COMPARATIVE ECONOMIC AND ENVIRONMENTAL TRADE-OFF ANALYSIS FOR MANITOBA COW-CALF PRODUCTION

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Marianne C. Possberg

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ABSTRACT

There were 12.5 million head of cattle in all of Canada as of January 1st, 2012, of which 7.4 million were on cow-calf farms. Of this population, 1.2 million head of cattle were in Manitoba, and within that, 880 thousand were on cow-calf farms. Canadian and Manitoba beef producers have experienced significant volatility in the cattle market. This is partly as a result of loss of exports of cattle to the United States, first due to occurrence of the Bovine spongiform encephalopathy (BSE) Crisis, and then through the Country of Origin Labelling (COOL) legislation developed in the United States.

While the beef industry has endured market fluctuations, the North American cattle herd has also been responsible for greenhouse gas (GHG) emissions, through enteric fermentation within their digestive tracks, storage of manure on farms, through the spread of manure on crop fields, and through the production of feed for cattle. Of the total Canadian GHG emissions, agriculture contributed 8 percent in 2013. For the same year, within the total agricultural GHG emissions, cattle and sheep production resulted in 40 percent of methane emissions, and 90 percent of nitrous oxide emissions, both expressed in carbon dioxide equivalent. Regionally, the share of agricultural GHG emissions in Manitoba make up a larger proportion of total provincial GHG emissions, at 31 percent of 21.4 Mt CO_2e, as the province has fewer emissions from transportation or stationary combustion..

The confluence of low profitability and larger amounts of GHG emission (relative to other provinces) has led to some discussion on adopting measures to reduce these emissions. This has caused some stress in the beef industry, as some of these proposed solutions could lead to further loss in profits. An European study of the beef sector has investigated the impact of some policy instruments, such as emission taxes, and has suggested that while such measures are effective, they would also be financially restrictive to beef producers, or result in high administrative costs for governments (Neufeldt and Schäfer 2008). However, these measures might be unnecessary, as the Manitoba Beef Producers (2011) have indicated that the Manitoba beef producers are willing to undertake alternate management practices to benefit environmental causes if they do not negatively affect their profitability or livelihoods. Therefore, providing methods that lead to lower GHG emissions while providing high levels of profitability, or maintaining current levels of

profitability would be considered a welcome set of information for the Manitoba beef cattle producers (and likely producers in other provinces).

In order to understand GHG emissions on beef farms, a Canada-wide survey was undertaken in 2012. Financial support for this survey was provided by a variety of interested parties including the University of Manitoba, Alberta Agriculture and Rural Development, the BC Ministry of Agriculture, Manitoba Agriculture Food and Rural Initiatives, and Agriculture and Agri-Food Canada, with the support of the Beef Cattle Research Council. Researcher Aklilu Alemu from the University of Manitoba used principle component analysis and cluster analysis to create eight clusters of representative farms across the country. Of the eight Canadian clusters, only four clusters had a population greater than one in Manitoba. The centroid from each cluster was chosen as a representative farm for this study. Estimates of GHG emissions from each farm were then determined using Holos, a GHG emission model developed by the Government of Canada.

To compare GHG emissions against profitability on a farm, this study evaluated revenues and costs of four Manitoba farms (One each from the four clusters). The revenues included the sale of weaned calves and cull cows, as well as the sale of unused feed and non-feed grain. The costs for the whole farm included the cost to grow feed for the cattle, while operating costs for each of these farms included veterinary, transportation, manure removal, and utility costs. The fixed costs (related to farm structures and machinery) were comprised of depreciation and interest costs. In order to understand the profitability of the beef enterprise as well as the whole farm, the costs and revenues were estimated at three levels: beef enterprise, the whole farm, and the family level.

With regards to the beef enterprise, the farm in Cluster Four had the highest level of profitability, at $0.05 per pound of live animal weight sold [or on a per pound sold (PPS) basis]. At the same time, this farm was also able to achieve the lowest GHG emissions, at 2.20 lbs. PPS basis measured in Carbon Dioxide Equivalent (CO_2e). The farm with the second lowest level of GHG emissions (9.68 lbs. CO_2e on a PPS basis) were estimated for the Cluster Six Farm, which also had the second highest profitability ($0.01 on a PPS basis).

When measured at the beef enterprise level, several farms had net GHG emissions. Higher farm level profitability was contributed by a high weaning weight, the lower cost to produce feed, and the strategic purchase of machinery to feed each herd. Lower emissions were noted on farms with tame pastureland and greater amounts of forage with alfalfa.

Comparing profits and GHG emissions at the whole farm level showed different results. The Cluster Seven farm had the highest level of profitability ($1.53 on a PPS basis) while it was also the largest contributor to GHG emissions (12.16 lbs. CO_2e on a PPS basis). Cluster Six farm was the second largest contributor to GHG emissions (7.54 lbs. CO_2e on a PPS basis), but also created the least profit on its farm ($0.13 on a PPS basis). The farms with net sequestration (i.e., GHG emissions were negative) were Cluster Four and Cluster One farms. Both of these farms were both able to create profitability. On a PPS basis, Cluster Four farm had the second highest profitability ($0.80 on a PPS Basis) and sequestered second greatest emissions (2.38 lbs CO_2e on a PPS basis). Cluster One farm had the second lowest profitability ($0.33 on a PPS basis) and sequestered the most GHGs (30.17 lbs CO_2e on a PPS basis). Increases in the level of net sequestration were due to tame pastureland and large amounts of unused hay growth which included legumes such as alfalfa. Increases in profitability were due to the sale of non-feed grains, feed grains or hay, as well as other factors noted above regarding the beef enterprise.

These findings suggest that Manitoba beef producers could provide greater profitability and lower GHG emissions if they increased their weaning weights, increased the size of their herds, invested in tame pastureland when possible, and cut their forage several times throughout the growing season.

Since this study is based on a single farm from four clusters, additional research is necessary. This may include studying several farms in each cluster in order to determine variability in long-term feed production, as well as in costs and revenues.

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CHAPTER 1 INTRODUCTION

1.1 Background

1.1.1 Beef Cattle Production in Canada and Manitoba[1]

Beef production is a significant contributor to the Canadian economy, as its value of sales was estimated at $23 billion in 2009 (Canadian Beef 2015). While the amount of cattle fed in Canada in 2011 decreased by 4 percent from its 2010 level (for a total loss of 623 thousand head), cattle and calf cash receipts increase by 5.5 percent to $6.49 billion in the same period (Statistics Canada 2015a; Canadian Beef 2015).

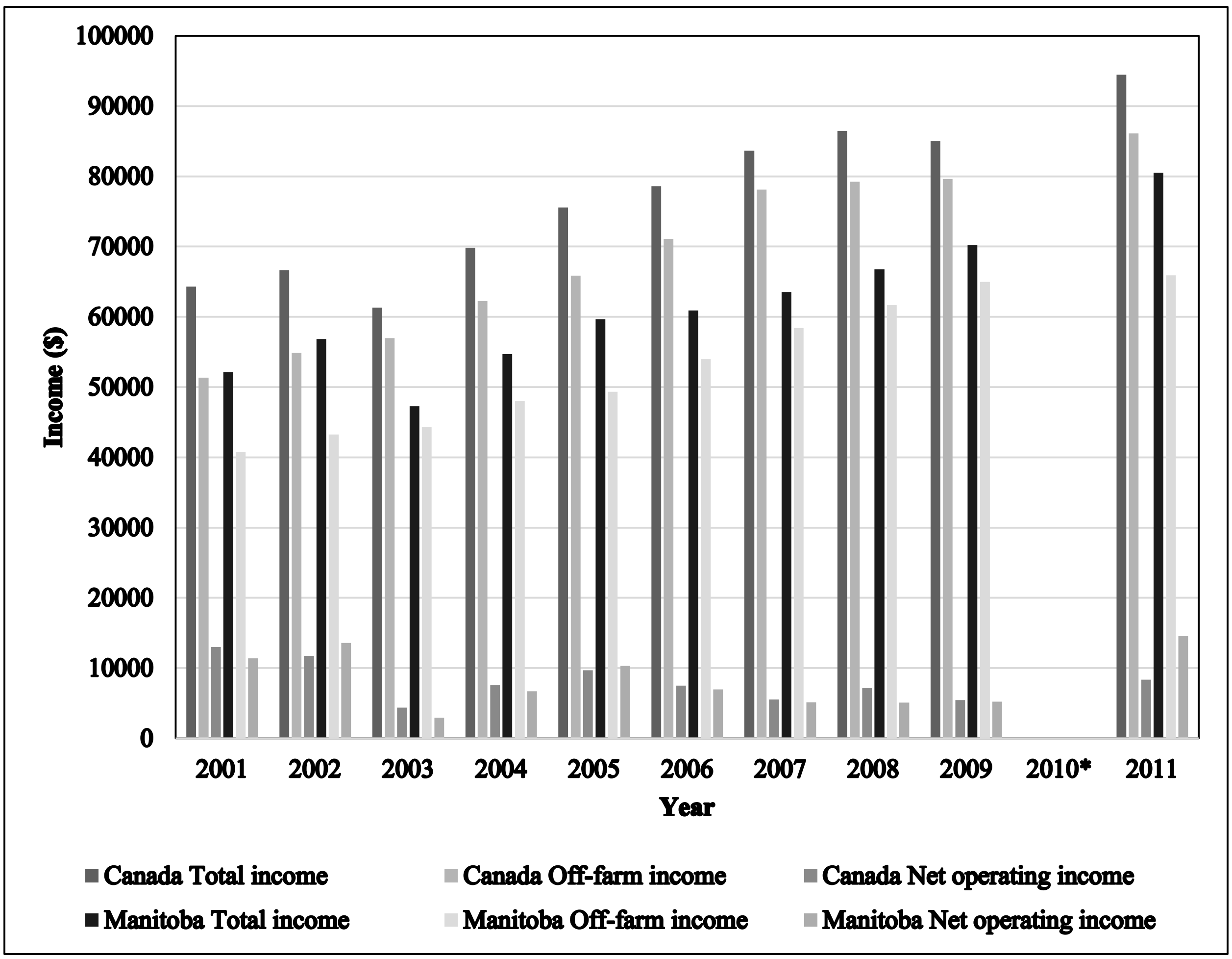
As of January 1st, 2012, there was a total of 12.5 million head of cattle and 4.1 million calves under 1 year of age in Canada. Notably, there was a steady decrease of cattle every year between 2006 and 2011, and then a small increase in 2012 (Statistics Canada 2012b). Of these cattle, 7.4 million head were on cow-calf farms, 1.6 million were on feeder and stocker operations, and 1.5 million were on finishing operations. The remainder were housed on dairy operations (Statistics Canada 2012b).

In Manitoba, there was a total of 1.2 million head of cattle and 407 thousand calves under 1 year of age (Statistics Canada 2012b). Of these cattle, 880 thousand head were on cow-calf farms, 119 thousand head were on feeder and stocker operations, and 85 thousand head were on finishing operations in the province. As above, the remainder were on dairy operations. Relative to Canada as a whole, the percentage of cattle on finishing operations in Manitoba were considerably lower, since only 7.3 percent were handled on these farms provincially as against 12.2 percent of such operations across the country (Statistics Canada 2012b).

As noted in Figure 1.1, average total income of beef cattle farms fluctuates from year to year. One of the significant observations from this figure is that in Canada as well in Manitoba, most of the income of beef cattle producers is obtained from off-farm sources (Statistics Canada

[1] Additional information regarding the beef industry in Canada and Manitoba is provided in Chapter 2.

2014c). The average annual total income of farm families, which identified themselves as beef cattle ranchers or farmers (including those with feedlots), increased from $64,317 in 2001 to $94,471 for all of Canada (Statistics Canada 2014c). However, this increase was mainly due to off-farm income, rather than income generated through beef operations. On an average Canadian beef farm, the off-farm income increased from $51,330 in 2001 to $86,110 in 2011 (Statistics Canada 2014c). Over the same period, their net operating income decreased from $12,987 in 2001 to $4,361 in 2003 and then increased slightly to $8,341 in 2011 (Statistics Canada 2014c).



