WORKERS		
Freedom of association and collective bargaining		
Labour-employer relations	**Description**	
	The right of workers and employers to form and join organizations of their own choosing is an integral part of a free and open society.	
Assessment factor	A proxy was used for this indicator, using the labour-employer relation score in 2013-2014 by the World Economic Forum (Schwab, 2014).	
Rating scale		Index score is ≤ 1.75
		Index score is > 1.75 and ≤ 3.5
		Index score is > 3.5 and ≤ 5.25
		Index score is > 5.25
Risk assessment	**Score**	
Comments	Canada's score: 4.9. Labour-employer relations ranked from 1 (generally confrontational) to 7 (generally cooperative).	
Labour relations legislation	**Description**	
	The Canadian Charter of Rights and Freedoms includes the right of freedom of association, although some exemptions for agriculture workers may apply at the provincial level. Two levels of exemptions were identified: "complete" refers to exemptions that apply unconditionally to all agricultural workers in all situations; while "partial" refers to either condition-specific situations or partial application of the freedom of association and collective bargaining.	
Assessment factor	Application of labour relations legislation to agricultural workers or existence of restrictions.	
Rating scale		Provincial labour relations legislation includes complete exemptions for agricultural workers
		Provincial labour relations legislation includes partial exemptions for agricultural workers
		---
		No exemptions apply to agricultural workers in provincial labour relations legislation

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Risk assessment	**Score**
Comment	In Alberta, the labour relation code excludes employers and employees in farm or ranch labour. In Ontario, the Labour Relations Act excludes employee within the meaning of the Agricultural Employees Protection Act, which does not allow agricultural employees to bargain collectively, but does allow them to join an association. In Québec and New Brunswick, the exemption depends on the minimum number of employees of an operation—three according to the Code du Travail (QC) and five according to the Industrial Relations Act (NB) (Barneston, 2009). The average risk score was weighted based on provincial population.
Equal opportunities/Discrimination	
Fair and equal opportunities	**Description** Men and women have the right to be treated fairly and to have access to equal opportunities (ILO).
Assessment factor	The ratio of the number of women in the labour force compared to the number of men[70] in 2013-2014 (WEF).
Rating scale	Ratio is ≤ 0.25
	Ratio is > 0.25 and ≤ 0.50
	Ratio is > 0.5 and ≤ 0.75
	Ratio is > 0.75
Risk assessment	**Score**
Comments	Canada's score: 0.91. This measure is the percentage of women aged 15-64 participating in the labour force divided by the percentage of men aged 15-64 participating in the labour force.
Rights of migrant workers	**Description** Assessment of the extent to which migrant workers' rights are respected by a state in terms of non-discrimination, human rights, employment and living/working conditions.
Assessment factor	Country status (convention signed and ratified) regarding the International Convention on the Protection of the Rights of All Migrant Workers and Members of their Families. (UN—OHCHR) (United Nations Human Rights, 2015)
Rating scale	No action—i.e. Convention not signed, nor ratified
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	Signatory—i.e. Convention signed
	State party—i.e. Convention signed and ratified
Risk assessment	**Score**

[70] This measure is the percentage of women aged 15-64 participating in the labour force divided by the percentage of men aged 15–64 participating in the labour force.

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Comments	The International Convention on the Protection of the Rights of all Migrant Workers and Members of their Families (MWC), adopted by the United Nations (UN) in 1990, came into force 13 years later, on July 1, 2003, after having been ratified by 20 signatory countries. The convention comprises two headings: one reiterating human rights, and one adding specific rights, including: right to be temporarily absent, freedom of movement, equality with nationals, provisions regarding employment contract violation and rights of undocumented workers. Please see sub-section 4.5.1.2 in SLCA life cycle impact assessment and interpretation for more details.	
SOCIETY		
Fair competition		
Anti-monopoly policy	**Description** The effectiveness of anti-monopoly policy indicator measures the extent to which national policies effectively promote competition.	
Assessment factor	Effectiveness of anti-monopoly policy in 2013-2014 (WEF).	
Rating scale		Index score is ≤ 1.75
		Index score is > 1.75 and ≤ 3.5
		Index score is > 3.5 and ≤ 5.25
		Index score is > 5.25
Risk assessment	**Score**	
Comments	Canada's score: 4.5. Extent of promotion of anti-monopoly policy ranked from 1 (does not promote competition) to 7 (effectively promotes competition).	
Respect of intellectual property		
Intellectual property protection	**Description** Assessment of the protection system for intellectual property (a form of creative endeavour that can be protected through a trademark, patent, copyright, industrial design or integrated circuit topography (Government of Canada, 2015) (Industry Canada).	
Assessment factor	Intellectual property protection in 2013-2014 (WEF).	
Rating scale		Index score is ≤ 1.75
		Index score is > 1.75 and ≤ 3.5
		Index score is > 3.5 and ≤ 5.25

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		Index score is > 5.25
Risk assessment	**Score**	
Comments	Canada's score: 5.6. Intellectual property protection ranked from 1 (extremely weak) to 7 (extremely strong).	
Corruption		
Ethical behaviour of firms	**Description**	
	Assessment of the ethical behaviour of firms. There are many unethical acts that can constitute corruption.	
Assessment factor	Ethical behaviour of firms in 2013-2014 (WEF).	
Rating scale		Index score is ≤ 1.75
		Index score is > 1.75 and ≤ 3.5
		Index score is > 3.5 and ≤ 5.25
		Index score is > 5.25
Risk assessment	**Score**	
Comments	Canada's score: 5.7. Ethical behaviour of firms ranked from 1 (extremely poor—among the worst in the world) to 7 (excellent—among the best in the world).	
Indigenous rights		
Respect of indigenous rights	**Description**	
	Assessment of instances of non-respect of indigenous rights based on official reports of 1) the US Department of State Country report on Human Rights (US Department of State, 2014) and 2) the State of the World's Human Rights country report of Amnesty International (Amnesty International, 2013).	
Assessment factor	Existence of cases of non-respect of indigenous rights (2013).	
Rating scale		There is at least one mention of non-respect of indigenous rights in one of the listed reports
		There are mentions of indigenous rights concerns without violation of indigenous rights
		---
		There is no mention of concerns related to indigenous peoples
Risk assessment	**Score**	

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Comments	There are some concerns in the State of the World's Human Rights country report of Amnesty International regarding respect of indigenous rights in Canada: "*the federal government acknowledged before the CERD*[71] *Committee that the UN Declaration on the Rights of Indigenous Peoples could be used when interpreting Canadian laws, but took no steps to work with Indigenous Peoples to implement the Declaration*". While this indicator covers indigenous human rights, land rights are another aspect that can be considered, although it was excluded from our assessment. Indeed, land colonized several hundred years ago remains occupied and this issue is a national one not specific to the beef industry and relevant to all land users across Canada (e.g. mining, logging, energy). We can however note that Canada is regulated with land use laws, zoning and First Nations Land Management Acts at the federal and provincial levels.

4.4.6 Consumption

4.4.6.1 Scope of assessment and source of data

No specific assessment was conducted for this life cycle stage. However, a few indicators assessed at different life cycle stages cover some aspects affecting beef consumers (e.g. transparency, food safety).

In 2009, a consumer satisfaction survey was conducted in Canada to identify how the eating quality of Canadian beef had changed since 2001. The study led to the following conclusions:

"Regardless of which steak they were given, consumer satisfaction was higher in 2009 than in 2001. This was true for tenderness (76% in 2009 vs 68% in 2001), juiciness (78% vs 72%) and flavour (82% vs 76%). No decreases in consumer satisfaction were reported for any of the steaks in any category. Overall, 86% to 87% of the consumers surveyed were satisfied with the top sirloin and strip loin steaks. Fewer consumers were satisfied with steaks from the boneless cross rib (75%) or inside round (69%). However, tenderness, juiciness and flavour ratings were considerably lower for the boneless cross rib and inside round than for the strip loin and top sirloin.

"The most common consumer complaints were related to toughness (39%), dryness (14%) and lack of flavour (10%). This (and the lower consumer satisfaction for the boneless cross rib and inside round) might be related to preparation methods. The boneless cross rib and inside round steaks were often not marinated before being cooked improperly (e.g. grilled, when they should have been simmered). In fact, these steaks were marinated much less than half the time, and were cooked properly less than 5% of the time, even if cooking instructions were provided. When consumers were asked "why wasn't your steak perfect", less than 20% of the consumers surveyed felt it was due to their preparation methods; over 80% blamed the beef. Efforts to increase the visibility, readability or consistency of cooking instructions on retail beef packages may help solve some of these problems. However, industry may need to introduce effective tenderness enhancing interventions that will allow tough cuts of beef to be tenderized before they are offered for sale to the retail consumer." (Canadian Cattlemen's Association, 2009)

Although no indicator was developed, the assessment is positive because satisfaction has increased overall and no decrease of satisfaction has been identified in any category.

[71] CRED : International Convention on the Elimination of All Forms of Racial Discrimination

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4.5 SLCA life cycle impact assessment and interpretation

The SLCA of Canadian beef consists of six sections, including four life cycle stages (beef production, meat packing, suppliers and distributors) and two ancillary levels (associations, and national legal and regulatory environment). The summary of results of the SLCA as a whole is presented in order to provide an integrated view of the potential occurrence of both negative and positive social impacts based on the risk assessment conducted throughout the Canadian beef life cycle. More detailed results at each assessment level are then presented to better understand the impacts specific to each life cycle stage throughout the Canadian beef value chain.

These results were drawn from the social assessment map presented below and based on the average scores of the characterization tables presented earlier in the report in the methodology section. Each box represents an indicator and its colour, and the level of risk associated with it (from high risk in red to very low risk in green).

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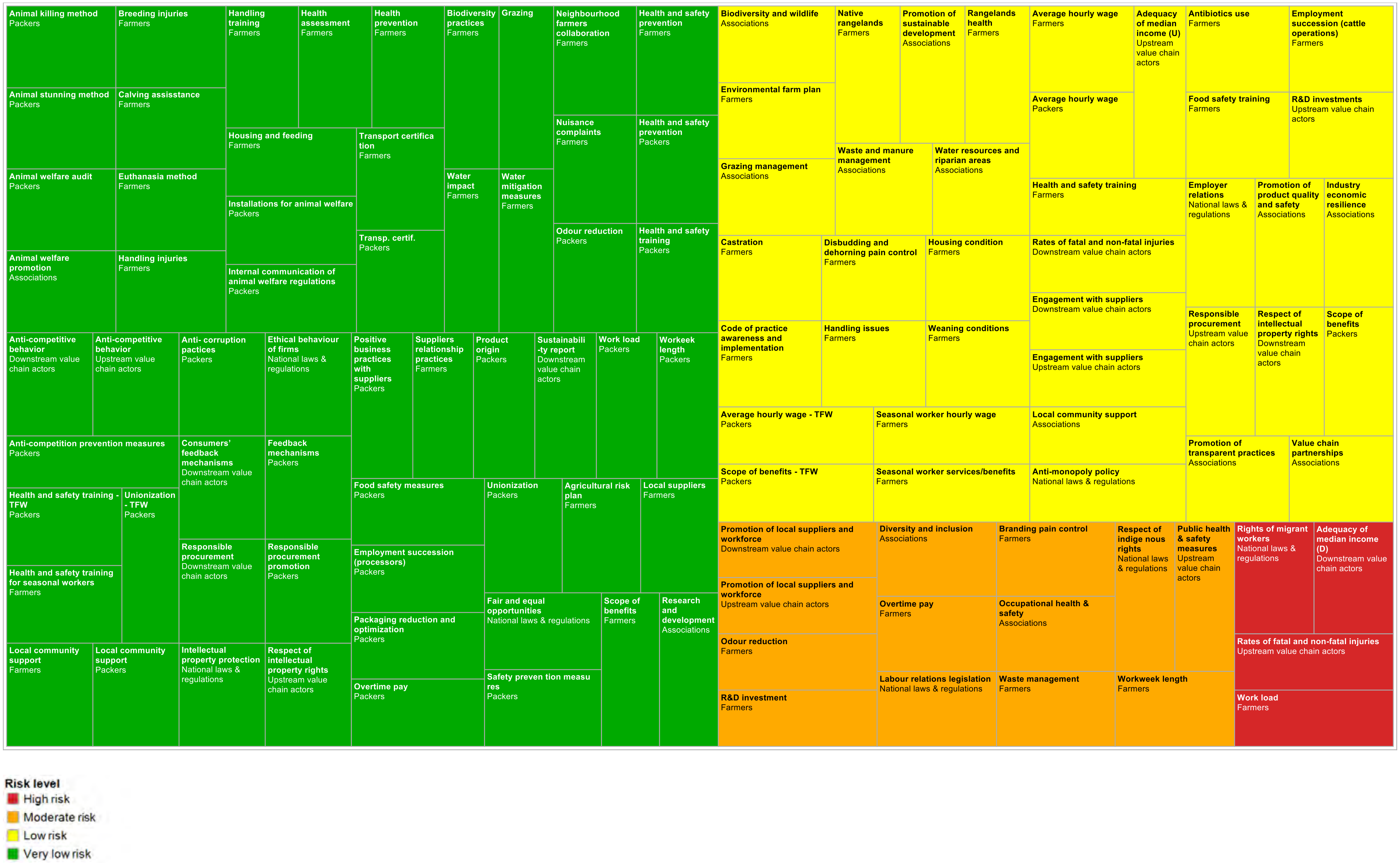

Figure 4-15 Social risk assessment map – overview

4.5.1 Assessment by category of impact

In the following sections, specific social topics are grouped together to provide a more holistic view of key sustainability aspects of beef production throughout the value chain. Overall, indicators show that the assessment of social practices is positive throughout the life cycle of the Canadian beef industry as represented by the green and yellow boxes of the social assessment map. However, several red (high risk) and orange (moderate risk) indicators can be considered potential hotspots for the industry. These will be identified in the following sections.

4.5.1.1 Animal welfare

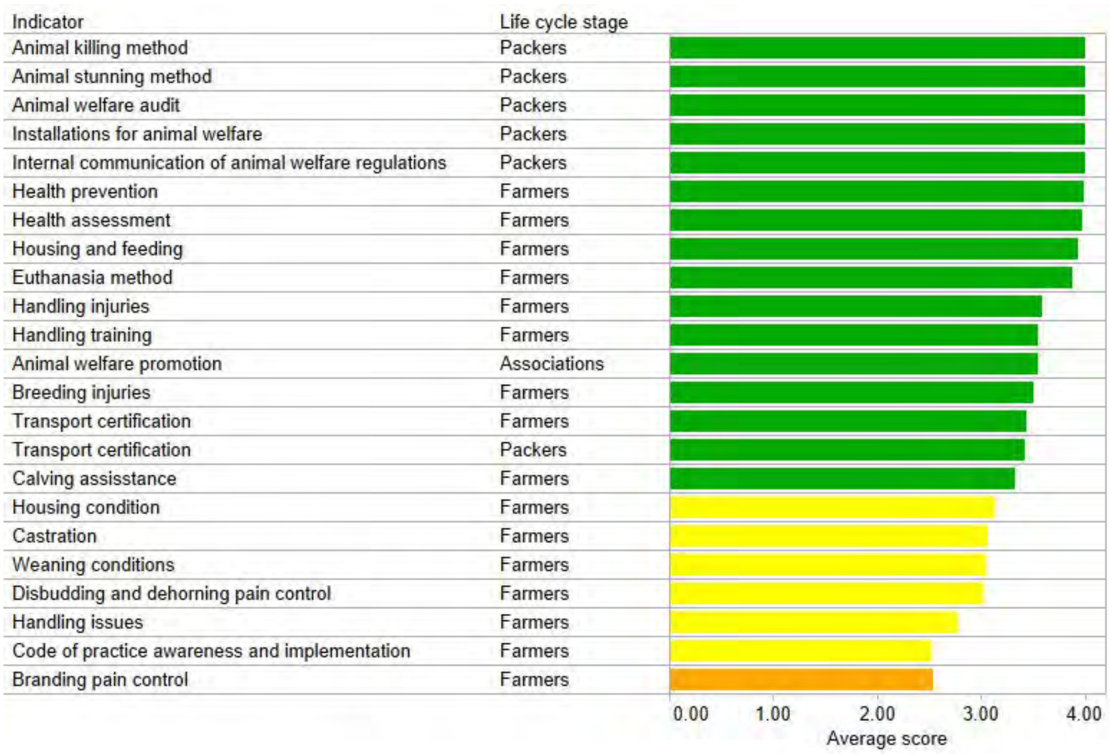

Figure 4-16 Animal welfare indicators

Animal welfare, which is a major topic for the food industry, has taken an important place in our assessment to provide a somewhat detailed view of the risks that might occur in the beef sector. The results show very good results for value chain actors overall, with only one indicator that could present a higher potential risk (branding) but not showing critical behaviour. Pain control techniques for cattle identification (branding) are lacking according to the Code of Practice, which explains why this is considered a high potential risk.

Industry associations' proactive promotion of animal care and handling practices could contribute to the positive practices observed in the cattle operation and meat packing plant surveys.

Having high animal care standards and practices has a multitude of positive outcomes. For instance, animals less subject to stressful conditions at the packing plant can produce meat with greater tenderness (Gruber, et al., 2010). Continually improving animal care can be a win-win strategy for the beef industry, in terms of both animal welfare and economic viability.

4.5.1.2 Workers

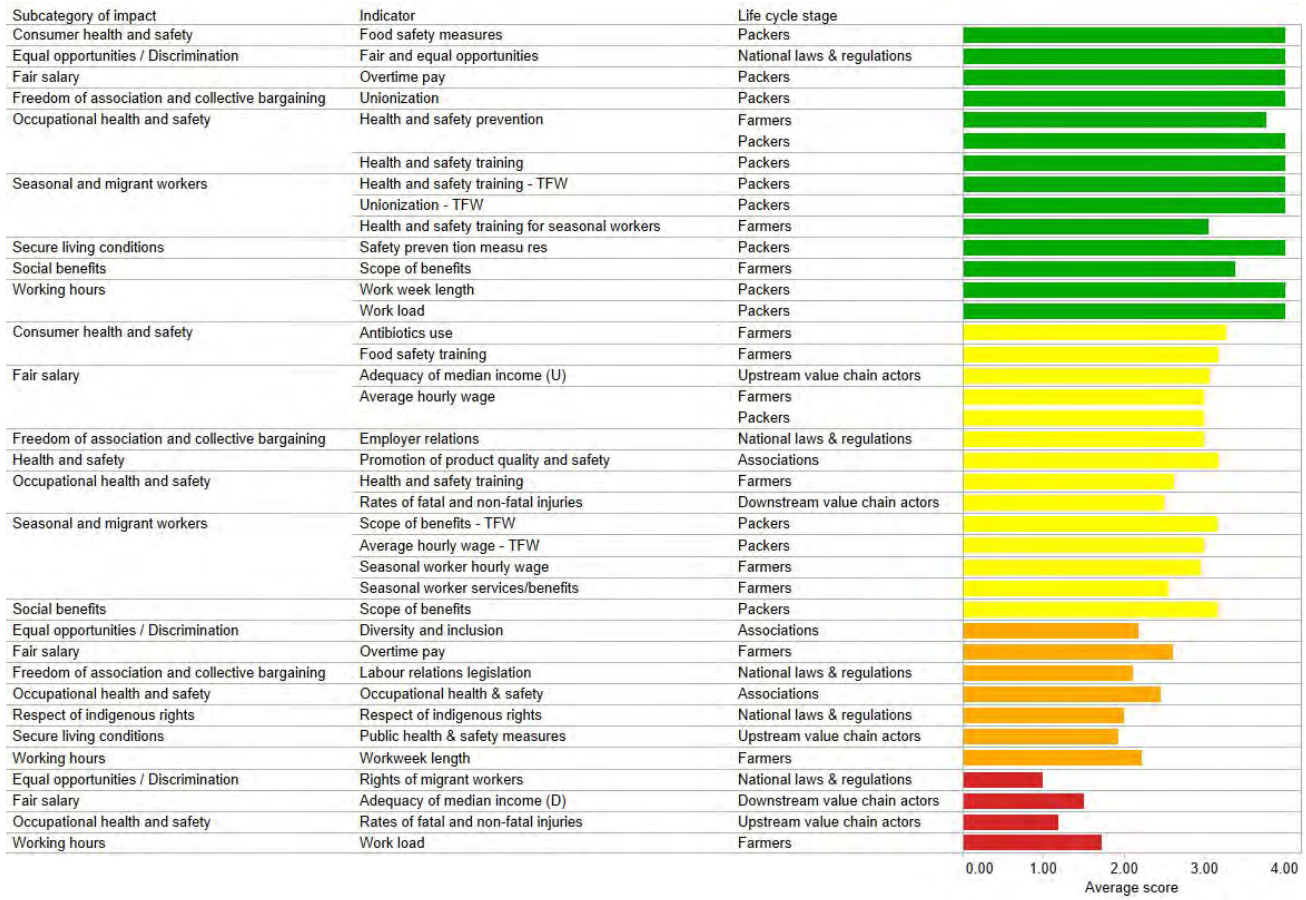

Figure 4-17 Worker-related indicators

For any industry, workers are a key component to assess in regard to social impacts. Here again, the practices collected from surveys and online research show overall low risks, but several indicators indicate potential areas for improvement.

Main subcategories for improvement showing moderate risk (orange) and high risk (red) include:

- Fair salary (overtime pay for farmers and median income for downstream value chain actors)
- Working hours in terms of work week length and workload for farmers
- Health and safety (promotion at the association level and injuries at the upstream value chain actors' level)
- Freedom of association through the unionization rate of farmers. However, this can be mitigated by the profile of cattle operations workers that largely includes small farms with self-employed or family-employed status
- Labour relations legislation at the provincial level show that some exemptions apply in certain provinces to agricultural workers in terms of freedom of association and collective bargaining
- Equal opportunities/discrimination (rights of migrant workers at the national level and promotion of diversity and inclusion at the association level)

Regarding rights of migrant workers, this indicator was assessed at the national level because of the difficulty of obtaining data at the local level (due to confidentiality and privacy reasons) and because the situation is highly dependent on regulations that are out of the industry's control. Nonetheless, respect of migrant workers' rights is an important topic for the industry that presents both risks (in particular due to the current regulatory context) and opportunities (due to their contribution to the industry in the face of workforce shortages). Although we have seen that packing plants are working towards migrant workers' integration, they remain, as the national indicator suggests, a group of at-risk workers. Furthermore, the survey was conducted with large packing plants which may not reflect smaller facilities.

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On the other hand, the majority of indicators show low (yellow) or very low (green) risks:

- Farm health and safety, packers and downstream value chain actors (retail, fast-food chains) are scoring positively
- Average hourly wage and benefits of packers and farm employees are low risk
- All seasonal worker-related indicators show a low or very low risk of negative social impacts, including health and safety training, hourly wage and benefits
- At the national level, Canada is showing low risks in terms of employment insecurity and labour-employer relations, as well as very low risks related to discrimination

In the following sections, indicators from the different value chain levels are gathered under common topics to provide another perspective of analysis.

4.5.1.3 Socio-economic repercussions

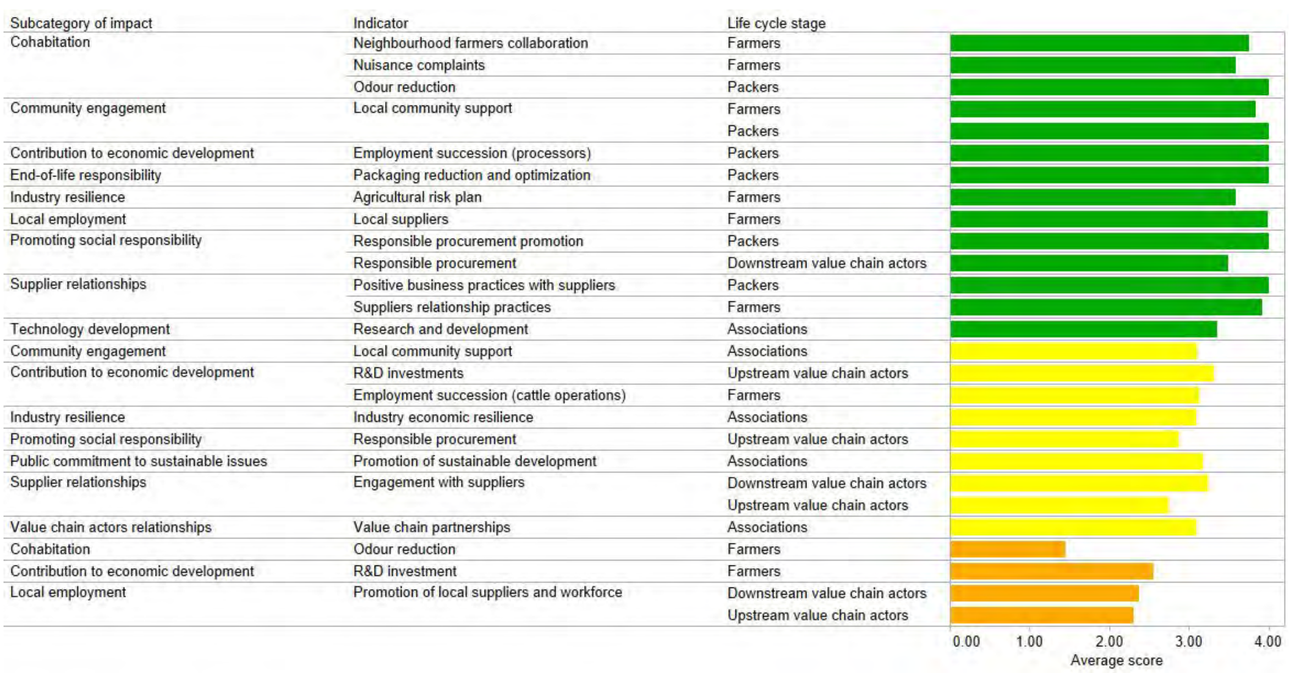

Figure 4-18 Socio-economic repercussions indicators

The overall assessment of socio-economic indicators is positive throughout the Canadian beef production life cycle. Socio-economic repercussions can range from impacts on neighbours to those on society in general:

- Farmers and packers have the overall highest scores, in terms of relationships with neighbours/local communities and suppliers
- Assessment of downstream and upstream value chain actors is also good for responsible procurement and engagement with suppliers
- Industry resilience at the farm/ranch level and the engagement of the industry's associations also show low to very low risks

Main areas for potential improvement include:

- Impacts on local communities: the number of odour complaints seems to be relatively limited for beef operations based on both survey results (nuisance complaints indicator is green) and information at the provincial level (for instance in Alberta, representing 40% of the Canadian beef production, 65 beef feedlot operations and 22 cow/calf operations were involved in complaints in 2012). Although low risks were identified due to implemented best management practices, other potential risk areas could include the impacts on health of local communities. As the Pew Commission on Industrial Farm Animal Production (2009) notes: "workers in and neighbours of IFAP

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facilities experience high levels of respiratory problems, including asthma". Air quality, particularly, should therefore be monitored with care.

- Promotion of local suppliers and workforce at both the downstream and upstream value chain actors' level shows moderate risk due to a lack of local hiring or procurement policies at the corporate level.
- R&D investments: although this indicator is marked as orange, potentially showing a moderate risk due to no investments in R&D at the farm level, the breakdown of results shows that 52% of respondents invest only 1% to 10% of their revenues in research and development.

This assessment is relevant from a planning perspective for the industry to better understand the risks and opportunities regarding workers in the beef industry. Workforce shortages are an issue at both the farm and processor levels.

4.5.1.4 Environmental practices

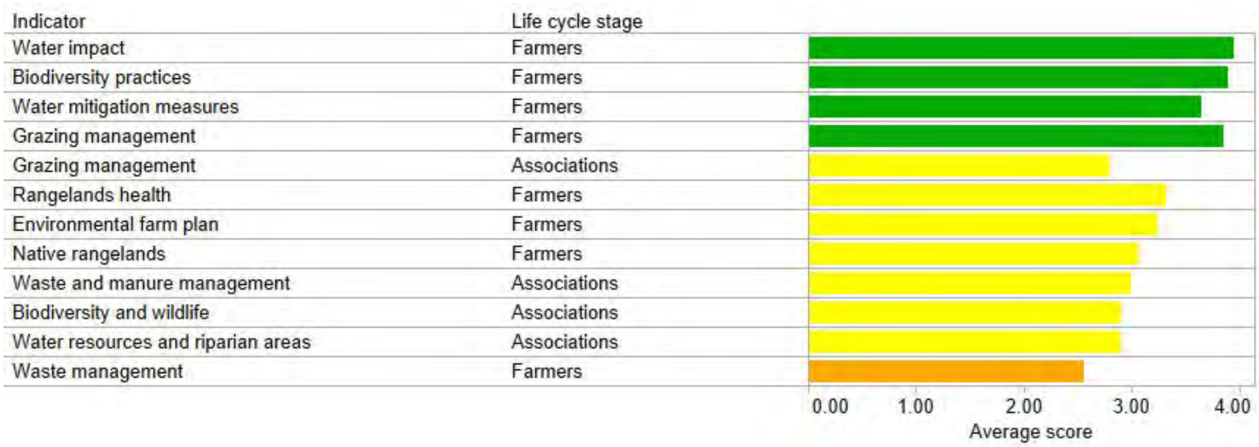

Figure 4-19 Environmental management practices indicators

These indicators all pertain to the subcategory of impact "public commitment to sustainable issues". Environmental practices at the farm level and their promotion at the association level are aspects of interest for social impacts of the beef industry. Although the subject is environmental, the consequences hold an important social meaning for society, for both present and future generations. It should also be noted that many beef industry associations partner on initiatives with other associations and groups—such as provincial forage councils, regional producer groups, and the national forage/grassland association—to promote sound environmental practices regarding biodiversity and wildlife, water resources and riparian areas or grazing management. Although not directly impacting beef production, this upstream value chain support is also important.

The results show an overall positive assessment at both the farm and association levels. This may be partially due by the uptake of Environmental Farm Plans.

Practices related to water quality at the farm show very low risks, with farm owners declaring that they implement several mitigation measures. Although practices related to water showed low risk in the assessment, the beef industry must remain committed to addressing this potential risk area. A study conducted in the Canadian Prairie Region shows that the adoption of agricultural beneficial management practices to protect riparian areas generally results in negative net economic benefits to the individual producer "primarily due to opportunity costs from foregone returns and BMP establishment costs" (Jeffrey, et al., 2014). The impacts of agriculture, including cattle operations, on riparian areas and therefore on water are well documented. Livestock grazing can cause stream bank erosion (Kaufmann & Kreuger, 1984). Overgrazing can cause physical damage to channels and banks (Fitch & Adams, 1998). Inversely, deposition of cattle manure away from streams can be attributed to water quality benefits (Larsen, et al., 1994). Water quality and associated on-farm practices are therefore of major importance for the industry and will constitute a key topic in the next phases of the project.

The rangelands-related indicator shows a low risk as, according to the surveyed farmers, the majority of rangelands have been assessed and were scored "healthy with problems" or "healthy".

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One indicator presents a moderate risk of negative impact: waste management. This result is due to surveyed farmers' practices and the limited options available in many provinces to recycle products (e.g. baling twine). These results are generally aligned with provincial data found on the subject for BC ((2cg Waste Management Consulting Services, 2012), AB (Blacksheep Strategy, 2012) and MB (CleanFARMS Inc., 2011).

4.5.1.5 Governance

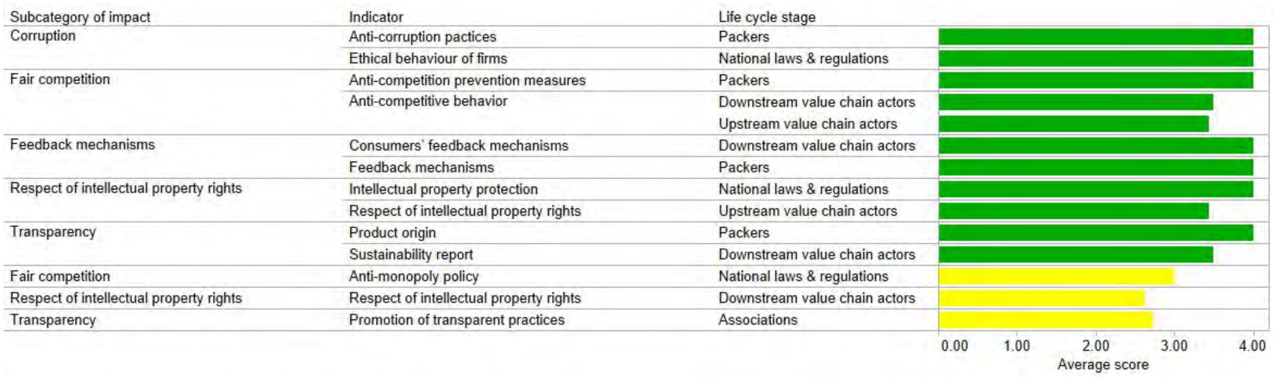

Figure 4-20 Governance indicators

Governance indicators cover several ethical business practices related to corruption, fair competition, intellectual property rights, and transparency and feedback mechanisms through multiple stakeholder perspectives, i.e. packers', value chain actors', associations' and national laws and regulations. All the indicators show very low to low risks throughout the Canadian beef production life cycle.

In the next section, the assessment results are reviewed by life cycle stage, with a presentation of the indicators, followed by the key messages drawn from them. For the survey-based indicators (cattle operations and meat packing plants), results are supported by secondary research findings.

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4.5.2 Cattle operations' level assessment

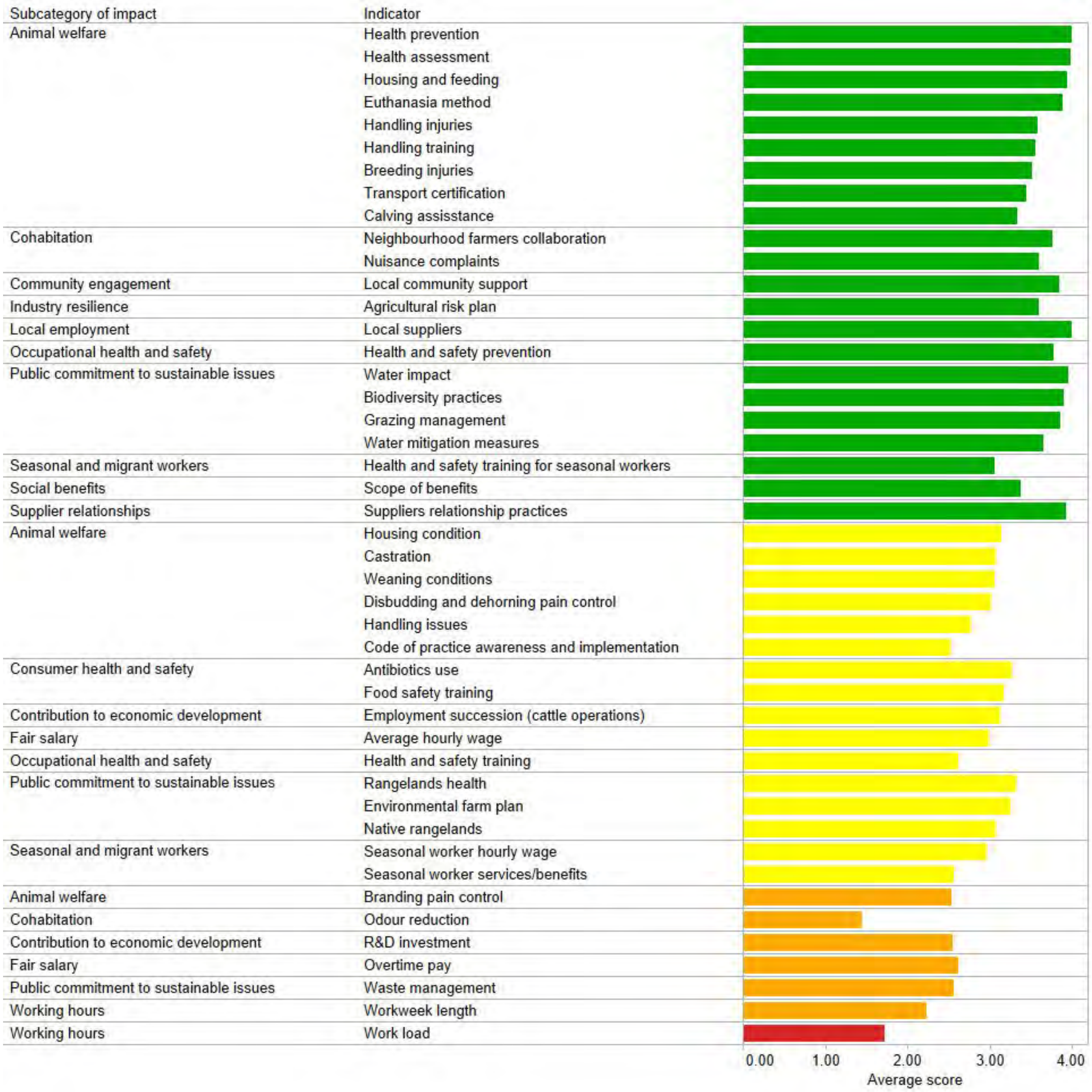

Figure 4-21 Cattle operations' indicators

- Social practices at the cattle operations' level show an overall positive assessment. It should be noted that the results are based on surveys completed by farm owners or operators only, and not by farm employees. As a context reminder and as the economic assessment shows, the beef industry is very diverse in terms of operational size and structure, including single producers with no employees.

