Implementing LCA Results for Primary Production in the Agri-Food Sector

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ABSTRACT

Consumer desire for sustainably sourced goods and services is transforming the way our food is grown and how products are made. Quantifying and assessing the environmental impacts of the inputs and outputs of each life cycle phase in primary agriculture production is a complex and resource-demanding task beyond the capabilities and affordability of individual producers. In collaboration with commodity groups and Alberta Agriculture and Rural Development, Quantis Canada completed four environmental footprints. In compliance with the International Organization for Standardization 14040 and 14044 standards, four primary agriculture life cycle assessments (LCA) were completed for Alberta produced canola, potato, egg, and broiler chickens. Hundreds of producers, through online and paper based data collection, participated in the study. This paper explores the use of an LCA approach to systematically identify opportunities to reduce the environmental impacts of primary agriculture production, and to document and communicate environmental performance to internal and external stakeholders.

Keywords: primary agriculture, life cycle assessment (LCA), beneficial management practices (BMP), sustainability, footprint

1. Introduction

Consumer desire for sustainably sourced goods and services is transforming the way our food is grown and how products are being made. In particular, the environmental sustainability is becoming an increasingly important consideration in consumer purchasing decisions. These consumers are those that are active stewards of the environment and are willing to pay a premium for green and socially responsible products (Ross et al. 2010). Environmentally sustainable production processes are becoming more prevalent in the marketplace due to this public pressure as well as shareholder transparency. But more importantly, there is growing evidence that firms that adopt proactive environmental management strategies become more efficient and competitive (Berry and Rondinelli 1998). Calls for corporate social responsibility are coming from investors, insurers, environmental interest groups, financial institutions, and international trading partners. Ultimately, the organizations with in-depth knowledge of how their business operations interact with the environment will remain competitive. In this context, sustainable sourcing is becoming a means of differentiation and access in the agri-food marketplace.

However, quantifying and assessing the environmental impacts of the inputs and outputs of each life cycle phase of primary agriculture production is a complex and resource-demanding task that cannot be afforded by individual producers. The life cycle assessment (LCA) approach systematically identifies opportunities to reduce the environmental impacts of primary agriculture production, and to document and communicate environmental performance to internal and external stakeholders. The objective of this study was to inform producers of the environmental footprint of their production, as well as identify the potential benefits and mitigation strategies producers and commodity associations could implement. The LCA methodology was chosen for this research, as the most comprehensive approach to analyze environmental footprints. To communicate the LCA results, concise and creative communication pieces were developed to inform producers and consumers. In addition, an environmental footprint calculator was developed for Alberta egg producers to measure the footprint of their farm, run different scenarios, and compare results to the benchmark regional average. The information can then be shared with stakeholders, including those who aim to conduct further LCAs of the commodity. This work is also part of an effort to make LCA information accessible and useful for sustainability decision making by producers and the supply chain.

2. Methods

In order to provide the industry with a better understanding of the environmental profiles of current conventional production in Alberta, Alberta Agriculture and Rural Development (ARD), along with Quantis Canada, completed LCAs for Alberta canola, potato, egg, and broiler chicken (including hatching egg) production. In collaboration with the commodity associations, the studies completed environmental assessments of the 2012 practices within the industry using LCA, a framework defined by the International Organization for Standardization (ISO) 14040 and14044 standards (ISO 2006a; ISO 2006b). On farm data was collected from producers through online and paper surveys. Environmental hotspots (those areas with the highest environmental impacts) for different impact categories were identified in each of the LCAs with Impact 2002+ methodology (Jolliet et al. 2003) and associated management recommendations were made. As one of main purposes of the studies was to communicate the results with internal and external stakeholders including non-LCA audiences, a combination of three end-point indicators (human health, ecosystem quality and resources) and two mid-point indicators (climate change and water consumption) were selected.

2.1. Boundaries and Assumptions

The system boundaries chosen for all four commodities identify the life cycle stages, processes, and flows considered in the LCA. The studies assessed the life cycle of Alberta canola, potato, egg and broiler chicken (including hatching egg) production, from the extraction and processing of all farm inputs, to the energy used to the farm gate. The LCA for egg production also included the two Alberta washing and grading facilities that go beyond the farm gate. Within each of these stages, each LCA considered all identifiable upstream inputs to provide a comprehensive view of the production systems. All inputs may therefore be traced back to the original extraction and processing of raw materials used at the various life cycle stages, which include: crop inputs, transportation, field operations, farm utilities, infrastructure, feed production, hatchery, farm operations, egg washing and grading, and waste management.