* Figures for 2010 were not reported by Statistics Canada
Source: Statistics Canada (2014a),

Figure 1.1 Average Total Income of Beef Cattle Ranching and Farming Families, Including Feedlots, Unincorporated Sector

Looking at the Manitoba situation, the trend was similar to that observed for Canada. Canadian beef producers made the lowest amount of annual average total income among all animal producing farms, creating only $94,451 in total income, of which $8,341, or 9 percent, was derived from beef operations. In Manitoba, while average annual total income increased from $52,152 in 2001 to $80,502 in 2011, most of this increase was due to off-farm income, which accounted for 78 percent of total income in 2001, and 81 percent of total income in 2011 (Statistics Canada 2014c). The province's beef producers also experienced more dramatic net income fluctuations than the average Canadian farm. Net operating farm income in Manitoba was $11,388 in 2001, which then decreased to $2,941 in 2003, and then increased to a ten year high of $14,578 in 2011 (Statistics Canada 2014c).

When beef cattle farms are compared with other types of farm operations in both Canada and Manitoba, the amount of annual average total income on beef farms is dramatically lower than that on oilseed and grain farms and for hog producers. In 2011, off-farm income for Canadian oilseed and grain producers consisted of only 67 percent of total income, worth $131,315 (Statistics Canada 2014c). Canadian hog producers made a total income of $109,174, of which only 54 percent was derived from off-farm income (Statistics Canada 2014c). This situation is similar in Manitoba. Manitoba oilseed and grain producers reported an average of $121,920 for 2011, with only 55 percent originating from off-farm income (Statistics Canada 2014c). The province's hog producers earned an average of $85,038 over the same period, with only 63 percent of this income from off-farm income (Statistics Canada 2014c). In comparison to these producers, Manitoba beef producers earned a total annual income of $80,502, of which $14,571 or 18 percent was derived from beef operations.

Table 1.1 notes that the income earned by beef producers in Canada is often below the capital cost allowance (value of depreciable business expenses). Only in one year (2012) was the operating income above the capital cost allowance level. It also notes that while operating revenues were often larger than a quarter million dollars, operating expenses were also equally high.

Table 1.1 Average Operating Revenues and Expenses in Canada on Beef Cattle Farms (average per farm ($), 2009-2013					
Year	**2009**	**2010**	**2011**	**2012**	**2013**
Total operating revenues (1)	211,764	214,596	250,334	281,484	277,611
Total operating expenses (2)	201,167	203,315	238,130	265,374	265,346
Net operating income (3) = (1) – (2)	**10,598**	**11,280**	**12,205**	**16,110**	**12,266**
Net program payments (4)	12,178	10,013	9,372	8,341	6,323
Net market income (5) = (3) – (4)	-1,580	1,267	2,833	7,770	5,943
Adjustment for capital cost allowance (CCA)[1] (6)	12,969	14,218	14,735	15,610	15,936
Net market income adjusted for CCA[1] (7) = (5) – (6)	-14,549	-12,951	-11,902	-7,840	-9,993
Net operating income adjusted for CCA (8) = (3) – (6)	**-2,371**	**-2,938**	**-2,530**	**501**	**-3,671**

[1]Capital Cost Allowance (CCA) is the deduction allowed by the Canadian Revenue Agency for property that wears out or becomes obsolete over time. This includes buildings, furniture, or equipment used for professional activities. (Canadian Revenue Agency, 2016)

Source: Statistics Canada (2015a)

1.1.2 Climate Change in Canada and Manitoba

Climate change refers to changes in long-term weather patterns caused by anthropogenic or human activities (Pachauri et al. 2015). A build-up of greenhouse gases (GHG), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), trap heat inside the earth's atmosphere. As a result, weather patterns become less predictable (Environment Canada, 2010). The Intergovernmental Panel on Climate Change (IPCC) has concluded that anthropogenic causes have influenced a rise in the global surface mean temperatures between 0.5°C and 1.3°C over the 1951 – 2010 period (IPCC 2013). Compared to the temperatures over the 1986 to 2005 period, a rise in temperature over the 2016-2035 period will likely fall between 0.3°C and 0.7°C (IPCC 2013). The IPCC also suggests that human activity has contributed to the loss of Arctic sea ice since 1970, the retreat of glaciers since 1960, and a reduced spring snow cover in the Northern Hemisphere since 1970 (IPCC, 2013).The Canadian Global Circulation Model (CGCM1) predicts that between the years 2040 and 2069, there will be a 3^0C to 9^0C change in the annual mean temperature for Canada, and a 2^0C to 4.25^0C change in the annual mean temperature for the prairies relative to that over

1961 – 1990 period (Nyirfa and Harron 2004). In the prairies, this could lead to a change in local ecosystems, as a large portion of southwest Saskatchewan and southeast Manitoba could suffer aridity due to reduced winter snowfalls and glacial retreat (Henderson and Sauchyn 2008), and also through greater evapotranspiration, which would deplete moisture from plants and crops (Nyirfa and Harron 2004).

Manitoba contributes a relatively small amount of GHGs to the total amount of Canadian GHG emissions, compared to other Canadian provinces, as noted in Table 1.2. Its 2013 level of total emissions, at 21.4 Mt CO_2e (Carbon Dioxide Equivalent[2]), are lower than those of Quebec, Ontario, Saskatchewan, Alberta, and British Columbia, and below the Canadian national average of 60.5 Mt CO_2e (Environment Canada 2012b).

Table 1.2 Greenhouse Gas Emissions in Mt CO_2e, 2009 - 2013, by Sector

Region	Year	Energy	Industrial Processes and Uses	Agriculture	Waste	Land Use	Total
Manitoba	2009	11.7	0.7	6.4	1.1	n/a	**19.9**
	2010	11.3	0.8	6.4	1.1	n/a	**19.6**
	2011	11.6	0.8	5.8	1.1	n/a	**19.4**
	2012	12.8	0.7	6.0	1.1	n/a	**20.7**
	2013	13.0	0.7	6.7	1.0	n/a	**21.4**
Canada	2009	563.4	49.1	57.9	28.2	-7.9	**698.4**
	2010	572.8	50.7	56.9	26.6	81.4	**707.0**
	2011	575.9	50.9	56.0	26.4	82.2	**709.2**
	2012	576.5	55.0	58.0	25.6	60.1	**715.2**
	2013	588.0	52.2	60.5	25.3	-15.1	**726.0**

Source: Government of Canada (2015)

Directly, the climate change could affect multiple economic sectors in Manitoba, as seen in Table 1.3. All of these changes reflect alterations in the length and severity of the cold season, as well as uncertain effects of precipitation, such as water availability for hydroelectric dams. Beef

[2] There are several types of gases responsible for climate change, which are noted in Section 2.8. The influence of these gases on climate differs from one another. In order to equivocate these gases, each gas's global warming potential (GWP) is compared to CO_2. This results in the value of carbon dioxide equivalency. In this study, methane's GWP was 25, whereas that for nitrous oxide was 298.

cattle will not be immune to these changes, as they are suited to cold temperatures (Kulshreshtha 2011). It will also affect meat quality, and levels of reproduction in cattle. In fact, according to Warren (2004), for every 5^0C rise in summer temperature reproduction decreases by 10 percent.

Table 1.3 Potential Impacts of Climate Change on Manitoba Sectors	
Sector	**Nature of Impact of Climate Change**
Agriculture	• Frequent Droughts • Heat stress on animals and crops • Greater prevalence of pests and diseases • Lower yields in southeast Manitoba
Forestry	• Decline in trees throughout the southern portion of the boreal forest • Possible extension of the forest further north
Energy	• Uncertain effect on hydro dams, which require consistent levels of water • Potential need to create new dams in areas with greater amounts of water
Transportation	• Shorter periods of operation for northern winter roads • Greater incidents of pavement buckling due to more freeze/thaw cycles
Urban	• Potential increase in snow removal costs • Water supplies may diminish, creating a shortage for drinking water
Northern Communities	• New, invasive species • Unsuitable conditions for hunting and trapping
Manufacturing and Technology	• Increased cost for cooling
Health and Welfare	• Greater prevalence of heat stress and allergies • Shorter season to enjoy winter sports • Increased flooding in cottage country

Source: Axworthy et al. (2001)

1.1.3 Beef Cattle GHG Emissions

In 2012 in Canada, 58 Mt CO_2e, or 8 percent of total GHG emissions, were directly related to animal and crop production (Environment Canada 2013b). This has increased by 9 Mt CO_2e since 1990. With regards to CH_4 and N_2O emissions, Canadian agriculture is responsible for 22 percent and 74 percent of the emissions, respectively (Environment Canada 2013b).

As noted in Table 1.2, Manitoba's emissions from agriculture in 2013 were proportionally higher than those in rest of the Canadian provinces, as approximately 31 percent of the province's total GHG emissions were attributed to agriculture (Manitoba Eco-Network 2014). Its CH_4 emissions from enteric fermentation comprised 37.3 percent of provincial agricultural GHG emissions and 11.68 percent of total provincial GHG emissions, while combined CH_4 and N_2O emissions from manure management contributed 11.6 percent of provincial agricultural emissions and 3.6 percent of the total provincial GHG emissions. These emissions increased from 1990 until 2005, when they plateaued and then slowly declined until 2013 (Manitoba Eco-Network 2014). According to Beauchemin [cited in Agriculture and Agri-Food Canada (2011b)], "approximately 40 percent of agricultural emissions in Canada come directly from CH_4, of which 90 percent are emitted by cattle and sheep as a result of feed digestion." Eighty percent of emissions from cattle occur during the cow-calf stage, when pasture conditions are a greater necessity, and feed is less efficient in their rumen (Beauchemin et al. 2010).

1.2 Problem Statement

Emissions of GHGs from various economic activities have an effect on climate, resulting in an increase of average temperatures throughout the world (IPCC 2013). These changes, as noted above, would affect many economic activities including beef cattle production, which among other changes, might result in change in the reproduction rate (Warren 2004). These impacts would make beef cattle profitability even more problematic, and consistent profitability for Manitoba beef producers would be more elusive (Statistics Canada 2014c).

The uncertain profitability creates weariness when pondering changes to common farm-level beef herd management practices. Scientists have suggested many management practices, including , a greater emphasis on organic production (Pacini et al. 2004), or adoption of policy instruments, such as emission taxes, emission caps, or nitrogen fertilizer taxes (Neufeldt and Schäfer 2008). Manitoba beef producers have also indicated their willingness to undertake alternate management practices to improve environmental conditions, if these practices do not negatively affect their profitability or their livelihoods (Manitoba Beef Producers 2011). Their core principles regarding the development of environmental policies demand the use of reputable science, cooperation between governments and producers, and the ability of producers to maintain their ability to adequately support themselves (Manitoba Beef Producers 2012). Creating management practices to reduce GHG emissions might provide a win-win scenario for producers if it does not increase costs or reduce revenues.

1.3 Need for this Study

1.3.1 Significance of Canadian Beef Farms

While there has been research related to pollution and profitability on farms, these studies have concentrated on specific types of pollution created by specific types of farms. While Hart and Ahuja (1996) found that firms can benefit from decreasing their waste, King and Lenox (2001) discovered that benefits from a diminished amount of pollution depends on a number of factors including firm size, capital intensity, growth, research and development (R&D) intensity, leverage, and regulatory stringency.

The beef industry in Canada is diverse when one looks at some of the following factors: the number of cattle varies per farm from under one hundred head to 10,000 head throughout the country; the amount of outside investment differs from operation to operation; sporadic innovation on various farms; and regulations regarding size and environmental standards differ throughout the country (Sheppard et al. 2015).

In addition to regional variability, beef farms in Canada differ from those in other nations. For example, the beef cattle industry in New Zealand competes with several other ruminants, such as dairy cattle and sheep (Beef + Land New Zealand 2014). Operations in Europe commonly use more pastureland (Wright 2005). The soil types and climates in countries, like Brazil are, in contrast, dramatically different from those found in Canada. Given that variability among farms exists throughout the world, as well as within Canada, many of the findings of these studies are not transferrable an anew investigation is needed. Such research should consider factors such as: available feed sources, seasonal impacts, and other restraints. This information would assist policy makers to clearly understand its economic restrictions and opportunities.