- Regarding animal welfare, there is potential for improvement with regard to pain control during branding. Permanent identification may be required in some cases, however tools to offset this risk area are currently lacking (i.e. no viable pain treatment). Other areas around animal welfare show low to very low risks. This reflects the strong engagement of beef producer associations in that field.

- Occupational health and safety indicators, i.e. training and awareness-building, also show very low to low risks only. However, although based on dated data, agriculture was the fourth most dangerous industry in which to work over the 1996-2005 period after mining, quarrying and oil wells, logging and forestry, and fishing and trapping (Sharpe & Hardt, 2006). The Canadian Agricultural Injury report mentions 123 animal-related fatalities between 1990 and 2008 (CAIR, 2012). In 2006, 6% of all beef farms reported injuries, behind dairy (9.7%) and

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hog and pig (8%) (Statistics Canada, 2014). For temporary foreign workers, a study shows that “immigrant men in their first five years in Canada are at increased risk of work-related injuries that require medical attention” (Smith & Mustard, 2009).

- Indicators regarding workload and work week length respectively show high and moderate risks—although these should be considered in the context of seasonality of the industry and business models of cattle operations. Workload and work week length were expected areas of potential risk common to the agricultural sector. These results are also aligned with the agriculture sector statistics showing that an average work week ranges between 38.9 hours in January and 50.4 in May. Those figures vary for employees (between 34.9 and 40 hours) and self-employed (between 40.7 and 57.3 hours). (Statistics Canada, 2015). Finally, it has been noted, following Steering Committee comments, that these relatively “long” hours compared to other industries can also present benefits such as high animal care, as farmers are dedicating time to ensure cattle well-being (e.g. calving assistance).
- The survey results also show that there is a good average hourly wage despite the fact that overtime pay practices, which are not required by law, are not predominant. The survey results show an average hourly wage of $18.05/hour for 2013, including seasonal workers. Based on statistics for the bovine sector, also including seasonal workers (Employment and Social Development Canada, 2015), and provincial distribution of beef production (Canada Beef, 2013), the calculated average hourly wage is $13.26/hour for 2014. Both figures, however, exclude Québec.
- Regarding environmental management practices, waste management shows a moderate risk due to both the practices of surveyed farmers and the limited options available in many provinces to recycle products (e.g. baling twine). On the other hand, grazing management and water are showing low to very low risks. For the reasons previously mentioned in 4.5.1.4 Environmental practices, despite being low, these potential risks should not be overlooked due to the severity of the potential impacts on water quality and riparian lands.
- The odour reduction indicator shows a potential risk—which is corroborated by a study showing that only 18.4% of beef farms in Canada have some method of odour control (Beaulieu, 2004). However, according to the survey results, participating farms indicate that they never or rarely receive complaints from neighbours.
- Risks related to industry resilience are low to very low, with risk management and employment succession marked green and yellow, respectively, which potentially demonstrates adherence to best practices.

4.5.3 Processors' level assessment

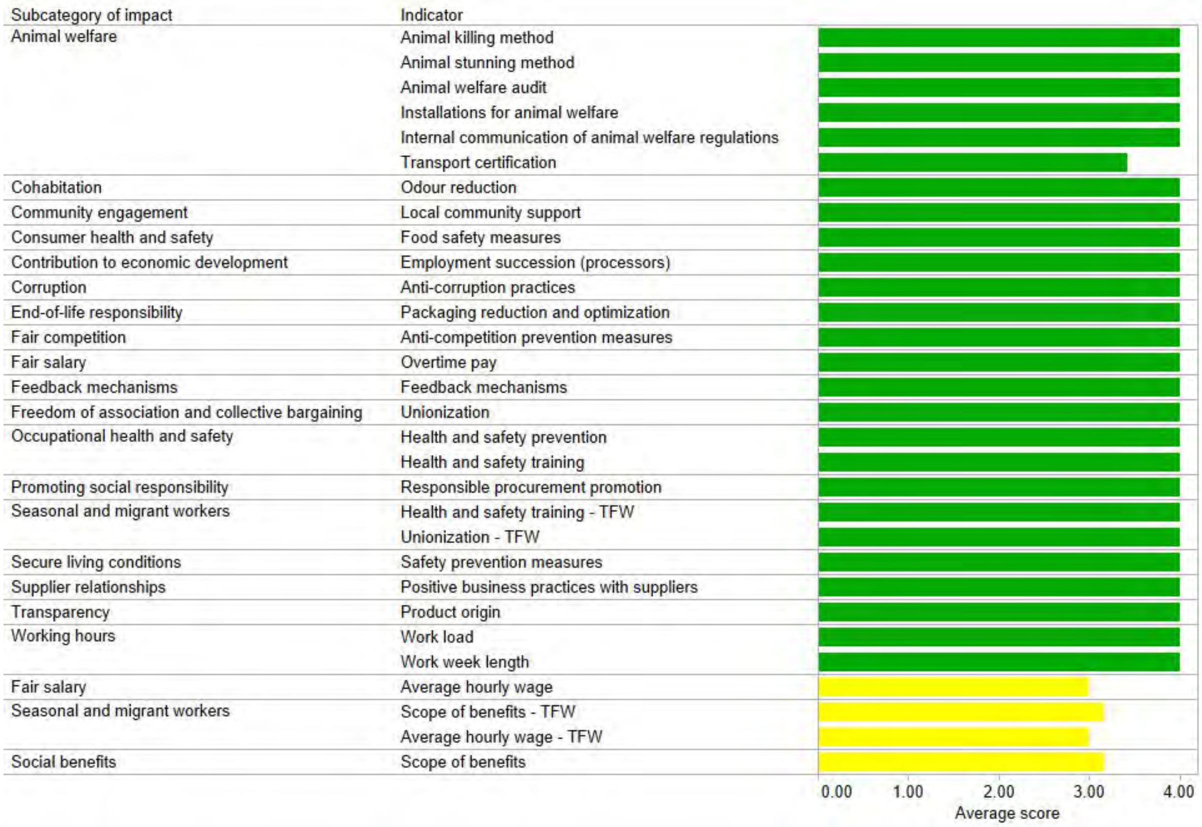

Figure 4-22 Processors' indicators

- Based on the survey results, the processors show overall low to very low social risks. However, it must be noted that only a portion of the industry was consulted for this assessment. Risks might therefore differ at smaller organizations, but determining this would require further research. Another limitation of these results relates to the respondents to the survey used to perform this assessment. The survey was intended to understand the risks behind practices and policies in place, rather than directly consulting employees about their working conditions. This additional research would provide a more balanced perspective but could not be conducted due to the project's budget and time limitations.
- Working conditions indicators show low to very low risks, including regarding workload, work week length, overtime pay, average hourly wage and scope of benefits. The good salary and non-salary practices in meat packing plants are in line with efforts made by the industry to attract more workers, considering a critical shortage of more than 1,000 butchers and meat cutters in processing plants (Canadian Meat Council, 2014). Indeed, it is reported that "rates of pay have been increasing faster than inflation and are not only well above minimum wage levels, but exceed those offered by competitors operating in the United States. Other employer sponsored employee benefits typically include medical, dental, disability, life insurance and pension plans." (ibid.) These labour shortages also have a direct impact on the employment of temporary foreign workers.
- Temporary foreign workers (TFW) indicators show low and very low risks in terms of health and safety training, unionization, scope of benefits and average hourly wage. This should, however, be put into perspective with the national-level indicator regarding rights of migrant workers, which shows a high risk in Canada as the country is not a signatory nor a state party of the ILO's international convention on the Protection of the Rights of All Migrant Workers and Members of their Families. This reflects the federal government's *Immigration and Refugee Protection Regulations* that restrict TFW from changing employers. That restriction, as well as the employers' ability to potentially sponsor TFW for permanent residency, can put migrant workers in a vulnerable position (Depatie-Pelletier & Dumont Robillard, 2013). For reference, they represented on average 14% of the meat packing plant workforce in 2013.
- All health and safety indicators for both workers and local communities also show very low risks (local safety prevention, occupational health and safety prevention and training of employees, including temporary foreign

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workers). According to the US Occupational Health and Safety Administration, the meat packing industry presents several potential hazards for workers, including knife cuts, falls, back injuries, toxic substances, cumulative trauma disorders and infectious diseases (OSHA, 2006). Special attention should therefore be given to health and safety measures and training. However, no national statistics or industry-wide reports were found through our secondary research to illustrate these risks.

- The unionization rate of workers, including temporary foreign workers, is above 75%—much higher than the national average at 32% and the manufacturing sector average at 27%. This indicator considers that a high unionization rate is positive as it benefits employees' interests. However, some stakeholders might interpret this indicator as negative, showing a need for employees to form groups and defend themselves against certain employment conditions or situations. For the purpose of this study, the high unionization rate was perceived as a positive sign of social impact, as presented in international standards such as the ILO's *Declaration on Fundamental Principles and Rights at Work*, through the principle of freedom of association and the right to collective bargaining (ILO, 1998). National statistics show that the average hourly wage for employees under union coverage was about $28/ hour in 2014, whereas those with no union coverage earned an average hourly wage of roughly $23/hour (Statistics Canada, 2014).
- All animal welfare indicators assessed show very low risks (animal welfare audits, on-site installation, stunning and post-euthanasia methods, transporters certification for the safe handling of animals and internal communication of animal welfare regulations). These results are in line with current trends in the meat industry, which has seen the development of the Professional Animal Auditor Certification Organization (PAACO), whose mission is to "promote the humane treatment of animals through education and certification of animal auditors, as well as the review and/or certification of animal audit instruments, assessments and programs" (PAACO, 2015). More and more companies, including large buyers such as McDonald's and Walmart, require their suppliers to be audited to ensure animal welfare at processors (Government of Manitoba, 2014).
- Anti-competition and anti-corruption are also well covered by the processors, respectively presenting very low and low risks.

4.5.4 Industry associations' level assessment

Figure 4-23 Associations' indicators

- Results from the industry association level demonstrate an overall good assessment of associations' engagement to support positive social impacts.
- Good support is given to farmers regarding food safety, R&D and economic resilience respectively through information sessions, dedicated budgets and development of tools and training to improve product marketability.
- Environmental management best practices are well promoted and supported in all four areas assessed: waste and manure management, biodiversity and wildlife, grazing management, and water and riparian areas. These results are in line with the assessment made at the cattle operators' level.
- Promotion of sustainability is generally done by all provincial associations, although it could be more structured.

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- Although usually not part of a formal program, associations also support local communities through different donations and sponsorship initiatives.
- "Promotion of transparent practices", i.e. communication of operational practices at both the cattle operations' and processors' levels, demonstrates some transparency from the industry.
- Less focus seems to be given to worker-related topics such as "occupational health and safety" and "promotion of diversity and inclusion".

4.5.5 Upstream supply chain's level assessment

Figure 4-24 Upstream supply chain's indicators

- The sample of suppliers demonstrates an excellent performance regarding respect of intellectual property rights and competitive behaviour.
- Regarding workers, average salary among suppliers to the industry is aligned with the national average salary. However, more attention could be given to local hiring and procurement practices.
- Suppliers generally show good performance in R&D with projects conducted in Canada, but they do not always have a national R&D centre or dedicated facility in the country.
- Relationships with suppliers appear to be generally good, with initiatives showing engagement between the parties. Suppliers' codes of conduct to promote responsible practices are common.
- Occupational health and safety presents a potential high risk as assessments for the sectors used as proxies present a rate of fatal injuries above the country average.
- Companies reviewed generally do not publicly communicate about specific practices to promote local hiring and procurement, presenting a potential low engagement in that area.
- Companies reviewed generally showed no public evidence of operational measures seeking to ensure safe and healthy living conditions of the local communities where they operate.

4.5.6 Downstream value chain's level

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Figure 4-25 Downstream value chain's indicators

- Most companies are communicating about their sustainability initiatives either through their website or through a sustainability report, showing transparency efforts.
- Regarding workers, potential risks are mitigated depending on the topic. Rate of injuries is lower than the national average. On the other hand, the sectors assessed to represent the downstream value chain actors (distribution and fast-food chains) show a low median income (i.e. on average, more than 50% lower than the national average). This may be explained by educational and skills requirements for sales positions in the retail sector (Government of Canada, 2014).
- Most of the companies assessed have not implemented any policy to promote local sourcing of products or employment of local workforces.

4.5.7 National legal and regulatory environment level

Figure 4-26 National indicators

- The national legal and regulatory environment shows low and very low levels of risks for the most part. However, a few subcategories of impact require more attention from the industry when dealing with these topics due to the laws and regulations in place that might affect operations and practices.
- Canada is among the top rankers for fair and equal opportunities, as well as intellectual property protection, and the ethical behaviour of all firms indicates a very low potential risk for these issues in the beef industry.
- Anti-monopoly policy, employment security and freedom of association and collective bargaining are other areas where Canada performs well (low risk).
- Canada is neither a signatory nor a state party of the ILO's international convention on the Protection of the Rights of All Migrant Workers and Members of their Families, showing a potential high risk in this area.
- The State of the World's Human Rights country report of Amnesty International mentions some concerns regarding the respect of indigenous rights in Canada, but does not report any formal violation of indigenous rights.
- Provincial legislation governing labour relations shows that some restrictions apply to agricultural workers in certain provinces (AB, QC, ON, NB) with regard to freedom of association and collective bargaining.

4.6 Social LCA results' limitations and challenges

The SLCA experienced four main challenges throughout its process, namely:

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- Identifying the right categories of impact and the best available indicator for it (scoping)
- Defining the right rating scale for each indicator (quantifying)
- Collecting the data to feed the indicator without introducing bias (measuring)
- Providing context to allow for a fair unbiased interpretation of the measure (interpretation)

A key challenge of this assessment was to provide a balanced and realistic view of social impacts throughout the Canadian beef life cycle stages. In order to mitigate the risks of providing a) a biased view of the industry, either positively or negatively, and b) an out-of-context analysis, we used two complementary approaches to support our work. The first one consisted of conducting a large social topics secondary review to cover most stakeholders' expectations and to build on this analysis by consulting with industry experts and specific topic specialists (such as animal welfare) to reflect the reality of Canadian beef production. The second approach involved comparing these views to international or national standards that we, as sustainability consultants, refer to in our day-to-day work and which the general public expects the beef industry to be benchmarked against.

Another challenge was the quantification of a social impact. While the exercise is now quite standardized in environmental LCA, there is no widespread consensus for its social counterpart. Social impacts happen over time in a given context, and affect—as much as they are affected by—a wide range of factors. Furthermore, the way a person values a social impact depends on their perspective, which is influenced by their core identity, including (but not limited to) social background, professional occupation, age, language, culture, beliefs, etc. While this means that there is no single way to translate a complex social impact into semi-quantitative data, it also drives one important outcome: the rating scales proposed for each indicator in this study are a result in themselves and can be seen as "Canadian beef industry specific rating scales". Indeed, those rating scales are the result of a collaborative and iterative effort by the consultants, the Steering Committee members and the industry specialists involved in this study to get them "right". In some instances, a rating scale may reflect how the industry looks at itself as much as it reflects some internationally-relevant reference standards. In that regard, the results of these studies lie as much in the actual measures (colour code/risk level assessment for each indicator) as in the quantification system selected, i.e. the rating scales themselves.

Some indicators and their associated rating scales have been debated several times within the assessment working groups—like, for instance, the rating scale for the number of hours worked per week: should it be based on international standards or on farmers'/industry point of view of what a reasonable work week is? Neither of these answers is wrong or right in itself, but we had to choose the one that seemed more relevant for the purpose of the study. In that case, we decided to stick with the international standards (using the 48 hour per week threshold as a reference point in our rating scale) while recognizing in the comment section that the indicator's result does not entirely encompass distinctions at the macro level (industry needs and challenges) or the micro level (individual needs, aspirations and motivations).

Our mitigation approach was two-fold for the interpretation process. First, we leveraged the additional comments section of indicators to contextualize the results. We are, however, conscious that some indicators could have been quantified in a different way, which could have influenced the results of the risk assessment. Eventually, and as noted by the UNEP/SETAC guidelines, the SLCA cannot provide a completely objective assessment of impacts, and subjective views cannot be dissociated from either the process or the results of the assessment. That being said, results drawn from our surveys could be further refined through a cross-check with national trends and statistics, scientific papers and reports, so we used the assessment's section to strengthen this aspect by complementing results with secondary research findings.

Finally, the critical review process led by third-parties supported our efforts to find the right balance and portray the social impacts of Canadian beef on its stakeholders as accurately as possible.

In the end, this exercise revealed some discrepancies between the survey results and the secondary research for impacts such as health and safety, working conditions and environmental practices. This consequently reveals an important limitation in the methodological choices used for this SLCA. This study has revealed, and documented, that on some aspects, there is a perception gap between the industry's internal stakeholders (cattle farm owners, meat packers) and the general public. In the next phases of the project, KPIs will be identified to help the industry determine if these public perceptions align with the actual performance of the industry.

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Table 4.9 presents a summary of the main limitations of the SLCA results, along with mitigation measures that were taken to minimize their impacts on the study, as well as recommendations for the next phases of the project.

Table 4.9 Summary of results' limitations, mitigation measures and recommendations

Limitation	Mitigation measure	Recommendations
Only farm owners and meat packing plant managers were consulted through a survey. Workers and local communities, affected by the practices of these two groups of stakeholders, were not consulted, which may have altered the results. As a result, some survey-based indicators may be biased.	Analysis of results was complemented with generic data to balance the answers provided by the surveys and compare them to national trends and statistics as well as other reference reports and scientific papers.	Engage with workers to understand their views and accordance, or not, with the results of the survey and the hotspots identified for further improvement of the industry's sustainability. KPIs to be developed in subsequent phases should particularly cover topics showing some discrepancies.
The sample of beef producers is not statistically representative.	Results analysis is based on a risk assessment rather than on a performance assessment approach.	For KPIs to be identified and monitored in the future, national panels of recurring surveys should be leveraged to cover a larger portion of the beef producer community, including farm employees.

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5 Conclusions and recommendations

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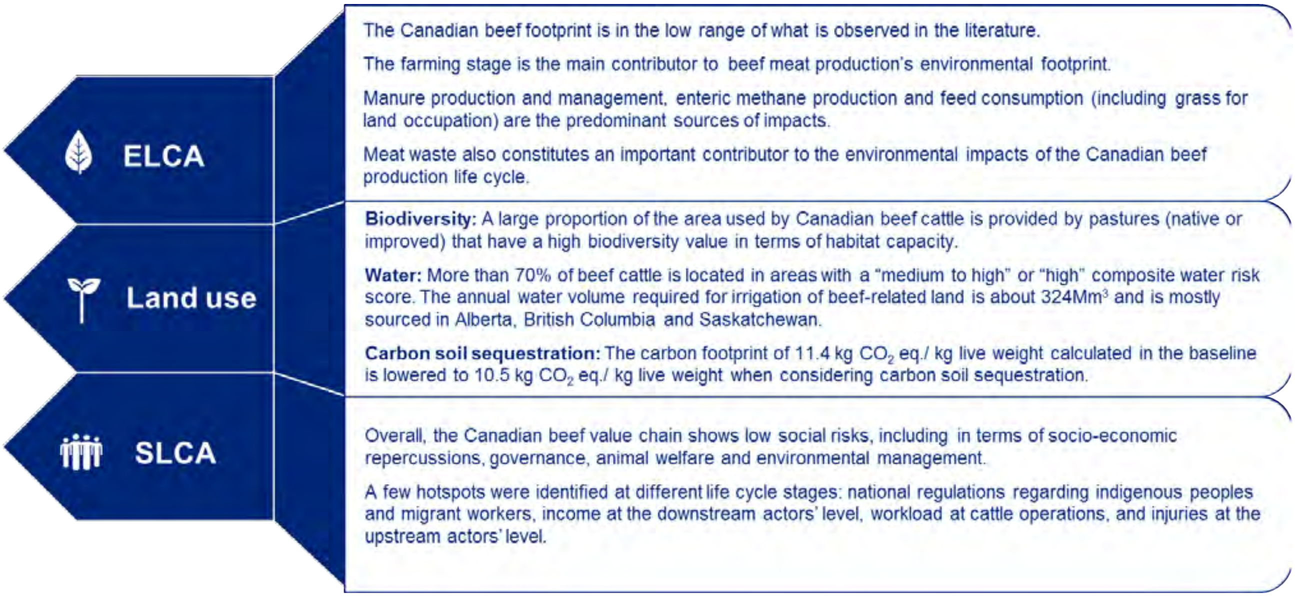
5.1 Overall conclusion

In this section, results from the study's three streams—1) Environmental LCA; 2) Land use assessment; and 3) Social LCA—are compiled to provide a holistic view of the sustainability of Canadian beef production by presenting environmental and social impacts throughout the value chain.



5.2 Key messages

5.2.1 Environmental life cycle assessment

At the outset, it should be noted that these conclusions are only valid under the assumptions and boundaries considered in this study. Resource consumption and emissions from different sources are considered to have occurred in the same place at the same time. The impacts assessed are therefore maximum potential impacts. They derive from modelling—hence simplifying—the real environment. The results are relative expressions that do not predict the effects on the final impacts by category or define thresholds, safety margins or risks. Consequently, these results should be interpreted with caution as additional information is required to compensate for the limitations inherent to impact assessments.

A baseline for the industry

This study provides an overview of the environmental impacts of the Canadian beef industry. It relies largely on activity data and models representative of the Canadian context. Most of the activity data were obtained through a large sample of farmers and packers. Secondary data and models were collected from Canadian sources or adapted to the Canadian context (e.g. Statistics Canada, Holos model, etc.). Data were reviewed and validated by scientific and/or industry experts, in addition to the members of the Steering Committee who provided a particularly critical review.

Methodological choices were made in full accordance with the latest standards in terms of life cycle assessment applied to food and farming products (e.g. ISO 14040-44, FAO LEAP guidelines).

Origin of the environmental impacts

This study identifies the farming stage as the main contributor to the environmental impacts of beef meat production. Other stages' impacts are mostly related to meat waste. Reducing meat waste appears as one major lever to reduce the value chain environmental footprint.

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The results are in the range of what has previously been observed in literature. For instance, the carbon footprint of Canadian beef meat production at the farm gate is 11.4 kg CO_2 eq. live weight, whereas literature values range from 10 to 19 kg. CO_2 eq./kg live weight.

Environmental impacts occurring during the farming stage are mostly related to manure production and management, enteric methane production and feed consumption (including grass for land occupation). Optimizing rations so as to limit the impacts of feed production and animal digestion (and thus enteric emissions and manure N and P content) appears to be key to mitigating the environmental impact of Canadian beef meat. Best practices with regard to crop production, and fertilization in particular, would also help reduce this environmental footprint.

Scenario analyses, comparing Eastern and Western practices, yearling-fed and calf-fed systems and the use of hormones or not provide some insight into practices enabling the reduction of environmental impacts. For the first two analyses, no clear advantage of one scenario over another appears: if Eastern animals are heavier and have a lower land footprint, the benefits are offset on some indicators by the larger amounts of feed used, inducing higher consumption of fertilizers, energy, etc. Similarly, if the life cycle of calf-fed animals is shorter, the longer finishing period and thus the higher amounts of feed required counterbalance this advantage on some indicators.

The use of hormones in the industry clearly enables mitigation of the environmental impacts quantified in this study. However, this study did not cover toxicity issues for lack of robust data.

Limitations and uncertainties of the study
Most of the data used in this study, input data as well as LCIs, satisfy a good quality level: they are representative and reliable given the objective of the study. However there is still room for improvement on the three following aspects in particular:

- Feed LCIs: some feed LCIs, such as corn and soybean, are not representative of the Canadian production system. More representative datasets for these crops could improve the results, especially for corn, which can be fed in large quantities in the East.
- Phosphorus losses from manure excreted on pasture: phosphorus excretion rates obtained from Statistics Canada are rough estimates, and the models implemented to assess P losses through run-off, leaching and soil erosion could be refined to be more representative of the Canadian situation.
- Meat waste occurring after the packers' gate: data are based on generic sources not specific to Canada (Canadian data were available but appeared less relevant to this context). Although they provide a good overview of the importance of food waste mitigation at the end of the life cycle, more accurate and representative data would help improve the overall quality of the results. This would also provide a more accurate view of the mitigation potential and strengthen key messages to concerned players (industry, retailers, and consumers) about how to reduce their environmental footprint.

5.2.2 Land use assessment

5.2.2.1 Water

The water risk assessment was based on the use of Aqueduct's global water risk mapping tool to perform a broad screening of water risk across Canada. In addition, we estimated the blue water footprint of Canadian beef cattle, and performed a sensitivity analysis on irrigation levels across Canada. This assessment aimed to provide a high level overview of the beef cattle-related impacts on water resources systems at the provincial level, with a sole focus on the direct/indirect consumption of irrigation water and recommendations on how rainfall information can be used in this context.

More than 70% of beef cattle are located in areas with a composite water risk score of medium to high or high (including risks such as baseline water stress, inter-annual variability and drought severity). The water volume required for beef cattle production is mostly sourced in Alberta and British Columbia, due to a combination of higher irrigation rates and larger herds in these provinces. The total blue water volume required by beef cattle in Canada (estimated at 324 million cubic metres for irrigation and 62 million cubic metres for drinking water) shows that this sector is significant in terms of water consumption.

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5.2.2.2 Biodiversity

This study focuses on a specific aspect of biodiversity—the land use impacts of beef cattle on biodiversity—by assessing the habitat capacity potential of areas required to feed the beef cattle herd. The analysis is derived from the approach used by the Wildlife Habitat Availability on Farmland Indicator (WHAFI, Agriculture Canada), customized with data at the provincial level.

Canadian beef cattle use 21.1 million ha for feed crops and pasture land, mostly located in Alberta and Saskatchewan (80%) and equivalent to 33% of all Canadian agricultural land. A large proportion of this area is provided by pastures (native or improved) that have high biodiversity value in terms of habitat capacity. This results in a high contribution (68%) of land used for beef cattle to the habitat capacity potential of the total agricultural land in Canada. This is especially true for Western provinces (production systems relying more on pastures) compared to Eastern provinces (more intensive production systems). As a steward for the maintenance of large areas of grasslands, the Canadian beef industry thus has the potential to assist conservation objectives. However this depends on maintaining native pastures and using sustainable management practices.

5.2.2.3 Carbon soil sequestration

Assessment of carbon soil sequestration is based on previous Canadian works from Shrestha *et al.* (2014). It considers the emissions and removals resulting from land use change (LUC) and land management change (LMC). The carbon footprint of 11.4 kg CO_2 eq./kg live weight calculated in the baseline is lowered to 10.5 kg CO_2 eq./kg live weight when considering carbon soil sequestration. Emissions due to LUC have a relatively minor impact on climate change, given that forest land conversion has decreased, while improved land management practices—mostly reduction or cessation of tillage—enables the storage of GHG emissions through soil absorption of atmospheric CO_2. To maintain, if not enhance, carbon soil sequestration, it would be a good practice to encourage crop producers to reduce tillage.

With no consideration of LUC and LMC, the absolute emissions related to beef meat production amount to 17 Mt CO_2 eq. per year, i.e. roughly 2.4% of Canadian overall GHG emissions.

5.2.3 Social life cycle assessment

Overall, the SLCA shows that the Canadian beef industry has low social risks, however some hotspots have been identified and some results showing positive impacts from survey results may be underestimated. These results are summarized in the following paragraphs.

Working conditions of employees and workers throughout the value chain should be considered alongside industry viability. Regarding farmers' workload, for instance, the small margins and large volumes that characterize the industry may lead producers to spend more time on their operations or have their employees work for more than 48 hours per week to keep the operation economically viable. Furthermore, labour shortages impacting the cattle industry lead producers (but also meat processors) to seek out non-domestic workers, such as employees under the temporary foreign workers program, to stabilize beef production in Canada. In terms of social impacts for temporary foreign workers, indicator risks are generally low and are similar to domestic workers (including in terms of social benefits, average hourly wage and unionization rate). However, these results should be considered within the larger federal context, which reflects a high risk due to federal regulations and the country's decision not to sign the international convention regarding migrant workers' rights.

Health and safety shows low to very low risks based on the survey results of farm owners and packers. However, additional secondary research revealed that these risks might be underestimated considering that the agricultural sector is the fourth most dangerous industry in which to work in Canada and that meat packing plant activities and equipment present diverse potential hazards for workers. The social assessment also reveals hotspots in the value chain, such as income of workers at the distributors' level and occupational health and safety at the suppliers' level, which both require attention from the industry and their stakeholders.

Animal welfare indicators show very good assessment results, with a majority of low to very low risks identified throughout the value chain based on survey results. These findings are consistent with industry associations'

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involvement in this issue. Although challenges to maintain animal welfare exist, the National Farm Animal Care Council (NFACC) has developed a Code of Practice for the Care and Handling of Beef Cattle that includes requirements and recommended practices to ensure animal welfare. This code of practice applies to beef producers, processors and other actors of the value chain. At the packers' level, we can also note the increase in audits performed and demanded by downstream value chain actors, which might have positively influenced the practices on-site.

Heightened food awareness, including how it is produced, is also increasingly important from a consumer demand point of view—regardless of whether it indicates a short-term consumer inclination or a long-term change in society and consumer behaviour. Promotion of transparent practices at the association level could consequently be improved to address the issues considered important by consumers.

Other major demand drivers are related to food safety and beef quality. Indicators related to consumers in the social assessment show overall low or limited levels of risks on these aspects, including in terms of food safety measures and training at both the producers' and processors' levels.

Environmental management practices show low risks based on farmer surveys and association practices. Regarding rangelands, the positive results are aligned with the findings of the biodiversity assessment through habitat capacity. Regarding water-related measures, including grazing management, riparian areas management and manure management, these risks need to be considered in conjunction with the results of the ELCA (water pollution indicators) and of the water risk assessment (blue water quantity used for beef cattle). Although surveyed farmers seem to implement mitigation measures to reduce their impacts, public perception towards the industry and its impacts on water resources are a recurring theme of media criticism, which may indicate a gap between actual practices and perceived impacts on water quality.

Assessment of governance aspects shows positive social impacts in terms of ethical business practices by actors across the value chain. These practices and the overall low levels of risks at the national level can therefore strengthen the position of Canadian beef on the global market.

Finally, positive socio-economic repercussions outlined in the SLCA are reflective of the industry's contribution to GDP, which amounted to $22 billion, and to employment, representing nearly 250,000 person-years in 2013 (Canfax Research Services, 2015).

5.3 Recommendations for next steps

The points listed below only cover preliminary findings from the results presented previously: a more comprehensive analysis will be developed in the next stages of the project, including SWOT analysis and the development of a dashboard to inform the strategy of the Canadian beef industry from a sustainability perspective.

5.3.1 Environmental LCA

The environmental life cycle impact assessment revealed several hotspots, but conclusions should not be drawn too hastily; more in-depth assessment will be conducted during the SWOT to gain further detail on the following findings:

- Best management practices regarding beef production systems are not always evident (manure management, calf-fed vs yearling-fed, etc.); a cross-analysis with technical and economic factors would help in assessing their feasibility and acceptance.
- The feed composition of the rations affects the results both in terms of enteric fermentation and manure-related emissions. An analysis of the nutrient intake recommendations in light of the associated environmental impacts would help identify best practices.
- Feed production: the impacts of feed were considered based on previous works. However, feed production appears as an issue for several impact indicators, mostly due to the use of fertilizers and pesticides or to irrigation. Recommendations addressed to feed producers should also be explored in the next stages of the project.

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5.3.2 Land use

The carbon soil sequestration approach is based on average values for stock change due to land use change and land management change. Similar values of carbon stock for croplands and tame pasture exist due to data limitations, Furthermore, average values are considered representative of the whole country. A refined vision of carbon sequestration could be obtained with regionalised data and specific carbon stock change per crop, to better understand the contribution of the beef industry.

The biodiversity assessment provided a high level view of the contribution of beef cattle production to the habitat capacity of agricultural land in Canada. The following recommendations could be further explored to refine and improve the robustness of our conclusions:

- Improve granularity of the analysis by assessing breeding and feeding requirements for wildlife separately, and by considering taxonomic groups or endangered species separately.
- Differentiate biodiversity impacts between native and tame and improved pastures, to allow a quantification of the contribution of beef production to the maintenance of biodiverse native pastures.
- Account for management intensity, since sustainable and grazing management practices can yield substantial biodiversity benefits.
- Develop more specific scenarios to assess sustainable beef production in relation to biodiversity (e.g. increase in the share of extensive beef production, impact of changes in beef rations on biodiversity).
- Broaden the approach though LCA models of ecosystem services or other types of biodiversity measures (e.g. an indicator of habitat connectivity or fragmentation).

The water risk analysis provided a comparative view of water risks and cattle herd location, with an assessment of the water volume required to grow feeds for beef cattle. Additional work could allow a refined assessment of the water risk:

- Analysis of water efficiency measures at the cattle producer level, to better take into account management practices in high and low water risks.
- Gathering more detailed data on irrigation prevalence and intensity on beef-related agricultural land use (feed and forage crops) to fine tune the estimation of the blue water footprint.
- Understanding the coping capacity of local water systems, under different precipitation patterns and climate change scenarios, to improve water risk management at a local level.

5.3.3 Social LCA

The SLCA results and their analysis revealed several hotspots and topics that will require focus in the next phase of the project.

- Workload: although this was identified as a hotspot at cattle operations, the economic assessment showed that producer viability and industry characteristics may be causing this outcome due to potential pressure to increase, or at least maintain, a certain level of productivity and profitability that may require a higher workload than what is commonly-observed in other industries. However, this may pose health and safety risks due to lower reactivity or awareness, for instance. Management practices around these different factors should be explored during the next phase of the study to identify possible solutions for the industry to be both economically viable and socially responsible.
- Occupational health and safety: although health and safety prevention indicators show good results at the operational level, our limited sample did not enable us to measure meaningful incident rates. Because farmers' workload is high, this incident rate should be monitored regularly. At the upstream level of the supply chain (i.e. cattle operators' suppliers), occupational health and safety is a hotspot. In the next steps of the project, an occupational health and safety KPI should be identified to cover that aspect.
- Average hourly wage: despite showing low risks based on survey results, beef sector statistics show a lower rate of average hourly wage compared to that reported by the survey's farmer respondents. This indicator will therefore constitute a key aspect to be covered in the next phase of the project.
- Human rights: respect of migrant workers' rights was identified as a hotspot at the national legal and regulatory level due to Canada's non-signatory/non-ratified status regarding the International Convention on the Protection of the Rights of All Migrant Workers and Members of their Families (UN—OHCHR) (United Nations Human Rights, 2015). However, assessment at the meat packers' level shows that migrants are treated the same as Canadians in terms of wage and scope of benefits. Respect of indigenous rights showed moderate risk at the national level as well. To minimize risks at the industry level, value chain actors

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should therefore be (or remain) proactive in their approach to ensure migrant workers enjoy the same rights and benefits as non-Aboriginal and non-migrant individuals living in Canada. They should also take steps to develop and implement any necessary additional provisions that would support this goal. Although Canada is not a country where human rights are generally at risk, these issues, as well as others assessed at the national level, are particularly important to understand in a context of global competition and strategic positioning for the Canadian beef industry relative to other beef-producing and exporting countries.