The study included the diversity of management practices implemented across the industry, and comparisons were made between combinations of practices to identify trade-offs between the various conditions. The project team worked in close collaboration with industry experts to better understand common farm practices and conventional Alberta production of the four commodities. Once the information was reviewed, appropriate scenarios were established for evaluation.

2.2. Data Collection

The quality of the LCA results depends on the quality of the data used as an input in the model. For this study, every effort was made to implement the most credible and representative information available. The life cycle inventory (LCI) was established based upon different data sources.

On farm data was collected to assess the overall environmental impacts of production in Alberta through online and paper surveys. In some cases, information came directly from provincial commodity association records. Data was collected for the 2012 production year. When possible, data was also collected for an additional two years (2011 and 2013) to allow for data gaps or unexplainable data points in the 2012 data. Survey questions covered the entire primary production practices such as acres planted, crop variety, agronomic practice, yield, flock management (diet, feed, and water consumption), manure management, and energy use. Because on farm data can be of variable quality, data from the farm surveys was verified by an industry specialist and compared to industry standards to insure good representativeness. High and low value points for important parameters were tested in sensitivity scenarios but no quantitative uncertainty assessment was realized. Important field emissions as nitrous oxide and ammonia from fertilizer application were based on local Canadian models (Rochette et al. 2008; Sheppard et al. 2010). As the Canadian models of direct nitrous oxide emissions were used in the study, it appeared that uncertainties in the modelling were likely lower in the study than using IPCC Tier 1 specifications.

When no site-specific data were available or the contributions to known impacts were minimal, LCI databases, mainly ecoinvent v2.2, were adapted or used as is. As a last resort, when assumptions were necessary and activity data was not available, stakeholders and experts were consulted to determine specific values.

SimaPro 7.3.3 was used for LCA modeling; it links the reference flows with the LCI database and computes the complete LCI of the systems. The final LCI result was calculated by combining foreground data (intermediate products and elementary flows) and generic datasets, providing cradle-to-gate background elementary flows to create a complete inventory.

3. Results

The four LCAs were assessed based on the environmental scores of Alberta production through five end-point indicators: human health, ecosystem quality, resources, climate change, and freshwater consumption, as well as water stress for potato production. Mid-point indicators of Impact 2002+ were also analyzed. It is important to note that LCA estimates relative, potential impacts rather than direct measurements of real impacts, and that results and conclusions should be considered applicable only within the scope of the study. The ecosystem quality indicator expresses the composite score of eight midpoint categories which measure toxicity effects of pesticides.

3.1. Alberta Canola Production

Crop inputs are responsible for the greatest proportion of impacts for all categories. The efficiency of the farm input use (e.g. fertilizers, pesticides, seeds) and land use is directly proportional to canola production yields. Electricity and gas consumption on farm varied significantly from one producer to the next showing potential room for improvement.

3.2. Alberta Potato Production

Crop inputs are responsible for the greatest share of environmental impacts for all indicators, except water stress, where irrigation is the main contributor. The production and emissions associated with synthetic fertilizers are significant contributors to impacts for climate change, human health, and resources. The proper management of synthetic fertilizers is therefore crucial to achieve considerable environmental impact reductions. The most variable parameters between farms are electricity consumption for potato storage and irrigation requirements. This is partly explained by the fact that not all producers store their potatoes and by the different efficiencies of storage facilities between producers.

3.3. Alberta Egg Production

Feed production was identified as the largest contributor to all environmental impacts, followed by farm operations. Fertilizer production and application, and land occupation are major causes of high environmental impact in feed production, while on farm energy use and manure management are responsible for most of the environmental impacts for the farm operations. Preliminary results of the enriched cage system indicate equivalent feed efficiency of the birds and globally slightly lower environmental impacts.

3.4. Alberta Hatching Egg and Broiler Chicken Production

The feed production stage is the main contributor to all impact categories, except climate change. The main impacts for climate change come from farm operations, specifically the energy used for heating the barn. Coal heated barns, which consume more fuel per functional unit compared to other energy sources, are responsible for causing a higher impact in this category. Hatching egg production is the third most important contributor to the life cycle impact of broiler production.