1.3.2 Regulatory Commitments

The Copenhagen Climate Change Conference was a meeting that brought together member countries of the United Nations, as well as non-government organizations, inter-government organizations, and faith-based organizations to address global climate change. There was a strong agreement with the view that a long-term goal of limiting the average temperature to an increase of only two degrees above pre-industrial levels was an important goal (United Nations 2009)[3].

The Canadian government has made climate change a priority, by signing the Copenhagen Accord Emission Target. This accord has led Canada to make a commitment to reduce its emissions by 17 percent by 2020 from its 2005 levels (Government of Canada 2013). More recently, it has agreed to be a part of an international effort to keep global warming to below 2 degrees Celsius (United Nations 2015). While the federal government's climate change plans have focused on the oil and gas sector (Environment Canada 2012a), it has also indicated that other major sources of emissions in each sector of the economy will have regulatory implementations (Government of Canada 2007)

1.3.3 Regulatory Obstacles

Lowering GHG emissions can occur through the adoption of various methods. Hatakeda et al. (2012) suggest three types of reduction methods available for firms: (i) They could be required to restrict their emissions through controls and through consumption regulations; (ii) they might face environmental taxes or emission trading to indirectly control emissions; or (iii) they might voluntarily reduce their emissions as certain measures are promoted by government or non-government organizations. Neufeldt and Schafer (2008) have found that there are high administration costs involved in administering environmental taxes or emissions caps in the agricultural industry. As there are a number of emission gateways in agricultural production (fuel

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[3] In 2015, various countries also met and agreed upon reduction of GHG emissions to lower level. More details can found in United Nations (2015).

use in tractors and other machinery use for crop and livestock enterprises, inorganic fertilizer use, manure spreading, and transporting animals and other agricultural products, among others), there are also many points to monitor, inspect, or regulate. Consequently, taxes or cap and trade systems are not easily enforceable in the Canadian beef industry. Methods to develop voluntary reductions might be the most effective measure to reduce GHG emissions. However, institutions involved in promoting lower emissions should first have an understanding as to which practices would result in an increase in net returns for beef operations, and environmental benefit in terms of reduced GHG emissions. Without a positive return, adoption of these measures might not be very popular among beef cattle producers.

1.3.4 Previous Studies of GHG Emissions from Cattle in Canada

Several Canadian studies have investigated the level of GHG emissions from cattle. As mentioned above, a whole-farm life cycle analysis from revealed that the cow-calf segment in beef production created 84 percent of the CH_4 emissions (Beauchemin et al. 2010). Dyer et al. (2010) estimated emissions in beef production compared to dairy production based on protein produced, and found beef cattle emitted CO_2 at a rate four times higher than dairy cattle.

There have also been studies investigating the mitigation of these emissions. Vergé et al., (2008) have shown that while total GHG emissions from the Canadian beef production, those studies which took into account GHG emissions based on per kg of a live animal noted declines, due to larger animal weights and production efficiencies. Research on genetics and residual feed intake has suggested that there could be CH_4 reductions (Basarab et al. 2013). This study acknowledged profitability, but only in terms of potential carbon credit profits. Corn distillers' dried grains (DDG) for beef feed replacing barley has shown the potential to lower emissions, though research was not completed as part of a whole farm analysis (McGinn et al. 2009). There have also been a number of possible solutions suggested by Stewart et al. (2009), which compared selected management practices at four different locations throughout Canada. They found reductions in GHG emissions when maintaining an alfalfa-grass pasture, among other findings, had the opposite effect. Beauchemin et al. (2011) found methods to decrease GHGs while using an eight year life cycle model of a beef farm in Alberta, which included changes in feed production and contents as well as animal husbandry. This research underwent a profitability analysis to determine the trade-offs between profitability and GHG emissions in each of the eight scenarios proposed. This analysis also suggested ways in which lower GHGs on a beef farm can be achieved while maintaining or creating a profit (Modongo 2014). While these data were valuable, they did not focus on existing common practices in Canada's beef industry in Manitoba, and thus not related to actual farm situations.

1.3.5 Canadian Beef Economics Studies

Previous economic research in the cattle industry has focused on issues that had become prominent at the time. New cattle breeds as well as management practices on cattle farms have been more popular areas of focus, as shown by Koots and Gibson (1998), who evaluated sixteen different genetic traits to understand those with the greatest economic value. Several studies have sought to understand genetic traits in the beef industry with regards to their risk (Kulak et al. 2003), proper breeding programs (Armstrong 1990), or the best genetic traits using a bio-economic model (Koots and Gibson 1998).

Crisis in the Canada's beef industry, such as the discovery of Bovine Spongiform Encephalopathy (BSE) and the Country of Origin Labelling (COOL) legislation in the U.S., have necessitated different economic research. Topics here included: impact of exchange rate appreciation, feed prices, mandatory country of origin labelling, and economic recessions in Canada and the United States (Twine and Rude 2012). Le Roy et al. (2007) investigated appropriate criteria for economic models to determine reactions from policy makers for events similar to the discovery of BSE in Canada. Seven countries were evaluated to determine the effectiveness of traceability systems, and the necessity of legislation similar to COOL in a study by Souza-monteiro and Caswell (2004).

The Canadian beef industry lends itself to research through a variety of methodologies. The life cycle analysis of beef production was evaluated using an econometric model by Chan (1981). An econometric model was also developed to understand the relationship between demand, supply and other variables throughout the Canadian beef production system (Kulshreshtha and Wilson 1972). Perillat et al. (2004) sought out to understand economic possibilities on backgrounding cattle farms in Saskatchewan, and found that pasture-fed cattle were as economically competitive as feedlot-fed cattle. A major contributor to economic studies of beef cattle is the Western Beef Development Centre, which has assisted producers by evaluating their economic performance, while also compiling economic data on a sample of farms since 2001 (WBDC 2014).

All of these studies noted above have assisted in the growth of the Canadian beef industry, or a segment of the beef industry in Canada. However, none of them have addressed sustainability issues with regards to lowering greenhouse gases while maintaining profitability on a beef cattle farm.

1.3.6 Studies Addressing Economics Performance and GHG Emissions

Studies, which included both economic performance and greenhouse gas emissions of beef cattle farms, were carried out for jurisdictions located outside Canada, such as France, Germany, and New Zealand, as well as to a limited degree in Canada. They all have indicated methods through which producers could reduce GHG emissions with varying effects on profitability[4]. These studies used models which accurately represent feed growing conditions, variety of cattle breeds, grazing strategies, and climate conditions. Canada's beef industry, however, has different constraints provided by transportation distance, alternate consumer tastes, supply chain management, etc. There are also concerns regarding the type of soil, different typical management practices, cattle breeds, and common feed availability. Therefore, data collected in these areas might be less applicable to the Canadian and Manitoban beef production system.

In Canada, research has not only been fairly limited to soil, animal, and plant science, but also by the ability of the models to calculate GHGs. Vergé et al. (2008) note that the models used previous to the one created by Agriculture and Agri-Food Canada, Holos, did not include a segment of research called "Land Use Change." These changes are through area devoted to perennial crops and tame pastureland, which reduces GHG emission through carbon sequestration.

Although Modongo (2014) did estimate potential benefits to selected feeding practices on a single synthetic farm in Vulcan County, Alberta, he did not investigate other factors which would affect both profitability and GHG emissions. Furthermore, this research exclusively accounted for

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[4] The results of these studies are discussed further in Section 3.2.1.7.

the beef industry, as no other enterprises on a mixed farm were included. This study can then address the variety of practices already prevalent in the Canadian beef industry, and determine the status of GHG emissions and a farm's economic viability.

Current management on cow-calf farms in Manitoba needs to be evaluated to understand their impact on profitability, as well as GHG emissions. Beef producers might not adopt GHG emission mitigation practices without considering their impact on profitability, as it will affect their long term viability. This, in turn, will lead to less compliance among beef producers. Thus, a combined knowledge of GHG emissions and profitability on a beef farm is warranted. Reduction in GHG emissions and improved profitability would be a move towards a sustainable beef cattle production system.

1.4 Objectives and Scope of Study

Beef production systems range throughout the world, as well as within Canada. Manitoba's beef cattle production systems are no exception to it. Therefore, this study identifies conditions for a sustainable beef production system, specifically in Manitoba. As a result, economic and environmental conditions are analyzed, and their trade-offs evaluated. The attributes on each farm are identified in order to understand conditions which might be more, or less, favourable to reduce GHG emissions while maintaining or increasing profitability.

1.5 Organization of Study

This thesis contains seven chapters, including the current one. The next chapter provides a background on the beef industry in Canada and in Manitoba, as well as its contribution of GHG emissions. The third chapter discusses previous research in this field. Chapter Four provides the economic background related to this research. Chapter Five documents the empirical methods used in this study to examine GHG emissions and profitability on Manitoba farms. Chapter Six provides results of this study in terms of farm level profitability and the associated GHG emissions. Finally, Chapter Seven summarizes this study and suggests further avenues for research.

CHAPTER 2 INDUSTRY BACKGROUND

2.1 Introduction

The beef cattle industry in Canada faces financial uncertainty while also emitting GHGs. In the past fifteen years, the Canadian beef industry has experienced bovine spongiform encephalopathy (BSE), a rising cost of production (CanFax 2011a), and Country of Origin Labelling legislation by the United States. These all have resulted in lower prices for Canadian beef, and have even caused the Canadian cow herd to contract (Canfax 2011b). The consumption of beef throughout the world peaked in 2007, and has wavered by several hundred thousand metric tonnes since this time (Cook 2015a). In Canada, however, consumption of beef has remained relatively constant within that period of time (Beef Canada 2013). Meanwhile, the amount of GHGs from enteric fermentation have increased between 1990 and 2005, though it has decreased slightly from 2006 to 2013 (Manitoba Eco-Network 2015). This chapter reviews the Canadian and Manitoba beef cattle industry, as well as its GHG emissions.

2.2 The World Beef Market

Beef production varies across the world. Different production practices and land availability, as well as infrastructure, provide comparative advantages to a variety of countries. The United States produces more beef than any other country in the world, at 11.2 million tonnes in 2014, or which is 19.08 percent of total world production. The next top four beef producing countries, Brazil, the European Union, China, and India, together with the United States, produce 28.5 million tonnes of the world’s beef, or 65.4 percent of total world beef production (Cook 2015c). In comparison, Canada produced only 1.03 million tonnes of meat in 2014, which constituted 1.74 percent of total world beef production, or. In fact, Canada was the 12th largest beef producer in the world (Cook 2015c).

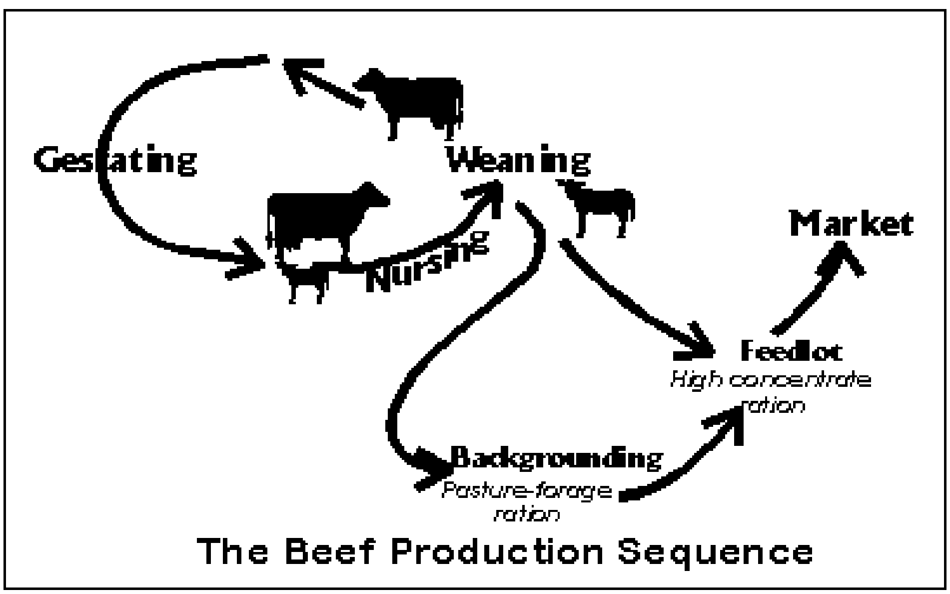
Though in line with production to a certain extent, beef consumption throughout the world also differs among countries. In 2015, Hong Kong consumed the most beef per capita than any other nation, at 123 pounds per capita per year. This was followed by Argentina (96.95 pounds), Uruguay (81.59 pounds), Brazil (60.40 pounds) and the United States (53.84 pounds). Japan, the European Union, Pakistan, China, and India were also significant consumers of beef (Cook 2015b).