- The link between animal welfare and consumer demand should be explored in more detail to strengthen future communication and ensure good practices at the operational levels. These issues should therefore be included in the SWOT analysis, along with opportunities for the industry to promote sustainability through continuous improvement. As mentioned in the SLCA section, some animal welfare best practices could also present benefits to the beef industry—providing the opportunity to realize a positive impact from the consumption and economic points of views.
- Environmental management: considering the discrepancies between the SLCA and the water risk assessment results, this topic will constitute a key aspect to be covered in the next phase of the project. A relevant KPI will need to be identified to enable the industry to provide a clear view of the Canadian beef industry on water, especially as this is a key resource that is highly scrutinized by environmental groups and public stakeholders.

6 Appendices

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6.1 ELCA & SLCA—Composition of the study's Steering Committee and critical review panel

Steering Committee composition

Name	Organization	Profile
Brenna Grant	Canfax	As Manager of Canfax Research Services, Brenna provides industry with statistical information and economic analysis, focusing on both the Canadian and global beef markets. Brenna is originally from a cow-calf operation at Val Marie, Saskatchewan.
Carrie Selin	ABMI	Carrie facilitates discussions with partners and stakeholders to create opportunities for ecosystem services and shares information to support the ES Assessment Project. She has over 15 years of experience in the agriculture industry and in government supporting environmental policy and enabling industry development programs. Carrie's expertise includes facilitating engagement processes and building capacity through awareness and education programs.
Clinton Dobson	ALMA	At ALMA, Clinton is responsible for coordinating, developing and facilitating the discussion of livestock and meat policy issues and initiatives. This includes analysis and evaluation of policy positions and strategic decisions that increase Alberta's industry competitiveness and affect exports to international markets. Clinton focuses on helping ALMA identify partnerships and projects that fit within larger strategic initiatives, actively working with stakeholders to develop the vision and bold ideas that advance Alberta's livestock and meat industry. Clinton has a MSc. in Agricultural Economics from the University of Saskatchewan and grew up on a mixed cattle and grain farm.
Dan Farr	ABMI	Dr. Farr, who completed his PhD at the University of Alberta in 1994, has been involved in the ABMI since its inception in 1997, after spending several years as a forest ecologist with the Foothills Model Forest in Hinton. In his first role at the ABMI as Program Coordinator, he took part in projects related to the conceptual framework for the monitoring program, integration of different field monitoring methods and the use of remote sensing to quantify landscape change.
Fawn Jackson	CCA	Managing environmental issues facing the industry, Fawn staffs the Environment Committee and participates in many research and joint initiatives between the industry, government and international groups. Fawn works on helping to set research directives, producer communication and environmental policy for the Canadian beef industry. Fawn represents Canadian cattle producers at the Global Roundtable for Sustainable Beef, the Commission for Environmental Cooperation, the International Meat Secretariat Sustainable Meat Committee and the Five Nations Beef Alliance Sustainability Committee. She played the lead role in setting up the Canadian Roundtable for Sustainable Beef.
Karen Beauchemin	AAFC	Dr. Beauchemin has developed a broad-based research program to improve feed utilization ruminants. She is recognized for her expertise in the areas of acidosis, rumen function and the fiber requirements of cattle.
Kerrianne Koehler-Munro	AAF	Kerrianne is an Environmental Program Specialist within the Environmental Stewardship Division of Alberta Agriculture and Forestry (AAF).
Lauren Stone	Cargill	Lauren is the Manager of Corporate Affairs and Sustainability for Cargill Canada. In her role, she is responsible for the sustainability efforts for Cargill's diverse businesses across Canada, as well as government and community relations for Western Canada. As a graduate from Queen's University, Lauren has a degree in Political Science, with a specialization in foreign policy and international political

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Name	Organization	Profile
		economy. Lauren has over five years of experience in agricultural and environmental policy. After graduating from Queen's University, Lauren was the Policy Analyst for the Manitoba Beef Producers, where she was responsible for government relations, policy development and producer relations. She also spent time as a Policy Analyst at the Manitoba Legislature, where she advised elected officials of the legislative assembly on key policy recommendations.
Paul Thoroughgood	Ducks Unlimited	Paul has been a regional agrologist of Prairie Canada for Ducks Unlimited Canada since 1997.
Reynold Bergen	BCRC	Dr. Bergen provides scientific and industry expertise to the BCRC and Beef Science Cluster, working with industry to identify research priorities and review research proposals and scientific reports, and engaging with industry and research experts on an ongoing basis. To ensure producers have access to current research information, he develops fact sheets for projects funded through the BCRC, and writes articles that are available through the CCA, provincial beef organizations, various agriculture media outlets and BeefResearch.ca. Reynold also works to gather and provide relevant research-based information for industry, public and government communications on specific issues.
Rich Smith	Alberta Beef Producers	Rich joined ABP as the Environmental Manager and moved into the role of Executive Director. He has a Bachelor's Degree in Agriculture and a Master's Degree in Agricultural Engineering, along with extensive experience in the development, design and management of livestock operations. As Executive Director, Rich is responsible for guiding the ABP staff as they work on behalf of producers to address the policy, production, communication, promotion, legal and financial issues that will help to strengthen the beef industry in Alberta. In the environmental area, he is still responsible for dealing with the policy, regulatory and stewardship matters that will affect continued access to the land and water resources necessary for cattle production in Alberta.
Thomas Lynch-Staunton	UofA	Tom currently works at Livestock Gentec in the Faculty of Agriculture, Life and Environmental Sciences at the University of Alberta as the Director of Industry Relations. He has strong practical and lifetime experience in the livestock industry. Currently, Tom's role at the university is in the Livestock Gentec executive management team working in strategic development of the genomics research program to facilitate coordination and development of research projects with industry, knowledge transfer, communications and application of genetic improvement tools in the beef industry. At the same time, Tom is also pursuing a part-time MBA at the UofA, specializing in Sustainability.
Tim McAllister	AAFC	Dr. McAllister has been a research scientist in Rumen Microbiology, Feed and Nutrition since 1997. His research focuses on microbiology, nutrition and beef production, and on food and environmental safety issues related to livestock production, strategies for mitigation of Escherichia coli O157:H7, prion inactivation within the environment and, more recently, studies of antimicrobial resistance in bacteria in feedlots. He also has extensive research experience in GHG emissions within animals from manure and the impact of manure handling procedures, such as composting, on emissions.

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Critical review panel composition

Panel Review Chair - LCA Specialist (US)	Academic / Industry Specialist (US)	Industry Specialist (Canada)	Academic / Industry Specialist (US)	Biodiversity Specialist (US)
Greg Norris	Mitloehner, F. M	Janice Bruynooghe,	Nicole Tichenor	Robin Reid
Harvard University	University of California, Davis	Spring Creek Land & Cattle Consulting	Tufts University Ph. D. in progress (Nutrition)	Center for Collaborative Conservation

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6.2 ELCA & SLCA—Critical review panel comments and questions on the goal and scope

Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
Introduction			
	Use of acronyms/terms	Be sure that throughout this, and all documents, that all acronyms and terminology are clearly defined (e.g. "cradle to grave", "SWOT", "dashboard", etc.). We recognize that this an initial draft but thought it was worthwhile to flag it now. Readers will have varying degrees of background and understanding of the topic so all information presented needs to be very clearly defined.	A specific section at the beginning of the report will be added to define technical terms and acronyms used.
Background	Background paragraph #1, sentence #1 "CCA has made a clear statement of its willingness to improve…"	Of course this is CCA and CRSB's call, but when reading this sentence a possible first impression is that as an industry the current situation is a bit bleak and therefore the reason for looking to improve. Further on within the document this is more clearly defined, but as an opening statement it might be worthwhile to also state that while the industry has a clear commitment to improve there is also have a strong current starting point of very positive impacts to build upon.	Paragraph has been nuanced accordingly. Suggested modification: "*By joining the Global Roundtable for Sustainable Beef (GRSB) in December 2012 and initiating the Canadian Roundtable for Sustainable Beef (CRSB), CCA—while recognizing the positive impacts of the Canadian beef industry—has made a clear statement of its willingness to improve its environmental, social and economic impacts, and contribute to constructive dialogue and actions.*"
Background	Background paragraph #2, middle of paragraph "However, more pasture is used for cattle than all other domesticated animals and crops combined."	This sentence can be confusing. Rather than "pasture" is "acres" or "land base" more accurate? Pasture is only used for ruminants and not linked to crops. Also in making the statement that more acres are used for cattle than other ag uses it may more explanatory to link it to the relative outputs/benefits. In addition many forage acres are on marginal lands which aren't practical for annual cropping.	Sentence modified accordingly.

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
Background	In paragraph three, add the following qualifier to the description of cattle system benefits: "From and environmental standpoint for instance, **well-managed** grazing maintains…"	There is a significant literature on the destructive impacts of over or mismanaged grazing in grassland ecosystems, ranging from water quality impairment, soil health and desertification, and biodiversity loss.	Sentence modified accordingly.
Background	Data is collected for beef production in year 2013, but will data for feed and pasture production be collected over multiple years?	Multiple year data is advisable because of significant potential variability in yields year-to-year.	The data used in calculation will be based on average production for Canada. In the biodiversity approach, where feed cropland surface is calculated, yields are averaged based on the last 10 years (2004 to 2014) to smooth outliers.
Background	Confusing use of the terms, 'environmental', 'social', 'economic' and 'socio-economic' LCA and impacts.	Need to be consistent and clear that (if we are correct in assuming so) this study includes an environmental, social and economic LCA?	All social LCA-related terms have been harmonized to avoided confusion.
Background	The following broad overstatement needs to be qualified: 'From an environmental standpoint for instance, grazing maintains the health of grasslands, improves soil quality with manure, and preserves open space and wildlife habitat. Additionally, carbon is sequestered in the grasses and soils of grazing lands'	The scientific support for this statement is moderate to weak. Historically, removing all the natural grazers (buffalo, others) and fencing the land was a very large negative for the environment. In the current time, current grazing studies provide some support of this notion, but they also support the opposite: that grazing can reduce the health of grasslands, that grazing requires fencing and thus reduces open space and puts access mostly in private ownership, that grazing can reduce carbon in the soil. *This should be modified to recognize there are both strong positive and strong negative impacts of beef production on the environment historically and in the current time.*	Recognizing that there is a history of profound land use changes, we will highlight those important aspects. However, the study will focus on current effects and will not cover the historical perspective in great detail.

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
Background	The following broad overstatement needs to be qualified: ‘From a socioeconomic standpoint, beef production also provides social benefits, such as job creation and the promotion of local communities’ vitality.’	As described above, there are large negative social impacts of land appropriation for beef production (and other activities) for First Nations. In the current time, for example, there are both positive and negative health effects of beef consumption on consumers. *This should be modified to recognize there are both strong positive and strong negative impacts of beef production on persons, communities and society in general historically and in the current time.*	The historic perspective will be recognized.
Background	Add a section on what is not covered in the LCA	*Given the above 2 comments, it would be helpful to insert a section, at an appropriate place, describing what this LCA will not cover. If there are impacts this assessment will not cover, this document should spell out the limitations of this assessment and what it will not cover.*	Section to be written in the final report.
Background	‘But if not sustainably managed, activities can also have negative impacts on the living conditions of surrounding communities through pollution.’	This statement needs to be broadened as follows: ‘But if not sustainably managed, activities can also have negative impacts on the living conditions of surrounding communities through pollution *and other effects*.’	Sentence modified accordingly.
Background	At the end of this section, it states that there will be both an environmental and social LCA.	This is clear, this should be brought up front in the document, where the LCA is first defined in the first paragraph. Currently the first paragraph just defines an environmental LCA.	We are not sure if we understand this comment, as the section describes both environmental and social approaches, and both streams are systematically mentioned together.
	**In several places, the document gives examples of environmental and social impacts, and most of these are positive.* [72]	**To give the document more credibility, it will be important to use both positive and negative examples of environmental and social impacts throughout the document.*	We'll introduce more balance between positive/negative impacts of beef production in the final report.
Goal and intended applications			

[72] Specific comments added by Deloitte to reflect the comment “Examples of environmental and social impacts used” in the *Important Issues* section

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
	Under Deloitte's objectives, it is mentioned that modelling and methodology tools will be developed. Does this include the development of a software tool? How about the development of a database that includes e.g., GHG for various feedstock?	The development of a database and a software tool would be important to the CCA because it would enable the industry to measure continuous improvement even long after the consulting company has finished their work. In one panelist's opinion, the ideal deliverable would be a product that goes beyond the guidelines (the "how to"). To measure continuous improvement, a database and software tool are needed. The danger always lies in developing a report that shows the status quo and therefore, the second to last bullet point of the Deloitte objectives is crucial and needs to be elaborated on.	No software will be developed by Deloitte during this study, but Simapro models will be transmitted to the client at its conclusion. Existing tools have already been developed (such as Holos for GHG emissions from farms) and are already available to farmers. Though very comprehensive, the question of the practical use of such tools by non-experts (e.g. farmers) is to be considered. Moreover, given the magnitude of this multi-stakeholder / multi-variable study, developing software would require years of work and would exceed the scope and budget for this mandate. However, Deloitte's intention is to develop a set of KPIs to measure continuous improvement and a methodology that will allow updates to the study in the future (e.g. in five years) with regard to the actions put in place following this assessment.
Intended applications	'Ultimately, the target external audience for the communication of the study results is consumers of beef.'	*Since environmental and social impacts of beef production (as above) go well beyond just the consumers of beef, this should modified as follows:* Ultimately, the target external audience for the communication of the study results is consumers of beef *and another concerned persons and communities*.	Sentence modified accordingly.

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
Goal of study	'This study may be used to understand the hotspots on a life cycle basis across a range of both environmental impacts, including climate change, biodiversity, water use, acidification, eutrophication, fossil fuel depletion, land use and toxicity; and socioeconomic impacts, including human rights, work conditions, governance, health & safety and socioeconomic impacts. Ultimately, the target external audience for the communication of the study results is consumers of beef.'	*Given this statement, the reader would expect the LCA to cover all the issues mentioned earlier in this table, including First Nations rights, original loss of native grazers and fencing, etc.*	The limitations of the study will be covered in a dedicated section.
LCA methodology			
Life cycle assessment methodology	Not clear if this is social or socioeconomic LCA	Specify the particular Life cycle assessment methodologies being applied.	Both terms can be used to designate what is commonly called a social life cycle assessment. For the purpose of clarification, all "socioeconomic" terms have been replaced by "social" (except in official definition from UNEP/SETAC).
System boundaries	What percentage of Canadian beef is further processed? Also, please provide the evidence cited that this stage is a minor contributor to environmental impacts. If none of these studies are for animal products, using IO data as a proxy may be a good option.		The percentage of Canadian beef further processed is not available. Reference of evidence added.

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
	Why are dairy animals excluded from the study?	It is understood that allocation issues are cumbersome. However, the dairy- and beef sector are strongly intertwined and to be meaningful in the assessment of the beef industry's impact, one must include the dairy portion of the system. The fact that the dairy industry does its own assessment does not mean that one should not include dairy in the present work. It is likely that the dairy versus beef industries use different methodologies and the dairy omission in this present work would render it incomplete.	Beef production (as opposed to dairy production) represents ~82% of beef meat production in Canada. Discussion has been held with the Dairy Farmers of Canada Association, but the final decision was that a joint consolidated study could not be developed given budget and time constraints. It should be noted, however, that production streams for these two sectors are very different (e.g. breed, rations, age of animal at slaughter, yield / quality of meat, etc.), and a consolidated life cycle assessment would have resulted in the end in two sets of very different recommendations. The initial purpose is to address the objectives of CCA and its members, which are stated in the introduction of the G&S—including mention that a review of dairy production wouldn't serve this purpose.
Systems boundaries	'All environmental impacts occurring post-consumption (e.g. human waste) are considered to be outside of the studied system boundaries.'	It is important to provide an explanation for why this is excluded.	Post-consumption impacts such as human waste are outside the scope of this LCA: 1) LCA does not aim to quantify the impact of a human life/natural; 2) a natural biologic function will happen no matter what food is ingested (whether beef, chicken or legume) and, being not ruminant, will not impact potential the global effect.
System boundaries: biogenic carbon	Soil C dynamics are modelled as steady state in the baseline. Sequestration is included in sensitivity analyzes though, correct?		Yes. Carbon stock change and corresponding release / sequestration depending on land use management / land use change are assessed separately as recommended by most of the standards.

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
Figure 1	Is land not considered an input into this LCA?	This point needs to be clarified in the document.	Land is considered an input; figure will be updated.
Geographical, technical and time boundaries	Does the LCA assess impacts that go beyond the consumer, to local communities and society in general?	For example, does it include the effects of methane on climate and its proportional knock-on effects of climate change on local communities around the world, on global economies, on biodiversity, sea level rise, and extreme weather events and so on? Or does it stop at climate change only?	Although the knock-on effect of methane (being an important part of the GHG emissions of cattle production) could be mentioned (e.g. part of beef production / agriculture in the overall country GHG emissions), LCA usually stops at the initial impact of methane on climate, and knock-on effects are beyond scope.
Geographical, technical and time boundaries	Each lb of beef produced contains in it the embedded historical environmental and social impacts, many of which were highly negative.	It is best to recognize this in the text, and say it is important but beyond the scope of this assessment, if, indeed, it truly is beyond the scope of this assessment.	Will be mentioned in the exclusions and limitations section.
System boundaries, socio-economic assessment	'They also provide a categorization of the main stakeholder groups potentially affected by the activities and practices of the organizations involved in the product's life cycle.'	It is helpful to say here that the report will spell out who these stakeholders are and where the boundaries are drawn later in this document.	A note has been added: "Typical stakeholders are workers, local community, society, consumers and value chain actors." Also, a link to the corresponding table has been added.
System boundaries, socio-economic assessment	'Whereas environmental impacts are assessed at the process level, socioeconomic impacts are assessed at a community or organization's level'	And social impacts are not assessed at the national and global scale? If this is outside the social system boundaries, it is best to state this limitation and why these social levels were excluded.	The assessment of impacts at the global scale is excluded from our system boundaries as, based on input from industry professionals, the majority of inputs are from national sources.
System boundaries, socio-economic assessment	'The assessment is mainly focused on three life cycle stages, namely: primary production, feeding sector and packing sector.'	Thus, this study will not cover human health effects of beef consumption? If not, this should be stated directly and a justification given for its exclusion. However, it would be best to include these impacts in this LCA, partly because these effects are known well by the public and will give the LCA more credibility.	As mentioned in the goal and scope, consumption is outside of the scope due to time and budget limitations.

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
Functional Unit	*The functional unit (FU) for this study is "one ton raw beef meat packaged, delivered and cooked" (see questions below), with an alternative FU for comparative assertions based on protein content ("amount of beef, chicken and pork required to provide 50 grams of protein to the end user"). The alternative FU is established because it is stated that comparing between types of meat "cannot be made on a one-to-one basis since a kg of chicken does not have the same functional equivalency to a kg of beef" (pg. 7).* *The scope of the study may be sufficient to provide results on a per-kg of meat and per-kg of protein basis for beef, which may be used internally by the industry for comparison purposes. The study scope is not deemed to be sufficiently comprehensive to provide an ISO-compliant basis for comparative assertions to be disclosed to the public about the environmental or social preferability of beef in comparison with other sources of protein*	*The current study only includes the Canadian beef system within its scope, not the potential comparison systems. ISO 14044 (sec. 4.2.3.7) states that "the scope of the study shall be defined in such a way that the systems can be compared." Critical in making comparisons between systems is establishing their equivalence, which includes harmonizing functional units, system boundaries, data quality, allocation and more. ISO 14044 (sec. 4.2.3.7) indicates that "any differences between systems regarding these parameters be identified and reported."*	Agreed. Alternative FUs (based on protein content or nutritional index) will be removed and no public comparative assertions will be made in the study. No claims as to comparative assessments with other protein systems will be made. We will keep our primary FU ("one ton of raw meat, which is then packaged, delivered and consumed") which aligns well with the recently released LEAP large ruminant FU guidelines.
Functional unit	Having "raw" and "cooked" in the functional unit can be confusing.	Perhaps a modification which would add clarity would be "one ton of raw meat, which is then packaged, delivered, and cooked.	Agreed. FU description modified accordingly.

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Chapter/ Section	Question or proposed change	Comment (and where relevant, justification for suggested change)	Decisions/replies from the authors
Studied system	'The impact related to the use of growth promotants. The use of growth promotants (GP) has a direct impact on the number of days on feed, weight intakes, etc. Several studies have confirmed the effect of GP on the environmental impact of the beef industry.'	Not sure why one possible impact is highlighted here, a potentially positive one. If the document highlights possible impacts, it is best to mention potential negative ones like impacts of GP's on human health.	The effects of growth promotants (GPs) on environmental and human health have been in hot debate for years, particularly in North America and the European Union (EU). As yet, no consensus has been reached regarding the approach that should be adopted by countries and producers. We can however observe that, on one hand, the use of GPs in the cattle industry and imports of meat of cattle administered with GPs are banned in the EU—although the WTO found that this decision was not supported by scientific evidence. On the other hand, Canada, the US and other countries (e.g. Australia, New Zealand, Japan and South Africa) authorize their use. Numerous studies show the benefits of GPs in terms of enhanced daily gain, and this effect was tested in a sensitivity analysis. However, for lack of sound data to model the impacts on environment and human health of GPs or antibiotic and the development of super-resistant bacteria, these will not be assessed in the E-LCA. The limitation of our study on that matter will be mentioned.

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Chapter/ Section	Question or proposed change	Comment (and where relevant, justification for suggested change)	Decisions/replies from the authors
Studied systems	Studied Systems – bullet #1 East vs.West: "…extensive winter pasturing (…) is much more common in theWest."	A panelist is concerned about the terminology "winter pasturing". It may be a bit misleading since for many it may imply that animals are grazing. It may be more explanatory to be broaden this statement in order to include winter feeding of bales, silage, etc. that does occur out in a field or pasture. These animals are not in a pen or dry lot system but they aren't grazing either. Would using the terms "extensive winter grazing/feeding" capture the production practices more accurately? See also notes related to this topic within the Draft Scenario template.	Sentence modified accordingly/
Cut-off criteria	Sometimes pesticides or other chemical inputs are below the 2% mass threshold, but still have a significant environmental impact. The literature review results are used to identify where this is relevant so that appropriate inputs can be included in the study.	Good choice, makes the study credible.	
Studied systems	Will foreground feed unit process data be regionally specific?		Rations will be based on regional specificities (e.g. rations include more barley in the West vs more corn in the East).
	Regarding feed scenarios: where will the data for the numerous feed crops come from? As described, forage and grains vary widely geographically and temporally. Efforts are underway to develop feed data bases for LCAs and it would be good to describe where the present effort will obtain data from.		In the ELCA approach, Canadian specific models have been identified and obtained from the Agriculture office of the government of Alberta. For feed that would not have been covered by Canadian studies, we will use best available LCIs from other databases (e.g. agri-footprint) and adapt key assumptions, such as fertilization and yields, to the LCIs of Canadian farming practices.
	The Allocation issue is among the most difficult and controversial ones within the LCA work. However, the text provided is too vague and simply extracted from ISO. More specificity is required.		Yes, it will be in the final report, with a dedicated chapter.

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Chapter/ Section	Question or proposed change	Comment (and where relevant, justification for suggested change)	Decisions/replies from the authors
Allocation	How does allocation apply for the social LCA?	It is best to be clear on this point.	There is no allocation in social LCA, as there is no “quantity of social impacts” and no ranking between these impacts. In the case of multifunctional process/steps, a mention will be added if an impact also affects other production streams. This will be further explained in the social LCA methodological choices.
Sensitivity and scenario modelling			
	List of parameters – bullet #3 “cattle feed composition”	We interpret this to mean different feed sources utilized within the animals’ ration, and wonder if there is an opportunity to add the grazing parameter. Considering different types of forage species that may be grazed (tame vs native) and grazing management strategies (i.e., rotational grazing), each has different environmental impacts (biodiversity, carbon capture, reducing soil degradation, etc.). While these are not easy to measure and data may be a bit challenging to find, environmental impacts are significantly different depending on the forage/grazing/pasture management scenarios. Something to consider. This has also been discussed within the Draft Scenario template comments.	As the LCA results will be known, we will be able to identify the hotspots in the life cycle of beef production. These hotspots will determine which parameter should be investigated in the sensitivity analyses. Grazing environmental impacts—based on forage species and grazing management practices—are indeed hard to measure at a national scale as relevant data sources are usually not available. Our study will thus not be able to differentiate quantitatively between the environmental impacts of those forage/grazing/pasture management scenarios, although this limitation will be pointed out in the study and indicated as an area that could warrant subsequent research.

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Chapter/ Section	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
	Why not include the impact of different breeds as sensitivity analyzes? You list 3 broad types in the scenarios document on pg. 7.	Genetic variations among cattle breeds would have different performance characteristics and potentially cut-outs. This may be particularly important for the baseline scenario that includes more grassing.	While genetic variation among cattle breeds has an impact on some performance characteristics, it was difficult to trace that factor across all levels of the value chain (cow/calf, backgrounding, feedlot, packers). As a consequence, no information on the genetic variation of cattle was requested in the farmers' survey and this aspect will not be covered in the study. This will be indicated as a limitation of the study and an area of potential further investigation.
	What are the on farm by-products that need to be allocated between beef and by-product?		Blood is one example of by-product. See third paragraph of the section "System boundaries: Environmental assessment"
Environmental data categories	Environmental data categories bullet #1 – "raw materials"	Can "raw materials" be defined more clearly? It is not clear what this category includes.	Raw materials include feeding material (hay, grass, grains, etc.). The definition will be included in the report.
Data categories, requirements and quality requirements			

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Chapter/ Section	Question or proposed change	Comment (and where relevant, justification for suggested change)	Decisions/replies from the authors
	Where will this data come from?	It is unclear from where Canada- or even region within Canada specific data will be gathered.	Primary data have been collected from a random sample of farmers. Over 70 farming operations responded, providing comprehensive information on their activities. For processing operations, we have obtained the support from the main organization in Canada, which represents over 90% of the market. Generic information was collected from several sources, including Agriculture Canada, Statistics Canada, Agricultural Census, provincial agricultural departments, producers organizations (e.g. CCA), etc.
Data Requirements	Data Requirements paragraph #2, last sentence “models for crops cultivation……representative of the crops used to feed Canadian beef cattle.”	More for interest sake but just confirming that forage/grazing data will be sourced as well?	Indeed, forage and grazing data have been collected.
Inventory analysis	Will you be estimating P emissions?	This is an important pollutant for livestock systems, particularly around manure management and feed crop production.	P emissions will be estimated.
Data requirements	‘For instance, models for crops cultivation will be tailored to consider inputs (e.g. pesticides, fertilizers) and outputs (e.g. yields) representative of the crops used to feed Canadian beef cattle.’	The literature suggests that most feed is sourced out of country for most countries, although this may not be the case for Canada. If it is the case for Canada, then this LCA should include all environmental and social impacts of the cultivation and transport of that feed in those countries. If this section implies this is included, it is best to make this clear. This comment also applies to any other part of the LCA that sources inputs outside of Canada (like veterinary inputs, others)	From the 70 farming operations surveyed, none sourced their feed outside Canada, regardless of the crop/feed considered or the type of operation. In most cases, feed is sourced locally or in the closest province.

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Chapter/ Section	Question or proposed change	Comment (and where relevant, justification for suggested change)	Decisions/replies from the authors
Inventory analysis	"Water" is listed as an inventory item. Is this blue water only?		The purpose will be to have the blue water footprint of the functional unit. Green water is considered indirectly (lower need for blue water for instance), and grey water is not taken into account given that existing assessment methods are debatable. However, this partial water footprint is complemented with a risk assessment to consider local availability/scarcity (see "preliminary response to the panel")
	Under Inventory Analysis, "Water" is listed. Does this refer to water use by cattle or impact of cattle on surface or ground water?		In this chapter, water refers to water flow. This means we are considering all water inputs and outputs of the considered system, in particular water consumed by animals, water used to grow crops and water used by packers.

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Chapter/ Section	Question or proposed change	Comment (and where relevant, justification for suggested change)	Decisions/replies from the authors
Life cycle impact assessment			
Environmental assessment	We are glad to see you are including biodiversity. Has the metric been validated? What is the source here?		The approach for biodiversity assessment has been finalized and validated by a committee of experts and we'll leverage the Wildlife Habitat Capacity on Farmland Indicator, developed by Agriculture Canada. A detailed methodology document is being developed and will be available for your review in the final report.
Environmental assessment	What about all of the knock-on effects of these impacts on environmental systems? Does this LCA stop at just primary impacts and does not assess secondary impacts?		See our response above. Knock-on effects are beyond the scope of this study.
Socio-economic assessment	Same comment as above, except for social impacts		Same response.
Missing section	At the end, it would be useful to add a section on recommendations for further work on the LCA of the beef industry to give CCA guidance for the future.		Good point. We will incorporate this section.

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6.3 ELCA—List of publications included in the literature review

Authors	Date	Title	Journal / publication
Avery et al & Koneswaran et al (respond)	2008	Beef production and greenhouse gas emissions	Environmental Health Perspectives
Basarab et al	2012	Greenhouse Gas Emissions from Calf- and Yearling-Fed Beef Production Systems, With and Without the Use of Growth Promotants	Animals
BASF	2013	More sustainable beef optimization project	Report
Beauchemin et al	2011	Mitigation of greenhouse gas emissions from beef production in Western Canada—Evaluation using farm-based life cycle assessment	Animal Feed Science and Technology
Beauchemin et al	2010	Life cycle assessment of greenhouse gas emissions from beef production in Western Canada: A case study	Agricultural Systems
Capper	2012	Is the Grass Always Greener? Comparing the Environmental Impact of Conventional, Natural and Grass-Fed Beef Production Systems	Animals
Capper	2011	The Carbon Footprint of Beef Production	64th Reciprocal Meat Conference
Capper	2011	Comparing the environmental impact of the US beef industry in 1977 to 2007	Journal of Animal Science
Casey and Holden	2006	Greenhouse Gas Emissions from Conventional, Agri-Environmental Scheme, and Organic Irish Suckler-Beef Units	Journal of Environmental Quality
Casey and Holden	2006	Quantification of GHG emissions from sucker-beef production in Ireland	Agricultural Systems
Casey, J.W., Holden, N.M.,	2006	Quantification of GHG emissions from suckler-beef production in Ireland. Agricultural Systems 90, 79–98	Article—Publication
Cederberg and Stadig	2003	System expansion and allocation in life cycle assessment of milk and beef production	Int. Journal of LCA
Cederberg et al	2009	Life cycle inventory of greenhouse gas emissions and use of land and energy in Brazilian beef production	Report
Cederberg, C., Darelius, K.,	2002	Using LCA methodology to assess the potential environmental impact of intensive beef and pork production (PhD Thesis)	PhD Thesis
Chai, L.L., Kröbel, R., Janzen, H.H., Beauchemin, K.A., McGinn, S.M., Bittman, S., Atia, A., et Edeogu, I.	2013	A mass balance model based on total ammoniacal nitrogen for estimating ammonia volatilization from beef cattle manure management in Alberta in Canada.	ASABE Annual International Meeting, Kansas City, MO, USA, July 21-24, 2013, paper #:1596572
Chassot et. Al	2005	Life cycle assessment (LCA) of two beef production systems	Poster Agroscope
Conestoga-Rovers & Associates	2010	Evaluating environmental and economic impact for beef production in Alberta using life cycle analysis	Report
FAO	2010	Greenhouse Gas Emissions from the Dairy Sector	Report

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Authors	Date	Title	Journal / publication
J. Capper	2012	Carbon Footprint of Beef Cattle	Sustainability
Koch et al	2014	Agribalyse - Rapport méthodologique / fiche de synthèse bœuf	Report
Kröbel, R., Janzen, H.H., Beauchemin, K.A., Bonesmo, H., Little, S.M., et McAllister, T.A.	2013	A proposed approach to estimate and reduce the environmental impact from whole farms.	Acta Agriculturae Scandinavica, Section A - Animal Science
McGeough, E. J., S. M. Little, H. H. Janzen, T. A. McAllister, S. M. McGinn, and K. A. Beauchemin.	2012	Life cycle assessment of greenhouse gas emissions from dairy production in Eastern Canada: A case study	Journal of Dairy Science, 95:5164-5175
Mekonnen and Hoeskstra	2012	A global assessment of the water footprint of farm animal products	Ecosystems
Núñez et al.	2005	Comparative life cycle assessment of beef, pork and ostrich meat: a critical point of view	International Journal of Agricultural Resources, Governance and Ecology
Ogino et al	2004	Environmental impacts of the Japanese beef-fattening system with different feeding lengths as evaluated by a life cycle assessment method	Journal of Animal Science
Ogino et al	2007	Evaluating environmental impacts of the Japanese beef cow/calf system by the life cycle assessment method	Animal Science Journal
Pelletier et al	2010	Comparative life cycle environmental impacts of three beef production strategies in the upper Midwestern United States	Agricultural Systems
Pierre Gerber	2013	Greenhouse gas emissions from ruminant supply chains—a global life cycle assessment	FAO
Quantis	2012	Environmental and socioeconomic LCA of Canadian milk	Dairy Farmers of Canada
Ridoutt et al.	2011	Comparing Carbon and Water Footprints for Beef Cattle Production in Southern Australia	Sustainability
Stewart, A.A. S.M. Little, K.H. Ominski, K.M. Wittenberg and H.H. Janzen.	2009	Evaluating greenhouse gas mitigation practices in livestock systems: an illustration using the whole-farm approach	Journal of Agricultural Science 147: 367-382
Ulf Sonesson, Christel Cederberg and Maria Berglund	2009	Greenhouse gas emissions in beef production	Report
Vergé et al	2008	Greenhouse gas emissions from the Canadian beef industry	Agricultural Systems
Vergé et al	2007	Greenhouse gas emissions from the Canadian Dairy Industry during 2001	Agricultural Systems
Vries et al.	2010	Comparing environmental impacts for livestock products: A review of life cycle assessments	Livestock science
Williams, A.G., Audsley, E., Sandars, D.L.,	2006	Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report Defra Research Project ISO205, Bedford: Cranfield University and Defra	Defra Report

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6.4 ELCA—Survey templates (cattle operations and meat processors)

Welcome

On behalf of the Canadian Cattlemen's Association and the Canadian Roundtable for Sustainable Beef, thank you for agreeing to take part in our survey.

The Canadian Roundtable for Sustainable Beef is conducting a Sustainability Assessment on all three pillars of sustainability - environment, social and economic. This study will enhance our ability to communicate to consumers domestically and internationally about the environmental and social benefits of Canada's beef industry. It will also inform stakeholders about what areas require additional research and focus. Hotspots and threats to the industry will be identified and a strategy developed to monitor progress and communicate how industry is addressing consumer concerns.

There are questions included in this survey that are in other surveys (e.g. the Agriculture Census) this allows us to use the results from those surveys in this study by providing a connecting benchmark between the two data sets that tell us how they relate.

Confidentiality

The complete form will be submitted directly to Deloitte. The data reported in it will not be shared by Deloitte with any other individual or entity and will be only used for this study.
The results from the survey will validate information collected from a literature review. Individual operation information will NOT be identifiable in the final results as it will be aggregated. Ranges for certain questions will be used for sensitivity testing within the Life Cycle model to determine the robustness of the results.

Instructions

The survey has two components. The environmental stream relates to production activities with emphasis on energy and natural resources consumption. The socioeconomic stream, which will be shared with you at a secondary stage, relates to the number of employees, animal welfare practices, and food safety.

Please fill out as much as possible and skip when you have no data. If the units do not apply, please ensure that you specify the unit that you use.