4. Discussion

LCA methodologies and background databases are becoming more accurate by depicting impacts at a regional level through environmental modeling. At the same time, agricultural technologies are evolving and becoming increasingly precise and efficient. As such, the four Alberta agri-food LCAs establish a benchmark, allowing industry to be prepared for market demands and reflect the new technological changes in the industry. With a credible baseline in hand, representing provincial average production systems, specific attention was given towards management recommendations. The LCA model was used to evaluate the environmental benefit of implementing beneficial management practices (BMP), focusing on parameters that producers have the ability to influence and/or that the LCA identified as a hotspot. A summary of the commodity-specific LCA results and associated BMP recommendations are provided below in Table 1.

Table 1. Environmental footprint results and BMP recommendations by commodity

Commodity	**Life cycle stage with largest footprint (descending order)**	**Primary BMP recommendations**
Canola	Crop inputs Farm utilities and infrastructure Field operations Waste management Transportation	‣ Adoption of 4R Nutrient Stewardship to manage nutrient sources ‣ Soil carbon sequestration from conservation tillage
Chicken	Farm operations Feed production Hatching egg Hatchery Transportation	‣ Phasing out coal barn heating for natural gas or biomass heated barns ‣ Encouraging use of the industry's efficient feed conversion ratio
Egg	Feed production Farm operations Hatchery Transportation Washing and grading	‣ Implementing on farm energy efficiency measures such as well-designed ventilation systems ‣ Soil carbon sequestration from conservation tillage
Potato	Crop inputs Farm utilities and infrastructure Irrigation Field operations Waste management	‣ Adoption of 4R Nutrient Stewardship to manage nutrient sources ‣ Ongoing improvement of irrigation infrastructure and delivery equipment, such as a variable rate irrigation system

4.1. Alberta Canola Production

The yield per acre improvement constitutes an important lever for producers considering that the efficiency of the farm input use and land use is directly proportional to canola production yields. The synthetic fertilizer production and emissions drive farm input impacts for all categories except ecosystem quality; therefore, improving fertilizer use efficiency is crucial to the reduction of environmental impacts through BMPs such as the 4Rs nutrient stewardship system - using the right fertilizer, right rate, right time and right place.

On-farm energy efficiency measures can be a significant potential mitigation area to reduce the environmental impacts of canola production. Reducing the number of passes and opting for operations that are less fuel intensive could reduce the impacts of field operations. It is important for industry to give priority to the high impact areas (i.e. hotspots indicating significant contribution to the total footprint) to ensure that targeted investments in BMPs yield significant environmental paybacks. Fertilizer management and tillage management BMPs are another potential mitigation strategy for reduction of environmental impacts. BMPs related to better fertilizer management are based on the "4R" nutrient stewardship principles. Potential greenhouse gas (GHG) emissions reductions ranged from 2% to 23% for fertilizer management. Depending on the tillage system, a potential reduction of impacts can be achieved by adopting conservation management practices such as no-till/zero-till and minimum/reduced systems. It can therefore be concluded that Alberta canola producers can manage their environmental impacts and footprint to a certain extent by continuing to adopt BMPs.

4.2. Alberta Potato Production

On-farm energy efficiency measures for potato storage and water pumping are important levers for growers, with significant potential for reducing the environmental impacts of potato production. Reducing the number of passes and opting for new measures, technologies, tools, or machinery that increase fuel efficiency could significantly reduce the impacts of field operations. Continued work on reducing water loss from sprinkler systems with variable rate irrigation and low pressure distribution systems at the farm would lower freshwater consumption. The "4Rs" of fertilizer management—the right product, right rate, right time and right place—could significantly reduce GHG emissions as well.

The potato growers have been adopting a number of BMPs related to fertilizer management, tillage management, irrigation management, and on-farm management. Over the past decade, Alberta potato growers have made steady progress in adopting many of the BMPs identified to reduce the environmental footprint of potato production. BMPs related to better fertilizer management were based on the 4R Nutrient Stewardship system. Potential impact reductions ranged from 1% to 25% for climate change and 11% and 13% for freshwater consumption. It can therefore be concluded that Alberta potato growers have opportunities to reduce the environmental footprint of their production through continuous improvement and adoption of BMPs.