As the locations where beef is produced is different than its place of consumption, international trading in this commodity is an important part of the world beef market.

2.3 Canada's Beef Production

Canada's production system consists of Bos Taurus breeds of cattle, rather than Bos Indicus (Canada Beef Inc 2012c)[5]. The latter type of cattle has been shown to have less tender meat, which is undeterred by the amount of marbling with a carcass. This is a notable difference from the herds in the United States and Australia, as both countries include Bos Indicus breeds, which are better suited for warmer climates. (Canada Beef Inc 2012c).

Although beef production systems differ throughout Canada, there are some similarities. It starts with the birth of a calf , which tends to occur in June and July (Canada Beef Inc 2012c). Figure 2.1 notes that these cows then gestate for nine months, birthing their calves in March or April in order to avoid cold winter weather (Canada Beef Inc 2012c).



Source: King (2006)

Figure 2.1 The Beef Production Sequence

[5] The Bos Taurus breed include Angus, Charolais, Hereford, Senepol, and Simmental. They are more adaptable to cooler climates, and have more tender meat with marbling. The Bos Indicus breeds include Brahman, Beefmaster, Brangus, and Sana Gertrudis. These breeds are more common in subtropical areas. (Godfrey n.d.)

After nursing their calves for approximately six months, weaning starts. This processes is one of the three main stages of beef production, called the cow-calf stage (King 2006). The next stage is stocker production, or backgrounding (King 2006). In this stage, weaned calves are placed on a low-energy diet in order to improve their skeletal and muscular build (Canada Beef Inc 2012c). However, larger animals are placed directly into the third stage, finishing operations (Canada Beef Inc 2012c). The finishing or feedlot operation places calves on high energy diets that usually consist of grains, such as barley and corn (Canada Beef Inc 2012c). While many producers in Canada are involved in only one stage of production, a few are involved in all three (King 2006).

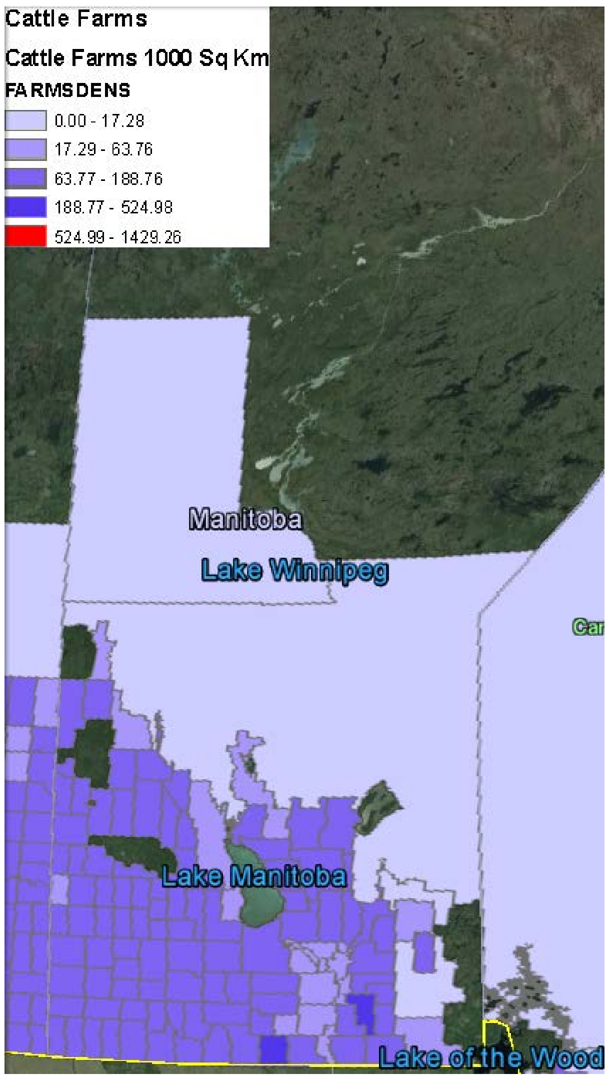
After steers and heifers have reached an appropriate weight, which is approximately 1,220 lbs for heifers, and 1,300 pounds for steers, they are sent to slaughter houses (Canada Beef Inc 2012b). There are few large slaughterhouses left in Canada. As of 2011, federally inspected plants for beef slaughter existed only in Alberta, Ontario, Quebec, and Prince Edward Island (Agriculture and Agri-Food Canada 2013). The largest slaughter plants exist in Brooks, Alberta and High River, Alberta (Broadway 2012). A large portion of this meat is then shipped to the United States, which imports 77.5 percent of Canadian beef (Canada Beef Inc 2012a).

Canada is a net exporter of beef. Between July and December, 2011, there were 44,400 head of cattle imported into the country (Statistics Canada 2012b). During the same period, there were 315,100 head exported out of Canada (Statistics Canada 2012b). The country's beef cattle industry also trades cattle between provincial borders. There were 962,000 head of cattle bought and sold which stayed inside the country, within the same period of time (Statistics Canada 2012b). This is a reflection of the movement of cattle between the different stages of production throughout Canada, and across provincial borders.

2.4 Manitoba's Beef Production

As of January 1, 2013, Manitoba had 12.5 percent of total Canadian beef cows, the third largest herd in the country behind Alberta and Saskatchewan (Canada Beef, 2015). The 2011 census , which provided information regarding the types of farms throughout Canada, noted that 9,240 farms, or 35 percent of all farms in Manitoba, were primarily beef farms (Statistics Canada 2008). In 2011, the majority of beef farms in Manitoba were cow-calf operations (77 percent), followed by feeder or stocker operations (16 percent), and feedlot operations (7 percent) (Honey 2012b). According to Manitoba Beef Producers (a non-profit organization meant to "represent cattle producers through communication, research, advocacy and education"), these producers purchase more than $300 million worth of feed, and $225 million in operating inputs each year, which supports small businesses and communities throughout the province (Manitoba Beef Producers 2011).

The beef farms are not uniformly located throughout the province. Instead, they are located in the southern region of the province, as shown in Figure 2.2. This region has the largest level of Manitoba's cattle population, as well as farmland.

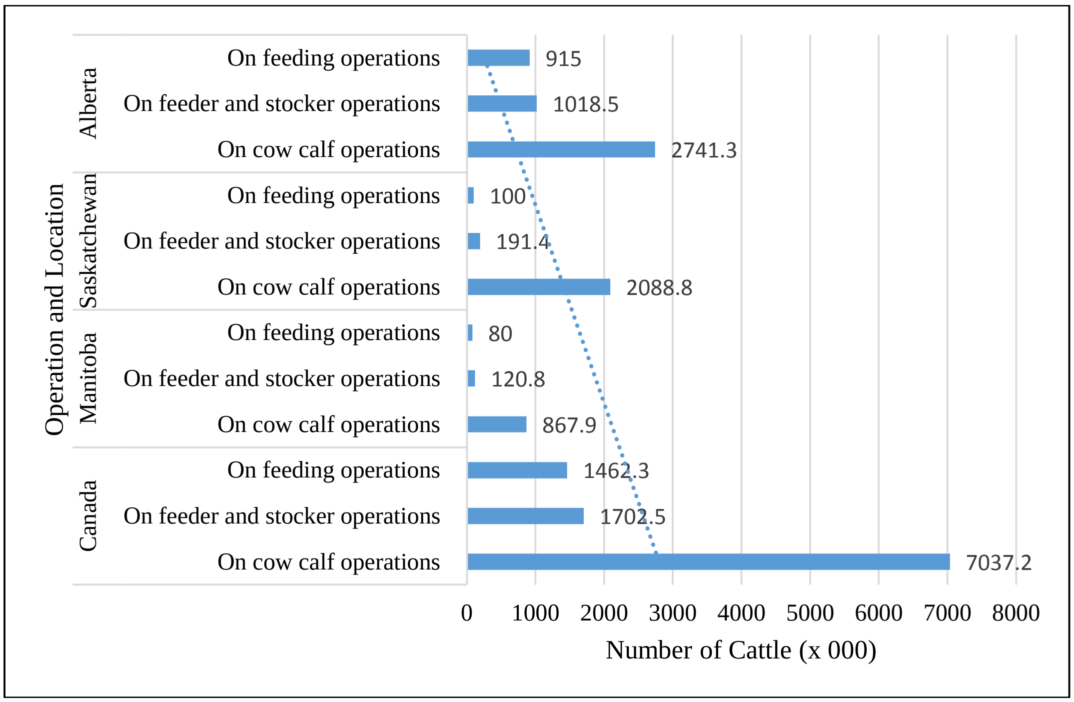


Source: Green (2006)

Figure 2.2 Cattle Density in Manitoba, 2006

Manitoba beef producers rely on international trade (later in the supply chain[6]) though most of its cattle are sold through interprovincial trade. There were 203,000 head of cattle exported out of the province between July and December, 2011 (Statistics Canada 2012b). Of these cattle, 18.6 percent of them were shipped internationally (Statistics Canada 2012b). The remaining cattle were exported to other provinces. It is likely that these cattle were exported to Alberta or Saskatchewan, as Saskatchewan and Alberta interprovincial imports accounted for 85,300 and 631,400 head of cattle (Statistics Canada 2012b).

Although, as shown in Figure 2.3, the two provinces (Alberta and Saskatchewan) have larger herds on cow-calf operations, they also have more backgrounding as well as finishing operations than Manitoba (Statistics Canada 2015e). Nationally, 69 percent of beef operations identify themselves as cow-calf farms. In Manitoba, 81 percent of beef operations were designated as cow-calf operations, as against 88 percent in Saskatchewan and only 59 percent of beef farms in Alberta. (Statistics Canada 2015e).