This data collection workbook contains several tabs which are listed in this index. Please fill in the appropriate sections that apply to your operation. For example, if you are solely a feedlot operator you may skip section E2. Or if you are a cow/calf operator who retains ownership of calves, please complete all sections. Also fill out section E5 if you grow feed.

You can click on the links at the top OR the tabs at the bottom of the excel worksheet to access each section.

You may need to click on the yellow bar at the top to "Enable Editing" before starting.

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Should you need any help for the data collection, please do not hesitate to contact:
Fawn Jackson (jacksonf@cattle.ca / (403) 275-8558) or Brenna Grant (grantb@canfax.ca / (403) 275-8558)
Christophe Ménigault (cmenigault@deloitte.ca / (514) 393- 8495) or Maeva Charles (macharles@deloitte.ca / (514) 393-6216)

Thank you again for your contribution.

Best regards,

Canadian Cattlmen's Association, the Canadian Roundtable for Sustainable Beef & Deloitte Sustainability Team

Contact information of the respondent:

Name	
Zip code (at your operation)	
Email address*:	
I authorize Deloitte and CCA to mention my name in the final report's list of contributors (Yes/No)	

** Your contact information will allow us to get in touch should we have questions about the information submitted and better understand the context of your operations, if needed.*

Contact details to return the survey:

By e-mail at: cmenigault@deloitte.ca
By fax at: 514 390 4115 "to the intention of Christophe Menigault"
By mail:
To the intention of Christophe Menigault
Deloitte
1, Place Ville Marie bureau 3000
Montréal QC, H3B 4T9
Canada

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Index	E1. General information	E2. Cow - calf	E3. Back-grounding	E4. Finishing	E5. Feed production

Environmental assessment – General information

Please fill out all light yellow cells and checkboxes
To the extent possible, only data relative to beef or forage production should be included.
Please note that, unless otherwise stated, data and information should be based on calendar year 2013.

Definitions:
- Beef production includes all activities linked to cattle raising on the farm whether done by you/your workers or a third-party (e.g. manure management, equipment use and maintenance, pen cleaning, etc.)
- A calf from birth to weaning
- Backgrounder from weaning until placed in a finishing lot or go to grass
- Yearling grasser from time placed on grass until placed into a finishing lot

a) Farm operations

Operations	Yes/No
Cow/calf	
Backgrounding	
Yearling grasser	
Finishing (conventional)	

Land, resources and energy consumption	Unit	Answer	Comment
Land surface dedicated to grazing (native grassland)	acres		
Land surface dedicated to grazing (tame grassland)	acres		
Land surface dedicated to farming for forage production	acres		
Total land use (including lease, rented land, and forestry permits for grazing), *excluding cash crop*	acres		
Electricity consumption dedicated to beef production	kWh / year		If not available, please provide estimates/total consumption
Natural gas consumption dedicated to beef production	cf/ year		If not available, please provide estimates/total consumption
Diesel consumption dedicated beef production	Liters / year		If not available, please provide estimates/total consumption
Gasoline consumption dedicated to beef production	Liters / year		If not available, please provide estimates/total consumption
Water source: please indicate how many days animals drink from each source			
Tap water	# of days		
River/stream water	# of days		
Lake water *(including dugouts)*	# of days		
Ground water *(wells)*	# of days		
Snow	# of days		
Other? - Please specify in comments	# of days		

Ouputs	Unit	Answer	Comment
Where does waste water go? e.g. filters into ground, flows into streams, flows into catch basin/ lagoon/ dugout	-		
Volume of water discharged annually? E.g. wash water (barn, equipment, farming implement, etc.)	m3 / year		
Others? Please specify units			

b) Feed source

Feed	On farm	Purchased feed			
	On farm production Share (%)	Share of purchased feed (%)	Origin of purchased feed (province or country)	If Canadian, average distance from supplier (km)	Comment
Forages					
Hay					
Green feed					
Corn silage					
Barley silage					
Grass silage					
Straw					
Others?					
Energy supplement					
Wheat					
Corn					
Barley					
Others?					
Protein supplement					
Soy meal					
Canola meal					
Dried distiller grain					
Screening pellets					
Others?					

c) Manure management

Manure management	Unit	Answer	Comment
How is solid manure stored? E.g. barn, bedding pack, storage vessel, outside manure pack, outside piles, use of an impermeable pad, coverage of the piles/packs, no storage facilities			
Manure stored	tonnes / year		If known.
Duration of storage for solid manure	days / year		

Manure handling	Unit	Answer	Comment
Manure application			
Solid manure applied to fields within your farm (other than natural spreading by cows)	tonnes		
How is manure runoff managed? E.g. Buffer zones, rotating pastures, rangeland, fencing, lagoons, wetland, no runoff potential, none			
Manure processing			
Manure used for anaerobic digestion	tonnes		
Energy produced	kWh		
Manure transfer			
Manure transfered out of the farm (e.g. neighboring farm, hauling service, etc.)	tonnes		

Environmental assessment – Cow-Calf

Please fill out all light yellow cells and checkboxes
To the extent possible, only data relative to beef or forage production should be included.
Please note that, unless otherwise stated, data and information should be based on calendar year 2013.

Definitions:
- A calf from birth to weaning
- Backgrounder from weaning until placed in a finishing lot or go to grass
- Yearling grasser from time placed on grass until placed into a finishing lot

a) Livestock management

Data	Unit	Answer	Comments
Livestock			
Corral surface area	acres		
Number of calves	# of head / year		
Number of yearlings	# of head / year		
Number of cows	# of head / year		
Number of bulls used	# of head / year		
Average Cow culling rate	%		
Calving period (month first calf was born to month last calf was born)	Month-Month		
Post-Weaning			
Age of calves at weaning	months		
Average calf weight at weaning	lb		
% of calves sold or kept for backgrounding	%		
% of calves sold or kept for finishing	%		
% of calves with destination unknown (e.g. if went to auction market)	%		
Age of yearlings at sale	months		
Average yearling weight at sale	lb		
Other Sales			
Number of bulls sold for breeding	units		
Number of bred heifers sold	units		
Number of bred cows sold	units		
Average age of cull cows at sale	years		
Average cow weight at sale	lb		
Age of bulls at sale	years		
Average bull weight at sale	lb		

b) Feeding practices

Feed	Unit	Calves	Yearlings	Cows	Bulls	Or Total	Comments
Forages							
Total number of grazing days	# of days						
Number of days of extended grazing - bale grazing	# of days						
Number of days of extended grazing - swath grazing	# of days						
Number of days of extended grazing - stockpiled grazing	# of days						
Grazing period	e.g. May-December						
Grass (Native)	% of total diet/year						
Grass (Tame)	% of total diet/year						
Hay	lb / year / head						
Corn silage	lb / year / head						
Barley silage	lb / year / head						
Grass silage	lb / year / head						
Straw (for feed)	lb / year / head						
Others?	lb / year / head						
Energy supplement							
Wheat	lb / year / head						
Corn	lb / year / head						
Barley	lb / year / head						
Others?	lb / year / head						
Protein supplement							
Soy meal	lb / year / head						
Canola meal	lb / year / head						
Dried distiller grains	lb / year / head						
Others?	lb / year / head						

c) Sanitary and veterinary products

Data	Unit						
	Unit	*Calves*	*Yearlings*	*Cows*	*Bulls*	*Other*	*Comments*
Number of sick animals treated per year	#						
Mortality rate	%						
Vaccines	*Unit*	*Calves*	*Yearlings*	*Cows*	*Bulls*	*Other*	*Comments*
What percentage of your cattle are vaccinated?	%						
Antimicrobial	*Unit*	*Calves*	*Yearlings*	*Cows*	*Bulls*	*Other*	*Comments*
What percentage of your cattle are treated with anti-microbials?	%						
Other veterinary products	*Unit*	*Calves*	*Yearlings*	*Cows*	*Bulls*	*Other*	*Comments*
What percentage of your cattle are treated with other veterinary products (e.g. Xylazine, Lidocaine, Ketropofen, Flunixin/Banamine, Metacam, Parasticides, other)? Please specify product name in comments.	%						
Growth Efficiency Technology (GET)	*Unit*	*Calves*	*Yearlings*	*Cows*	*Bulls*	*Other*	*Comments*
What percentage of your cattle do you implant/feed with natural hormone-based products?	%						
What percentage of your cattle do you implant/feed with synthetic hormone-based products?	%						
What percentage of your cattle receive feed additives?	%						
Bedding material	*Unit*	*Calves*	*Yearlings*	*Cows*	*Bulls*	*Other*	*Comments*
Straw (for bed)	tons/ year						
Wood chips	tons/ year						
Other litter materials ? *Specify type in comments*	tons/ year						

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Environmental assessment – Backgrounding

Please fill out all light yellow cells and checkboxes
To the extent possible, only data relative to beef or forage production should be included.
Please note that, unless otherwise stated, data and information should be based on calendar year 2013.

*** If you already have provided data related to yearling grassers in the E2. Cow/Calf section and when applicable, please do not double count in this section (e.g. number of grazing days).**

Definitions:
- A calf from birth to weaning
- Backgrounder from weaning until placed in a finishing lot or go to grass
- Yearling grasser from time placed on grass until placed into a finishing lot

a) General

Data	Unit	Heifers	Steers	Comments
Number of calves backgrounded	# of head			
Number of days of backgrounding	days			
Average weight of animal entering backgrounding	lb			
Average weight of animal exiting backgrounding	lb			
Percentage of backgrounded cattle sent to grass as yearlings	%			
Percentage of backgrounded cattle sent to finishing lot	%			
Corral surface area (if not already accounted for in E2. cow/calf)	acres			
Total feedlot capacity	# of head			
Total length of bunk	ft			

b) Feeding practices

Feed	Unit	Heifers	Steers	Comments
Forage				
Calves backgrounded on pasture	%			
Total number of grazing days (for calves backgrounded on pasture)	days			in cow calf section
Number of days of extended grazing - bale grazing	days			
Number of days of extended grazing - swath grazing	days			
Number of days of extended grazing - stockpiled grazing	days			
Grazing period	Range e.g. May-December			
Grass (Native or Tame)	% of total diet/year?			
Backgrounding period in pens	Range e.g. December-March			
Hay (as fed)	lb / head / day			
Corn silage (as fed)	lb / head / day			
Barley silage (as fed)	lb / head / day			
Grass silage (as fed)	lb / head / day			
Straw (as fed)	lb / head / day			
Others? (as fed)	lb / head / day			
Energy supplement (as fed)				
Wheat	lb / head / day			
Corn	lb / head / day			
Barley	lb / head / day			
Others?	lb / head / day			
Protein supplement (as fed)				
Soy meal	lb / head / day			
Canola meal	lb / head / day			
Dried distiller grains	lb / head / day			
Others?	lb / head / day			

c) Sanitary and Veterinary products

Data	Unit				
	Unit	***Calves***	***Yearlings***	***Other***	***Comments***
Number of sick animals treated per year	#				
Mortality rate	%				
Vaccines	***Unit***	***Calves***	***Yearlings***	***Other***	***Comments***
What percentage of your cattle are vaccinated?	%				
Antimicrobial	***Unit***	***Calves***	***Yearlings***	***Other***	***Comments***
What percentage of your cattle are treated with anti-microbials?	%				
Other veterinary products	***Unit***	***Calves***	***Yearlings***	***Other***	***Comments***
What percentage of your cattle is treated with other veterinary products (e.g. Xylazine, Lidocaine, Ketropofen, Flunixin/Banamine, Metacam, Parasticides, other)? Please specify product name in comments.	%				
Growth Efficiency Technology (GET)	***Unit***	***Calves***	***Yearlings***	***Other***	***Comments***
What percentage of your cattle do you implant/feed with natural hormone-based products?	%				
What percentage of your cattle do you implant/feed with synthetic hormone-based products?	%				
What percentage of your cattle receive feed additives?	%				
Bedding material	***Unit***	***Calves***	***Yearlings***	***Other***	***Comments***
Straw	tons/ year				
Wood chips	tons/ year				
Other litter materials ? *Specify type in comments*	tons/ year				

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Environmental assessment – Finishing

Please fill out all light yellow cells and checkboxes
To the extent possible, only data relative to beef or forage production should be included.
Please note that, unless otherwise stated, data and information should be based on calendar year 2013.

Definitions:
- A calf from birth to weaning
- Backgrounder from weaning until placed in a finishing lot or go to grass
- Yearling grasser from time placed on grass until placed into a finishing lot

a) General

Data	Unit	Heifers	Steers	Comment
Number of calves	# of head			
Number of yearlings	# of head			
Corral surface area (if not already accounted for in E2. cow/calf or E3. Backgrounding)	acres			
Total feedlot capacity	# of head			
Total length of bunk	feet			

b) Conventional finishing

Data	Unit	Heifers	Steers	Comment
Livestock				
Average weight entering the feedlot	lb			
Average weight exiting the feedlot	lb			
Number of days on feed	days			

Data	Unit	Heifers	Steers	Comment
Forages (as fed)				
Hay	lb / head / day			
Corn silage	lb / head / day			
Barley silage	lb / head / day			
Grass silage	lb / head / day			
Straw	lb / head / day			
Others?	lb / head / day			
Energy supplement (as fed)				
Wheat	lb / head / day			
Corn	lb / head / day			
Barley	lb / head / day			
Others?	lb / head / day			
Protein supplement (as fed)				
Soy meal	lb / head / day			
Canola meal	lb / head / day			
Dried distiller grains	lb / head / day			
Others?	lb / head / day			

c) Sanitary and Veterinary products

Data	Unit				
	Unit	*Calves*	*Yearlings*	*Other*	*Comments*
Number of sick animals treated per year	#				
Mortality rate	%				
Vaccines	*Unit*	*Calves*	*Yearlings*	*Other*	*Comments*
What percentage of your cattle are vaccinated?	%				
Antimicrobial	*Unit*	*Calves*	*Yearlings*	*Other*	*Comments*
What percentage of your cattle are treated with anti-microbials?	%				
Other veterinary products	*Unit*	*Calves*	*Yearlings*	*Other*	*Comments*
What percentage of your cattle are treated with other veterinary products (e.g. Xylazine, Lidocaine, Ketropofen, Flunixin/Banamine, Metacam, Parasticides, other)? Please specify product name in comments.	%				
Growth Efficiency Technology (GET)	*Unit*	*Calves*	*Yearlings*	*Other*	*Comments*
What percentage of your cattle do you implant/feed with natural hormone-based products?	%				
What percentage of your cattle do you implant/feed with synthetic hormone-based products?	%				
What percentage of your cattle receive beta agonists?	%				
What percentage of your cattle receive feed additives?	%				
Bedding material	*Unit*	*Calves*	*Yearlings*	*Others?*	*Comments*
Straw	tons/ year				
Wood chips	tons/ year				
Other litter materials ? *Specify type in comments*	tons/ year				

Index | E1. General information | E2. Cow - calf | E3. Back-grounding | E4. Finishing | E5. Feed production

Environmental assessment – Feed production

Please fill out all light yellow cells and checkboxes
To the extent possible, only data relative to beef or forage production should be included.
Please note that, unless otherwise stated, data and information should be based on calendar year 2013.

a) General

Inputs	Unit	Answer	Comment
Diesel consumption for cultivation (if not already accounted for in E1. General)	Liters / year		If not available, please provide an estimate.
Water for irrigation of feed crops (excluding cash crops)	m3 / year		If not available, please provide an estimate.
Water/stream origin for irrigation (if known)			
River water	%		
Lake water	%		
Ground water	%		
Other - specify type in comments	%		

Please list in the table below all feed crops GROWN AND USED on the farm (excluding cash crops).
Provide information in the tables below for the main three ones.

Crops on farm

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b) Crop 1 (as entered in the table above)

Data	Unit	Answer	Comment
General			
Dedicated surface	acres / year		
Yield	t / acre / year		Please indicate unit used
Straw yield	t / acre / year		if known
Moisture content at harvest	%		
Seed			
Seeding rate	lb / acre / year		
Distance from seed supplier	km		
Organic fertilisation			
Exportable residues (straw or chaff) left on field	Yes/ No		
Manure spread	t / acre / year		
Moisture content of manure spread	%		
Other - *specify type in comments*	lb / acre / year		
Average distance from supplier	km		
Mineral fertilisation			
Nitrogen mineral supply	lb N / acre / year		Urea
Phosphorus mineral supply	lb P / acre / year		precise type of P fertiliser (triplesuperphosphate, etc.)
Potassium mineral supply	lb K / acre / year		precise type of K fertiliser (Potassium chloride, etc.)
Sulfur mineral supply	lb S / acre / year		precise type of S fertiliser
Others?	lb / acre / year		to be precised
Average distance from supplier	km		
Herbicides, Pesticides, and Fungicides Used (if average available, please provide for higher representativity)			
	litres/acre		Name of product to be specified
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
Water			
Water for irrigation	m3 / acre / year		If not available, please provide an estimate.
Farming practices			
Conventional tillage	% of acres		
No-till	% of acres		
Variable technologies	Yes / No		
GPS	Yes / No		
Other - *Please specify type in comments*			

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c) Crop 2 (as entered in the table above)

Data	Unit	Answer	Comment
General			
Dedicated surface	acres / year		
Yield	t / acre / year		Please indicate unit used
Straw yield	t / acre / year		if known
Moisture content at harvest	%		
Seeds			
Seeding rate	lb / acre / year		
Distance from seed supplier	km		
Organic fertilisation			
Exportable residues (straw or chaff) left on field	Yes/ No		
Manure spread	t / acre / year		
Moisture content of manure spread	%		
Other - *Please specify type in comments*	lb / acre / year		Please specify
Average distance from supplier	km		
Mineral fertilisation			
Nitrogen mineral supply	lb N / acre / year		precise type of N fertiliser (urea, ammonitrate, monoammonium phosphate, etc.)
Phosphorus mineral supply	lb P / acre / year		precise type of P fertiliser (triplesuperphosphate, etc.)
Potassium mineral supply	lb K / acre / year		precise type of K fertiliser (Potassium chloride, etc.)
Sulfur mineral supply	lb S / acre / year		precise type of S fertiliser
Others?	lb / acre / year		to be precised
Average distance from supplier	km		
Herbicides, Pesticides, and Fungicides Used			
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
Water			
Water for irrigation	m3 / acre / year		If not available, please provide an estimate.
Farming practices			
Conventional tillage	% of acres		
No-till	% of acres		
Variable technologies	Yes / No		
GPS	Yes / No		
Other - *Please specify type in comments*			

d) Crop 3 (as entered in the table above)

Data	Unit	Answer	Comment
General			
Dedicated surface	acres / year		
Yield	t / acre / year		Please indicate unit used
Straw yield	t / acre / year		if known
Moisture content at harvest	%		
Seed			
Seeding rate	lb / acre / year		
Distance from seed supplier	km		
Organic fertilisation			
Exportable residues (straw or chaff) left on field	Yes/ No		
Manure spread	t / acre / year		
Moisture content of manure spread	%		
Other - *Please specify type in comments*	lb / acre / year		Please specify
Average distance from supplier	km		
Mineral fertilisation			
Nitrogen mineral supply	lb N / acre / year		precise type of N fertiliser (urea, ammonitrate, monoammonium phosphate, etc.)
Phosphorus mineral supply	lb P / acre / year		precise type of P fertiliser (triplesuperphosphate, etc.)
Potassium mineral supply	lb K / acre / year		precise type of K fertiliser (Potassium chloride, etc.)
Sulfur mineral supply	lb S / acre / year		precise type of S fertiliser
Others?	lb / acre / year		to be precised
Average distance from supplier	km		
Herbicides, Pesticides, and Fungicides Used			
	litres/acre		Name of product to be specified
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
	litres/acre		
Water			
Water for irrigation	m3 / acre / year		If not available, please provide an estimate.
Farming practices			
Conventional tillage	% of acres		
No-till	% of acres		
Variable technologies	Yes / No		
GPS	Yes / No		
Other - *Please specify type in comments*			

Welcome

On behalf of the Canadian Cattlemen's Association and the Canadian Roundtable for Sustainable Beef, thank you

The purpose of this study is to generate information on the environmental and socioeconomic impacts of the Canadian beef industry. Ultimately, this information should enhance our ability to communicate to Canadians and our international trading partners on the environmental and social benefits of Canada's beef industry. This information will also be used to better inform all stakeholders about what areas require additional research and focus.

What do we need?

The survey is essentially divided into two components. The first will obtain environmental data relating to your production activities with emphasis on energy and natural resources consumption. The second component is designed around socioeconomic questions, such as, the size of your operation, number of employees, animal welfare, and food safety. These two sections will then be combined to provide factual data relating to environmental and socioeconomic issues pertaining to beef production in Canada.

Should you need any help for the data collection, please do not hesitate to contact Christophe Ménigault (cmenigault@deloitte.ca / 514-393- 8495) or Maeva Charles (macharles@deloitte.ca / 514-393-6216) for any additional information.

This form is to be handled and viewed only by CCA and Deloitte personnnel. The data reported in it will not be shared by Deloitte with any other individual or entity. None of the information will be individually identifiable as it will be aggregated and used in the Sustainability model.

Thank you again for your contribution.

Best regards,

Canadian Cattlmen's Association, the Canadian Roundtable for Sustainable Beef &
Deloitte Sustainability Team

A. Environmental assessment

Please fill out yellow cells. When available, data sources to be mentioned in comments.
If no precise data is availabe, please specify in the comments where estimates have been provided.
Please note that unless otherwise stated, data and information should be based on year 2013.

Meat production	Unit	Calves	Yearling-Fed	Cull Cows	Bulls	Comment
Nb of heads slaughtered per year	heads / year					
Average dressing rate	lb					
Annual meat production	tonnes / year					
Main buyers of meat products	tonnes / year					
Export sales	tonnes / year					

Consumptions	Unit	Value	Comment
Energy			
Electricity consumption	kWh / year		
Of which (if known):			
Electricity from renewable energy	%		Type of renewable energy to be precised
Locally produced electricity	%		
Natural gas consumption	kWh / year		
Heavy fuel oil consumption	Liters / year		
Diesel consumption	Liters / year		
Renewable energy (except. Electricity)	kWh / year		Type to be precised (lines to be added for each type of renewable energy)
Of which locally produced energy	%		Type to be precised (lines to be added for each type of renewable energy)
Water			
Water use	m3 / year		
Water origin (if known)			
River water	%		
Lake water	%		
Ground water	%		
Material (incl. Packaging material)			
Corrugated cardboard	tonnes / year		
PE film	tonnes / year		
Wood (pallet for instance)	tonnes / year		
	tonnes / year		type to be precised
	tonnes / year		type to be precised
	tonnes / year		type to be precised
Others?	tonnes / year		type to be precised
Miscellaneous			
Chemicals	Liters / year		Type and use (e.g. disinfection, cleaning) to be precised
Refrigerants	lb / year		Type to be precised
Others?			Type to be precised

By-products	Mass (tonnes / year)	Becoming	Selling price (if relevant)	Comment
Blood				
Offals				
Bones				
Skins and Leathers				
Others?				Type to be precised

Waste (incl. Ashes from local incineration)	Mass (tonnes / year)	Becoming	Comment
Ashes from local incineration			composition of the ashes to be precised
			Type to be precised
			Type to be precised
			Type to be precised
			Type to be precised

Other ouputs	Unit	Value	Comment
Waste water			
Waste water	m3 / year		
Waste water BOD	mg/L		if known
Waste water COD	mg/L		if known
Others?			Please precise any rejected waste water substance concentration known from incinerator for instance
Air emissions			
Others?			Type to be precised

6.5 ELCA—Selection of environmental impact indicators

To select the indicators to be included in the study, the level of uncertainty of the impact indicators as well as the recommendations from relevant standards were taken into account. Table 6.1 displays the outcomes of this analysis and the selected indicators for the study.

Table 6.1 Indicators selected in the study

Impact category	Indicator of potential impact	Units	Uncer-tainty[73]	What standards say on indicators for meat LCAs[74]		Indicators included in the study
				FAO—LEAP[75]	PCR *Meat of mammals*[76]	
Climate change	**Climate change**	kg CO_2 eq.	20%	1	1	☑
Resources consumption	**Fossil fuel depletion**	kg oil eq.	20%	1		☑
	Water depletion	liters	20%	1	2	☑
Air pollution	**Terrestrial acidification**	kg SO_2 eq.	20%	1	1	☑
	Photochemical oxidant formation	g NMVOC eq.	50%		1	☑
	Particulate matter formation	kg PM_{10} eq.	100%			☒
	Ozone depletion	mg CFC^{-11} eq.	20%			☒
Water pollution	**Marine eutrophication**	kg N eq.	50%	1		☑
	Freshwater eutrophication	g P eq.	50%	1	1	☑
Land use	**Agricultural land occupation**	m^2	20%	1	2	☑
Toxicity[77]	Human toxicity, non-cancer effects	CTUh	100%			☒
	Human toxicity, cancer effects	CTUh	100%			☒
	Freshwater ecotoxicity	CTUe	100%			☒
Solid waste	Solid waste	kg			2	☒

[73] Uncertainty values based on Deloitte's experience, taking the commonly observed values for each indicator
[74] 1 = recommended indicators; 2 = potential additional indicators
[75] LEAP guidelines on large ruminants also recommend the assessment of biodiversity change, assessment being included in our study in the chapter *Land related environmental impacts* (FAO, 2015)
[76] Product category rules: meat of mammals, developed in the framework of the International EPD® system operating in accordance with ISO 14025:2006. Available at: http://www.environdec.com/en/PCR/Detail/?Pcr=7842#.VkXVb3bRbq4
[77] Toxicity potential associated with beef meat production is mostly due to the release of heavy metals into the environment. As methods to assess toxicity potentials do not apply well to metals, we suggested not covering toxicity indicators in this study. Further work would be needed to address this issue.

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6.6 ELCA—Comparison of activity data with literature

Whether they were obtained from the survey or from generic sources, data were compared to existing data from other sources, and potential adjustments were made for significant gaps.

Animal stage durations

Animal stage	Stage duration (days)					Comments
	Sample average	Beauchemin (2010)	AARD (2010)	Basarab (2012)	Values used in the model	
Calves—weaning age	210	214	184	162.5	**231**	Average weaning age of 210 days plus 21 days for transition to next phase
Cows	365	365	365	365	**365**	
Bulls	365	365	365	365	**365**	
BG heifers	172.2	110	120	191	**120**	Survey values above the literature values. Figures lowered to 120 days (conservative value when comparing to literature)
BG steers	157.7	110	120	191	**120**	
Yearling heifers	213.3	129	120	95	**120**	
Yearling steers	179.6	129	120	95	**120**	
Finished heifers	185	170	213	141.5	**225 (Calf-fed) 150 (Yearling-fed)**	Adjustment of the finishing duration according to long or short fed practices
Finished steers	192	170	213	141.5		
Total calf-fed scenario	399.2	494	517	380	**456**	
Total yearling scenario	760.6		608	639	**621**	

Mortality rates

Animal stage	Mortality rates				Comments
	Sample average	AARD (2010)	WBDC (2014)	Values used in the model	
Calves	3.0%	3%	7%	**3.0%**	Survey number consistent with the CRA study, but lower than the WCCCS. Results would not vary significantly with the use of 3% or 7%.
Cows	0.9%	1%		**0.9%**	
Bulls	0.7%	1%		**0.7%**	
BG heifers	1.8%	2%		**1.8%**	
BG steers	1.7%	2%		**1.7%**	

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Yearling heifers	0.6%	1%		**0.6%**	
Yearling steers	0.6%	3%		**0.6%**	
Finishers	1.9%	1%		**1.9%**	

Animal weights

Animal stage	Animal end-weights (lb)						Comments
	Sample average	Beauche-min (2010)	AARD (2010)	Basarab (2012)	WBDC (2014)	Values used in the model	
Calves	543	528	500			**650 (calf-fed)** **450 (yearling-fed)**	
Cows	1,307	1,320	1,333	1,435	1,374	**1,381**	Sample average considered too low by experts; adjustment based on 2014 statistics of cow weights and average dressing rate
Bulls	1,773	1,804	2,195	1,909		**1,773**	
BG heifers	n.c.	770	600			**625**	Experts consulted to obtain these values
BG steers		770	600				
Yearling heifers						**890**	
Yearling steers							
Finishing heifers	1,324	1,334	1,350	1,358		**1,350**	Expert adjustment: 1,350 for the West, but 1,450 for the East calf-fed and 1,550 for the East long-yearling
Finishing steers	1,395	1,334	1,450.	1,358			

Energy use

Animal stage	Energy use			Comments
	Sample average	AARD (2010)	Values used in the model	
Electricity (kWh/day)	0.04	0.65	**0.04**	Our sample may have underestimated values, but energy consumption has a minor contribution to environmental
Natural Gas (m3/day)	0.0001	0.001	**0.0001**	
Diesel (litres/day)	0.02	0.2790	**0.02**	
Gasoline (litres/days)	0.003	0.0502	**0.003**	

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Waste Water (litres/day)	0.17		**0.17**	impacts.

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6.7 ELCA—Detailed methodological assumptions

6.7.1 Economic allocation

The following table details the distribution of impacts between meat and by-products following the economic allocation.

Table 6.2 Distribution of the environmental impacts between meat and by-products. Economic allocation values were obtained from surveyed packers.

Stage	Data	Unit	Animal
Live weight - Farm gate	Impact	kg eq. CO2 / kg LW	14.10
	Mass	kg LW	1.00

Stage	Data	Unit	Meat	By-products	Total
Carcass weight	Economic allocation (from live-weight)		95%	5%	
	Unitary Impact	kg eq. CO2 / kg by product	21.96	1.81	
	Mass	kg by-product	0.61	0.39	
	Total impact	kg eq. CO2 / amount of by product	13.40	0.71	14.10
		in % of total impact	0.95	0.05	1.00

Stage	Data	Unit	Meat	By-products	Total
Bone-free - Packers gate	Economic allocation (from live-weight)		90%	10%	
	Unitary Impact	kg eq. CO2 / kg by product	28.08	2.57	
	Mass	kg by-product	0.45	0.55	
	Total impact	kg eq. CO2 / amount of by product	12.69	1.41	14.10
		in % of total impact	0.90	0.10	1.00

6.7.2 Methane emissions from enteric fermentation

Thus, according to the IPCC guidelines (2006):

$$CH_{4enteric}\ rate = GE \times (Ym / 55.65) \times (1 - AR / 100)$$

Where:

- $CH_{4enteric}$ rate = methane enteric emissions (kg CH_4/head/day)
- GE = gross energy intake (MJ/head/day). Note that GEI = 18.45 x DMI. Data related to the DMI are calculated according to the diet provided to cattle
- Ym = methane conversion factor (see Table 6.3)
- 55.65 = energy content of CH_4 (MJ/kg CH_4)
- AR = additive reduction factor. By default AR = 0

.

Table 6.3 Dry matter intake (DMI) and methane conversion factor from enteric emissions ("Ym") obtained from Anele (2014) and Holos model

Animal type	Manure management	Gender	Region	Calculated DMI (kg/day)		Ym	
				Yearling-fed system	Calf-fed system	Yearling-fed system	Calf-fed system
Calves on grass	in pasture	M/F	East	2.55	3.54	0.06	0.06
			West	2.67	3.84	0.06	0.06
Calves on feed	deep bedding		East	4.35	6.44	0.07	0.07
			West	4.28	6.75	0.07	0.07
	solid storage		East	4.35	6.44	0.07	0.07
			West	4.28	6.75	0.07	0.07
	composting		East	4.35	6.44	0.07	0.07
			West	4.28	6.75	0.07	0.07
Backgrounders on grass	in pasture	M	East	5.62	-	0.07	-
			West	5.35	-	0.07	-
		F	East	5.62	-	0.07	-
			West	5.35	-	0.07	-
Backgrounders on feed	deep bedding	M	East	5.50	-	0.07	-
			West	5.25	-	0.07	-
		F	East	5.50	-	0.07	-
			West	5.25	-	0.07	-
	solid storage	M	East	5.50	-	0.07	-
			West	5.25	-	0.07	-
		F	East	5.50	-	0.07	-
			West	5.25	-	0.07	-
	composting	M	East	5.50	-	0.07	-
			West	5.25	-	0.07	-
		F	East	5.50	-	0.07	-
			West	5.25	-	0.07	-
Yearlings on grass	in pasture	M	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
		F	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
Yearlings on feed	deep bedding	M	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
		F	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
	solid storage	M	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
		F	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
	composting	M	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
		F	East	8.43	-	0.07	-
			West	7.73	-	0.07	-
Finishers on feed	deep bedding	M/F	East	10.88	8.40	0.03	0.03
		M	West	10.50	9.15	0.04	0.04
		F	West	10.50	9.15	0.04	0.04
Finishers - storage	solid storage	M/F	East	10.88	8.40	0.03	0.03
		M	West	10.50	9.15	0.04	0.04
		F	West	10.50	9.15	0.04	0.04
Finishers - composting	composting	M/F	East	10.88	8.40	0.03	0.03
		M	West	10.50	9.15	0.04	0.04
		F	West	10.50	9.15	0.04	0.04
Cows on grass	in pasture	F	East	12.00	12.00	0.07	0.07
			West	12.00	12.00	0.07	0.07
Cows on feed	deep bedding		East	12.00	12.00	0.07	0.07
			West	12.00	12.00	0.07	0.07
	solid storage		East	12.00	12.00	0.07	0.07
			West	12.00	12.00	0.07	0.07
	composting		East	12.00	12.00	0.07	0.07
			West	12.00	12.00	0.07	0.07
Bulls on grass	in pasture	M	East	18.00	18.00	0.07	0.07
			West	18.00	18.00	0.07	0.07
Bulls on feed	deep bedding		East	18.00	18.00	0.07	0.07
			West	18.00	18.00	0.07	0.07
	solid storage		East	18.00	18.00	0.07	0.07
			West	18.00	18.00	0.07	0.07
	composting		East	18.00	18.00	0.07	0.07
			West	18.00	18.00	0.07	0.07

Source: (US National Research Council, 2015; Little et al., 2008)

6.7.3 Manure-related emissions

Methane (CH_4) emissions

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According to the IPCC guidelines (2006):

$$CH_{4manure}\ rate = VS \times B_0 \times MCF \times 0.67$$

Where:

- $CH_{4manure}$ rate = methane emissions from manure (kg CH_4/head/day)
- VS = volatile solids excreted in manure (kg/head/day)
- B_0 = methane producing capacity (m^3 CH_4/kg VS). By default, the value of 0.19 is used (IPCC, 2006)
- MCF = methane conversion factor (see Table 6.4)
- 0.67 = conversion factor from volume to mass (kg/m^3)

Methane conversion factors are indicated below:

Table 6.4 Methane conversion factor for emissions for manure (IPCC, 2006) (Little et al, Holos, 2008)

Handling system	*MCF*
Pasture/range/ paddock-beef	0.010
Solid storage-beef	0.020
Compost - intensive windrow-beef	0.005
Compost - passive windrow-beef	0.005
Deep bedding > 1 month, no mixing -beef	0.170

Volatile solids are calculated from the IPCC guidelines (2006), based on the diet provided to the cattle:

$$VS = [\ GE \times (1-TDN/100) + (0.04 \times GE)\ ] \times (1-Ash/100) / 18.45$$

Where:

- GE = gross energy intake (MJ/head/day). Note that GE/18.45 = dry matter intake (DMI) (see Table 6.3)
- TDN = percent total digestible nutrients in feed (see Table 6.3)
- Ash = ash content of manure. By default: 8% (IPCC, 2006)

Volatile solids excreted in manure are set out in Table 6.5.