4.3. Alberta Egg Production

Considering that the feed production stage is the main contributor to all impact categories, optimizing feed efficiency is a key lever to reducing the egg footprint. Furthermore, feed is one of the major contributors to the cost of production. Nonetheless, collected surveys indicate that feed efficiency can vary significantly between farms. The next step for industry should be to focus on working with nutritionists and published literature to produce appropriate recommendations to producers. Another significant impact is the production of feed, therefore promoting BMPs back to the feed producers could lower the egg footprint (lower impact of producing the feed will lead to a lower impact of the egg).

Due to the importance of energy consumption in the farm operations stage, energy reduction measures were investigated. Energy efficiency measures at farm could save up to 21% on electricity consumption. Implementation of renewable energy in the electricity grid mix or at farm could be also be beneficial, but to a lesser extent. The difference in the results between the baseline scenario and the use of 30% of renewable energy in the grid mix did not exceed 3%. Feed transport is the major contributor to transportation impacts. Therefore, increased proportion of farm-grown and locally grown feeds should be used for feed formulation to avoid the transportation of feed crops from the United States and other provinces.

4.4. Alberta Hatching Egg and Broiler Chicken Production

Optimizing feed efficiency is a key factor to reducing the environmental footprint of broiler production. Feed is one of the major contributors to the cost of production. Similar to egg production, collected surveys for this project indicate that feed efficiency can vary significantly between farms. As suggested previously with regard to eggs, a next step could be to focus on working with nutritionists and published literature to produce appropriate recommendations for producers. Hence, broiler producers would benefit from being informed regarding the research on feed efficiency in order to align all factors to favor a better feed conversion ratio (FCR).

Promoting beneficial practices to feed producers could significantly lower the broiler footprint (lower impact of producing the feed will lead to a lower impact for the broiler). In particular, an increased understanding and the adoption of BMPs for fertilizer use in feed production could be further investigated. Also, prioritizing on farm energy efficiency measures for space heating, phasing out of coal furnaces to natural gas powered furnaces, or implementing biomass or litter capable furnaces, would be beneficial to lower GHG emissions.

Being very similar to its broiler counterpart, hatching egg production can orient its priorities accordingly, particularly by reducing the FCR and using feed with a lesser impact. One important aspect to work on is hatchability, as only 79% of fertilized eggs are sold as broiler chicks. Reducing the loss rate would greatly improve the impact of this stage.

The key impact findings of this study can be addressed by adoption of BMPs related to feed, energy, and operational changes. GHG emission reductions can result in 1% to 5% for feed, and 1% to 33% for energy related BMPs. Hence, broiler chicken producers have considerable leverage over their environmental impacts by implementing certain BMPs.

5. Conclusion

Alberta Agriculture and Rural Development (ARD) commissioned the LCA of four commodities in order to better understand and quantify the environmental impacts of the province's agri-food industry. ARD is dedicated to ensuring that Alberta's agricultural producers remain competitive, adaptive, and responsive in the marketplace. With the studies completed, highlights and key findings have been documented for easy-to-communicate two-pager factsheets that will be distributed to industry associations and producers in an effort to raise awareness and highlight opportunities to reduce environmental impacts, especially GHG emissions and freshwater consumption. In addition, a calculator for producers to assess the footprint of their farm is available to all Alberta Egg Farmers online. This will enable the egg producers of Alberta to benchmark their farms and identify farm specific reduction opportunities. Later, stewardship initiatives to help producers implement environmentally, technically, and economically sound BMPs on their farms may be launched.

This holistic and systematic environmental assessment helps to identify environmental hotspots of primary production in Alberta and propose potential mitigation strategies that could improve environmental performance of the systems. Indeed, an opportunity to reduce GHGs and the shift by certain European jurisdictions toward a multi-criteria environmental food product labeling system has led to the creation of sustainability-based markets.

This study provides industry with a better understanding of the environmental profiles of conventional production in Alberta. The study also aimed to set out a scientifically robust and transparent environmental assessment of current practices of the industry. This Alberta benchmark will provide a way to measure improvements and focus on identifying opportunities to enhance the environmental performance of Alberta's agri-food industry. In addition to providing a benchmark, the work established a protocol for data collection and an approach for continuous improvement throughout the industry. The initiative will also serve as a model for the analysis of other local and international agricultural commodities.

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