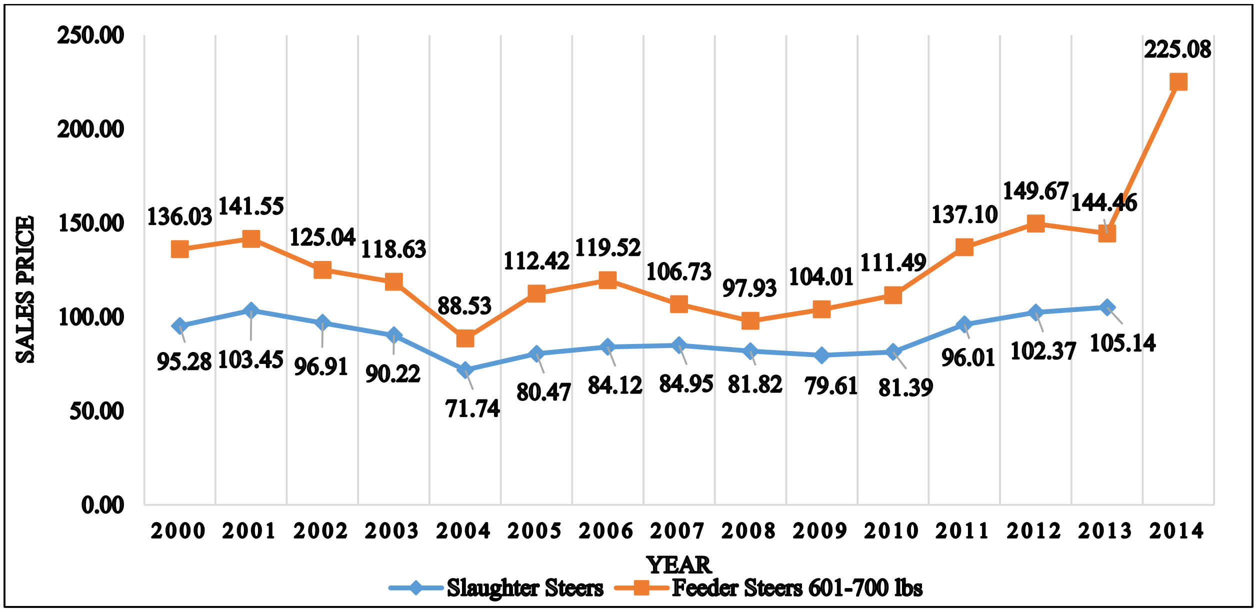
Source: Statistics Canada (2014e**)**

Figure 2.3 Number of Cattle, Selected Provinces and Canada, by Farm Type, 2011

[6] This topic is discussed further in Section 2.5

Profitability has been elusive to some cattle farms in Manitoba, as already shown in Table 1.1. Aggregate evidence in this table shows that after the adjustment for capital cost allowance, an average producer has not made enough profit to adequately provide for themselves (Statistics Canada 2014c; Statistics Canada 2015d). This might be the result of a smaller herds on these farms, as the fixed costs to feed a herd of 10 might be similar to those necessary to feed a herd of 100. Honey (2012b) notes that while prices were higher in 2011, "fewer calves were born and fewer cattle sold lowered farm cash receipts to $421 million."

The price of cattle varied significantly during 2000 and 2004 period (Figure 2.4). It details the increases and decreases in price, in $ per cwt, for slaughter steers and feeder steers in Manitoba between 2000 and 2014. The sales price for slaughter steers was not available for 2014. The figure shows that the price of feeder steers increased in 2001 by 8.1 percent from the previous year, while the price of slaughter steers increases by 8.4 percent.



Note: Prices for 2014 slaughter steers were not available.

Source: Agriculture and Agri-Food Canada (2008)

Figure 2.4 Weighted Average Price for Slaughter Steers and Feeder Steers, per 100 lbs, Manitoba, 2000-2014

Average prices for slaughter steers and heifers are consistently lower in Manitoba. Prices have been consistently lower in the province compared to the national average by $7 per animal in 2001, and by $137 per animal in 2014 (Statistics Canada 2014d). The Manitoba Cattle

Enhancement Council estimates that in addition to lower prices at auction sales, an additional cost of $50 per head is added to Manitoba cattle. This cost, which is lower in Alberta, rises with the cost of fuel (Manitoba Cattle Enhancement Council 2012).

After the BSE crisis in 2003, which affected the Canadian cattle industry,[7] there was a decreasing trend on herd size in the province until 2011. While most businesses have not completely regained its pre-BSE strength, their situation has been slowly improving. In Manitoba, the number of beef cows declined from 619.1 thousand head in 2006 to 420.5 thousand head in 2014 (Statistics Canada 2015e). The total number of beef calves in Manitoba had declined from 413 thousand on January 1st, 2005 to 295.2 thousand January 1st, 2013 (Statistics Canada 2014a).

Beef cattle prices in Manitoba reacted to this short supply, over the post-BSE period. The price for slaughtered steers has also risen since 2011. For example, steer price rose from $137.10 per cwt in 2011 to $149.67 per cwt in 2012 in Manitoba. In 2014, it has increased further to $225.08 per cwt.

2.4.1 Feeding Strategies in Beef Production Sequence

Cow-calf operations can use one or more of several pasture feeding strategies[8]. The native pasture grazing method, rather than the tame pasture grazing method, accounts for 78 percent of total pasture area in Manitoba. Nationally this share is 73 percent (Table 2.1). The area of tame pastureland in Manitoba is also less than that in Saskatchewan, Alberta, and the national level.

Table 2.1 Land Area under Pastures, National and Selected Provinces, 2011

Pasture Type	Canada	Manitoba	Saskatchewan	Alberta
% Area Tame Pasture	27%	22%	30%	27%
% Area Natural Pasture	73%	78%	70%	73%
Total Pasture Area In Canada (Acres)	50,004,207	4,651,241	16,987,852	21,823,780

Source: Statistics Canada (2015a)

[7] This is discussed in greater length in Section 2.7.1

[8] Producers use an array of strategies to feed their cattle, including pastures, bale grazing, swath grazing, cereal grains, screenings, ethanol fuel byproducts, sprouted grains, and greenfeed, among others (Manitoba Agriculture Food and Rural Initiatives 2015a).

Pastureland, in general, benefits Manitoba's ecosystem as it stores carbon, absorbs excess moisture, controls soil salinity, and prevents erosion (Climate Change Connection 2014). While using native pastures results in lower input costs, as seeding and other chemicals are not used, it also yields lower rates of animal weight gain and therefore, lower output per acre of pasture (Boadi et al. 2002).

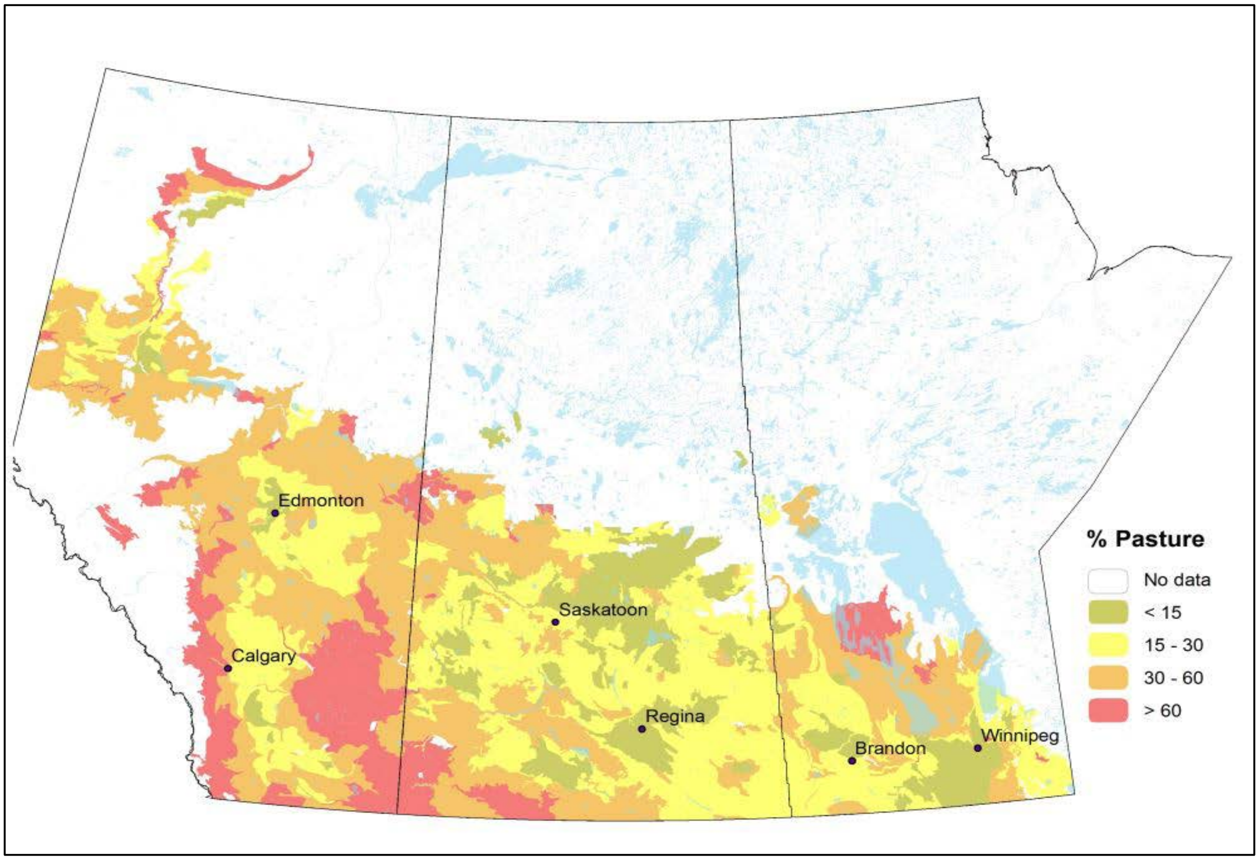
A tame pasture allows cattle to graze on grass and legumes, resulting in a greater rate of weight gain than possible on native pastures. Manitoba producers are encouraged by their provincial government to use tame pasturelands (Agriculture Food and Rural Development 2014), often seeded with an alfalfa-brome mix, in order to increase their incomes. However, it does have higher input costs as proper grasses and legumes should be planted every ten years to rejuvenate the area, and fertilizer might need be used occasionally (Agriculture Food and Rural Development 2014).

During the year 2011, there were 1,026,284 acres of tame or seeded pasture, and 3,624,957 acres of natural land for pasture in Manitoba. This amounted to 5.7 percent and 20.1 percent of the total land in the province, respectively (Manitoba Agriculture Food and Rural Initiatives 2013). Figure 2.5 shows the concentration of pastures across the Canadian Prairies. The red (or darkest) area indicates greater amounts of pasture in the region. Visually, it confirms the previous observation that relative to Alberta and Saskatchewan, Manitoba has fewer pastures, whether tame or native. This also establishes that the location of most cow-calf operations are in southern Manitoba.

Rotational grazing, which uses paddocks to segment tame pastureland, allows forage[9] to rest while it grows. In addition, it prevents grass and legume competition with weeds, decreases the probability of winterkill in alfalfa, and ensures that all of the plant life is eaten, before cattle move to a different area. It also ensures that manure is properly spread throughout the pasture (Climate Change Connection 2014; Scott 2010). Notably, however, this technique involves a higher degree of complexity in livestock management, as producers must move their cattle every few days (Climate Change Connection 2014). The practice is not common in Manitoba, as only 34 percent of Manitoba farms manage their pastureland in this manner (Statistics Canada 2015c;

[9] Forages refer to hay composed of alfalfa and alfalfa grass mixes for the purposes of feeding livestock.