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Table 6.5 Total digestible nutrient (TDN) in feed and volatile solids (VS) excreted for beef cattle

Animal type	Manure management	Gender	Region	TDN (%)		Volatils solids (kg/day)	
				Yearling-fed system	Calf-fed system	Yearling-fed system	Calf-fed system
Calves on grass	in pasture	M/F	East	65%	65%	0.9	1.3
			West	65%	65%	1.0	1.4
Calves on feed	deep bedding		East	65%	65%	1.6	2.3
			West	65%	65%	1.5	2.4
	solid storage		East	65%	65%	1.6	2.3
			West	65%	65%	1.5	2.4
	composting		East	65%	65%	1.6	2.3
			West	65%	65%	1.5	2.4
Backgrounders on grass	in pasture	M	East	65%	-	2.0	-
			West	65%	-	1.9	-
		F	East	65%	-	2.0	-
			West	65%	-	1.9	-
Backgrounders on feed	deep bedding	M	East	70%	-	1.7	-
			West	70%	-	1.6	-
		F	East	70%	-	1.7	-
			West	70%	-	1.6	-
	solid storage	M	East	70%	-	1.7	-
			West	70%	-	1.6	-
		F	East	70%	-	1.7	-
			West	70%	-	1.6	-
	composting	M	East	70%	-	1.7	-
			West	70%	-	1.6	-
		F	East	70%	-	1.7	-
			West	70%	-	1.6	-
Yearlings on grass	in pasture	M	East	60%	-	3.4	-
			West	60%	-	3.1	-
		F	East	60%	-	3.4	-
			West	60%	-	3.1	-
Yearlings on feed	deep bedding	M	East	60%	-	3.4	-
			West	60%	-	3.1	-
		F	East	60%	-	3.4	-
			West	60%	-	3.1	-
	solid storage	M	East	60%	-	3.4	-
			West	60%	-	3.1	-
		F	East	60%	-	3.4	-
			West	60%	-	3.1	-
	composting	M	East	60%	-	3.4	-
			West	60%	-	3.1	-
		F	East	60%	-	3.4	-
			West	60%	-	3.1	-
Finishers on feed	deep bedding	M/F	East	85%	85%	1.9	1.5
		M	West	80%	80%	2.3	2.0
		F	West	80%	80%	2.3	2.0
Finishers - storage	solid storage	M/F	East	85%	85%	1.9	1.5
		M	West	80%	80%	2.3	2.0
		F	West	80%	80%	2.3	2.0
Finishers - composting	composting	M/F	East	85%	85%	1.9	1.5
		M	West	80%	80%	2.3	2.0
		F	West	80%	80%	2.3	2.0
Cows on grass	in pasture	F	East	55%	55%	5.4	5.4
			West	55%	55%	5.4	5.4
Cows on feed	deep bedding		East	55%	55%	5.4	5.4
			West	55%	55%	5.4	5.4
	solid storage		East	55%	55%	5.4	5.4
			West	55%	55%	5.4	5.4
	composting		East	55%	55%	5.4	5.4
			West	55%	55%	5.4	5.4
Bulls on grass	in pasture	M	East	55%	55%	8.1	8.1
			West	55%	55%	8.1	8.1
Bulls on feed	deep bedding		East	55%	55%	8.1	8.1
			West	55%	55%	8.1	8.1
	solid storage		East	55%	55%	8.1	8.1
			West	55%	55%	8.1	8.1
	composting		East	55%	55%	8.1	8.1
			West	55%	55%	8.1	8.1

Nitrous oxide (N_2O) emissions

Direct and indirect N_2O emissions depend on the quantities of nitrogen excreted in manure for the various animal categories. These quantities are calculated based on the nitrogen content of the provided diet, its digestibility and the retention capacity of animals (US National Research Council, 2015). Data related to nitrogen excretion are indicated in Table 6.7.

Direct nitrous oxide emissions

According to the IPCC guidelines (2006):

$$N_2O\text{-}N_{direct}\ rate = N_{excretion} rate \times EF_{direct}$$

Where:

- $N_2O\text{-}N_{direct}$ rate = manure direct N_2O-N emission rate (kg N/head/day)
- $N_{excretion}$ rate = quantity of nitrogen excreted in manure (kg N/kg manure)
- EF_{direct} = emissions factor representing the share of N transformed into N_2O (kg N_2O-N/kg N). It is expressed for storage and pasture. The emissions factors are set out in **Table 6.6**

Indirect nitrous oxide emissions from N volatilization

According to the IPCC guidelines (2006):

$$N_2O\text{-}N_{volatilization} rate = N_{excretion} rate \times Frac_{volatilization} \times EF_{volatilization}$$

Where:

- $N_2O\text{-}N_{volatilization}$rate = manure indirect N_2O-N emission rate from N volatilization (kg N/head/day)
- $N_{excretion}$rate = quantity of nitrogen excreted in manure (kg N/kg manure)
- $Frac_{volatilization}$ = fraction of N that is lost by volatilization (no unit)
- $EF_{volatilization}$ = emissions factor representing the share of volatilized N transformed into N_2O (kg N_2O-N/kg N). It is expressed for storage and pasture. The emissions factors are set out in Table 6.6.

Indirect nitrous oxide emissions from N leaching

According to the IPCC guidelines (2006):

$$N_2O\text{-}N_{leaching} rate = N_{excretion} rate \times Frac_{leaching} \times EF_{leaching}$$

Where:

- $N_2O\text{-}N_{leaching}$ rate = manure indirect N_2O-N emission rate from N leaching (kg N/head/day)
- $N_{excretion}$ rate = quantity of nitrogen excreted in manure (kg N/kg manure)
- $Frac_{leaching}$ = fraction of N that is lost by leaching and run-off to water (no unit)
- $EF_{leaching}$ = emissions factor representing the share of leached N transformed into N_2O (kg N_2O-N/kg N). It is expressed for storage and pasture. The emissions factors are set out in Table 6.6.

According to the IPCC (2006), it is assumed that leaching only occurs in pastures. The leaching fraction is calculated by the equation of (Rochette et al., 2007) included in Little et al (2008).

$$Frac_{leaching} = 0.3247 \times P/PE \times 0.0247$$

Where:

- P = growing season precipitation (May–November)
- PE = growing season evapotranspiration (May–November)

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The ratio P/PE for Canada was calculated according to the data from CGIAR-CSI (Consortium for Spatial Information (CGIAR-CSI), n.d.). The average P/PE ratio is assumed to be 0.84, and, $Frac_{leaching}$ is estimated to 24.7%. In Western Canada, the P/PE ratio is 0.74 and in Eastern Canada, it is 1.29, which leads respectively to $Frac_{leaching}$ of 21.5% and 39.3% for Western and Eastern Canada.

Total nitrous oxide emissions

Total nitrous oxide emissions, from direct and indirect sources are indicated in Table 6.8.

Table 6.6 Emission factors for N_2O emissions

Handling system	*MCF*	EF_{direct} [kg N_2O-N (kg N)$^{-1}$]	$Frac_{volatilization}$	$EF_{volatilization}$ [kg N_2O-N (kg N)$^{-1}$]	$Frac_{leach}$	EF_{leach} [kg N_2O-N (kg N)$^{-1}$]
Pasture/range/ paddock-beef	0.010	0.02	0.20	0.01	calculated*	0.0075
Solid storage-beef	0.020	0.005	0.45	0.01	0	0.0075
Compost - intensive windrow-beef	0.005	0.1	0.45	0.01	0	0.0075
Compost - passive windrow-beef	0.005	0.01	0.45	0.01	0	0.0075
Deep bedding > 1 month, no mixing -beef	0.170	0.01	0.30	0.01	0	0.0075

IPCC 2006.

*Pasture manure value calculated in soil N_2O emissions, equation (1.22).

Source: (Little et al., 2008)

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Table 6.7 Daily nitrogen excretion in beef cattle manure

Animal type	Manure management	Gender	Region	Total N excretion (g/day)	
				Yearling-fed system	Calf-fed system
Calves on grass	in pasture	M/F	East	47.5	66.4
			West	49.6	73.3
Calves on feed	deep bedding		East	88.8	137.0
			West	87.2	144.8
	solid storage		East	88.8	137.0
			West	87.2	144.8
	composting		East	88.8	137.0
			West	87.2	144.8
Backgrounders on grass	in pasture	M	East	115.0	-
			West	109.3	-
		F	East	115.1	-
			West	109.3	-
Backgrounders on feed	deep bedding	M	East	94.3	-
			West	89.1	-
		F	East	94.3	-
			West	89.1	-
	solid storage	M	East	94.3	-
			West	89.1	-
		F	East	94.3	-
			West	89.1	-
	composting	M	East	94.3	-
			West	89.1	-
		F	East	94.3	-
			West	89.1	-
Yearlings on grass	in pasture	M	East	149.3	-
			West	136.2	-
		F	East	149.3	-
			West	136.2	-
Yearlings on feed	deep bedding	M	East	149.3	-
			West	136.2	-
		F	East	149.3	-
			West	136.2	-
	solid storage	M	East	149.3	-
			West	136.2	-
		F	East	149.3	-
			West	136.2	-
	composting	M	East	149.3	-
			West	136.2	-
		F	East	149.3	-
			West	136.2	-
Finishers on feed	deep bedding	M/F	East	160.6	120.3
		M	West	215.3	180.0
		F	West	215.3	180.0
Finishers - storage	solid storage	M/F	East	160.6	120.3
		M	West	215.3	180.0
		F	West	215.3	180.0
Finishers - composting	composting	M/F	East	160.6	120.3
		M	West	215.3	180.0
		F	West	215.3	180.0
Cows on grass	in pasture	F	East	222.2	222.2
			West	222.2	222.2
Cows on feed	deep bedding		East	222.2	222.2
			West	222.2	222.2
	solid storage		East	222.2	222.2
			West	222.2	222.2
	composting		East	222.2	222.2
			West	222.2	222.2
Bulls on grass	in pasture	M	East	330.4	330.4
			West	330.4	330.4
Bulls on feed	deep bedding		East	330.4	330.4
			West	330.4	330.4
	solid storage		East	330.4	330.4
			West	330.4	330.4
	composting		East	330.4	330.4
			West	330.4	330.4

.

Table 6.8 Direct and indirect nitrous oxide emissions from beef cattle manure

Animal type	Manure management	Gender	Region	Direct N2O emissions (kg/day)	Indirect N2O emissions - volatilization (kg/day)	Indirect N2O emissions - leaching (kg/day)	Direct N2O emissions (kg/day)	Indirect N2O emissions - volatilization (kg/day)	Indirect N2O emissions - leaching (kg/day)
				Yearling-fed system			Calf-fed system		
Calves on grass	in pasture	M/F	East	0.0015	0.0001	0.0002	0.0021	0.0002	0.0003
Calves on grass	in pasture	M/F	West	0.0016	0.0002	0.0001	0.0023	0.0002	0.0002
Calves on feed	deep bedding	M/F	East	0.0014	0.0004	na	0.0022	0.0006	na
Calves on feed	deep bedding	M/F	West	0.0014	0.0004	na	0.0023	0.0007	na
Calves on feed	solid storage	M/F	East	0.0007	0.0006	na	0.0011	0.0010	na
Calves on feed	solid storage	M/F	West	0.0007	0.0006	na	0.0011	0.0010	na
Calves on feed	composting	M/F	East	0.0140	0.0006	na	0.0215	0.0010	na
Calves on feed	composting	M/F	West	0.0137	0.0006	na	0.0228	0.0010	na
Backgrounders on grass	in pasture	M	East	0.0036	0.0004	0.0004	-	-	-
Backgrounders on grass	in pasture	M	West	0.0034	0.0003	0.0003	-	-	-
Backgrounders on grass	in pasture	F	East	0.0036	0.0004	0.0005	-	-	-
Backgrounders on grass	in pasture	F	West	0.0034	0.0003	0.0003	-	-	-
Backgrounders on feed	deep bedding	M	East	0.0015	0.0004	na	-	-	-
Backgrounders on feed	deep bedding	M	West	0.0014	0.0004	na	-	-	-
Backgrounders on feed	deep bedding	F	East	0.0015	0.0004	na	-	-	-
Backgrounders on feed	deep bedding	F	West	0.0014	0.0004	na	-	-	-
Backgrounders on feed	solid storage	M	East	0.0007	0.0007	na	-	-	-
Backgrounders on feed	solid storage	M	West	0.0007	0.0006	na	-	-	-
Backgrounders on feed	solid storage	F	East	0.0007	0.0007	na	-	-	-
Backgrounders on feed	solid storage	F	West	0.0007	0.0006	na	-	-	-
Backgrounders on feed	composting	M	East	0.0148	0.0007	na	-	-	-
Backgrounders on feed	composting	M	West	0.0140	0.0006	na	-	-	-
Backgrounders on feed	composting	F	East	0.0148	0.0007	na	-	-	-
Backgrounders on feed	composting	F	West	0.0140	0.0006	na	-	-	-
Yearlings on grass	in pasture	M	East	0.0047	0.0005	0.0007	-	-	-
Yearlings on grass	in pasture	M	West	0.0043	0.0004	0.0003	-	-	-
Yearlings on grass	in pasture	F	East	0.0047	0.0005	0.0007	-	-	-
Yearlings on grass	in pasture	F	West	0.0043	0.0004	0.0003	-	-	-
Yearlings on feed	deep bedding	M	East	0.0023	0.0007	na	-	-	-
Yearlings on feed	deep bedding	M	West	0.0021	0.0006	na	-	-	-
Yearlings on feed	deep bedding	F	East	0.0023	0.0007	na	-	-	-
Yearlings on feed	deep bedding	F	West	0.0021	0.0006	na	-	-	-
Yearlings on feed	solid storage	M	East	0.0012	0.0011	na	-	-	-
Yearlings on feed	solid storage	M	West	0.0011	0.0010	na	-	-	-
Yearlings on feed	solid storage	F	East	0.0012	0.0011	na	-	-	-
Yearlings on feed	solid storage	F	West	0.0011	0.0010	na	-	-	-
Yearlings on feed	composting	M	East	0.0235	0.0011	na	-	-	-
Yearlings on feed	composting	M	West	0.0214	0.0010	na	-	-	-
Yearlings on feed	composting	F	East	0.0235	0.0011	na	-	-	-
Yearlings on feed	composting	F	West	0.0214	0.0010	na	-	-	-

Table 6.7 (continued) Direct and indirect nitrous oxide emissions from beef cattle manure

Animal type	Manure management	Gender	Region	Direct N2O emissions (kg/day)	Indirect N2O emissions - volatilization (kg/day)	Indirect N2O emissions - leaching (kg/day)	Direct N2O emissions (kg/day)	Indirect N2O emissions - volatilization (kg/day)	Indirect N2O emissions - leaching (kg/day)
				Yearling-fed system			Calf-fed system		
Finishers on feed	deep bedding	M/F	East	0.0025	0.0008	na	0.0019	0.0006	na
		M	West	0.0034	0.0010	na	0.0028	0.0008	na
		F	West	0.0034	0.0010	na	0.0028	0.0008	na
Finishers - storage	solid storage	M/F	East	0.0013	0.0011	na	0.0009	0.0009	na
		M	West	0.0017	0.0015	na	0.0014	0.0013	na
		F	West	0.0017	0.0015	na	0.0014	0.0013	na
Finishers - composting	composting	M/F	East	0.0252	0.0011	na	0.0189	0.0009	na
		M	West	0.0338	0.0015	na	0.0283	0.0013	na
		F	West	0.0338	0.0015	na	0.0283	0.0013	na
Cows on grass	in pasture	F	East	0.0070	0.0007	0.0010	0.0070	0.0007	0.0010
			West	0.0070	0.0007	0.0006	0.0070	0.0007	0.0006
Cows on feed	deep bedding		East	0.0035	0.0010	na	0.0035	0.0010	na
			West	0.0035	0.0010	na	0.0035	0.0010	na
	solid storage		East	0.0017	0.0016	na	0.0017	0.0016	na
			West	0.0017	0.0016	na	0.0017	0.0016	na
	composting		East	0.0349	0.0016	na	0.0349	0.0016	na
			West	0.0349	0.0016	na	0.0349	0.0016	na
Bulls on grass	in pasture	M	East	0.0104	0.0010	0.0015	0.0104	0.0010	0.0015
			West	0.0104	0.0010	0.0008	0.0104	0.0010	0.0008
Bulls on feed	deep bedding		East	0.0052	0.0016	na	0.0052	0.0016	na
			West	0.0052	0.0016	na	0.0052	0.0016	na
	solid storage		East	0.0026	0.0023	na	0.0026	0.0023	na
			West	0.0026	0.0023	na	0.0026	0.0023	na
	composting		East	0.0519	0.0023	na	0.0519	0.0023	na
			West	0.0519	0.0023	na	0.0519	0.0023	na

.

Ammonia (NH_3) emissions

According to Chai et al (2014):

$$NH_3\ rate = TAN_{excreted}\ x\ EF\ x\ ATA\ x\ 17/14$$

Where:

- $NH_{3confinement}$ rate = ammonia emissions from manure (kg NH_3/head/day)
- $TAN_{excreted}$ = N excreted in animal urine (see Table 6.9). As for nitrogen excretion, the TAN is calculated based on the diet provided to cattle
- EF = ammonia emission factor (kg NH_3-N/kg TAN)
- ATA = ambient temperature-based adjustments (monthly) used to correct NH3 emission factors for the different manure management systems (without dimension)
- 17/14 = conversion factor from NH_3-N to NH_3

Concerning the corrected ammonia emission factor (EF x ATA), default data will be used. As suggested in Chai et al. (2014), they are obtained from Sheppard and Bittman (2012) for deep bedding, solid storage (in piles), composting and pasture. Data for feedlot are from McGinn et al. (2007).

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Table 6.9 N excreted in animal urine (TAN) and corrected ammonia emission factor (EF)

Animal Type	Manure management	Gender	Region	TAN (kg TAN/day/animal)	EF (kg NH3-N/kg TAN)	TAN (kg TAN/day/animal)	EF (kg NH3-N/kg TAN)
				Yearling-fed system		Calf-fed system	
Calves on grass	in pasture	M/F	East	0,017	0,100	0,03	0,10
			West	0,018	0,100	0,03	0,10
Calves on feed	deep bedding		East	0,042	0,210	0,08	0,21
			West	0,041	0,210	0,08	0,21
	solid storage		East	0,042	0,350	0,08	0,35
			West	0,041	0,350	0,08	0,35
	composting		East	0,042	0,700	0,08	0,70
			West	0,041	0,700	0,08	0,70
Backgrounders on grass	in pasture	M	East	0,047	0,100	-	-
			West	0,042	0,100	-	-
		F	East	0,047	0,100	-	-
			West	0,042	0,100	-	-
Backgrounders on feed	deep bedding	M	East	0,058	0,210	-	-
			West	0,054	0,210	-	-
		F	East	0,058	0,210	-	-
			West	0,054	0,210	-	-
	solid storage	M	East	0,058	0,350	-	-
			West	0,054	0,350	-	-
		F	East	0,058	0,350	-	-
			West	0,054	0,350	-	-
	composting	M	East	0,058	0,700	-	-
			West	0,054	0,700	-	-
		F	East	0,058	0,700	-	-
			West	0,054	0,700	-	-
Yearlings on grass	in pasture	M	East	0,084	0,100	-	-
			West	0,074	0,100	-	-
		F	East	0,084	0,100	-	-
			West	0,074	0,100	-	-
Yearlings on feed	deep bedding	M	East	0,084	0,210	-	-
			West	0,074	0,210	-	-
		F	East	0,084	0,210	-	-
			West	0,074	0,210	-	-
	solid storage	M	East	0,084	0,350	-	-
			West	0,074	0,350	-	-
		F	East	0,084	0,350	-	-
			West	0,074	0,350	-	-
	composting	M	East	0,084	0,700	-	-
			West	0,074	0,700	-	-
		F	East	0,084	0,700	-	-
			West	0,074	0,700	-	-
Finishers on feed	deep bedding	M/F	East	0,099	0,900	0,07	0,90
		M	West	0,143	0,900	0,11	0,90
		F	West	0,143	0,900	0,11	0,90
Finishers - storage	solid storage	M/F	East	0,099	0,350	0,07	0,35
		M	West	0,143	0,350	0,11	0,35
		F	West	0,143	0,350	0,11	0,35
Finishers - composting	composting	M/F	East	0,099	0,700	0,07	0,70
		M	West	0,143	0,700	0,11	0,70
		F	West	0,143	0,700	0,11	0,70
Cows on grass	in pasture	F	East	0,143	0,100	0,14	0,10
			West	0,143	0,100	0,14	0,10
Cows on feed	deep bedding		East	0,143	0,210	0,14	0,21
			West	0,143	0,210	0,14	0,21
	solid storage		East	0,143	0,350	0,14	0,35
			West	0,143	0,350	0,14	0,35
	composting		East	0,143	0,700	0,14	0,70
			West	0,143	0,700	0,14	0,70
Bulls on grass	in pasture	M	East	0,244	0,100	0,24	0,10
			West	0,244	0,100	0,24	0,10
Bulls on feed	deep bedding		East	0,244	0,210	0,24	0,21
			West	0,244	0,210	0,24	0,21
	solid storage		East	0,244	0,350	0,24	0,35
			West	0,244	0,350	0,24	0,35
	composting		East	0,244	0,700	0,24	0,70
			West	0,244	0,700	0,24	0,70

Conversion rate from NH3-N to NH3: 1,21

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Nitrate (NO_3^-) emissions

Calculation of nitrate emissions is described in the main the report.

Phosphate (PO_4^{3-}) emissions

Unlike nitrogen losses, due to lack of data regarding the phosphorous content of the diet, the calculation of P losses are only based on generic data that are, as far as possible, representative of Canada.

Leaching of soluble phosphate to groundwater

According to the SALCA emissions model for phosphorus in (Prasuhn, 2006) which is also used in the ecoinvent database (Nemecek, 2013):

$$P_{gw} = P_{gwl} \times F_{gw}$$

Where:

- P_{gw} = quantity of P lost by leaching to groundwater (kg P/ha/day)
- P_{gwl} = average quantity of P leached to groundwater for a land use category. For permanent pastures and meadow P_{gwl} = 0.06 kg P/ha/year. The daily quantity of P leached is obtained by dividing the yearly quantity of P leached by 365 i.e. 0.00016 kg P/ha/day
- F_{gw} = correction factor for fertilization by slurry
- $F_{gw} = 1+0.2/80 \times P_2O_{5slurry}$

Where $P_2O_{5slurry}$ is the quantity of P_2O_5 contained in the slurry or liquid sewage sludge applied (kg/ha). Here, it is assumed that only solid manure is produced. Consequently, F_{gw} = 1.

Run-off of soluble phosphate to surface water

According to the SALCA emissions model for phosphorus in Prasuhn (2006), which is also used in the ecoinvent database:

$$P_{ro} = P_{rol} \times F_{ro}$$

Where:

- P_{ro} = quantity of P lost by run-off to surface water (kg P/ha/day)
- P_{rol} = average quantity of P lost by run-off for a land use category. For intensive permanent pastures and meadow P_{rol} = 0.25 kg P/ha/year. The daily quantity of P lost by run-off is obtained by dividing the yearly quantity of P leached by 365 i.e. 0.00068 kg P/ha/day
- F_{ro} = correction factor for fertilization
- $F_{ro} = 1+0.2/80 \times P_2O_{5mineral} + 0.7/80 \times P_2O_{5slurry} + 0.4/80 \times P_2O_{5solid}$

Where:

- $P_2O_{5mineral}$ = quantity of P_2O_5 contained in the mineral fertilizer applied (kg/ha)
- $P_2O_{5slurry}$ = quantity of P_2O_5 contained in the slurry or liquid sewage sludge applied (kg/ha)
- P_2O_{5solid} = quantity of P_2O_5 contained in the solid manure applied (kg/ha)

Here, it is assumed that only solid manure is produced. The quantity of P_2O_5 excreted and applied to one hectare of pasture is calculated by using the livestock density and the quantity of P_2O_5 excreted by one animal unit[78] (Government of Alberta, 2015) (equivalent to one cow and one calf) (see Table 6.7Table 6.10). Thus:

$$P2O5solid = (Pcow + P\ calf) \times 2.3 \times LD$$

[78] The number of animals is expressed in animal unit equivalents. This allows the calculation of the total number of animals regardless of their type (cows, calves, but also horses, deer, etc.). The standard animal unit is defined as one mature 1,000 lb cow with a calf, or equivalent, and is based on the average daily forage intake of 26 lb dry matter per day. Then, the animal unit equivalent is calculated according to the quantity of forage required by each type of animal. Additional information is available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq6722?opendocument .

Where:

- P_{cow} = daily quantity of total P excreted by cow (kg P/cow/day). Data on the quantity of P excreted in manure are from Statistics Canada (2006). In this source, the data provided are expressed in total P excreted per animal per year. As for nitrogen, the daily quantity of excreted phosphorus is obtained by dividing the yearly quantity of excreted phosphorus by 365. No additional recent data were found for Canada
- P_{calf} = daily quantity of total P excreted by calf (kg P/calf/day). As for cows, the data comes directly from Statistics Canada (2006)
- 2.3 = conversion factor from total P excreted to P_2O_5 excreted, considering that about 30% of the phosphorus in manure is in mineral form (P_2O_5) that is already available to plants. (Government of Saskatchewan, n.d.)
- LD = average livestock density in Canada, calculated according to the total number of animal units divided by the total pasture area (see chapter 7). Thus, the average Canadian livestock density is 0.57 animal units/ha pasture

Table 6.10 Daily phosphorus as P_2O_5 excretion for one animal unit (beef)

Category of animals in Statistics Canada (2006)	Category of animals within the project	Yearly phosphorus excretion	Daily phosphorus as P205 excretion
		Kg P / year	Kg P2O5 / day
Beef cows (1400 lb)	Cows (1400 lb)	21.3	0.15
Calves (450 lb)	Calves (450 lb)	6.9	0.10
	1 animal unit (beef)	28.2	0.25

Erosion of soil particle containing phosphorus

For water erosion, according to the SALCA emissions model for phosphorus in Prasuhn (2006), which is also used in the ecoinvent database:

$$P_{er} = S_{er} \times P_{cs} \times F_{enr} \times F_{erw}$$

Where:

- P_{er} = quantity of P lost by erosion to surface water (kg P/ha/day)
- S_{er} = quantity of soil eroded (kg soil/ha/day)
- P_c = P content in the top soil (kg P/kg soil). By default the average value of 0.00095 kg/kg is used (Prasuhn, 2006)
- F_{enr} = enrichment factor for P. The factor takes account of the fact that the eroded soil particles contained more P than the average soil. By default, the average value of 1.86 is used (Wilke & Schaub, 1996) (Prasuhn, 2006)
- F_{erw} = fraction of the eroded soil that reaches the river. By default, the average value of 0.2 is used (Prasuhn, 2006)

No data on the amount of soil erosion in Canada were found by the authors. Consequently, S_{er} was calculated using the Revised Universal Soil Loss Equation (RUSLE) and data from the Ministry of Agriculture, Food and Rural Affairs in Ontario (Government of Ontario, 2012):

$$S_{er} = R \times K \times LS \times C \times P$$

Where:

- R = rainfall/run-off factor. By default, the R factor of 100 was used

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- K = soil erodibility (kg soil lost/ha). By default, the median value was used, i.e. 0.47 kg soil lost/ha
- LS = slope length gradient factor. By default, the median value was used, i.e. 0.73
- C = cover management. The value for pasture was used, i.e. 0.2
- P = supporting practices. By default, the value used 1, for up and down slope, without contouring

Thus, it is estimated that 686 kg of soil is eroded per hectare of pasture in Canada per year, i.e. 0.94 kg soil/ha/day.

Here, only water erosion is considered. Wind erosion should also be taken into account. Models have been developed for the estimation of soil erosion by wind, some of them being used at national level, such as the WATEM model using the RWEQ equation (Revised Universal Wind Erosion Equation) (BIO by Deloitte , 2014). However, no consensual model and data are available to estimate the quantity of phosphorus lost from wind erosion either at the international level or at the Canadian level.

Total phosphorus losses to water

As a result, the total phosphorus losses per hectare of pasture are indicated in Table 6.8 and Table 6.11.

Table 6.11 Total phosphorus losses per hectare of pasture for beef production in Canada

Type of P losses	P losses (kg P/ha/day)
P losses from leaching	0.00016
P losses from run-off	0.00069
P losses by erosion	0.00066
TOTAL P losses in pasture for beef production in Canada	**0.0015**

By default, it is assumed that the P losses per area of pasture for a certain quantity of P applied in pasture is distributed to each type of grazing animal according to the quantity of P excreted per animal type.

Regarding the quantity of phosphorus excreted, the data on the quantity of phosphorus excreted in manure per year come from Statistics Canada (2006), as mentioned earlier. Available data relates to five animal categories: bulls (~1,600 lb), cows (~1,400 lb), steers (~1,000 lb), heifers (~926 lb) and calves (~450 lb). As for nitrogen, considering the weight of the animals, it is assumed that:

- Animals called “steers” and “heifers” are considered in our project as “yearling heifers” and “yearling steers” respectively.
- The phosphorus excretion is about proportional to the animal weight. Consequently, the daily phosphorus excretion for backgrounded animals is estimated by averaging the daily phosphorus excretion of calves and heifers/steers for backgrounded animals.
- The daily phosphorus excretion of post-backgrounding animals under one year old and replacement animal under one year old are similar to the daily phosphorus excretion of backgrounded animals.
- The daily phosphorus excretion of replacement animals over one year old is similar to the daily phosphorus excretion of yearling animals.

Data related to phosphorus excretion are presented in Table 6.12.

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Table 6.12 Daily phosphorus excretion from beef cattle manure[79] (grazing animals only)

Category of animals in Statistics Canada (2006)	Yearly phosphorus excretion	Category of animals within the project	Daily phosphorus excretion
	Kg P / year		Kg P / day
Beef cows (1,400 lb)	21.3	Cows	0.058
Bulls (1,600 lb)	24.4	Bulls	0.067
Calves (450 lb)	6.9	Calves	0.019
		BG Heifers	0.029
		BG Steers	0.030
Heifers (926 lb)	14.1	Yearling heifers	0.039
Steers (1,000 lb)	15.2	Yearling steers	0.042

[79] Finishers are excluded from this table since they do not go to pasture

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6.8 ELCA—LCIs used in the environmental assessment

Stage	Category	Input data	Used LCI	Source and assumptions
Farming	Energy	Electricity mix	Electricity mix, AC, consumption mix, at consumer, < 1kV/CA energy	Agri-footprint (2014)
		Natural gas	Natural gas, high pressure {CA-AB}| natural gas production | Alloc Rec, U	ecoinvent (2014)
		Diesel	Diesel, burned in diesel-electric generating set {GLO}| processing | Alloc Rec, U _ L	ecoinvent (2014)
		Petrol	PetrolConsumption_L	Gasoline production and consumption taken from transport, passenger car, petrol consumption, from ecoinvent (2014)
	Feed	Energy supplement: Barley	Barley, AB, grain	AARD (2014)—irrigation adapted to match average Canadian practices
		Energy supplement: Corn	Corn, grain	AARD (2014)—irrigation adapted to match average Canadian practices
		Energy supplement: Mill run pellet	Wheat, grain, AB	Wheat grain LCI from AARD (2014) used as proxy (minor amount of mill run pellet in animal rations)—irrigation adapted to match average Canadian practices
		Energy supplement: Oat grain	Oats, grain, at farm, Alberta, no-tillage, milled system	AARD (2014)—irrigation adapted to match average Canadian practices
		Energy supplement: Screening pellet	Energy feed, gross {GLO}| corn grain to generic market for energy feed | Alloc Rec	ecoinvent v3 energy feed LCI adapted with corn LCI from AARD (2014)
		Energy supplement: Soybean	Soybean	Soybean LCI from AARD (2014) used as proxy (minor amount of soybean silage in animal rations)—irrigation adapted to match average Canadian practices
		Energy supplement: Triticale grain	Triticale, at farm/FR Mass	French triticale LCI from Agri-footprint (2014) used as proxy (minor amount of triticale silage in animal rations)
		Energy supplement: Wheat	Wheat, grain, AB	AARD (2014)
		Forages: Alfalfa	Alfalfa-grass mixture, Swiss integrated production {CH}| production | Alloc Rec	Swiss Alfalfa LCI from ecoinvent v3 used as proxy (minor amount of alfalfa in animal rations
		Forages: Barley silage	Barley, AB, silage	Barley grain LCI from AARD (2014) adapted for yield to model a barley silage LCI
		Forages: Corn silage	Corn, silage	Corn grain LCI from AARD (2014) adapted for yield to model a corn silage LCI

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		Forages: Grass silage	Hay silage	Hay LCI used as proxy
		Forages: Hay	Hay	Hay, Swiss integrated production, extensive {CH}| production | Alloc Rec, U – irrigation and N fertilization adapted to match Canadian practices
		Forages: Oat silage	Oats, silage, at farm, Alberta, no-tillage, milled system	Oat grain LCI from AARD (2014) adapted for yield to model an oat silage LCI
		Forages: Pea silage	Peas, silage, at farm, Alberta, no-tillage, milled system	AARD (2014)—irrigation adapted to match average Canadian practices
		Forages: Straw (for feed)	Barley, AB, straw	Barley straw LCI calculated from barley grain LCI from AARD (2014), using dry matter allocation factors of French barley grain and straw LCI from Agri-footprint (58.5:41.5)
		Forages: Triticale silage	Triticale, at farm/FR Mass	French triticale LCI from Agri-footprint (2014) used as proxy (minor amount of triticale silage in animal rations)
		Forages: Wheat silage	Wheat, silage, AB	Wheat grain LCI from AARD (2014) adapted for yield to model a wheat silage LCI
		Protein supplement: Canola meal	Canola, AB	AARD (2014)—irrigation adapted to match average Canadian practices
		Protein supplement: Dried distiller grains	Distiller's Dried Grains with Solubles {GLO}| market for | Alloc Rec	ecoinvent v3 global dried distiller's grain LCI used as proxy
		Protein supplement: Tubs	Protein feed, 100% crude {GLO}| corn grain to generic market for energy feed | Alloc Rec	ecoinvent v3 energy feed LCI adapted with corn LCI from AARD (2014) used as proxy
	Animal transportation	Transport	Transport, truck >20t, EURO5, 80%LF, default/GLO energy	Agri-footprint (2014)
Packing	Energy	Electricity mix	Electricity mix, AC, consumption mix, at consumer, < 1kV/CA energy	Agri-footprint (2014)
		Heat, district or industrial, natural gas	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Alloc Rec, U	ecoinvent v3 (2014)
		Heat district or industrial, other than natural gas	Heat, district or industrial, other than natural gas {RoW}| heat production, heavy fuel oil, at industrial furnace 1MW | Alloc Rec, U	ecoinvent v3 (2014)
		Diesel, burned in diesel-electric generating set	Diesel, burned in diesel-electric generating set {GLO}| processing | Alloc Rec, U	ecoinvent v3 (2014)
		Heat, central or small-scale, other than natural gas	Heat, central or small-scale, other than natural gas {CH}| treatment of biogas, burned in micro gas turbine 100kWe | Alloc Rec, U	ecoinvent v3 (2014)

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	Water	Tap water	Tap water {CA-QC}| tap water production, conventional treatment | Alloc Rec, U	ecoinvent v3 (2014)
	Materials	Corrugated board box	Corrugated board box {CA-QC}| production | Alloc Rec, U	ecoinvent v3 (2014),
		Polyethylene, low density, granulate	Polyethylene, low density, granulate {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014),
		Extrusion, plastic film	Extrusion, plastic film {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014),
		Acetic acid, without water, in 98% solution state	Acetic acid, without water, in 98% solution state {GLO}| market for | Alloc Rec, U	ecoinvent v3 (2014),
		Bromine	Diesel, burned in diesel-electric generating set	ecoinvent v3 (2014)
		Sulfuric acid production	Sulfuric acid {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)
		Anhydrous ammonia	Nitrous dioxide {GLO}| market for | Alloc Rec, U	ecoinvent v3 (2014), used as proxy
Processing	Packaging	Polystyrene	Polystyrene, expandable {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)
		Polystyrene injection	Injection moulding {RoW}| processing | Alloc Rec, U	ecoinvent v3 (2014)
		Polyethylene	Polyethylene, low density, granulate {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)
		Polyethylene extrusion	Extrusion, plastic film {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)
		Corrugated cardboard	Corrugated board box {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)
		Polyethylene	Polyethylene, low density, granulate {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)
		Polyethylene extrusion	Extrusion, plastic film {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)
		Wood pallet	EUR-flat pallet {RoW}| production | Alloc Rec, U	ecoinvent v3 (2014)

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6.9 ELCA—Data quality

Both the quality of the activity data and the used LCIs were assessed. Activity data quality was assessed considering both reliability and representativeness, while only representativeness was assessed for LCIs. Reliability of the LCIs was not included, because the objective was not to perform an assessment of already reviewed LCIs.

Table 6.13 Scoring system to assess data quality

Quality level		Reliability *Robustness of the data considering both completeness and accuracy*	Representativeness *Degree to which the data set reflects the true population of interest regarding technology, geography and time, including for included background data sets, if any.*
High quality	1	Specific data	Good technological, geographical and time representativeness
Decent quality	2	Mainly expert estimations or mix of specific data and other verified sources	Acceptable lack of technological, geographical and time reprentativeness
Low quality	3	Most of the data comes from estimates, based on sound assumptions	Lack of technological, geographical and time reprentativeness
Poor quality	4	Data based on rough assumptions	Proxy data used

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Table 6.14 Outcomes of the data quality assessment

Life cycle stage	Data		Sensitivity of the results	Input data		LCI
				Representativeness	Reliability	Representativeness
Farming	Mortality rates		**High**	1	2	n.a.
	"Animal stage" duration	Time spent on pasture	**High**	1	2	n.a.
		Time spent confined	**High**	1	2	n.a.
	Animal weight		**High**	1	2	n.a.
	On-farm energy consumption		Med-Low	1	1	1
	Water	Animal consumption	**High**	1	2	n.a.
		On-farm consumption	**High**	1	1	1
		Waste water	Low	1	1	2
		Crop irrigation	**High**	1	2	2
	Land used by animals		**High**	1	1	n.a.
	Feed (primary)	Composition	**High**	1	2	2
		Quantity	**High**	1	2	n.a.
	Feed (secondary)	Composition	Med-High	1	2	3
		Quantity	Med-High	1	2	n.a.
	Feed (all)	Transportation	Med-Low	2	3	2
	Enteric emissions		**High**	1	1	1
	Manure nitrogen losses and emissions*		**High**	1	1 - 2	1
	Manure phosphorus losses*		**High**	2	3	1
	Manure management		**High**	1	1	2
	Animal transportation		Med-Low	2	3	2
Packing	Energy consumption		Med-Low	1	1	1
	Water consumption		Low	1	1	1
	Material consumption		Med-Low	1	1	2
	Emissions		Med-Low	1	1	2
Secondary processing	Material consumption		Med-Low	1	2	2
	Meat waste		**High**	3	2	n.a.
Retail	Meat waste		**High**	3	2	n.a.
	Energy and refrigerant consumption		Low	3	3	1
Consumption	Meat waste		**High**	3	2	n.a.
	Energy and refrigerant consumption		Low	2	2	1

* Excl. Manure applied on crops

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6.10 Land use/biodiversity—Land covers available in the Annual Crop Type Inventory (ACI)

Label	Definition
Cloud	Areas unclassified due to cloud, shadow or other image quality factors.
Water	Water bodies (lakes, reservoirs, rivers, streams, salt water, etc.).
Exposed land / Barren	Land that is predominately non-vegetated and non-developed. Includes: glacier, rock, sediments, burned areas, rubble, mines and other naturally occurring non-vegetated surfaces. Excludes fallow agriculture.
Developed	Land that is predominantly built-up or developed and vegetation associated with these land covers. This includes road surfaces, railway surfaces, buildings and paved surfaces, urban areas, industrial sites, mine structures, etc.
Greenhouses	Greenhouses have been identified in British Columbia, Ontario, Prince Edward Island.
Shrubland	Predominantly woody vegetation of relatively low height (generally +/-2 metres). May include grass or wetlands with woody vegetation, regenerating forest.
Wetland	Land with a water table near/at/above soil surface for enough time to promote wetland or aquatic processes (semi-permanent or permanent wetland vegetation, including fens, bogs, swamps, sloughs, marshes etc.).
Grassland	Predominantly native grasses and other herbaceous vegetation; may include some shrubland cover.
Agriculture (undifferentiated)	Agricultural land, including annual and perennial crops, excluding grassland. This class is mapped only if the distinction of sub-agricultural covers (classes 132-199) is not possible.
Pasture / Forages	Periodically cultivated. Includes tame grasses and other perennial crops such as alfalfa and clover grown alone or as mixtures for hay, pasture or seed.
Too wet to be seeded	Agricultural fields that are normally seeded that remain unseeded due to excess spring moisture.
Fallow	Plowed and harrowed fields that are left unsown for the growing season.
Cereals	This class is mapped only if the distinction of sub-cereal covers (classes 133-146) is not possible.
Barley	
Other grains	
Millet	
Oats	
Rye	
Spelt	
Triticale	
Wheat	This sub-cereal class is mapped only if the distinction of sub-wheat covers (classes 145-146) is not possible.
Switchgrass	
Winter wheat	
Spring wheat	
Corn	
Tobacco	
Ginseng	
Oilseeds	This class is mapped only if the distinction of sub-oilseed covers (classes 151-158) is not possible.
Borage	
Camelina	
Canola / Rapeseed	
Flaxseed	
Mustard	
Safflower	

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Label	Definition
Sunflower	
Soybeans	
Pulses	This class is mapped only if the distinction of sub-pulse covers (classes 162-174) is not possible.
Peas	
Beans	
Lentils	
Vegetables	This class is mapped only if the distinction of sub-vegetable covers (classes 176-179) is not possible.
Tomatoes	
Potatoes	
Sugarbeets	
Other vegetables	
Fruits	This class is mapped only if the distinction of sub-fruit covers (classes 181-190) is not possible.
Berries	
Cranberry	
Orchards	
Other fruits	
Vineyards	
Hops	
Sod	
Herbs	
Nursery	
Buckwheat	
Canary seed	
Hemp	
Vetch	
Other crops	
Forest (undifferentiated)	Predominantly forested or treed areas. This class is mapped only if the distinction of sub-forest covers (classes 210-230) is not possible.
Coniferous	Predominantly coniferous forests or treed areas.
Broadleaf	Predominantly broadleaf/deciduous forests or treed areas.
Mixedwood	Forest that is a combination of both the coniferous and broadleaf classes

Source: Annual Crop Inventory, Data Product Specification, AAFC

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6.11 Land use/biodiversity—Yield references

Provinces	Atlantic	Québec	Ontario	Manitoba	Saskat-chewan	Alberta	British Columbia	References	Description
Energy supplement: Barley	3,009.09	3,054.55	3,354.55	3,263.64	2,900.00	3,463.64	2,772.73	Statistics Canada	2004-2014 average
Energy supplement: Corn	7,283.30	8,666.67	9,766.67	6,833.33	-	6,880.00	-	Statistics Canada	2009-2014 average
Energy supplement: Wheat	3,164.00	3,027.27	4,936.36	3,027.27	2,436.36	3,172.73	2,781.82	Statistics Canada	2004-2014 average
Energy supplement: Oat grain	-	2,445.50	2,609.10	3,045.50	2,854.50	2,881.80	2,590.90	Statistics Canada	2004-2014 average
Energy supplement: Screening pellet, Mill run pellet and tubs	7,413.27	7,413.27	7,413.27	4,124.26	4,124.26	4,124.26	4,124.26	Statistics Canada + Deloitte analysis	
Forages: Barley silage	15,437.59	15,437.59	15,437.59	15,437.59	15,437.59	15,437.59	15,437.59	Statistics Canada + Deloitte analysis	
Forages: Corn silage	28,008.85	33,328.76	37,558.95	26,278.45	-	26,457.91	-	Statistics Canada + Deloitte analysis	
Forages: Grass silage	13,500.00	13,500.00	13,500.00	13,500.00	13,500.00	13,500.00	13,500.00	European average from LCI database ecoinvent	
Forages: Hay	5,150.00	5,170.91	5,538.18	3,902.73	3,094.55	3,827.27	3,970.00	Statistics Canada	2004-2014 average for tame hay
Forages: Oat silage	15,058.98	15,058.98	15,058.98	15,058.98	15,058.98	15,058.98	15,058.98	Statistics Canada + Deloitte analysis	
Forages: Wheat silage	8,743.48	8,743.48	8,743.48	8,743.48	8,743.48	8,743.48	8,743.48	Statistics Canada + Deloitte analysis	

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6.12 SLCA—Survey templates (cattle operations, meat processors, associations)

Welcome

On behalf of the Canadian Cattlemen's Association and the Canadian Roundtable for Sustainable Beef, thank you for agreeing to take part in our survey.

The Canadian Roundtable for Sustainable Beef is conducting a Sustainability Assessment on all three pillars of sustainability - environment, social and economic. This study will enhance our ability to communicate to consumers domestically and internationally about the environmental and social benefits of Canada's beef industry. It will also inform stakeholders about what areas require additional research and focus. Hotspots and threats to the industry will be identified and a strategy developed to monitor progress and communicate how industry is addressing consumer concerns.

There are questions included in this survey that are in other surveys (e.g. the Agriculture Census) this allows us to use the results from those surveys in this study by providing a connecting benchmark between the two data sets that tell us how they relate.

Confidentiality

The complete form will be submitted directly to Deloitte. The data reported in it will not be shared by Deloitte with any other individual or entity and will be only used for this study.
The results from the survey will validate information collected from a literature review. Individual operation information will NOT be identifiable in the final results as it will be aggregated. Ranges for certain questions will be used for sensitivity testing within the Life Cycle model to determine the robustness of the results.

Instructions

This is the socioeconomic stream of the survey. It relates to topics such as the number of employees, animal welfare practices, and food safety.

Please fill out as much as possible and skip when you have no data. If the units do not apply, please ensure that you specify the unit that you use.
You may need to click on the yellow bar at the top to "Enable Editing" before starting.

Should you need any help for the data collection, please do not hesitate to contact:
Fawn Jackson (jacksonf@cattle.ca / (403) 275-8558) or Brenna Grant (grantb@canfax.ca / (403) 275-8558)
Christophe Ménigault (cmenigault@deloitte.ca / (514) 393- 8495) or Maeva Charles (macharles@deloitte.ca / (514) 393-6216)

Thank you again for your contribution.

Best regards,

Canadian Cattlmen's Association, the Canadian Roundtable for Sustainable Beef & Deloitte Sustainability Team

Contact information of the respondent:

Name	
Zip code (at your operation)	
Type of operations (Cow-Calf, backgrounding, yearling grasser; finishing)	
Email address*:	
I authorize Deloitte and CCA to mention my name in the final report's list of contributors (Yes/No)	

** Your contact information will allow us to get in touch should we have questions about the information submitted and better understand the context of your operations, if needed.*

Contact details to return the survey:

By e-mail at: cmenigault@deloitte.ca
By fax at: 514 390 4115 "to the intention of Christophe Menigault"
By mail:
To the intention of Christophe Menigault
Deloitte
1, Place Ville Marie bureau 3000
Montréal QC, H3B 4T9
Canada

S1. Profile | S2. Employment | S3. Animal Welfare | S4. Local communities | S5. Long term impacts

Social assessment – Socioeconomic Profile

Please fill out all light yellow cells with "x" marks for multiple choice questions or enter answers for open-ended questions.
As far as possible, only data relative to beef or forage production should be mentioned.
Please note that, unless otherwise stated, data and information should be based on year 2013.

Data/information	Choices	Mark (X) or enter answer
Gender of the primary decision-maker	Male	
	Female	
Farmer generation	1st	
	2nd	
	3rd	
	4th +	
If you are newly immigrated, which country do you come from?	Please specify >>>	
Year of birth of the primary decision-maker (e.g. 1960)		
Number of household members (#)		

Data/information	Choices	Mark (X) or enter answer
Beef production operations gross revenue in 2013	$0 - $50k	
	$50 - $100k	
	$100 - $200k	
	$200 - $500k	
	$500k - $1million	
	$1million - $2million	
	$2million+	
Number of household members working at the farm in 2013		
Number of full time workers employed in 2013		
Number of part-time, seasonal, and contractors employed in 2013		

S1. Profile | **S2. Employment** | S3. Animal Welfare | S4. Local communities | S5. Long term impacts

Social assessment – Employment and working conditions

Please fill out all light yellow cells with "x" marks for multiple choice questions or enter answers for open-ended questions.
As far as possible, only data relative to beef or forage production should be mentioned.
Please note that, unless otherwise stated, data and information should be based on year 2013.

a) Fair salary

Data/information	Choices	Mark (X) or enter answer
Are employees paid overtime?	Yes	
	No	
*if yes, do they receive an overtime premium?	Yes	
	No	
What is the average hourly wage paid to employees working at your farm? ($/h)		
What is the lowest hourly wage paid to employees working at your farm? ($/h)		

b) Working hours

Data/information	Choices	Mark (X) or enter answer
What is the average number of hours worked per week on your farm during peak season?	< 40 hours	
	40-48 hours	
	49-60 hours	
	61 hours +	
What is the average number of hours worked per week on your farm during low season?	< 30 hours	
	30 - 39 hours	
	40 - 48 hours	
	48 hours +	
How many weeks per year exceed a 48 hour/week threshold?	0 week	
	1-13 weeks	
	14 - 26 weeks	
	26 weeks or more	

c) Social Benefits/Social Security

Data/information	Choices	Mark (X) or enter answer
Among this list, what are the benefits typically offered to your farm/site's employees/workers? Mark all that apply	Medical care	
	Sickness benefit	
	Unemployment benefit	
	Old-age benefit	
	Employment injury benefit	
	Family benefit	
	Maternity/paternity benefit	
	Invalidity benefit	
	Survivor's benefit	
	Other: Please specify >>>	

d) Equal Opportunities

Data/information	Choices	Mark (X) or enter answer
What percentage of your employees are women?	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
How many of your employees identify themselves as:	An aboriginal person?	
	A person with a disability?	
	A visible minority?	
What are the countries of origin of your employees?	Please specify >>>	

e) Occupational health and Safety

Data/information	Choices	Mark (X) or enter answer
Is a formal policy concerning health & safety in place?	Yes	
	No	
Do preventive measures exist to avoid accidents and injuries?	Yes	
	No	
*if yes, to what extent are employees made aware of these measures?	Information display	
	Verbal communication	
	Training / simulation	
	Other	
Does an emergency protocol exist to react in case of accident or injury?	Yes	
	No	
*if yes, to what extent are employees made aware of this protocol?	Information display	
	Verbal communication	
	Training / simulation	
	Other	
How many working days were lost due to incidents in 2013?		
What percentage of your employees/workers received a health & safety training?	0%	
	1 - 25%	
	26 - 50%	
	51 - 75%	
	76 - 99%	
	100%	

f) Seasonal workers

Data/information	Choices	Mark (X) or enter answer
What percentage of the workforce do seasonal workers represent?	0%	
	1 - 25%	
	26 - 50%	
	51 - 75%	
	76 - 99%	
	100%	
What percentage of your seasonal workers are residents of Canada?	0%	
	1 - 25%	
	26 - 50%	
	51 - 75%	
	76 - 99%	
	100%	
What percentage, if any, of your seasonal workers are students? (i.e. enrolled at university or college)	0%	
	1 - 25%	
	26 - 50%	
	51 - 75%	
	76 - 99%	
	100%	
What percentage, if any, of your seasonal workers are youth? (i.e. below 18)	0%	
	1 - 25%	
	26 - 50%	
	51 - 75%	
	76 - 99%	
	100%	
What is the average gross hourly wage of seasonal workers? ($/h)		
Which of the following do you provide to seasonal workers? Mark all that apply	Transportation cost from country of origin	
	Work permit processing fees	
	Meals	
	Housing	
	Transportation costs to work	
	Protective clothes	
	Health insurance	
What costs do you transfer to seasonal workers? Mark all that apply	Transportation cost from country of origin	
	Work permit processing fees	
	Meals	
	Housing	
	Transportation costs to work	
	Protective clothes	
	Health insurance	
Do you provide seasonal workers a health & safety training session?	Yes	
	No	

e) Unionization

Data/information	Choices	Mark (X) or enter answer
What percentage of your full-time employees/workers are unionized?	0%	
	1 - 25%	
	26 - 50%	
	51 - 75%	
	76 - 99%	
	100%	
What percentage of your seasonal workers are unionized?	0%	
	1 - 25%	
	26 - 50%	
	51 - 75%	
	76 - 99%	
	100%	

S1. Profile | S2. Employment | S3. Animal Welfare | S4. Local communities | S5. Long term impacts

Social assessment – Animal welfare

Please fill out all light yellow cells with "x" marks for multiple choice questions or enter answers for open-ended questions.
As far as possible, only data relative to beef or forage production should be mentioned.
Please note that, unless otherwise stated, data and information should be based on year

a) Code of practice

Data/information	Choices	Mark (X) or enter answer
Are you aware of the 2013 beef code of practice?	Yes	
	No	
To what extent are other workers at your farm aware of the 2013 beef code of practice?	All of them are aware	
	Some of them are aware	
	None of them are aware	
	I don't know	
To what extent is the 2013 beef code of practice implemented at your facility?	Basic requirements are partially implemented	
	Basic requirements are all implemented	
	Some additional recommendations are implemented	
	All additional recommendations are implemented	
	Have not read it but intend to	
	Have not read and do not intend to	

b) Branding

Data/information	Choices	Mark (X) or enter answer
Which animals do you brand? *(if none, please skip to section c) Dehorning)*	All	
	Calves	
	Cows	
	Heifer replacements	
	Breeding bulls	
	Feedlot steers	
Do you use any pain control technique?	No	
	Yes, Anesthetic only	
	Yes, analgesic only	
	Yes, both anesthetic and analgesic	
Do you use one iron or multiple irons?	No	
	Yes, one	
	Yes, two	
	Yes, Three	

c) Dehorning

Data/information	Choices	Mark (X) or enter answer
What percentage of your calves were born polled? *(if 100% then go to section d) Castration)*	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
Do you dehorn your calves? *(if no then go to section d) Castration)*	Yes	
	No	
When do you dehorn/disbudd your calves?	In the first weeks after birth	
	Before horn attachment (2-3 months)	
	After horn attachment (4 months and older)	
Do you use any pain control technique for dihorning/disbudding?	No	
	Yes, Anesthetic only	
	Yes, analgesic only	
	Yes, both anesthetic and analgesic	

d) Castration

Data/information	Choices	Mark (X) or enter answer
Do you castrate your bull calves? (if no then go to Weaning section)	Yes	
	No	
When do you castrate your bull calves?	Shortly after birth	
	Before 6 months	
	Before 9 months	
	10 months or older	
Do you use any pain control technique for castration?	No	
	Yes, Anesthetic only	
	Yes, analgesic only	
	Yes, both anesthetic and analgesic	

e) Weaning

Data/information	Choices	Mark (X) or enter answer
How do you wean the majority of your calves?	Separation by truck/distance (i.e. to auction or feedlot)	
	Two-stage weaning	
	Nose tags	
	Fenceline weaning	
	Delayed weaning	
	Other: Specify in cell >>>	
Do you pre-condition your calves (minimum 45 days) prior to sale or shipping? This includes castration, dehorning, weaning, parasitic, vaccination (Clostridial and IBR) and bunk-broke	Yes	
	No	

f) Handling

Data/information	Choices	Mark (X) or enter answer
Pick two main ways you primarily learned to handle cattle?	Passed down from parents/employers	
	Cattle handling course (e.g. Temple Grandin, Bud Williams)	
	By just doing it	
	Books / literature	
	Other	
What percentage of your employees are trained for cattle handling?	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
*If part or all of your employees are trained for cattle handling, who performs the training?	Self-training with dedicated references and documentation	
	You or someone already trained working at the farm/feedlot	
	Someone external to the farm/feedlot	
	A certified trainer	
How often do you use the following handling aids and practices on your operation? **Please enter corresponding figure:** **1. Never** **2. <0-5% (including 5%) of the time** **3. <6-20%** **4. <21-50%** **5. >50%** **6. Always**	Prod with charge	
	Prod without charge	
	Stick, or whip	
	Plastic paddles, rattles or flags	
	Stock dogs	
	Horses	
	Quads	
	Yelling, whistling	
	Chasing	
	Walking, back and forth movement	
How often do you observe the following handling issues ? **Please enter corresponding figure:** **1. Never** **2. <0-5% (including 5%) of the time** **3. <6-20%** **4. <21-50%** **5. >50%** **6. Always**	Stopping, balking at entrance/exit to, or in chute	
	Vocalization	
	Falling (belly or torso touches ground)	
	Slipping (knee contacts ground)	
	Chute pile up	
	Running, slamming into fences, gates and chutes	
	Climbing or jumping out crowd tub or chute	
	Failing to move through handling facility without excessive force (prod)	
	Flipping in chute	
	Animal struck in chute requiring dismantling of chute sides	
	Choking in head gate	
Have you made any changes to your facilities to improve handling?	Yes	
	No	
*If yes, what type?	Solid sided chutes	
	Curved chutes and crowed tubs	
	Bud box	
	Open sided chutes	
	Grooved floors, or installation of non-slip surfaces	
	Hydraulic squeeze chute	
	Other: Please specify >>>	
How many times did you observe the following injuries on your farm in 2013? **Please enter corresponding figure:** **1. Never** **2. <0-5% (including 5%) of the time** **3. <6-20%** **4. <21-50%** **5. >50%** **6. Always**	Broken leg (handling)	
	Broken leg (non-human related)	
	Abcesses	
	Lacerations	
	Predator related	

g) Breeding

Data/information	Choices	Mark (X) or enter answer
What percentage of your heifer and cow herd did you assist in calving? (in %)		
What percentage of heifer and cow required c-sections or calving related emergencies? (in %)		
What percentage of bulls were injured during the breeding season? (in %)		

h) Housing and feeding

Data/information	Choices	Mark (X) or enter answer
How often do you typically clean the pens? (X times / month)		
How do you support cattle during extreme cold? Check all that apply	Wind shelter	
	Heated wated bowls	
	Additional feed	
	Bedding	
	Cleaning of pen more frequent	
	Other: Please specify >>>	
How do you support cattle during high temperature and humidity? Check all that apply	By providing shade	
	By avoiding handling cattle	
	By feeding cattle at dusk or dawn	
	By cooling the ground in part of the pen	
	By sprinkling cattle with water	
	Other: Please specify >>>	
How do you manage mud during spring thaw? Please check all that apply	Additional straw/other bedding material	
	Cleaning of pen more frequent	
	Proper drainage	
	Other: Please specify >>>	
Do you have a drought management plan for feed and water? Check all that apply	No	
	Stockpiled grazing/feed	
	Sale of animals	
	Land renting	
	Backup water trucks or pumps	
	Designated sacrificial pastures	
	Other: Please specify >>>	

i) Health

Data/information	Choices	Mark (X) or enter answer
How often are feedlot or dry lot cattle typically assessed for health problems?	Daily	
	2-3 times per week	
	Weekly	
	Monthly or less often	
	N/A	
How often are pastured cattle typically assessed for health problems?	Daily	
	2-3 times per week	
	Weekly	
	Twice per month	
	Once a month	
	Once every two months or less often	
	N/A	
Have you established an ongoing Veterinarian/Client/Patient Relationship (VCPR)?	Yes	
	No	
Do you follow a Herd Health Management Program?	Yes	
	No	
Do you have a disease prevention strategy?	Yes	
	No	
Do you divide your herd to provide different levels of care to those in need of extra attention, nutrition, observation?	Yes	
	No	

j) Euthanasia

Data/information	Choices	Mark (X) or enter answer
How frequently are chronic animals assessed for potential need of euthanasia?	Hourly	
	Twice per day	
	Daily	
	2-3 times per week	
	Weekly	
	Less often than weekly	
How are animals identified for on farm euthanasia typically handled?	Approved euthanasia drugs administered by a veterinarian	
	Gunshot	
	Penetrating captive bolt device & secondary kill	
	Non-penetrating captive bolt device and bleeding	
	Captive bolt	
	Bleeding out	
	Manually-applied blunt trauma to the head	
	Other: Please specify >>>	
Do you confirm insensibility and death after application of euthanasia method?	Yes	
	No	

k) Certification

Data/information	Choices	Mark (X) or enter answer
If applicable, what percentage of your transporters are certified by the Canadian Livestock Transport program?	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	

I) Food safety

Data/information	Choices	Mark (X) or enter answer
Have you or your employees been trained under the Verified Beef Production (VBP) on-farm food safety program?	Yes, I was trained	
	Yes, all workers were trained	
	Yes, part of the workers were trained	
	No	
*if yes, is your farm registered under the VBP program (audited farm)?	Yes	
	No	
Have you or your employees been trained on food safety - other than under the VBP program?	Yes, I was trained	
	Yes, all workers were trained	
	Yes, part of the workers were trained	
	No	

S1. Profile | S2. Employment | S3. Animal Welfare | S4. Local communities | S5. Long term impacts

Social assessment – Impacts on local communities and society

Please fill out all light yellow cells with "x" marks for multiple choice questions or enter answers for open-ended questions.
As far as possible, only data relative to beef or forage production should be mentioned.
Please note that, unless otherwise stated, data and information should be based on year 2013.

a) Community engagement

Data/information	Choices	Mark (X) or enter answer
How does your farm or organization support the local community? Mark all that apply	On-farm free visits	
	Volunteering	
	Donations & sponsorships	
	Local purchase of goods and equipment	
	Other: Please specify >>>	

b) Suppliers

Data/information	Choices	Mark (X) or enter answer
What is the regional breakdown of your purchase spending to suppliers? (including for animal purchase)		
Provincial	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
From neighbor province	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
National *(excluding the two previous categories)*	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
International	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
* If international suppliers, what is their main country of origin?	Enter country >>>	
Do you usually consider the social and environmental criteria of the suppliers or products you chose?	Yes	
	No	

c) Cohabitation practices

Data/information	Choices	Mark (X) or enter answer
If applicable, please identify how you collaborate with your neighbors.	Purchase of grains	
	Land sharing	
	Equipment sharing	
	Labour sharing	
	Other	
Do you get complaints from neighbors?	Yes, often	
	Yes, sometimes	
	Yes, rarely	
	No, never	
*If yes, what kinds of complaints? Mark all that apply	Noise	
	Odor	
	Fence conditions	
	Unsightliness	
	Other	
Which of the following manure odor management practices do you implement?	Practices preventing the release and transport of odours (e.g. cover of manure storage)	
	Use of biofilters	
	Windbreaks	
	Practices to manage in-barn conditions (e.g. solid/liquid separation; use of silica fume cements)	
	Odors treating	
	Use of odor control additives	
	Other	
	None	

d) Research and development

Data/information	Choices	Mark (X) or enter answer
What percentage of your farm revenues was invested in R&D or an on-farm experiment in 2013? E.g. feed or genetics trial	0%	
	1-5%	
	6-10%	
	11% or more	
Is your farm involved in any research and development project?	Yes	
	No	
*if yes, for what kind of project?	Feed/nutrition trial	
	Genetics trial	
	Technology transfer	
	Automation or use of robotics	
	Animal well-being practices	
	Environmental management practices	
	Other: please specify >>>	
*if yes, at what level?	Personal	
	Provincial	
	Regional	
	National	
	International	

e) Relationship with suppliers

Data/information	Choices	Mark (X) or enter answer
Do you undertake retained ownership throughout supply chain?	Yes	
	No	
*if yes, what retained ownership processes do you use that occurs on farm? Mark all that apply.	Drylot (bakcground)	
	Pasture (background)	
	Yearling grasser	
	Finishing feedlot	
	Other: Please specify >>>	
*if yes, what retained ownership processes do you use that occurs elsewhere? Mark all that apply.	Drylot (bakcground)	
	Pasture (background)	
	Yearling grasser	
	Finishing feedlot	
	Other: Please specify >>>	
Do you have a good relationship with your suppliers (e.g. mineral, feed, vet products, etc.)? Mark all that apply.	Respectful communication	
	Sufficient lead time is provided	
	Appropriate order size is available	
	Timely availability of products	
	Timely payments to suppliers	
	Other: Please specify >>>	

S1. Profile | S2. Employment | S3. Animal Welfare | S4. Local communities | S5. Long term impacts

Social assessment – Long-term impacts

Please fill out all light yellow cells with "x" marks for multiple choice questions or enter answers for open-ended questions.
As far as possible, only data relative to beef or forage production should be mentioned.
Please note that, unless otherwise stated, data and information should be based on year 2013.

a) Environmental impacts

Data/information	Choices	Mark (X) or enter answer
Does your farm have an Environmental Farm Plan?	Yes	
	No	
*if yes, has it been reviewed by a third-party?	Yes	
	No	
How do you manage the following agricultural non-organic waste? **Please enter the corresponding figure:** **1: Burning** **2 : Recycling** **3: Disposal** **4: On farm storage** **5: Sharp item container** **6 Other (please specify)**	Twine	
	Silage tarp	
	Forage plastic wrap	
	Tires	
	Chemical plastic containers	
	Forage plastic wrap	
	Machinery	
	Battery	
	Electronics	
	Machinery oil	
	Paints	
	Veterinary products	
	Building materials	
	Treated fence posts	
How do you manage the grazing around wetlands/riparian areas?	Free access to wetlands/riparian areas	
	Shoreline fence	
	Remote water stations/tanks	
	Access ramp	
	Stream crossing	
	Grazing control (e.g. use of salt block to contain cows in particular areas)	
	Grazing certain times of the year only	
	Other: Please specify >>>	

b) Biodiversity and ecosystem health

Data/information	Choices	Mark (X) or enter answer
What is the percentage of your lands that are native (vs tamed) rangelands?	0%	
	1 - 25 %	
	26 - 50 %	
	51 - 75 %	
	76 - 99 %	
	100%	
Do you or someone else assess the health of your rangelands?	Yes	
	No	
*if yes, when was the last time your performed this type of assessment? (e.g. 2012)		
**Overall, how did your grasslands, forests and tame pastures score?	Healthy	
	Healthy with problems	
	Unhealthy	
	Unknown	
What practices with beneficial impacts on water are you following? Mark all that apply	Nutrient management	
	Alternative cattle water sources	
	Appropriate grazing management	
	Sediment and erosion control measures	
	Water resources management measures (e.g. ditch, water control structure, water supply management)	
	Conservation buffers	
	Fence installation	
	High intensity areas management	
	Animal mortality management	
	Wellhead protection	
	Wetlands and springs protection	
	Prescribed burning	
	Integrated pest management	
	Safe disposal of pharmaceuticals	
	Other: Please specify >>>	
Which of the following water impact mitigation measures have you implemented? Mark all that apply	Moving wintering areas away from streams	
	Using ridges and ditches to divert corral run off into lagoons	
	Sloping corral away from water sources	
	Maintaining buffer zones around water sources	
	Other: Please specify >>>	
Which of the following practices with beneficial impacts on biodiversity are you following? Mark all that apply	Seeded to permanent pasture	
	Rangeland-field boundaries (shelterbelts, windbreaks, living fences, wild strips)	
	Maintain healthy rangelands	
	Nuttrients recycling mechanisms (e.g. crop/livestock mixed systems)	
	Availability of blooming plants for polinators	
	Reduction/appropriate use of pesticides	
	Reintroduction/inoculation of soil beneficial organisms	
	Promotion of on-farm habitats that reduce pests and increase natural enemies (e.g. hawk nest platform)	
	Maintain healthy riparian areas	
	Rotational grazing	
	Other: Please specify >>>	
Has someone estimated wildlife population growth at your farm?	Yes	
	No	
* if yes, what was the last observed trend? (added question)	Decrease of wildlife	
	Stable wildlife	
	Increase of wildlife	
Have you or your employees followed a range management course?	Yes	
	No	

c) Industry resilience

Data/information	Choices	Mark (X) or enter answer
Have you taken any measures to ensure employment succession ? Mark all that apply	No	
	Trainee/internship programs	
	Family member training	
	Partnership with training centers	
	Other: Please specify >>>	
Do you subscribe to any agricultural insurance?	Yield / production insurance	
	Price insurance	
	Other: Please specify >>>	
Do you have any risk management plan (processes/actions/initiatives) for the following risks?	Drought	
	Floods	
	Local market competition	
	International market competition	
	Commodities price	
	Other: Please specify >>>	

Meat processor survey

B. Social assessment

Please fill out yellow cells. When available, data sources are to be mentioned in comments.
If no precise data is available, please specify in the comments where estimates have been provided.
Please note that unless otherwise stated, data and information should be based on year 2013.