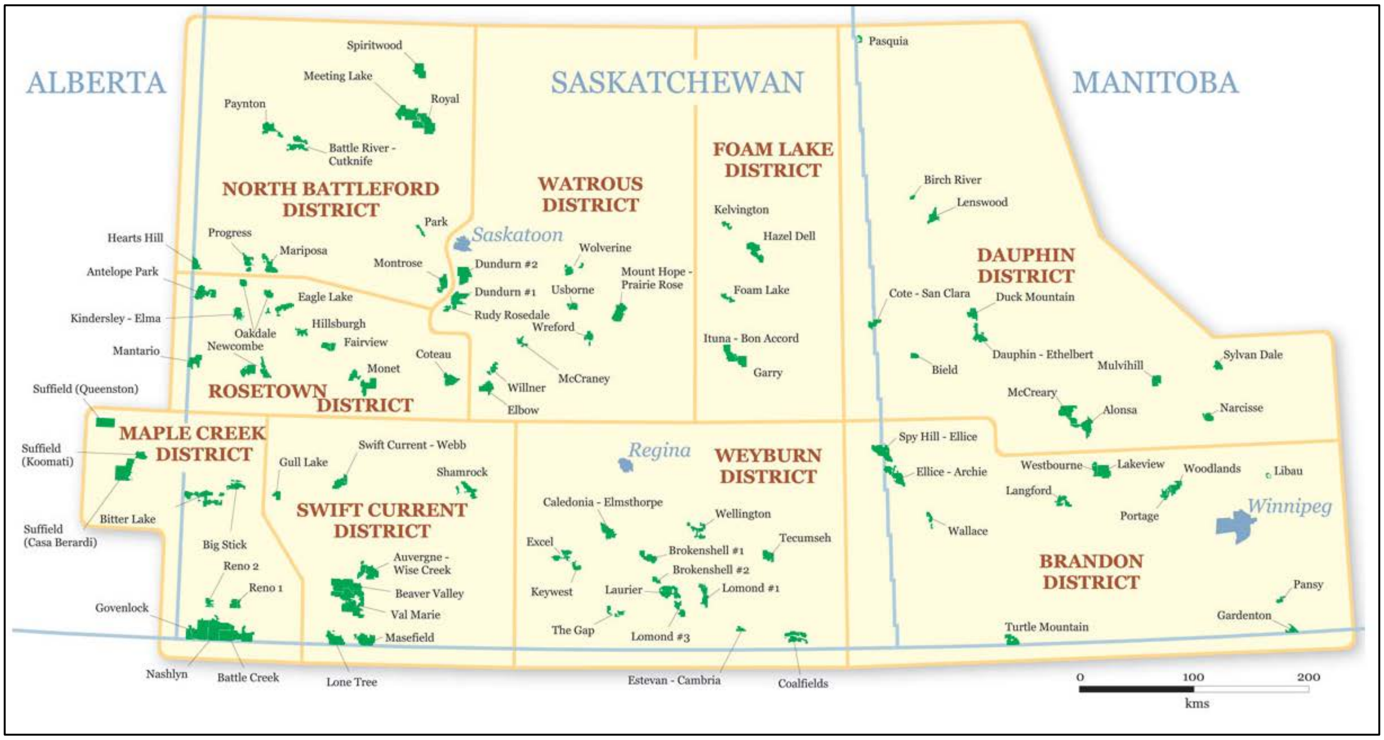
Statistics Canada 2015b). Its use, however, is proportionally higher in Manitoba than in Saskatchewan (27 percent),although lower than Alberta (35 percent) (Statistics Canada 2015c; Statistics Canada 2015b).



Source: Beef Cattle Research Council (2014)

Figure 2.5 Spatial Distribution of Pastureland in the Canadian Prairies, 2014

In addition to using private tame or native pastures, producers have an option to use community pastures. Community pastures in the province of Manitoba are used to stabilize capital costs for producers, and reduce management responsibilities (Agriculture Food and Rural Development 2014). Some of the pasturelands are managed under the federal community pasture program. Figure 2.6 shows the locations of these pastures throughout the Canadian Prairies. This program, developed in the 1930's, rehabilitated soil and land that was badly eroded during the droughts of 1930s (Agriculture and Agri-Food Canada 2011a). Community pastures were meant to be an example of productive, ecologically diverse land, while also providing land to livestock producers as a resource (Agriculture and Agri-Food Canada 2011a). There are a total of 24 provincial and federal community pastures in the Manitoba (Government of Manitoba 2014).



Source: Agriculture and Agri-Food Canada (2012)*

* In 2014, Manitoba's community pastures, both federal and provincial, have started to transition into the responsibility of a new non-profit group -- the Association of Manitoba Community Pastures, rather than being managed directly under the mandate of either level of the governments (Government of Manitoba 2014).

Figure 2.6 Prairie Farm Rehabilitation Administration Pastures in the Canadian Prairies, 2012, by Districts

In order to use community pastures, producers must bear the cost of transporting their cattle to these pastures. There are also strict rules on the time period during which the cattle have to be transported to and from these pastures. Producers also choose between continuous grazing, rotational grazing, complementary grazing, strip grazing, or mechanical grazing[10] (Agriculture Food and Rural Development 2014).

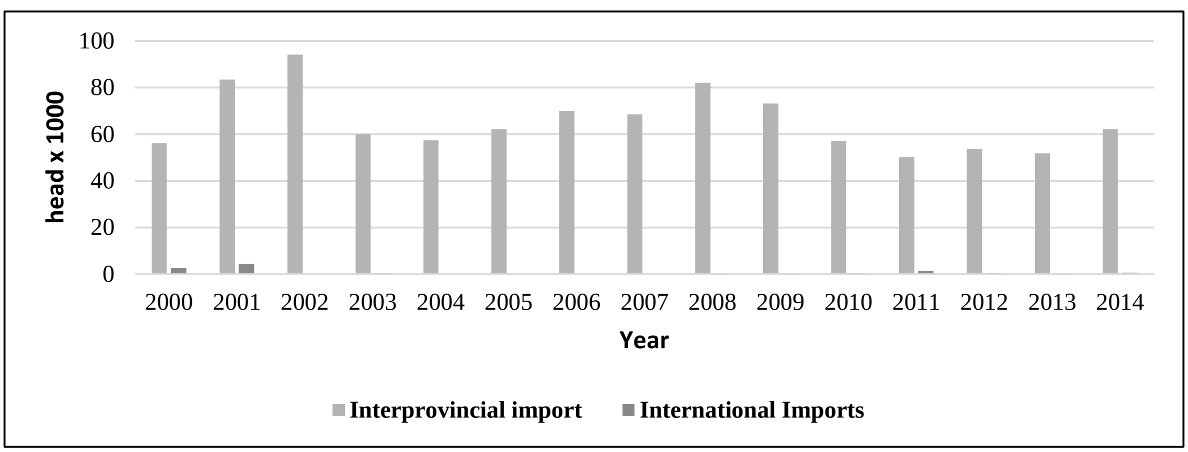
[10] Mechanical grazing, also known as zero grazing, is a process in which forage is cut daily, and then hauled to cattle for feeding (Agriculture Food and Rural Development 2014).

2.4.2 Slaughter Capacity

The province of Manitoba no longer has large slaughter houses to process cattle. While the province was able to process 581,000 head in five major cattle slaughter facilities in 1976, that number dropped by 97 percent in 1996 (Honey 2012b). Presently, there is only one federally inspected slaughtering plant, and 23 provincially inspected plants that, in 2011, had the combined capacity to process 11,800 head (Honey 2012b). This change was catalyzed by a subsidized beef industry in Alberta, a booming grain industry which promoted more crops and less ranching, and aging existing plants, which could not be reinvested due to competition with several newer plants from all over North America (Rance 2013).

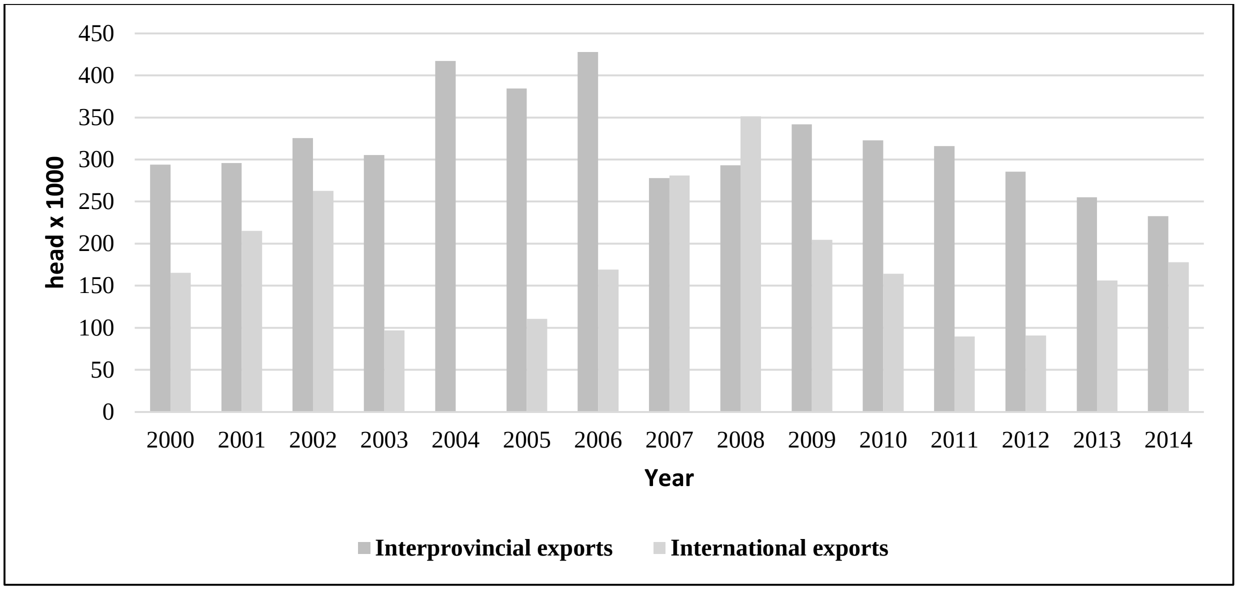
2.4.3 Trade in Manitoba Beef Cattle

Due to the low slaughter capacity in the province, most of the cattle are exported either inter-provincially or internationally. Figures 2.7 and 2.8 show that Manitoba's beef industry relies heavily on interprovincial and international trade, where exports of beef cattle from Manitoba far exceed the imports into the province. Figure 2.8 shows that the province's beef industry relies mainly on interprovincial exports, though international exports are valuable as well. These international exports decreased by more than half in 2003 compared to 2002, and then stopped completely in 2004, due to the BSE crisis (as described further in Section 2.7.1). International exports of Manitoba beef cattle exceeded interprovincial exports of Manitoba cattle in years 2007 and 2008.



Source: Statistics Canada (2015a)

Figure 2.7 Imports of Manitoba Cattle, 2000 - 2014



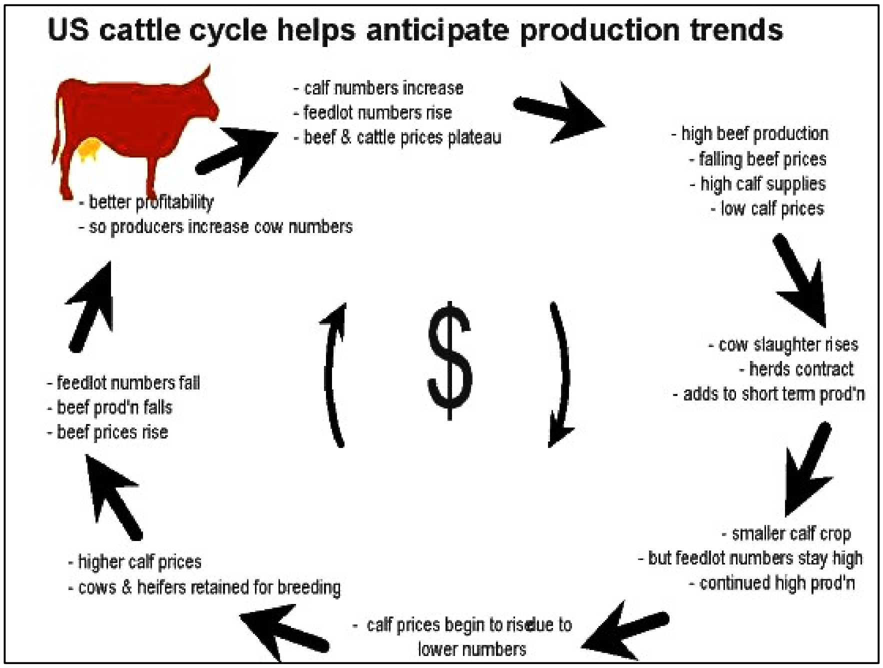
Source: Statistics Canada (2015a)

Figure 2.8 Exports of Manitoba Cattle, 2000 - 2014

2.5 Canada Beef Industry's Dependence on the US Market and its Cattle Cycle

Since Canada's livestock industry is closely tied to the US market, it follows the trends in that cattle market as well. The beef cattle prices are largely driven by the production in the United States, and not necessarily in Canada. This is so because the size of Canada's beef market is one tenth the size of the beef herd in the United States (Matthews et al. 1999). Also, the North American Free Trade Agreement has economically integrated the beef industry of Canada, Mexico, and the United States (Hahn et al. 2005). Therefore, if prices for cattle increase or decrease in the United States, it is not only a reflection on their consumption but also their input costs. As noted in Figure 2.9, the cattle cycle leads to increases and decreases in prices over a 10-year period. This cycle is dependent on the supply of calves in the market, and the prices beef producers receive for them. If costs are high and revenues are low, producers will decrease the size of their herd. As the price for calves increase, herd sizes will also increase (Griffith and Alford 2002). There are ebbs and flows which hinge on the number of calves born each year from herds, the number of retained cows and heifers, and the amount of cattle bought for feedlot operations.