1. Profile

		Site	
Data/information	Unit / Multiple choice items	Answer	Comment
Site	Text		
Company/Organization	Text		
Province	Text		
Nearest city	Text		
Postal code	Text		

2. General

Data/information	Unit / Multiple choice items	Answer	Comment
Total number of employees	#		
Total number of cattle processed per day	#		
Total meat production	Tonnes		
Total revenues in 2013	$		

3. Employment and working conditions

Data/information	Unit / Multiple choice items	Answer	Comment
Fair salary			
Are employees paid overtime?	Yes/No		
*if yes, do they receive an overtime premium?	Yes/No		
What is the lowest hourly wage paid to employees working on your farm/site?	$/h		
Average hourly wage	$/h		
Working hours			
What is the average number of hours worked per week?	> 40h ; 41-48 h ; 49-60 h ; 60h +		
How many cumulative weeks per year exceed the 48h/week threshold?	0 week, less than 5 weeks, between 6 and 12 weeks, more than 13 weeks		

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Social Benefits/Social Security			
Among this list, what are the benefits typically offered to your farm/site's employees/workers? Select all that apply	Medical care, sickness benefit, unemployment benefit, old-age benefit, employment injury benefit, family benefit, maternity benefit, invalidity benefit, survivors' benefit; other: specify		
Equal Opportunities/ Discrimination			
What percentage of your employees are women?	Less than 25% ; 26-50% ; 51-75% ; More than 75% ; 100%		
Do you monitor diversity?	Yes/No		
*if yes, what percentage of your employees identify themselves as an aboriginal person?	%		
*if yes, what percentage of your employees identify themselves as a person with a disability?	%		
*if yes, what percentage of your employees identify themselves as a visible minority?	%		
Occupational health and Safety			
Is a formal policy concerning health & safety in place?	Yes/No		
Do preventive measures exist to avoid accidents and injuries?	Yes/No		
*if yes, to what extent are employees made aware of these measures?	Information display, verbal communication, training		
Does an emergency protocol exist to react in case of accident or injury?	Yes/No		
*if yes, to what extent are employees made aware of this protocol?	Information display, verbal communication, training/simulation		
How many working days were lost due to incidents?	#		
What percentage of your employees/workers received a health & safety training?	Less than 25% ; 26-50% ; 51-75% ; More than 75% ; 100%		
Temporary foreign workers			
Does your site employs temporary foreign workers? Yes/No,	Yes/No		

If yes, what percentage of the workforce did temporary foreign workers represent in 2013 (study reference year)?	%		
What is the average hourly wage of temporary foreign workers (gross)?	$/h		
What are the benefits received by Foreign Temporary Workers? - Mark all that apply	Medical care, sickness benefit, unemployment benefit, old-age benefit, employment injury benefit, family benefit, maternity benefit, invalidity benefit, survivors' benefit; other: specify		
What are the initiatives implemented to promote the integration of Foreign Temporary Workers?	English-course ; Access to social activities ; Other: please specify ;None		
Do you provide temporary foreign workers a health & safety training session?	Yes/No		
If yes, what percentage received a health and training session?	Less than 25% ; 26-50% ; 51-75% ; More than 75% ; 100%		
Freedom of Association and Collective Bargaining			
What percentage of your employees/workers are unionized?	0%, Less than 25% ; 26-50% ; 51-75% ; More than 75% ; 100%		
If applicable, what percentage of your foreign workers are unionized?	0%, Less than 25% ; 26-50% ; 51-75% ; More than 75% ; 100%		

4. Animal welfare

Data/information	Unit / Multiple choice items	Answer	Comment
Technologies/installations for animal welfare			

Which of the following technologies/installations are used/in place to improve animal welfare? Select all that apply	Non-slip flooring in stunning box; Ventilation equipment in lairage facilities; Passage ways allow 2 or more animals to walk side-by-side; Non-slip flooring in lairage and passage ways; one-way flow of animals to slaughter; Indirect lighting; Noise reducers; Passage ways without sharp angles; Ramp inclination < 20 degrees; Blinders; Other: specify		
*If no technologies/installations are used/in place, what are the constraints/reasons? Select all that apply	Cost of technologies/ installations; Lack of awareness; Other: specify		
Regulations			
Are the guidelines and procedures for the proper unloading, holding and movement of animals in slaughter facilities defined by the federal Meat Inspection Regulations communicated to employees?	Yes/No		
*if yes, how are these guidelines communicated to employees?	Information display, verbal communication, training by internal resource, training by third-party		
Stunning			
Are cattle stunned before being killed? (if no then go to question 4.4)	Yes/No		
*if yes, what method is used to stun cattle?	Penetrating captive bolt; Non-penetrating captive bolt; Exposure to a gas or gas mixture; Electronarcosis; Electrocution; Other: specify		
Is the effectiveness of the stun monitored?	Yes/No		

*if yes, what percentage of cattle are monitored to assess stun effectiveness?	0% ; Up to 25% ; Up to 50 % ; Up to 75% ; 100%		
*What percentage of cattle is slaughtered without prior stunning?	Up to 25% ; Up to 50 % ; Up to 75% ; 100%		
Killing			
What bleeding technique is used to slaughter cattle?	One carotid artery; Two carotid arteries; Chest sticking; other: specify		
Certification			
What percentage of your plant workers are certified by the Canadian Livestock Transport program?	0% ; Up to 25% ; Up to 50 % ; Up to 75% ; 100%		
If applicable, what percentage of your unloading crews are certified by the Canadian Livestock Transport program?	0% ; Up to 25% ; Up to 50 % ; Up to 75% ; 100%		
If applicable, what percentage of your transporters are certified by the Canadian Livestock Transport program?	0% ; Up to 25% ; Up to 50 % ; Up to 75% ; 100%		
Audit			
Does your company perform internal audits on animal welfare issues?	Yes/No		
*if yes, at what frequency are they performed?	At least twice a year ; Once per year ; Once every two years ; Every three years or more		
Is your company audited by your client on animal welfare issues?	Yes/No		
*if yes, at what frequency are they performed?	At least twice a year ; Once per year ; Once every two years ; Every three years or more		
Does your company audit suppliers on animal welfare issues?	Yes/No		
* If yes, what percentage of your suppliers have already been audited?	Up to 25% ; Up to 50 % ; Up to 75% ; 100%		

5. Food safety

Data/information	Unit / Multiple choice items	Answer	Comment

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Consumer health & safety			
Is there a food safety risk management plan in place?	Yes/No		
* If yes, how is it communicated?	information display, verbal communication, training/simulation		
Are the plant's employees trained on food safety?	Yes/No		
*if yes, what is the form of their training?	Self-training through access of documentation; training by internal resource; training by third-party (external); other: specify		
Transparency			
Do you track the origin of your cattle?	Yes/No		
Are your products graded by the Canadian Beef Grading Agency (CBGA)? If yes, what percentage are graded and what are the grades attributed to your products?	Yes/No		
*if yes, what percentage are graded and what are the grades attributed to your products?	AAA: X% ; AA: X% ; A: X% ; total graded: X%		
Feedback mechanisms			
Is there any mechanism in place allowing customers to share their questions/comments?	Yes/No		
*if yes, what kind of mechanism is in place? Select all that apply	Mail address; phone number/hotline; website form; e-mail; social media; other: specify		
End-of-life responsibility			
Have your company implemented initiatives to reduce or optimize packaging?	Yes, to reduce packaging; Yes, to optimize packaging ; Yes, to reduce and optimize packaging ; No		

6. Impacts on local communities and society

Data/information	Unit / Multiple choice items	Answer	Comment
Safe & Healthy living conditions			

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Are your employees/workers trained to ensure the safe use of chemicals and avoid nuisance of local communities in case of incidents? Yes/no	Yes/No		
Are your employees/workers trained to ensure the safe disposal of meat production waste in order to avoid negative effects on local communities? Yes/no	Yes/No		
Community engagement			
How does your company support the local community? Select all that apply	Written policy on community consultation, volunteering, donations & sponsorships; other: specify		
Local employment			
What is the origin of your suppliers? Select all that apply	Provincial, Regional, National, International		
What is the origin of your workers? Select all that apply	Provincial, Regional, National, International		
What percentage of your purchase spending do they each represent?	Less than 25 %; Between 26% and 50%, between 51% and 75%, more than 75%		
Cohabitation practices			
Which of the following odour management mechanisms are in place at your site? Select all that apply	site design, process design and management, control technologies; other: specify		
Technology development			
What percentage of your site revenues was invested in R&D in 2013?	$		
Is your company involved in any technology transfer program or projects?	Yes/No		
*if yes, at what level?	Provincial, regional, national, international		
Corruption			
Which of the following anti-corruption mechanisms are in place at your site? Select all that apply	existence of anti-corruption guidelines; training; whistleblowing mechanism; other: specify		

7. Relationships with value chain actors

Data/information	Unit / Multiple choice items	Answer	Comment
Fair competition			
Does your company have a business ethics code?	Yes/No		
Which of the following initiatives against anti-competitive behaviours is your company following? Select all that apply	Membership in alliances that denounce anti-competitive practices; Documented statement or procedures (policy, strategy etc.) to prevent engaging in or being complicit in anticompetitive behaviour; Communication to employees/workers of the importance of compliance with competition legislation and fair competition; other: specify		
Social responsibility			

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Which of the following initiatives related to responsible procurement have your company implemented?	Membership in an initiative that promotes social responsibility along the supply chain; integration of ethical, social, environmental and/or regarding gender equality criterions in purchasing policy, distribution policy and/or contract signatures; Support to suppliers in terms of consciousness-raising and counselling concerning the social responsibility issues; Presence of explicit code of conduct that protect human rights of workers among suppliers; Performance of suppliers audit with regard to social responsibility: other: specify		
Relationships with suppliers			
According to you, which ones of the following elements define your relationships with your suppliers? Select all that apply	Absence of coercive communication with suppliers, Sufficient lead time, Reasonable volume fluctuations, Payments on time to suppliers ; Other: specify		

8. Impacts on future generations

Data/information	Unit / Multiple choice items	Answer	Comment
Industry resilience			
Have your company taken any measures to ensure employment succession?	Yes/No		
*if yes, please specify how.	Trainee/internship programs; partnership with training centres; other: specify		

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Industry associations’ survey

Stakeholder	Subcategory of impact	Indicator	Questions	Unit	Association	
					Answer	If available, details and/or references (link to website, document)
Local community	Community engagement	Local community support	Has your association implemented or supported any initiatives aiming at supporting local communities?	Yes/No		
			If yes, what type of initiatives?	Text		
			Are these initiatives part of a formal program?	Yes/No		
			Does your association have a donation and sponsorship budget dedicated to these initiatives?	Yes/No		
Society	Public commitment to sustainable issues	Promotion of sustainable development	Does your association promote the industry's sustainability?	Yes/No		
			If yes, how so?	Text		
			Does your association have a sustainability program, policy or objectives?	Yes/No		
			If yes, is it publicly available?	Yes/No		
Society	Environmental management	Environmental management	Does your association provide or support members with funding environmental management tools? (e.g. guidelines, best practices)	Yes/No		
			If yes, what type of tools or programs?	Text		
			Is your association involved in the delivery of environmental management tools or programs (eg. guidelines, best practices) for members in the following areas?			
			- Waste & manure management	Yes/No		
			- Biodiversity & wildlife	Yes/No		
			- Water resources & riparian areas	Yes/No		
			- Grazing management	Yes/No		
			- Other (please specify in column G)	Yes/No		
			Please indicate if any of the BMPs supported by your association were developed in collaboration with provincial/federal government? (Please provide details in Column G)			
			- Waste & manure management	Yes/No		
			- Biodiversity & wildlife	Yes/No		
			- Water resources & riparian areas	Yes/No		
			- Grazing management	Yes/No		
			- Other (please specify in column G)	Yes/No		
			Is your association financially supporting or involved in capacity-building activities and/or training programs to support the implementation of BMPs in the following areas?			
			- Waste & manure management	Yes/No		
			- Biodiversity & wildlife	Yes/No		
			- Water resources & riparian areas	Yes/No		
			- Grazing management	Yes/No		

Stakeholder	Subcategory of impact	Indicator	Questions	Unit	Association	
					Answer	If available, details and/or references (link to website, document)
Society	Animal welfare	Animal welfare promotion	Does your association promote animal welfare practices? (e.g. diffusion of code of practice)	Yes/No		
			If yes, how so?	Text		
			Does your association provide training or informative sessions (in person or online) on animal welfare?	Yes/No		
Society	Technology development	Research and development	Is your association involved in any R&D activities?	Yes/No		
			If yes, what type of R&D activities?	Text		
			Does your association have a budget dedicated to R&D activities?	Yes/No		
Society	Economic contribution	Industry economic resilience	Does your association communicate information on market trends?	Yes/No		
			If yes, what type of information?	Text		
			Does your association provide any tool or training to further support farmers in improving their product marketability?	Yes/No		
Value chain actors	Value chain actors relationships	Value chain partnerships	Does your association have partnerships in place with industry's value chain actors?	Yes/No		
			If yes, with which actors?	Text		
			Are these partnerships part of a formal strategy plan/objectives?	Yes/No		
Value chain actors	Transparency	Promotion of transparent practices	Does your association support transparent communication on your members' production processes?	Yes/No		
			If yes, how so?	Text		
			Do these initiatives involve active stakeholder consultation?	Yes/No		
Value chain actors	Health and safety	Promotion of product quality and safety	Does your association promote product quality and safety?	Yes/No		
			If yes, how so?	Text		
			Is your association involved in providing training or informative sessions on product quality and safety? (e.g. on farm food safety program)	Yes/No		
Workers	Equal opportunities/ Discrimination	Diversity and inclusion	Does your association promote diversity and inclusion of the beef production workforce?	Yes/No		
			If yes, please provide details as to the programs or initiatives scope.	Text		
			Is this promotion part of a formal policy/plan/strategy?	Yes/No		
Workers	Health and safety	Occupational health & safety	Does your association promote or is involved in the promotion of occupational health and safety at producers' level?	Yes/No		
			If yes, how so?	Text		
			Is your association involved in providing training or informative sessions on occupational health and safety at producers' level?	Yes/No		

6.13 SLCA—Rationale for hormones exclusion

The objective of this appendix is to present the rationale behind the exclusion of hormones assessment in the SLCA.

Definition

Growth-enhancing technologies (GETs) or growth–promoting compounds (GPCs) encompass compounds and implants administered to cattle to increase their growth rate and efficiency.
Three main categories of GETs were considered in our literature review: steroids and equivalents, beta-agonists and ionophores. They can be administered at different life cycle stages either alone or in combination.

- **Steroids and equivalent**

Six types of growth promoting compounds (natural steroids and their artificial equivalent) are authorized for use in the cattle industry in Canada (Chevalier P., 2011):

Table 6.15 Authorized steroids and equivalent in Canada

Natural	Artificial
Estradiol	Zeranol (non-steroidal)
Progesterone	Melengestrol acetate (MGA)
Testosterone	Trenbolone acetate (TBA)

They are all administered through ear implants at the cow/calf, backgrounding and finishing operations via single or combined compounds products with the exception of MGA, which is sometimes incorporated into rations for feedlot heifers.

- **Beta-agonists**

This category of GET is structurally similar to adrenaline and is used as a feed additive to increase feed efficiency and muscle growth in feedlot cattle. They are non-steroidal and do not affect the hormone status of animals as the effect occurs at the cellular level (Radunz, 2011). Beta-agonists are used during the last 21-35 days prior to slaughter at the finishing stage. The practice is usually under veterinary prescription and/or oversight.

- **Ionophores**

Ionophores are antimicrobial feed additives that alter volatile fatty acid proportions in a manner that reduces the risk of bloat, reduces methane production and improves feed efficiency. They are also used to prevent coccidiosis. Ionophores may be administered throughout cattle's life but primarily during the backgrounding and finishing phases.

Overview of impacts

While the driving force for the use of hormones is mainly economic, with the aim of optimizing return on economic investment by maximizing cattle growth, feed efficiency and carcass quality (Montgomery et al., 2011), the use of GETs also has positive environmental impacts by reducing land use, resource consumption and emissions. Indeed, administered animals grow more rapidly and require less food to reach their finishing weight, which implies a reduction of cattle direct (enteric fermentation, manure) and indirect environmental impacts (feed production).

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In contrast, European Union members have adopted a precautionary approach regarding these products because of perceived potential risks to human and environmental health. We will review both perspectives in our approach presented below.

Literature review results

The effects of GET on environmental and human health have been in hot debate for years, particularly in North America and the European Union (EU). To date, no consensus has been reached regarding the approach that should be adopted by countries and producers. We can however observe that, on one hand, the use of GETs in the cattle industry and imports of meat of cattle administered with GETs are banned in the EU—although the WTO found that this decision was not supported by scientific evidence. On the other hand, Canada, the US and other countries (e.g. Australia, New Zealand, Japan and South Africa) authorize their use.

Regarding the socioeconomic impacts, the following aspects were more specifically looked at:

- **Impacts associated with beef enhanced growth**

Two main groups of stakeholders and categories of benefits can be identified from the use of GETs in beef production.

  - **Reduced costs for beef producers**

As a direct consequence of the optimization of beef production, beef producers using GETs experience lower cost of operations, as shown by Capper J.L. and Hayes D.J. (2012) study:

> "Withdrawing GET from US beef systems increased total production costs from \$3.14/kg beef to \$3.43/kg beef, a 9.1% increase. When adjusted for GET cost at \$0.0282/ kg beef added to the aforementioned baseline costs described above, the total economic impact of withdrawing GET from the system is to increase costs by 8.2% (\$3.17/ kg for CON vs. \$3.43/kg for NOT)."

This is supported by three main outcomes: improved growth rate, feed efficiency and yield grade (carcass lean meat yield) (Montgomery, et al., 2001).
Strictly economic aspects were not part of the scope of the social life cycle assessment.

  - **Greater affordability for consumers**

The reduced beef production cost has beneficial repercussions on the price of meat offered to consumers, which therefore increases the affordability of meat products.
It should be noted that studies show that the quality of beef produced using GET can be reduced (Girard I. et al, 2012; Lopez-Campos O., 2013), especially when inappropriately used in the wrong classes of cattle, at a wrong timing or in combination as part of various strategies (Montgomery, et al., 2001).
Some practices can help mitigate the effects of GETs on quality grade and palatability, such as "altering timing of implant administration in relation to slaughter" (Duckett & Andrae, 2001). (Schneider, et al., 2007) "Post mortem aging periods of 14 to 28 days were effective for mitigating the detrimental effects of mild or moderately aggressive heifer implant programs on the predicted consumer acceptability". In addition, the number of implants and the age at which the animal is implanted (Platter W.J. et al., 2009) also provide control over the meat quality.
Finally, it should be noted that collateral economic impacts of using or not using GETs are varied across the value chain (e.g. demand for feed, technology, research and development, etc.). However, these were not covered by Deloitte as part of this assessment.

- **Impacts associated with GETs compounds residue**

The potential impacts of GETs on human health depend on the concentration of GETs residue found in meat for consumption and whether this remaining concentration is considered dangerous for human health.
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As previously mentioned, there is still no global consensus on this issue. Although Canada, the US and other countries consider the impact of these residues negligible or harmless to human health (GET residue levels found in beef are orders of magnitude lower than lowest-observed-adverse effect (LOAEL) or no-observable-adverse-effect (NOAEL) levels), the European Union has adopted a precautionary approach and decided to ban the import and production of beef raised using GETs, despite the WTO's ruling.
A report published by the Public Health Institute in Québec (Chevalier P., 2011) provides a clear overview of this subject and concludes that, to date, reports and research by both supporters and opponents of GETs lead to a difference of opinion, although their respective assessment or interpretation are often based on the same fundamental data. The report also suggests that any questioning of current practices could only rely on new and validated scientific research and knowledge.
Considering these divergent views, the impact of GETs used in the beef industry on human health was not assessed within the scope of this study.

References

Chevalier P. (2011) *L'usage des stimulateurs de croissance en production animale: position des experts et gouvernements.* Collection Politiques Publiques et Santé: Institut National de Santé Publique du Québec.

Girard I. et al. (2012) *Modification of beef quality through steer age at slaughter, breed cross and growth promotants.* Canadian Journal of Animal Science. 92: 175-188.

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Radunz A.E. (2011), *Use of beta agonists as a growth promoting feed additive for finishing beef cattle.* UW Extension Wisconsin Beef Information Centre: http://fyi.uwex.edu/wbic/files/2010/11/Beta-Agonists-Factsheet.pdf (accessed: December 1, 2014)

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6.14 SLCA—Recommendations for improving SLCA survey and process

While the limits of our approach were mentioned throughout the report, some recommendations can be identified to improve the process for a next assessment. These recommendations include survey wording improvement and general process improvement. Because the social life cycle assessment is still a field in development, we hope that these elements can help other practitioners refine their methodology as well.

Cattle operations—Questionnaire platform

Participants were asked to fill out Excel files and PDF versions of the Excel file. However, some had difficulties opening or navigating these files. An online version of the survey could be easier for respondents to access and use. This option was ruled out at the beginning of our survey to align with the format of the environmental life cycle assessment survey, which was more difficult to conduct on an online platform.

Cattle operations—Questionnaire format

Because this is the first baseline conducted for the industry, a quite extensive number of topics needed to be covered by the survey sent to cattle operators, which resulted in a rather long questionnaire. To minimize the time spent by cattle operators filling out the survey, questions were formulated, as much as possible, as “yes/no” or “multiple-choice” questions. However, this approach also has its limits. For instance, for questions involving percentages, brackets were used, which makes it difficult to calculate average scores. Also, we developed our survey questionnaire before finalizing our rating scales and, ultimately, some questions were not used to build indicators because they were not sufficiently explicit. It is thus recommended to:

1) Build the rating scales for each indicator at the same time the survey questions are developed to make sure all survey answers feed into the indicators’ rating scale or a comments’ section
2) Switch some answers from multiple choice (e.g. brackets of %) to open questions (X%)

Below are some examples of changes we suggest for some questions we used in our survey.

Cattle operations—Revenues

For reference, question included in the survey:

Beef production operations gross revenue in 2013	\$0 - \$50k
	\$50 - \$100k
	\$100 - \$200k
	\$200 - \$500k
	\$500k - \$1million
	\$1million - \$2million
	\$2million+

Recommendation: Align brackets of revenues with Statistics Canada’s brackets of revenues.

Cattle operations—Dehorning

For reference, question included in the survey:

What percentage of your calves were born polled? *(if 100% then go to section d) Castration)*	0%
	1 - 25 %
	26 - 50 %
	51 - 75 %
	76 - 99 %

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	100%

Recommendation: Remove the brackets and replace with an open answer.

Cattle operations—Cattle handle training

For reference, question included in the survey

How often do you use the following handling aids and practices on your operation? **Please enter corresponding figure:** **1. Never** **2. <0-5% (including 5%) of the time** **3. <6-20%** **4. <21-50%** **5. >50%** **6. Always**	Prod with charge
	Prod without charge
	Stick, or whip
	Plastic paddles, rattles or flags
	Stock dogs
	Horses
	Quads
	Yelling, whistling
	Chasing
	Walking, back and forth movement

Recommendation: Create open question to ask which percentage of cattle are handled using handling aids, instead of asking how often they are used with brackets of %.
New question: What percentage of cattle is handled using each of these handlings aids or practices? Open answer in %.

Cattle operations—Health & safety training

For reference, question included in the survey

What percentage of your employees/workers received a health & safety training?	0%
	1 - 25%
	26 - 50%
	51 - 75%
	76 - 99%
	100%

Recommendation: Reformulate question to be more specific about the type of training given to employees/workers and remove brackets of %.
New question: What percentage of your employees received either formal or informal health and safety training to teach them about operational risks and/or best practices? Open answer in %.

Cattle operations—Workload

For reference, question included in the survey

How many weeks per year exceed a 48 hour/week threshold?	0 week
	1-13 weeks
	14 - 26 weeks
	26 weeks or more

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Recommendation: Reformulate question to better take into consideration the agricultural context. Because this topic is sensitive and complex, several questions are needed to fully understand the context of workload at cattle operations.
New questions:
1) How many weeks does the peak season last at your operation? Open answer in # of weeks.
2) How many hours per week do you [owner] work during the peak season? Open answer in # of hours.
3) How many hours per week do employees usually work at your operation during the peak season? Open answer in # of hours.
4) How many hours per week do you [owner] work during the low season? Open answer in # of hours.
5) How many hours per week do employees usually work at your operation during the low season? Open answer in # of hours.

Cattle operations—Overtime pay
For reference, question included in the survey

Are employees paid overtime?	Yes
	No
*if yes, do they receive an overtime premium?	Yes
	No

Recommendation: Reformulate question to better reflect employment trends during the agricultural season.
New questions:
1) Do you employ workers at your operation that are paid on an hourly basis? Yes/no answer.
2) Do you employ workers paid on a full-time basis (e.g. fixed two-weeks or monthly salary for a certain number of hours per week)? Yes/no answer.
3) Are employees/workers paid overtime (additional hours worked after 40 hours per week)?
Yes, both employees and workers are paid overtime.
Yes, workers are paid overtime but employees are not / or employees are paid overtime but workers are not.
No, but employees and workers can bank time.
No, neither employees nor workers are paid overtime.

Cattle operations—Rangelands indicators
Questions should be modified to cover “habitat” instead of “rangelands” in order to be applicable to the East and naturally forested areas.

Packers—Sample
The processors surveyed in our analysis represent about 80% of Canadian beef production. However, it has been noted by the Steering Committee that it would be interesting to include smaller scale packers in a future assessment as their practices and challenges may differ from those surveyed for this study. Unfortunately, none were available to answer at the time of our assessment. It is therefore recommended to include them in the process for the next iteration of this study.

Packers—Third-party audit
Considering that meat packing plants surveyed declared that they audit their operations for animal welfare on a regular basis, it is recommended to ask who uses third-party audits in the future.
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6.15 ELCA & SLCA – Critical review panel comments on the complete report

Compilation and synthesis of peer review panel comments on
"Canadian beef sustainability: A baseline LCA of environmental and social impacts"

Prepared for:	CCA
Author of LCA report:	Deloitte
Peer review panel	Janice Bruynooghe Frank Miltoehner Robin Ried Nicole Tichenor Gregory A. Norris (chair)
Date of peer review comment summary:	17 March 2016
Date of Deloitte answers:	6 June 2016

General comments
Reviewers found that the final document is strongly improved from the second draft. The figures are clear and the text reads much better; the Executive Summary is clear and concise; the Glossary is useful.
Regarding readability and editing, we note that page numbering contains some errors, and typos remain, starting in the first paragraph, indicating the need for a copy editor. Also, consistent inter-paragraph line spacing should be used.

A copy-editor reviewed the document after we made all the necessary changes.

Important topic: "LCA plus"
The report has an ambitious remit, we recognize. It seeks to provide ISO-compliant LCA contributions on both environmental and social dimensions (already ambitious) while also addressing sustainability issues associated with the Canadian beef industry for audiences who are not LCA specialists, and/or whose interests may include topics beyond the scope of traditional LCAs. Fortunately our panel contains both LCA specialists and folks who think more broadly; so you will see that some of our panelist comments are particular to LCA methodology conformance and the ISO standards, while others ask for additions or clarifications (for example, discussion of the "knock-on effects" of climate change) which might more routinely be omitted from a pure "cut and dried" LCA report. We include the full breadth of reviewer input in this review synthesis report, not only the comments focused on LCA methodology and ISO compliance.

Thanks for this, which we appreciate.

Important topic: Manure credit
There needs to be a clarification added to ensure that benefits of manure have not been double-counted or over-estimated. In the study, manure is used to offset N required for feed production (which is a fairly common practice), but then *also* the assessment uses system expansion so that the entire manure surplus replaced synthetic N production for other non-feed crops in Canada. In the table below, we raise four reasons why this latter assumption may be overly optimistic, and at a minimum needs further documentation to ensure that the assumptions are in fact valid. Please also at a bare minimum document that the credit for providing manure to non-feed crops reflects only the balance of manure surplus remaining after counting for its application in feed production, and that

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the expected use (as N replacement) is actually occurring with the full quantity of manure being credited.

We revised our approach. Indeed, Alberta agriculture LCIs were based on the assumption of 5% of nitrogen needs met by organic fertilizer supply. However, given cattle excretion of manure, this assumption is likely to be underestimated for beef feed crops, as they are mostly produced on farm or nearby. Manure amounts are thus likely to be higher. When assessing overall manure excreted by the animal cohort, and corresponding nitrogen content, assuming all manure was allocated to feed crops is equivalent to meeting 28% of crops' N needs with organic fertilizer supply, which is a consistent value (discussion with Dr. Karen Beauchemin and Dr. Tim McAllister from AAFC). Alberta agriculture LCIs were thus adjusted, to reduce the volume of chemical fertilizers from 95% to 72% of crop nitrogen supply. No surplus was consequently considered to be exported to other crops.

Important topic: Land use assessment methodology
The land use assessment methodology should be described at the same time as the environmental and social assessment approaches, since it holds such a prominent place in this report.

We agree and have described the land use assessment methodology at the beginning of the report as well.

Important topic: LCA type
After the six LEAP guidelines had been published, a topic that had not discussed previously became centre stage: The question of whether an "Attributional versus Consequential LCA approach" should have been used. The present report needs to discuss this item and justify the choices made.

In the goal and scope section of the study, section 1.3.3, we have added the following text:
LCA modelling approach
Attributional and consequential modelling are the two mainstream practices, and are defined as follows:

- Attributional approach: "System modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system according to a normative rule." (UNEP/SETAC Life Cycle Initiative, 2011).

- Consequential approach: "System modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change as a consequence of a change in demand for the functional unit." (UNEP/SETAC Life Cycle Initiative, 2011).

Considering the objectives of this study focusing on a clearly defined single product system at a certain point in time, the Canadian beef meat industry in 2013, an attributional approach was chosen.

Important topic: Dairy vs beef
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Inclusion of information on the dairy sector portions that affect the beef industry needs to be included. While allocation makes this topic difficult, it nevertheless is important. For example, bull calves from dairies ending up as veal or in feedlots need to be considered as part of the Canadian beef supply chain.

Dairy Farmers of Canada (DFC) did a life cycle assessment study three years ago but it was not peer reviewed so we could not include it. While we discussed the potential to include dairy in the study with the DFC, we concluded it would be too difficult given scope and budget. We do however agree it is important. In fact, dairy animals are responsible for roughly15% of Canadian beef production, which is not negligible. We also mentioned Legesse's study which indeed shows a footprint of 12.7 kg CO_2 eq./kg of LW when considering beef for meat production only, and 12.0 kg CO_2 eq./kg of LW when including meat from dairy production. We also added some clarifications on the functional unit in the ELCA to make it clear that we focus only on the meat industry (details added at the end of 1.3.4.1).

Important topic: Data inventory for feed

It is not clear where the data for the feed portion of this beef LCA comes from. The document states that most feed commodity data is not available for Canada. However, feed is among the most important parts of the livestock supply chain and it affects the overall impacts of beef substantially. It also affects other impact categories, such as water use. How can water use be determined if no specific Canadian feed data are available, with growing of crop being a main water use area of the beef supply chain?

Our feeding information is based on known composition of the diet that was fed to cattle across Eastern and Western Canada, as observed in the survey and validated with nutrition experts.
For the feed LCI, we took Canadian/US data where possible. However for hay, we used a Swiss LCI and performed sensitivity analysis on the carbon footprint value with C data we had from Manitoba. It didn't change much. We also adjusted the land use and water footprint of all non-Canadian LCIs to current Canadian yields and irrigation practices, based on Statistics Canada Agric. Water Survey, yield and areas, in order to get a true picture of Canadian practices (see p. 31 and p. 47).

Important topic: Feed additives

How was the topic of feed additives addressed? Both the production of these additives (microminerals, ionophores, beta-agonists etc.) as well as their modes of action in the animal and beyond can have environmental impacts. Hormone implants were discussed but the others should at least be mentioned and their exclusion justified, ideally with estimates of the consequences of having done so.

We do recognize this is a limitation of our study but Canadian data on feed additives was limited, and due to lack of a proper model to assess toxicity impacts (lack of characterization factors for hormone and feed additives substances, heavy metals inappropriate characterization model) we decided not to assess toxicity indicators and excluded the effects of feed additives. Note that Canadian specific data is currently being generated on this topic and will be considered in future updates of the study.

Important topic: Blue water footprint

Without having Canada specific crop production data, we lack sufficient assurance that the Blue Water footprint results can be determined accurately. The extremely low

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numbers for water use by Canadian beef raise a sense of caution among some reviewers, and we recommend that this issue be put in front additional experts in this field.

We have highlighted and/or provided additional context to the methodology that was selected (focused on blue water footprint, in particular irrigation requirements for feed/forage crops). When compared to other numbers with similar scope, the numbers are low but in the same order of magnitude, which we believe is explained by the lower irrigation level in Canada (as per our answers on the data inventory for feed). We are aware that other approaches have been used and presented to the general public (including, for example, green and grey water) and show much higher numbers, which relates to different scope in the methodology used. Canadian research is currently being conducted to comparatively assess these different approaches and will be considered in future updates of the study.

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Specific Comments and questions

Chapter/ Section	*Page #*	*Question or proposed change*	*Comment (and where relevant, justification for suggested change)*	*Decisions/replies from the authors*
Executive Summary				
	iii	"This highlights the important role that extensive beef production systems play in maintaining healthy native rangelands and supporting the associated biodiversity"	One again, this report assumes extensive ranching is only positive for habitat and biodiversity. This is not always true, which is recognized in the Executive Summary. This sentence contradicts previous statements and should be revised adding the word 'potentially', as in "potentially helping to maintain"	Agreed, wording modified accordingly.
Chapter 1: Introduction				
1.2	3	Use correct chemical formula	Use CH_4 and not CH^4	Ok, corrected.
1.2	3	List references chronologically (oldest first)	Literature citations in the text should follow journal standards.	Ok, corrected

Goal of the study	4	Change "Recognize and achieve sustainable beef production" to "Recognize and achieve a sustainable Canadian beef industry"	CRSB's goals are explicitly about Canadian beef industry sustainability, not about the sustainability of beef production as a whole. Internal sustainability to an industry is likely very different than sustainability of the system as a whole, particularly for a product like beef. The exclusion of beef from dairy cattle, for example, illustrates that this study is focused on industry sustainability. A recent review of beef LCAs determined that beef from dairy or dual purpose breeds had the greatest potential to reduce the environmental impacts of beef (de Vries et al., 2015). Shifting production away from beef breeds and toward these potentially more sustainable systems is out of scope in the present study. Furthermore, a strong science-based argument could be made that beef production should decrease, and dramatically, to achieve sustainable levels of production. This is obviously not considered in the present study.	Agreed, adjustment made in the goal of the study.

	5	Dairy animals are excluded from the present study. How about related allocation issues? How do you deal with bull dairy calves that end up in the beef supply chain?		Dairy animals are excluded from the scope. In particular, the veal industry (confined mostly to Quebec; small amount in total) is not included. However, we do recognize that, in Canada, cows in the dairy sector enter the same feedlot and get into the same packing plants as beef cattle. So regarding impacts at these two stages, those animals are directly included in the assessment. We have thus corrected some key values to reflect the scope of our study (e.g. carcass weight information adjusted for culled cows in the East to reflect beef cattle weights only). We have not done more subtle adjustments, such as differentiate ADG for dairy vs beef bull calves in feedlot. If we had included dairy culled cows, both from a feedlot and packing plant stages perspectives, it would most likely have lowered the average impact per kg of meat, given that we would have had to allocate a large portion of the environmental impact based on the economic value of milk. We have highlighted the above considerations in the scope and allocation discussion, as well as mentioned that the per unit results (e.g. /kg LW) are most likely conservative given that we have excluded the dairy sector. We have also suggested this topic as an area of research for future updates of this report.
Geographic boundaries	6		Here it is important to clarify if the boundaries include non-Canadian sources for any products in this section. For example, does the assessment include the impacts of energy extracted outside of Canada used to transport beef to market? How about mining impacts. This point needs to be clear in this section, as well as later on page 8 (where it currently appears).	Agreed. We added p.6: "The system is representative of Canadian production, where the large majority of the inputs are domestically produced (e.g. feed, electricity, etc.)."
1.3.4.2	7	It is stated that the scope of the social assessment differs from that of the environmental assessment. But the UNEP/SETAC guidelines are explicit about the		The product system is indeed the same, however due to budget constraints and the approach selected, some life cycle stages were not taken into account, namely: consumption and waste. For communication reasons and based on the US social life cycle assessment for beef, which results were difficult to interpret from our point of view, we decided not to use the functional unit in the SLCA but to instead adopt a methodology with indicators relying on a common risk scale with four levels to enable comparison and ranking between the indicators.

		point that the actual product system is the same for both environmental and SLCA. Many important social impacts addressed by the Guidelines can be assessed at the same unit process level as for ELCA. Finally, regarding the use of qualitative data, this can be used in a functional unit-related way through application of Life Cycle Attribute Assessment: quantifying the worker-hours at various levels of risk, by unit process, per functional unit. This approach too is referenced by the guidelines, and has been documented in numerous case studies, and is supported by available databases usable in LCA software.		
Exclusions and	8-9	Explicitly state here that toxicity	These are categories that are available in LCA and	We have specified that these indicators were not assessed and have been explained (see p.8-9). As background, we did perform an assessment of human and ecosystem

limitations		impacts on ecosystems and human health were not addressed	have been addressed in other national scale industry studies (for example, the US dairy industry did this). I'd like to see more justification here for why toxicological impacts were excluded when we have LCIA methods for assessing the tox impacts for metals, pesticides, etc. There are likely tox differences between intensive and extensive beef systems or production stages that are not discussed here.	toxicity potentials, which were largely dominated by metals. However, given the high uncertainties (see below), we decided jointly with the Steering Committee to remove these indicators. We have added the following paragraph: Toxicity impacts have not been assessed, given that current methods to measure the corresponding indicators are not adapted to agricultural production, including USETox, which is the most mature method. There are several reasons for this: - First, potentially toxic substances, such as pesticides or growth-enhancing technology substances, lack characterization factors. In some cases, toxicity potentials can be assessed but they strongly depend on local conditions, and models are still highly uncertain. Proxies could have been used as well, but here again results would not have been accurate. - Second, other toxic substances include metallic trace elements found in chemical pesticides and fertilizers. However, the USETox models for ecotoxicity and human toxicity do not currently apply well to metals (JRC—European Commission, 2010). - Finally, emission factors of toxic substances are very dependent on the local climate and soil conditions, and it is very difficult to model which share of the applied amounts end in air, water, soil and living organisms. Given the high uncertainties on both the emission factors and the characterization factors, it was decided not to assess these potential impact indicators.
Functional unit	9	Remove "consumed nutrition" from third paragraph	None of the stated functional units are specific to nutrition.	Ok – removed.
	9	'The assessment of impacts at the global scale (e.g. climate change knock-on effects) is excluded from our system boundaries.'	These knock-on effects are <u>VERY important</u> and this report would be much more credible if these were included. For example, the portion (%) of the total GHG emissions from the Canadian beef sector, of total emissions, could be calculated. Then a statement could be added like this: ' xxx% of total	We followed your suggestion. First, we removed the following sentence from the G&S: "The assessment of impacts at the global scale (e.g. climate change knock-on effects) is excluded from our system boundaries." Second, in the *Land use* section (Carbon soil sequestration, 3.5.4 Result), we assessed the share of Canadian global emissions coming from the beef industry. Third, in the section (2.5.1.2 Breakdown of indicators by life cycle stages), we added the following sentence: "As Canada's total GHG emissions in 2013 were estimated to be 726 Mt CO2 eq., beef meat production accounts for approximately 2.4% of Canada's overall GHG emissions (see 3.5.4 Greenhouse gas emissions from beef meat production paragraph). While the proportion of global impacts are very small, this still contributes to the massive global

			global greenhouse emissions are caused by the Canadian beef value chain. While the proportion of global impacts are very small, this still contributes to the massive global impact of climate change on most earth systems, with strong current and future consequences for people and millions of other species the earth supports. We refer the reader to the IPCC reports to understand the wide range and complexity of these impacts.'	impact of climate change on most earth systems, with strong current and future consequences for people and the millions of other species the earth supports. We refer the reader to the IPCC reports to understand the wide range and complexity of these impacts."
Chapter 1 as a whole			In all of chapter 1, there is no mention of the land-use assessment that appears from page 79 on. This needs to be described in chapter 1.	An introduction to the land use assessment was added in Chapter 1.
Chapter 2: Environmental life cycle assessment				
	20	We understand that the report focuses on beef but the dairy bull calves must still be addressed.		cf. answer to question 5.
2.1.2	21	Footnote 8 indicates that different backgrounding and finishing rations for the different production systems were not modeled.		This statement was inaccurate and it has been removed, as the rations of both stages were modelled using specific data from the surveyed farms. Backgrounding and finishing rations used in the model are distinct.

		This seems to be a major omission, if I understand this correctly. This would be a primary source of difference in resource use and emissions between the systems. How is this defensible?		
2.1.3	21-22	How long were each of the breeding herd animals in the cohort fed for?		This information was indeed missing in this last version. It has now been added in section 2.2.2.1.
2.1.3	22	You assume 1:1 replacement of heifers and cows, but you would have two pools of replacement heifers– calves and then more mature, due to the length of the cattle cycle. The same would be true for bulls. This should have been accounted for.		Yes, this is probably a limitation of the simplified display in this chart, but we do consider that for one finisher, we have both young replacement animals (calves) and more mature animals (>1 year old). Instead of presenting the "number of animal category associated with the production of one finisher", we think it would be more understandable to present the number of days of each animal category which are attributed to one finishing animal. Indeed, for cows for instance, a finisher does not need precisely 1.11 cows, but rather 1.11 year of one cow, given birth frequency and mortality. The chart was revised accordingly.
Cattle description	25	Please report a sensitivity analysis with the farm reported durations, or an explicit estimate of how different they were from the assumptions that were made.	It is plausible that the durations in the literature could be too optimistic, depending on their data sources, which are often expert opinion and other literature. Unless there is reason to believe that the producers who responded to your survey would be	The original figures are presented in appendix 6.6 (and are referred to in the core of the report). Given that the survey was not built to track one animal from birth to slaughter, original data do not provide a proper view of the industry. Compiling data from several farmers to model an average life revealed its limitations, not because producers would underperform, but simply because averaging and summing period lengths from different farmers was not appropriate. Given that the original figures had no tangible meaning, using them in the model would not provide proper results, and the outcome of a sensitivity analysis would not add much value compared to what is already presented in appendix 6.6.

			underperforming systematically, which is not mentioned.	
Cattle description	26	Why is the backgrounder system not modeled separately, as it is indicated there are three distinct production systems earlier?		As mentioned on p.21 of the document, "The present study aims to encompass a variety of practices representative of Canadian beef production. The following systems have been studied: Eastern and Western production systems, calf-fed and yearling-fed production systems, implanted and hormone-free animals. Given the predominance of Western beef production, this scenario was chosen as baseline." The calf-fed and yearling-fed systems were chosen as they represent the two extremes (backgrounder being the middle range) and provide a range of environmental impacts of the production system. Further, in our sample, very few animals were backgrounded and directly sent to finishing. We obtained the following distribution: 59% of yearling-fed animals and 41% of calf-fed, which was in line with industry figures.
Cattle description	28	Is the cow weight reported an average across both regions? This might unfairly give the West an advantage over the East	These cow weights look high, likely due to averaging across regions. If finished cattle are heavier in the East due largely to breed differences, as is stated, the dams that birthed them would be larger as well. If cows are averaged across the two regions but not their progeny, the West is getting an unfair bump in cull meat and the East is getting docked.	We have double checked our assumptions and supporting data. Heavier finishers in the East are—as explained to us by experts (Christoph Wand, Livestock Sustainability Specialists and Brian Pogue, Beef Cattle Program Lead—Ontario Ministry of Agriculture, Food and Rural Affairs)—the results of two complementary factors: breed (higher proportion of continental blood—Simmental, Charolais and Limousin in particular—in Ontario and Quebec) and response of feedlots to market requirements from packers. Packers in the East indeed request heavier animals to compensate for a shortage of animals. As a consequence, feedlots in the East heavily feed their calves regardless of their origin (probably half or more of fed cattle in the East are now Western in origin) to provide heavier animals to the packers. Cow carcass weight data from Federal & Provincial Slaughter in our 2013 baseline year are as follows: • West: 676 lb at 50% dressing percentage = 1,352 lb (very close to the Western Cow/Calf Survey number of 1,381 lb) • East: 648 lb at 50% dressing percentage = 1,296 lb (pulled lower due to holsteins) Given the expert commentary on the combined importance of breed and feedlot responses to market demand on finishers' weights, we think that 1,381 lb for both East and West culled cows' weights is our best assumption, as we do not have any data justifying a change and, if it changed, to what value. We thus **suggest keeping culled cow weight as-is** (i.e. 1,381 lb for both East and West) and have **added further explanations for carcass weights in table 2.5** (mentioning the impact of breed and of feedlots' response to market/packers requirements).
	28	Impacts of feed produced outside	In this section on methods, it is important to	Agreed, adjustment provided at the end of the section "2.2.2.1. Feed ration: *"Furthermore, farm surveys highlight that most feed (more than 70%) is produced locally,*

		of Canada	be clear what proportion of feed comes from outside Canada and why these impacts were excluded (if they were). This appears on page 32 but should also appear here.	*i.e. on beef farms, and the majority of purchased feed comes from the same province, within a radius of 50 km* (AARD, 2010).*"*
First mention in main text		Need to define term	Need to define 'photochemical oxidant formation' and what effects this has on the environment	We suggest mentioning that all the terms are defined in the glossary, for if we define "photochemical oxidant formation" here, we will have to define eutrophication, acidification, etc. which would lengthen an already dense report. A footnote was added at the first mention of these terms in the main text.
Feed rations	28-29	Within each feedstock category, how different were the feedstocks used between the regions and the phases?		No differences were made within the feedstock categories independent of final use (animal age or producing region): a given feedstock was modelled similarly for all regions and animal ages. This was added at the end of Section 2.2.2.1. Feed ration. However specific yields were used for each province in Section 3.2.3. Results of the beef land cover footprint.
Land use	30	Where is table 2.21?		The reference was updated.
	32	For those feedstuff that were transported long distances via rail or truck, one should describe the loading status of that transport vehicle on its return (empty, half full, or full).		The following sentence was added in Section 2.2.2.2 Transport: "*For lack of better data, for all transportation stages, default loading status from the ecoinvent v3 database were used: an occupation of 80% of truck capacity when the truck is loaded and, for the return, 20% of the emissions of the first trip are dedicated to the return trip."*
Figure 2.2	35	Suggest a more detailed explanation of the 'animal cohort' numerical assignment. Not clearly explained.		(repeated from comment above) Instead of presenting the "number of animal category associated with the production of one finisher", we think it would be more understandable to present the number of days of each animal category which are attributed to one finishing animal. Indeed, for cows for instance, a finisher does not need precisely 1.11 cows, but rather 1.11 year of one cow, given birth frequency and mortality. The chart was revised accordingly.

Considerin g manure production surplus	37	This application of system expansion is not in line with common practice in livestock LCA. Beef production should not be getting an offset for manure surplus beyond feed production, and the amount of manure export or surplus ought to be stated explicitly. If manure application is included in ration LCIs, anything beyond that should be considered a residual at the farm gate. Additionally insufficient detail is given for how this method was executed.	The beef system should not get credit for avoided fertilizer N that is outside its system boundary because a) no evidence is cited that this is how surplus manure is actually used b) meeting N requirements with manure will likely result in over-application of P, which is not accounted for here and c) this is impractical at a country scale, unless Canadian crop producers are going to report that additional burden with their own sustainability assessment. Otherwise, there are disappearing emissions d) this is inherently biased toward concentrated feeding operations that export manure. This is therefore a questionable application of system expansion, in the opinion of at two of our panel members.	As mentioned in the *Important topic* section, we have revised our model and do not apply a system expansion anymore. See section 2.3.2.5.
Figure 2.6	40	Y axis label is cut off		OK, fixed.
Nitrous oxide emissions	42	N leaching during manure storage not on pasture should be included.	IPCC does *not* say leaching only occurs on pastures. There is a different Frac_leach parameter which is supposed to be country-specific for manure management systems, but	In pens, catch basins are often implemented to collect the residual nutrient losses by run-off. In addition, soil in pens is often compacted, which limits the nutrient losses by leaching. On this basis, we made assumptions that no N losses occur during storage. This assumption was also made in the Holos tool to determine the indirect N2O emissions from N leaching. Nonetheless, we performed a sensitivity analysis with a Frac_leach of 10% and 20% during storage and included this analysis in the report.

			a range of 0-20% is given. At the very least, the median estimate of 10% should be used in the absence of better data, especially since the leaching rates for pastures are 20+%. Additionally, 20 and 40% of manure N are lost in solid storage and compost systems, with nitrate the second highest N form lost (Rotz, 2004, Management to reduce nitrogen losses in animal production).	
2.2.2.1	43	(Water Use) Last sentence, second last paragraph on the page reads: "However, reviewing 2014 Agricultural Water Survey…….the substantial volumes of water used on irrigated areas make the overall impact of irrigation non-negligible." The wording in this statement makes it unclear and difficult to understand. The intent is fine but a more direct statement rather than 'non-negligible' would		This sentence has been rephrased p 31: "*Reviewing the 2014 Agricultural Water Survey (Statistics Canada, 2015), it appeared that irrigation is a limited practice across Canada. However the overall impact of irrigation is still significant, due to the substantial volumes of water used on irrigated areas.*"

		make the statement more concise.		
Phosphate emissions	46	Why wasn't phosphorus excretion estimated?	If ration composition was available, feeds databases (like Dairy One or Feedipedia) could have been used to estimate P content of the rations. There are equations by ASABE that could have been used to estimate excretion of P by beef animals.	We recognize this gap. We have highlighted it as such and emphasized that it should be an area of future research. We assessed it was a bit out of scope for this first iteration of the study as we felt this was not as simple as just calculating the P content. Indeed, one also needs to look at P mobility (e.g. greater in the East than in the West) and the migration risk (depending on the soil structure, etc.) to effectively assess the potential impacts. In our view, one needs to look at the bigger picture to make meaningful conclusions. Again we recognize this as a gap and have suggested addressing it in the next version of this study.
Phosphate emissions	46	Phosphate emissions should be calculated for all production phases or excluded.	There is no evidence cited for the defensibility of only assuming P loss occurs in pastures.	P losses mostly occur by run-off and erosion. Erosion occurs in pasture. Run-off occurs in pasture but also during storage. In pens, catch basins are often implemented to collect the residual nutrient losses by run-off and P is not volatile. Consequently, we made assumptions that no P losses occur during storage (which is consistent with the approach for N).
	48	How was feedmill processing of feed commodities accounted for? Do any Canadian data exist for feedmill processing?		No Canadian data were found to model feedmill, but the processing of energy feed, protein feed and DDGS were found in the ecoinvent v3 database and were used as proxies for Canadian practices (table 2.21).
2.2.2.4	48	Cooking: first para on the page, last line: test "Figure 2.9" is repeated.		OK, corrected.

2.3.2.6	49	Was feed loss during storage and feeding included?		We revised our calculation to take them into account. Feed losses and waste are now presented in Table 2.6.
Table 2.15	52	Data based on animal categories and then sub-groups for gender, etc. very useful but difficult to interpret as presented. There may be value in providing a more detailed explanation of the reported differences. For example, questions that came to mind when reviewing the values included: * for backgrounders, why are grass values lower than feed? * or yearlings, why are grass and feed values the same? * for cows and bulls, why no difference between grass and feed? The addition of further text defining why calculations resulted in differences (or lack		We added the following paragraph above Table 2.16: "*The GEI of an animal can be estimated from the DMI, considering that GEI = 18.45 x DMI. DMI were calculated based on the mid-weight and the equations from Anele et al. (2014).* *To obtain daily enteric emission values, the DMI is then multiplied by the methane emission factor (Ym). The calculation method, based on the IPCC guidelines (2006) as well as data sources, is detailed in Appendix 6.5. Calculated daily methane enteric emissions are indicated in Table 2.16.* *While similar conditions of age, gender, weight and location (East or West) lead to a similar Ym, DMI may vary depending on the ingested diet. In particular, DMI is different depending on whether animals are fed or grazing. This potential difference of DMI between animals of the same category (e.g. backgrounders on feed or on grass) explains the difference of enteric methane emissions."*

		thereof) will provide clarity. Also be aware of statements re: irrigation rates on page 68 to ensure that they do not contradict.		
2.5.1.2	54	The other reason pasture N20 emissions are higher is because that is essentially storage and application, whereas in MMS, only the storage emissions are considered.		Agreed.
2.5.1.2	55	The other reason the water footprint results might be low is because of the manure crediting used here.		The approach on manure credit was revised, and there is no more credit applied.
	75	Page numbering	About here the page numbering goes haywire for a while, please correct.	OK, corrected.
Section 2.5.2	76	First para, second sentence: "Animal breeding accounts for most of all the environmental impact indicators…" The statement is confusing and poorly worded. What is meant by		OK, corrected.

		"animal breeding"? Is this the animal production phases?		
Figures 2.25 and 2.26			Very clear figure, but please add a symbol showing when the two scenarios are significantly different on each graphic.	Agreed.
	80	First sentence, top of the page: "Packing mainly contributes to water depletion, fossil fuel depletion…" there is a space missing between the words "fuel" and "depletion".		OK, corrected.
2.5.5.1	Pg. 81 of PDF – misnumbering of report pages here as well	More documentation should be provided for estimates of LCI parameter uncertainty, in an appendix, perhaps.		The following statement was added in Section 2.5.5.1 (note 30): "*The uncertainty on the LCI parameters is established by the creators of the LCI (ecoinvent, Agri-footprint). In most cases, it follows a log-normal distribution, and standard deviation is calculated according to the pedigree matrix (https://www.pre-sustainability.com/improved-pedigree-matrix-approach-for-ecoinvent).*"
2.5.5.1	Pg. 81 of PDF	Why is a 75% instead of 95% confidence interval used when comparing scenario results?		Indeed, the justification was missing. The footnote 33 was added: "*The rationale for considering 75% confidence intervals was the following: with system A having an impact illustrated by the red curve and system B having an impact illustrated by the blue curve, the deterministic calculation yields to the impact of A being lower than the impact of B. If we assume that the maximum of the 75% confidence interval of A is equal to the minimum of the 75% confidence interval of B, a sufficient condition for the impact of B being lower than the impact of A corresponds to the impact of A being greater than the maximum of the 75% confidence interval of A and the impact of B being lower than the minimum of the 75% confidence interval of B at the same time. The probability of this occurring is 12.5%*12.5%<1.6%. If we had considered the 95% confidence intervals for each system, this probability would have been lower than 0.07%. As such, taking 75% confidence intervals was considered sufficiently "strict" to ensure that differences in impacts are significant.*"

2.5.5.2	Pg.83 of PDF	If the results are not statistically significantly different, even at the 75%, there should be no need to report them.		The various scenario analyses were performed to reflect the diversity of practices. And even a non-significant difference is a learning. In this case, it stresses that there is no clear evidence that one production system performs better than the other from an environmental point of view. This reinforces the message that, although there is still room for improvement, the various production systems all have their place in the Canadian industry, both from a year-long supply perspective and an environmental standpoint.
2.5.5.2	84	Carbon footprint section: top of page 84, last sentence in this section (just before Water Depletion section): "In addition, enteric emissions per kg of live weight are numerically higher in the West scenario than in the East scenario. This is mostly due to lower finishing weights of Western animals". Comment relates back to table 2.15. When making these statements more details explaining the factors that are part of these outcomes need to be included. It is difficult to follow (particularly since the data is presented many pages earlier) how the actual values have been used to		OK, we added the following paragraph in the section 2.5.5.2 Carbon footprint: "*Since cattle spend more time indoors in Eastern Canada (57% of their time vs 33% in the West), a higher amount of manure is collected and stored, resulting in higher emissions during storage. Conversely, in the West, animals spend more time on pasture, resulting in higher emissions from manure applied on grazing lands. Although grazing practices in the West imply higher overall manure-related emissions, this output is offset by less time spent on feed (42% v. 57% in the East), which reduces the Western system's impacts associated with feed production as compared to the Eastern system. In addition, enteric emissions per kg of live weight are numerically higher in the West scenario than they are in the East scenario. This is mostly due to the lower finishing weights of Western animals (1,350 lb vs 1,550 lb in the East).*"

		reach these conclusions. And because there are so many factors involved repeating some of the specifics would make it easier for the reader to understand how conclusions were reached.		
	84	Fossil Fuel Depletion section: Last sentences in that paragraph, "As mentioned above….and these additional impacts are not compensated by the heavier weights of the animals." These statements are confusing and require further explanation. Why are heavier weights not compensating for additional impacts? Are eastern animals less feed efficient? Further clarity will help the reader understand the statement. This comment also relates to similar statements in Sections that follow		This statement only refers to the additional impacts of feed production in the East. We have added the following paragraph at the end of the paragraph of Section 2.5.5.2 Fossil fuel depletion: "*These results do not show that Eastern animals are less feed efficient, as the amounts of grass ingested are not taken into account in "feed production". However, they highlight the fact that the heavier finishing weight of Eastern animals does not compensate for the additional burdens associated with higher amounts of cropped feed consumed.*"

		including "Marine eutrophication" and "Photochemical oxidant formation".		
2.5.5.2	All charts	Bar charts comparing results should include error bars for the uncertainties assessed.		For readability purposes, we put an asterisk beside the charts when results are meaningful.
2.5.5.2	Entire section	Per ISO, sensitivity analyses should be conducted for all allocation decisions. This should be included in the scenario section. Additionally, scenarios should be run around manure handling, given the controversial methods choices made.		We performed a sensitivity analysis on the meat co-product allocation, using economic allocation as the baseline. We then compared it to a mass allocation. Given the revision approach on manure, no sensitivity analysis is necessary on that part.
Chapter 3: Land use assessment				
	88		Congratulations on the innovation used in this chapter in the analysis. Well done!	Thank you.
	91	Review papers to reference	Milchunas, D. G., O. E. Sala, and W. K. Lauenroth. 1988. A	The first (American Naturalist) is not really relevant since we focused the review on empirical evidence, and this paper proposes a theoretical model of the effect of grazing on plant communities.

			generalized model of the effects of grazing by large herbivores on grassland community structure. American Naturalist **132**:87-106. Milchunas, D. G., and W. K. Laurenroth. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. Ecological Monographs **63**:327-366.	The second is a meta-analysis of empirical studies of grazing vs grazing exclusion, but not specifically focused on Canada. It is thus more relevant, although the conclusions are not fully relevant. We cited the paper for good measure and included it in the references list.
3.2.2	Pg. 97 of PDF	What level of resolution is the beef cattle production data?		We added a mention that beef cattle production data is at the census consolidated subdivision (CCS) level in the Interpolated Agricultural Census of Agriculture. We then used this to build a county level view.
3.2.2	Pg. 97 of PDF	Not enough detail provided for land area for grazing estimation. How was the productivity of the different land cover types estimated? How were the grazing needs of non-beef cattle determined (i.e., how is it known how many dairy cattle graze and for how long)?		We didn't assess the productivity of the different grazing land covers at it was too complex. We did a top down allocation approach based on Animal Unit Equivalents of both beef cattle and non-beef cattle inventories across Canada. This approach does not require an estimate of the productivity of the different land cover types.
3.2.2	Pg. 98 of PDF	Byproducts, but not wastes, should be assigned a land use.	Co-products, such as DDGS or soymeal should be assigned a land use using economic allocation, as was done in the ELCA section.	We assessed DDGS land use footprint based on two different economic allocation scenarios and provided a note to the results under Figure 3.4.

3.2.3	Pg. 100 of PDF	However, it can already be noted that arable land requirements for cattle feed (all land suitable for cash crops and human food production, including fallow) represents only 4% of total arable land available in Canada, once pasture and forage land cover types have been excluded (i.e. natural land for pasture, tame or seeded pasture, alfalfa and alfalfa mixtures, all other tame hay and fodder crops land cover types excluded).	This study does not address suitability of forage land for crop production. It is thus unclear whether the forage land is arable or suitable for human food production or not. Additionally, including alfalfa and alfalfa mixtures in the “forage land” category is questionable, as alfalfa is often grown in rotation with corn silage or corn.	We had based this statement on experts’ view that, historically, forage has been pushed onto marginal land as higher returns from cash crops take precedence and that, when in rotation (as suggested in Eastern Canada), it is usually for soil management (hence sustainability). However, we agree that our study does not demonstrate this point and we cannot state that all forage land is not arable or suitable for human food production. We have therefore clarified the wording to improve accuracy. We compared land requirements for grain cattle feed (barley + corn + oat + wheat + DDGS) with the total land use from the “Land in crops” and the “Summerfallow” categories from the Agr. Census and comment on the result, without broadening the conclusion to arable land or land suitable for human food production.
	100	‘Reflecting the scenarios described in 3.3.2.2 and in Table 3.2, a 10% change in the number of cattle in Canada impacts only 37% of the area used for the beef cattle production as natural pasture is	Sentence does not make logical sense	Sentence rephrased, reflecting also the clarifications on the scenarios.

		not impacted.'		
	105	Paragraph above Section 3.3.1.3. Last part of this paragraph discusses spread of invasive species. Yes, livestock production is a vector however this paragraph places over-emphasis on livestock without mention of other factors in the spread of invasive species. Report should present a more balanced statement and/or further citations.		A caveat was added that the forestry and ornamental plant sectors are also important vectors. Note that the paragraph simply refers to spread of invasive alien plant species (not all alien species).
Impact assessment of livestock production	Pg. 106 of PDF	It's not clear how the second, top down method that is mentioned is an estimate of biodiversity impacts.	Eshel et al. 2014 looked at land use, not biodiversity impacts.	This is a good point, and a sentence was added to clarify this. We in fact use a mix of this approach and the LCA in our study and (a) link it with a spatially explicit biodiversity index, the WHAFI and (b) check coherence among top-down (national statistics on livestock production, crop production) and bottom-up (LCA) ration data.
	107	Water indicators chosen	The indicators chosen make sense in drier western Canada, but what about flood occurrence in eastern Canada. Please explain why the chosen indicators apply to both eastern and western Canada in the text.	We do agree that flood occurrence would have been a good risk indicator in Eastern Canada. However, given available data we decided not to use it. Our water risk assessment relied indeed on using outputs from WRI's Aqueduct tool. The flood occurrence indicator in Aqueduct is not a measure of the likelihood of flood occurrence, but rather a simple record of historic floods from 1985 to 2011. This indicator relies on actual flood occurrence data as opposed to modelling flood occurrence, and is therefore limited by the availability of flood data. Flood recording in Canada is generally poor and there is a great deal of research currently underway to improve flood tracking, especially in Eastern Canada. We have added a sentence to highlight this limitation, as well as the need for research to better track flood occurrence in Eastern Canada. This could be a particularly interesting area for future research as this metric could affect P run-off values and be affected by

				climate change knock-on effects.
Fig 3.7	111	Great work on the assessment of impacts on biodiversity. When looking at the land cover types were wetland areas (with the highest MCVs) factored in at all when assessing biodiversity impacts of cattle? Wetland/riparian areas are very often part of pasture landscapes and protected/managed within grazed areas as compared to other land uses where wetlands are often drained and destroyed. Maintenance of wetlands is often associated with good grazing management plans. Should a portion of wetland values be included in calculation of wildlife habitat capacity? Or have they been already? On page 117 wetland connection		Wetland areas were not factored in at all as it was difficult to assess how much was part of pasture landscapes. It would consequently have been difficult to include a portion (how much?) of wetland values in calculation of the wildlife habitat capacity of beef-related land. We have added this as a conservative limitation, included in the initial discussion on page 111. This area has been mentioned as an area of future research given current limitations in datasets available (e.g. wetland inventories on pasture land).

		to grazed land is included as a limitation. This is a significant shortfall when calculating positive impacts. That being said, if not possible to include then this limitation needs to be mentioned in the initial discussion on page 111.		
Scenarios	Pg. 112 - 113 of PDF	These scenarios seem to have no empirical basis.	In particular: - "A reduction in beef production is thus assumed to lead to the conversion of pastures and land used to grow feedstock to more intensive agricultural uses or cash crops for human use (i.e. Malt barley, canola, soy, etc.); **the option of land**	We agree with the comment as it is very hard to provide a scientific empirical basis to one or another scenario. We based our scenario on historical data showing a positive correlation between tame pasture areas and beef cow herd throughout historical cattle cycles. We also have anecdotal evidence of increased grassland losses in recent years, with higher corn and soy prices relative to beef in Dakota (Wright & Wimberly, 2013) (Reitsma, et al., 2015). Regarding the potential impact of land abandonment, members of our Steering Committee can also point to anecdotal evidence of cases leading towards a decrease of biodiversity. Given the complexity of potential ecological succession scenarios, it was difficult for us to easily model one method or the other. As we could not generate (and defend) a general case, we preferred to transparently state that land abandonment was not considered. Finally, on the assumption that utilization of natural pasture does not change in either scenario, it was again hard to identify empirical data to back this up. However as the scenarios are based on a 10% change in the cattle herd only, we decided to model inertia on the natural pasture areas (both up and down). We do agree that the scenario modelling is not a linear one and that a larger cattle herd change (e.g. +25%) would

			abandonment or regeneration is not considered." This could be highly misleading, given that ecological succession in these communities could likely increase biodiversity. - The assumption that utilization of natural pasture does not change in either scenario does not seem fair and is based on expert opinion from a cattle marketing agency representative.	probably lead to more substantial change in the natural pasture. Overall, to address this comment, we suggest including and further highlighting the limitations in the scenarios interpretation. As such, we have suggested this topic as an area of research for future updates of this report.
Sec 3.3.3.2	115	Middle of second paragraph: discussion of crested wheatgrass as an invasive species in the same light as leafy spurge and spotted knapweed is misleading. If mismanaged, crested wheatgrass can and has		We agree that CWG should not be compared on the same footage as spotted knapweed and leafy spurge. However, we did not find any evidence in the literature that CWG can have no negative ecological impacts. As we understand, it has very good forage properties and thus high economic value for farmers, but as time passed and larger areas of CWG were planted, its negative environmental effects became more obvious: mainly, it is often seeded in monocultures and outcompetes native grasses, such that—even 40 years after planting—native grasses remain <10%, leading to reductions in soil diversity/soil structure. We rephrased the part about CWG to provide a more balanced perspective. We replaced 'grasses' with 'plants'.

		impacted native grasslands. However, proper management makes it a valuable forage source without negative impacts to biodiversity. These statements needs to be further quantified if left in the document. CWG is not comparable to leafy spurge or spotted knapweed. Suggest to reference additional studies which present this balance. Also in that same paragraph: knapweed and leafy spurge are incorrectly referred to as “grasses”. Rather they should be referred to as “invasive plants”.		
	115	Third paragraph, first sentence: “…..proper grazing management is an area where the beef industry can, and in some cases already does, improve biodiversity.” This		We agree with the comment. Entire section was reviewed by Mike Alexander, Director, Range Resource Stewardship at Alberta Environment and Parks, to include some more detail regarding the benefits of those actions and to present a clearer link to the earlier discussion, and some additional scientific references were added to the section.

		is an important statement. Many examples do exist – suggestion to include a few scientific references to support this statement. Last line in third paragraph which includes bullet points for suggested grazing management actions. Include more detail regarding benefits of these actions. As presented they are fragmented and do not present a clear link to the discussion earlier in this paragraph.		

Water risk	119	This statement is problematic: "Those beef producers who recognize the role of natural vegetation in retaining nutrients and who maintain vegetation buffers are capable of providing a net positive impact on water quality as they effectively remove more nutrients than their operations produce"	This does not make any sense. They cannot be removing more nutrients than their operations produce. At best, they are capturing some of the nutrients that would otherwise runoff without buffers or with low vegetation.	We agree with the comment. We have rephrased the statement as follows "*Those beef producers who recognize the role of natural vegetation in retaining nutrients and who maintain vegetation buffers are capturing some of the nutrients produced by their farms or upstream farms. By doing so, they effectively improve water quality by reducing nutrients contamination of downstream water streams and water bodies.*"
	127	'Beef production is the primary reason that many native grasslands continue to exist in Western Canada, since cattle are the primary users of these grasslands.'	This is an exaggeration since the same land is likely not largely suitable for tame pastures or cropping, but is suitable for only wildlife use, which would likely sequester more carbon. It would be more accurate to say: 'To the extent that beef production on native grasslands prevents more intensive use of the land for cropping or tame pastures, this production system may serve to 'protect' native grasslands and their sequestered carbon in Canada.'	We agree with the suggested rewording. *"To the extent that beef production on native grasslands prevents more intensive use of the land for cropping or tame pastures, this production system may serve to 'protect' native grasslands and their sequestered carbon in Canada."*

Table 3.4	127	Title of table needs to include “Ratio (as %)”		Ok, corrected.

Carbon sequestrati on	134	Using data on C sequestration for canola on Canadian prairie from one study for all feeds, including rangeland, does not seem like an acceptable assumption to make. At the very least the uncertainty of the estimate should be addressed.		We have mentioned the uncertainty of the proposed methodology which is 21% from the National Inventory Report (Environment Canada, 2014). We believe that the proposed approach is transparent, and as complete and fair as possible considering the national system (Canadian beef) we need to cover. We reference the following paper that discusses the options for treating soil C change for LCA: "Accounting for soil carbon changes in agricultural life cycle assessment (LCA): a review" (Goglio et al., 2015). As discussed in the paper, there is no easy solution to choice of methods. When considering large scale assessments, the method needs to capture the wide range of soil-crop-climate situations. Beef production is very large scale because much cropland is part of the beef system. So the rationale of setting the system boundaries as all of Canada is justifiable. The method, being comprehensive, captures all leakage (e.g. land being converted to pasture in one part of Canada while being reduced in another part) that could easily happen if boundaries do not include the full nation. Are these appropriate for rangeland alone? No, but we argue they are appropriate for the beef system including rangeland. The other potentially controversial issue is whether to include land use change (LUC). Agricultural land economics are so affected by beef that it is hard to argue that beef does not affect LUC. Including LUC makes the estimates conservative so there can be no argument that it cherry picks situations that are more favourable.

Table 3.9	135	Why is carbon stock value for tame pasture less than that for cropland?		We have validated assumptions with Brian McConkey, Research Scientist, Science and Technology Branch at Agriculture and Agri-Food Canada. It confirmed that carbon stock value for tame pasture—on average across Canada—is lower than that for cropland, but it also allowed us to identify a computing error for stock of carbon (SOC) values for unimproved pasture, which now moves from 113.1 to 74.5 at a Canadian average, i.e. lower than cropland as well. Now our revised SOC average values for Canada are as follow: cropland 75.9; tame pasture 71.2; unimproved pasture 74.5. As we suspect this will come even more as a surprise to those who expressed this comment, here are some explanations. SOC is a powerful indicator of inherent soil productivity. So at the provincial scale, land use is affected more by inherent SOC amount than inherent SOC amount is affected by land use. Let's consider the economics textbook case where soils and landforms are well drained and uniform except for SOC. The SOC reflects inherent productivity, and high productivity soils are more profitable as cropland than grassland. So, economics will drive all high SOC land to cropland and all low SOC to grassland. SOC will drop on cropland but, if any cropland SOC drops below the SOC of any grassland, economics will drive that grassland to be broken to cropland and that cropland to be converted to grass. So there will be three classes of agricultural land: cropland, improved pasture that alternates with cropland depending on changes in economic conditions and SOC amount, and unimproved grassland. Thus the economically expected SOC situation is: cropland > improved grassland > unimproved grassland. One major wrinkle is that poorly drained soil has high SOC but low productivity. Unless artificially drained, the poorly drained soils are more profitable as grassland. Also, on the well-drained high SOC soils, there are limitations like rocks, topography or accessibility that make grassland uses more profitable than cropland. So although we expect more SOC on cropland than grassland, especially because of the poorly drained soils, there can be a lot of grassland on high SOC soils. This is actually the case in the wetter eastern provinces of Quebec and Ontario. Limitations only confirm the use of low SOC for grassland, although productivity limitations can be overcome by, for example, irrigation plus heavy use of fertilizer, so some low SOC land is used for cropland. When rolled out over an entire province, the situation becomes extremely complex—so it is not surprising that SOC does not vary considerably between cropland, improved pasture and unimproved grassland. In the Prairies and BC, there is lot of soil in dry areas with low SOC that are predominantly used as grassland, while cropland tends to have more SOC than improved grassland. In the more humid provinces, the poorly drained high SOC soils in grass becomes so important that grassland area, albeit a very small area, has more SOC than cropland. There is the case from the soil textbook where economics are ignored and the only difference over a uniform soil is land use. Under this model, land use drives SOC rather than SOC driving land use, so SOC will follow the pattern of unimproved grassland > improved grassland > cropland. Typically, we assume Canadian land inventory classes 1,2 are best used as cropland, 3 is well suited to cropland or forages, 4 is marginal as cropland and better for forages/pasture, and 5 and 6 are best used for pastures or forages. I am aware of only one situation in Canada where there is CLI class 1 or 2 soils in unimproved grassland at the scale of a commercial beef operation. It is also a bit of a historical accident, and is kept in that land use by the University of Saskatchewan. That SOC is very fragile since, if controls are removed, economics would have that high SOC grassland broken to cropland as fast as humanly possible. It has been the site of much research from all over the world because the situation of good soil with entirely grazing-controlled SOC content is so unusual in the global sense. Around where Brian McConkey lives, it is possible for class 4 and especially 5 soils that are otherwise uniform to be in cropland, improved grass or unimproved grass. The economics are similar, so the land use choice depends on preference, capital, ability and risk aversion of the land owner/operator. In this case, the SOC will

				follow the soils textbook: unimproved grassland > improved grassland > cropland. However, these class 4 and 5 soils are all relatively low SOC soils. But it is nice to know that there are a few real situations where land use drives SOC in the land.
Chapter 4: Social life cycle assessment				
Section 4.2		As noted in comments on the social system boundaries, it is not clear how the decision to avoid the use of LCAA-based SLCA as described in the UNEP/SETAC guidelines was made, especially given the goal of identifying hotspots and identifying areas for monitoring and improvement. The data in available sources such as the Social Hotspots Database could have been used to enable identification of hotspots and to supplement the desk research done in this study. Mention is not even made of this resource or rather mainstream SLCA approach in the		Agreed regarding details of the approach rationale. Section was completed to refine our justification, including the exclusion of the Social Hotspot Database. Because the activities and supplies covered by the scope of the study mainly occur in Canada, it was decided not to use the Social Hotspot Database (SHDB), which enables an assessment at the country level. With targeted indicators, we aimed to provide a more customized approach for the industry by reviewing practices of major companies active in the different fields, in both upstream and downstream beef production. That being said, the SHDB could have been used to support or refute the exclusions listed in Table 4.5.

		report. The database could have been used as well to either support or refute the exclusions listed in Table 4.5.		
	216-217	Industry Associations' "Public Commitment to sustainable issues": It is important to note that for promotion of BMPs for 'biodiversity and wildlife', 'water resources and riparian areas' and 'grazing management' many beef industry associations partner on initiatives with other associations and groups such as provincial forage councils, regional producer groups, national forage/grassland association, etc. Although not direct delivery, beef industry associations do often provide project funding/support for		Agreed, added to the section.

		these focused initiatives.		
Fig 4.15	229	Very difficult to read and understand box labels. A suggestion may be to bold the indicator title to differentiate it from the life cycle stage. Some labels need correction. For example: Top centre – “Native” what?; Centre: “Castration” of animals. Right side – “Local” what?		Ok, corrected.
	230	Section 4.5.1 and 4.5.2 – error in labeling sections?		Ok, corrected.
Chapter 5: Conclusions and recommendations				
	231	Figure at top of the page	Please reorder the 3 sections of the land use assessment so it follows the order in the chapter (carbon sequestration last)	Ok, corrected.
		Section 5.2.2 on land use	Same comment as above	Ok, corrected.

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