As noted above in Figure 2.9, these prices increase and decrease within a 10-year cycle, though throughout the past fifteen years, there have been three increases and decreases in price in the United States (Schulz 2013). Yet, due to the factors noted throughout Section 2.7 (which include the BSE crisis and COOL legislation), the Canadian beef industry did not experience this typical cycle (Statistics Canada 2014d). In addition, the expansion or reduction of beef herds does have other causes, such as the age of farmers and their risk aversion (Larson 2014).



Source: Griffith and Alford (2002)

Figure 2.9 US Cattle Cycle

2.6 Public Programs

Cattle producers rely on several different programs to reduce risk throughout the cattle cycle, and to avert losses resulting from an unexpected shock to the market. Some programs, such as crop insurance, protect only crops, while other programs protect the entire farm. The latter types of programs include: AgriInvest, AgriStability, and AgriRecovery. They are federal and provincial programs or frameworks mandated to reduce variability in farm incomes.

AgriRecovery is available to producers upon request of a province or territory, after a disaster has occurred. This initiative has been used to deal with flooding and forage shortages (Agriculture and Agri-Food Canada 2014). AgriInvest refers to an initiative which replaced the previous program called the Net Income Stabilization Account. It encourages farmers to save a portion of their income for times when the production cycle takes a downturn. Both producers and the federal government contribute to the account (Statistics Canada 2009). AgriStability is a program that ensures producers' income does not fall by more than 70 percent below the average of the previous three out of five years, with the lowest and highest income years excluded (Agriculture and Agri-Food Canada 2015). Through the use of these programs, cattle producers are able to weather significant problems, and also maintain profitability throughout the cattle cycle.

Manitoba producers felt that the AgriStability and AgriRecovery, as well as the Disaster Financial Assistance during flooding in 2008, were outdated or not meant to handle natural disasters (Manitoba Beef Producers 2011). Therefore, the introduction of the Western Livestock Price Insurance Program[11] in 2014 was welcome for the Manitoba livestock sector. However, it was not available during the period of this research.

2.7 Impediments to Canada's Beef Cattle Industry

Carcass prices reached a very high level in 2004, which was never witnessed in Canada before 2001. As shown in Figure 2.4, price of feeder steers of weight between 601-700 lbs was $141.55 per cwt. However, the catastrophic event, known as BSE, significantly decreased the prices of cattle, which weakened the Canadian beef market. Other subsequent challenges such as the COOL legislation also placed increased strain on the market.

2.7.1 The BSE Crisis

Concern for this disease affecting the health of cattle revolves around a link between BSE and the human disease called Creutzfeldt-Jakob disease. This disease is believed to emerge when an individual human eats risk-prone elements of a diseased animal (Center for Disease Control, 2013). The discovery of BSE on an Alberta cow shut down international beef trade from Canada, devastating a market that exported more than one million head of live cattle per year. This resulted in a loss of $5.3 billion for the cattle industry by the end of 2004 (Statistics Canada 2006). While

[11] The Western Livestock Price Insurance Program ensures that cattle and hog producers are compensated for unexpected drops in prices over a period of time. The program is divided into three different segments, which are associated with the three stages of production. However, this program was not available in 2011, which is the period of this study (Western Livestock Price Insurance Program 2012).

there was domestic moral support for the beef industry, Canada lacked the slaughterhouse capacity to process cattle, which were previously shipped to the United States. Therefore, the beef herd grew, and in 2004, it was sold off at the depressed prices of $71.74 per cwt for feeder steers. After July, 2005, the US border opened to live animals under 30 months of age (Statistics Canada 2007), bringing some relief for the industry.

2.7.2 COOL Legislation

Following the financial devastation faced by farmers as a result of the BSE crisis, Canada's largest trading partner, the United States, implemented “Country of Origin Labelling” legislation. The law, meant not just for traceability to guard food safety but also to inform consumers, ensured that any consumer of meat products in the United States knows the national source of their product (Food Safety and Inspection Service 2010). It was first designed as part of the 2002 US Farm Bill, and then later enacted as part of the 2008 US Farm Bill (Keller and Heckman LLP 2014). To enact this law, slaughterhouses in the United States were required to segregate Canadian steers, heifers, cows, and bulls so that they can be accurately labelled as Canadian beef. As Canada has only three major packing plants[12] in the country, there is little capacity to process excess[13] Canadian beef cattle. The Canadian Cattlemen's Association has stated that increased transportation costs and fewer processing days in United States packing plants have resulted in $90 less per animal in Canada, to a total annual loss of $400 million throughout the Canadian cattle industry (Jensen 2008).

2.7.3 Ongoing Concerns in Manitoba's Beef Cattle Industry

According to the Manitoba Beef Producers (2011), there are several concerns in the province's beef industry. First, beef producers in the province have asked for any programs meant to improve the beef industry to be voluntary, compensated, and controlled by producers. These programs include traceability and biosecurity concerns. Producers worry that mandatory systems could create more costs. Second, they demand that infrastructure controlling the flow of water

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[12] Two of the three beef packing plants are owned by Cargill, located in High River Alberta, and Guelph, Ontario. JBS Canada owns the third packing plant, located in Brooks, Alberta.

[13] Excess capacity existed in Canada as the amount of product normally exported to the United States declined due to the restrictions imposed by the COOL legislation.

should include impacts on beef producers, as flooding has become common near bodies of water, such as Lake Manitoba, Lake Dauphin, and the Red River Valley. They also asked for short-term assistance, including compensation, along with long-term assistance requiring greater predictability for beef producers, so that they can plan financially. Third, Manitoba beef producers have asked for compensation for costs incurred while proceeding with mandatory testing for BSE. While this testing is important, they argue that it is a public good that adds to their costs. Fourth, since predators are imminent dangers on pastureland, producers have asked for incentives to increase trapping of wolves and coyotes, in addition to compensation for lost farm animals. They hope to reduce their operation costs and losses by doing so. Fifth, producers hope to limit the spread of disease[14] by discouraging members of the public from accessing crown lands while cattle use this land, so that less animals are lost, and veterinarian costs are reduced. Sixth, as traceability remains a primary method of gaining accurate and relevant data on every animal, Manitoba producers have requested that these costs fall on government entities (Manitoba Beef Producers 2011). While this list is not exhaustive, it does encapsulate the main concerns in the Manitoba beef industry. It also displays several different areas in which costs could increase for producers, which could further decrease their net revenue.

2.8 Emissions of GHG from the Beef Cattle Industry

2.8.1 Canada GHG Emissions

The majority of GHG emissions are through three types of gases: carbon dioxide, (CO_2), methane, (CH_4), and nitrous oxide, (N_2O)[15]. Not all of these emissions are released directly from an animal, but they are also generated indirectly through the entire production cycle ranging from feed production through to manure spreading. In order to fully capture total GHG emissions, a whole farm analysis is needed.

In Canada, agriculture is not the leading emitter of GHGs. Transportation, oil and gas production, and electricity generation, among others, have produced more GHGs than agriculture

[14] The policy document from Manitoba Beef Producers did not detail the type of diseases that could occur.

[15] Other minor GHGs that are not included in this study are: hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride.

(Environment Canada 2013a). As noted above, the GHG emissions from cattle and other ruminants come through enteric fermentation and application of manure to crop fields, as described by Wittenberg and Boadi (2001):

> "The dominant GHG's (CH_4 and N_2O) associated with livestock agriculture are produced as a result of natural biological processes of microbial breakdown of feed components. Microbial enteric fermentation in the gastrointestinal tract of livestock can produce CH_4 gas as a by-product. On average, about 4-12 percent of gross energy intake (GEI) is converted to CH_4 gas. Ruminants with their large fore-stomach contribute the most per head per day" (Wittenberg and Boadi 2001).

According to the IPCC Fourth Assessment, N_2O has a Global Warming Potential[16] (GWP) of 298 (Environment Canada 2010). It stays in the atmosphere for 114 years before its destruction due to chemical reactions, or before it is absorbed into a soil sink (US Environmental Protection Agency 2014). When converted in terms of its global warming potential, it constitutes almost 10 percent of total greenhouse gases in the atmosphere. Agriculture plays a role in its increased level of GHG emissions through ammonia inputs into the soil, and through the return of animal waste onto the soil.

The CH_4 gas is produced through several sources, including wetlands, oceans, termites, burning fossil fuels (such as coal), landfills, waste water, rice production, and livestock (Johnson and Johnson 1995). While it has a shorter lifespan than N_2O, has a GWP of 25 due to its ability to trap radiation in the atmosphere (Environmental Protection Agency 2014; Environment Canada 2010). In 2011, approximately 72 percent of CH_4 emissions in Canada originated from cattle and crop production (Environment Canada 2013b). CH_4 emissions from cattle are affected by the level of feed intake, the type of carbohydrate in feed, whether or not the forage is ground or processed into pellets, and an increase or addition of lipids (Johnson and Johnson 1995). In the beef production system, the cow-calf and backgrounding segments are more likely to produce an increased level of methane, as they rely more on forages. The finishing segment relies on grains, which is used more efficiently by the rumen (Vergé et al. 2008).

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[16] GWP is a method which allows various GHG emissions to be compared to each other. The base GHG is CO_2, which has a GWP of 1. Therefore, all other gases are compared to CO_2 according to their ability to trap heat in the atmosphere (Environment Canada 2010).

Beef production contributes to carbon dioxide emissions through several sources: “farm fieldwork, haulage by farm-owned trucks, electricity use, heating (including grain drying), and manufacture and supply of both farm machinery and synthetic fertilizer” (Vergé et al. 2008). The beef industry in other parts of the world have contributed to CO_2 pollution through burning crop residues (which is less frequent in Canada, on account of the practice of no-till farming), desertification of pastureland, and the expansion of pastures into forests (Steinfeld and Wassenaar 2007). However, intensive livestock operations, as seen in Canada, are more likely to use a greater amount of fuel to utilize fertilizer, produce feed, and transport animal or meat. Producers also expand their crops into forests, and till their pastures into crops (Steinfeld and Wassenaar 2007).

For the U.S. beef sector, Capper (2011) used a whole farm analysis to determine total GHG emissions in 1977 to 2007. By 2007, these emissions were lower due to a smaller energy requirement for these animals, less land and water needed to grow feed, and less waste output per kg of cattle in the country. This gain in productivity is due, in part, to cattle genetics from Europe that have increased the size of animals, increased the size of steaks, and therefore increased efficiency on the farm (Capper 2011). These changes are related to higher productivity throughout the agriculture sector. However, Capper (2011) also noted that it is not likely that consumers will want these larger portions, and therefore steak sizes will not increase further. Therefore, the beef industry needs to increase its efficiency and decrease its GHG emissions through other methods.

In Canada, due to a variety of feeding conditions and manure management strategies, the amount of GHG emissions from cattle differs. However, Manitoba Agriculture Food and Rural Initiatives (2011a) estimates that an average of 65 kg of CH_4 is produced every day from one cow through enteric fermentation, which equates to 23,725 kg per annum. The cow-calf herd produces 84 percent of the province’s enteric fermentation emissions (Beauchemin et al. 2010). The amount of N_2O and CH_4 further differs from farm to farm due to differences in manure storage systems, manure characteristics, and its quantity. Canadian cow-calf operations emit 80 percent of all of the GHG emissions from beef cattle (Beauchemin et al. 2011).

2.8.2 Manitoba GHG Emissions

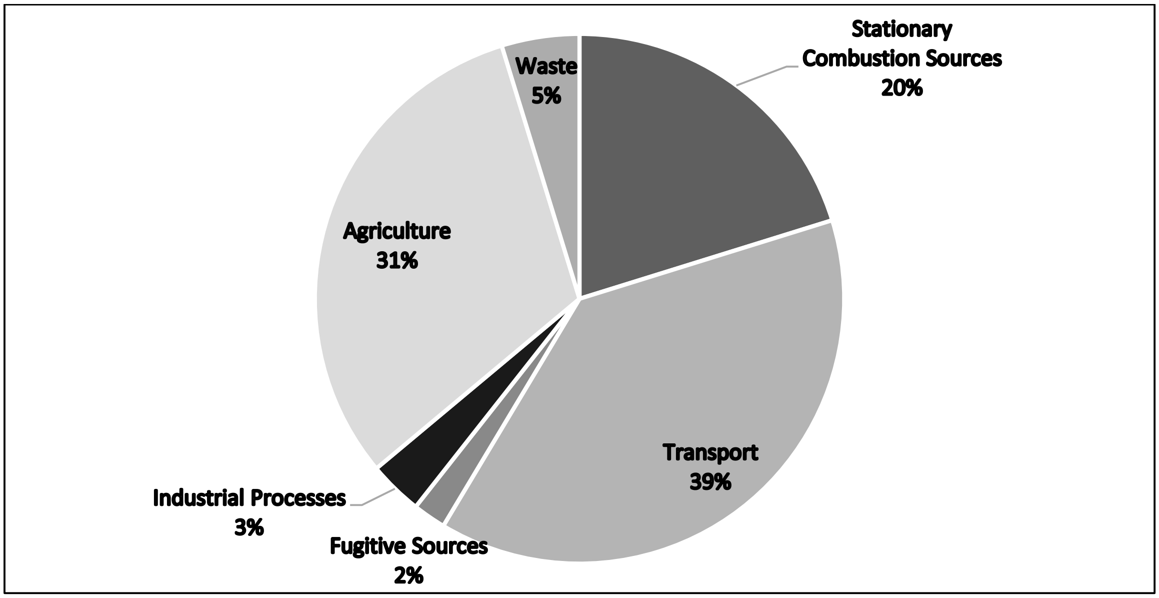
The agriculture sector in Manitoba emits a significant amount of the province’s GHGs. Manitoba and Canada’s total GHG emissions from agriculture are noted in Table 2.2. As shown in Figure 2.10, this sector's emissions are slightly less than the transportation sub-sector.[17]. Stationary combustion, which includes power plants, is low in Manitoba as it relies on hydro power (Environment Canada 2013b). Emissions from Manitoba's agriculture sector have proportionally been higher than those in Canada, as seen in Figures 2.10 and 2.11. CH_4 and N_2O emissions from agriculture in Canada created 4.6 percent of total GHG emissions (Manitoba Eco-Network 2014b). However, CH_4 and N_2O emissions from agriculture in Manitoba comprised 15.3 percent of all emissions (Manitoba Eco-Network 2014b). In 2013, there were 3,260 CO_2e kt of GHG emissions from enteric fermentation and manure management in the agricultural sector (Manitoba Eco-Network 2014b).

Table 2.2 Source of Agricultural Emissions by Region, 2009 - 2013

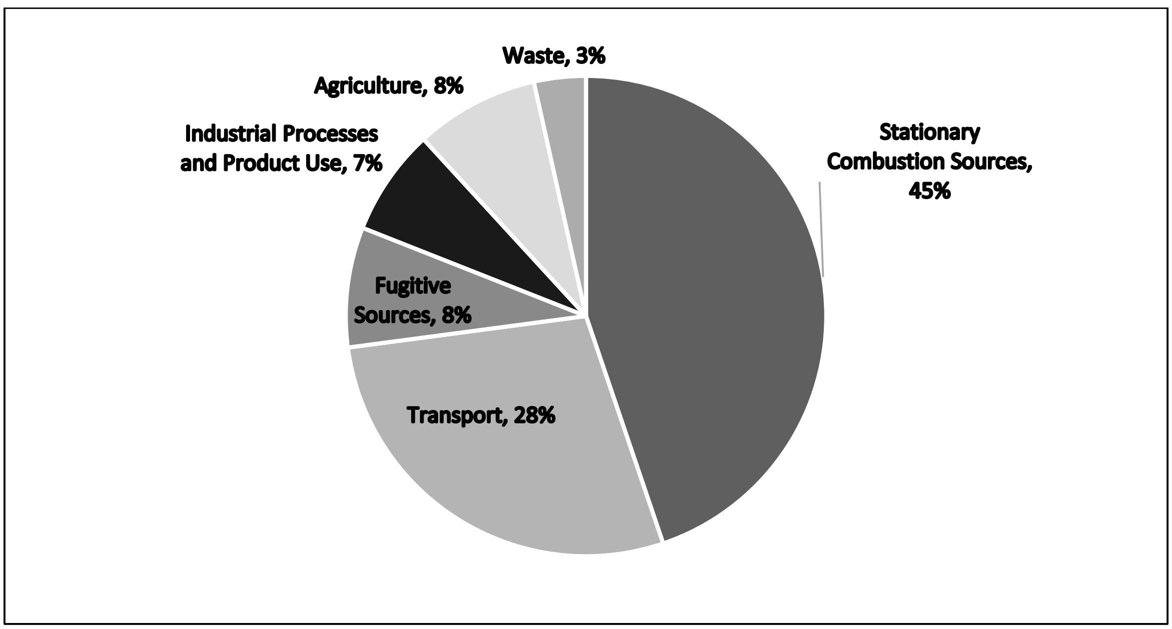
Region	Emission Source	2009	2010	2011	2012	2013
Manitoba	Enteric Fermentation	2,804	2,657	2,506	2,447	2,476
	Manure Management	786	790	770	764	784
	Agriculture Soils	2,602	2,688	2,318	2,589	3,127
	Field Burning of Agricultural Residues	22	16	10	17	21
	Liming, Urea Application and Other Carbon-containing Fertilizers	213	208	217	220	275
Canada	Enteric Fermentation	26,914	25,820	25,141	25,185	25,234
	Manure Management	8,679	8,503	8,380	8,400	8,434
	Agriculture Soils	20,402	20,750	20,482	22,099	24,160
	Field Burning of Agricultural Residues	50	33	30	39	52
	Liming, Urea Application and Other Carbon-containing Fertilizers	1,836	1,784	1,999	2,326	2,617

Source: Government of Canada (2015)

[17] The Energy Sector, noted in Table 1.2, consists of three sub-sectors, noted in Figure 2.10. They are Stationary Combustion, Transport, and Fugitive Sources. For more information, see Table A9-2: Canada's 1990−2013 GHG Emissions by Sector (Government of Canada 2015)



Source: Manitoba Eco-Network (2014b**)**
Figure 2.10 Manitoba GHG Emissions in 2013



Source: Government of Canada (2015)

Figure 2.11 Canada GHG Emissions in 2013

In the agricultural sector, its GHG emissions have been increasing between 1990 and 2012 (Manitoba Eco-Network 2014a). GHGs from soil management have increased by 18 percent during this time, while enteric fermentation has increased by 19 percent (Manitoba Eco-Network 2014a).

2.9 Summary

In the past 15 years, the world's beef market, and in particular the Canadian market, has been influenced by the cattle cycle, by diseases such as BSE, and by legislations like COOL introduced in the United States. This has influenced the number of cattle and the prices for these in Canada. The beef sector in Manitoba, which consists mainly of cow-calf farms that depend on native pastureland, has also been influenced by these factors. This is evidenced by fluctuations in prices for weaned calves. The GHG emissions from beef cattle production are also a concern in the industry, since agricultural emissions constitute second highest source in Manitoba. The next chapter investigates the different practices and production factors throughout the world, as seen through economic investigative studies and the theory of the firm. It also describes methods to analyze farms and their productivity.

CHAPTER 3 LITERATURE REVIEW

3.1 Introduction

Beef production varies throughout the world, as a result of national and regional policies, sociological motives, soil and crop types, as well as regional cattle breeds. As a result, methodologies for the analysis of beef production also vary. Studies of beef production have been undertaken at the international, Canada and Manitoba level. These studies differ in terms of their objective function, models and concepts used. A partial review of these studies has been provided in Section 1.3.4 for studies describing findings of animal and climate science, and in Section 1.3.5 for Canadian beef production studies. This chapter differs from the earlier review, as it presents economic factors affecting beef production. Section 3.2 describes different practices and production factors internationally, as well as in Canada and Manitoba. It also describes enterprises on the farm, as well as budgeting evaluations in Section 3.3. Methods to analyze farms and their economic productivity are reviewed in Section 3.4. Trade-off analysis is discussed in Section 3.5. A summary of the findings in this chapter is presented in Section 3.6.

3.2 Economics of Beef Production

3.2.1 International Studies

3.2.1.1 Profits

There are a number of motivations which could prompt profitability among beef producers. In a study conducted in Texas, economic and social incentives were shown to wither increases or hamper profits (Young and Shunway 1991). Economic motives, such as a desire to increase net worth, perceiving the cattle industry as a business venture, and partaking in off-farm employment, increased income on farms. While sociological motives, such as the enjoyment of ranching, wanting a child to become a rancher, and ranching as a method of relaxation, were noted to decrease the probability of profitability, motives such as ranching to be a part of community and permitting children to grow up in this environment increased the probability of profitability (Young and Shunway 1991). Notably, the sociological motives that increased the probability of profitability were not philosophically opposed to the economic motives (Young and Shunway

1991). The Young and Shunway study also noted that beef producers have extensive motives for working in their field. In other words, not all producers are profit maximizers (Young and Shunway 1991). However, Dunn et al. (2000) noted that an understanding of breakeven values on the farm was largely credited to gaining profitability on the farm. A review of 185 cow-calf enterprises in South Dakota, Nebraska, Montana, Minnesota, Iowa, Wyoming, and North Dakota between 1991 and 1999 showed that profits were routinely low for these producers (Dunn et al. 2000). Total net income for these producers was $16,764, which was enough to cover all family expenses and unpaid family labour (Dunn et al. 2000). This review also noted that the average percentage return on assets changed little between the time period noted and a survey from 1960 (Dunn et al. 2000).

3.2.1.2 Revenue

One of the most deterministic factors for profitability on cow-calf farms is the body weight of weaned calves. In long term studies in Illinois and Iowa, the body weight of these animals had a more significant impact on the return to unpaid management and labour per cow than calf price (Miller et al. 2001). On average, the study by Miller et al. (2001) yielded US$1.18 for each additional kg of a weaned calf's body weight. As there are a number of methods to increase the weaning weight of calves, they might affect the costs of each farm, as discussed in Section 3.2.1.3.

According to Schroeder et al. (1997), buying and selling cattle is based on two concepts: price determination and price discovery. Price discovery depends on the market structure, market behavior, market information and price reporting, and on the futures markets as well as risk management alternatives so that buyers and sellers might arrive at a transaction price (Schroeder et al. 1997). Price determination, on the other hand, depends on an expansive relationship between supply and demand in order to reach the market price level. This relationship refers to the cost of inputs, production technology for producers, while consumer interests are studied through complementary and substitute products, consumer tastes, preferences, and income (Schroeder et al. 1997).

3.2.1.3 Costs

Miller et al. (2001) notes that there are five factors that make a critical difference in the cost, and thus profitability, of a beef farm: feed cost, operating costs, depreciation cost, capital charge, and hired labour. Other research has corroborated that feed costs, along with the selling price of calves and the number of cows in the herd, are largely responsible for the variation in profits from herds in North Dakota (Hughes 1991).

3.2.1.4 Feed

Feed costs can range dramatically from farm to farm, as shown by Miller et al. (2001), and can account for 50 percent of the variation in profitability of beef herds. Such costs comprise 63 percent of the total annual cost for cows (Miller et al. 2001). For those producers, who rely heavily on pastures to raise their animals, costs can be considerably lower than for those using other feeding methods. “Grazing is typically the most cost-effective means of meeting beef cows’ nutritional needs. Hence, low-cost systems would be expected to use little purchased or raised feed that has been mechanically harvested, stored, and hauled” (Ramsey et al. 2005). There are more input costs for forage production, and still more for some types of grain production, such as investments, operating costs, depreciation, capital charge, and family labour (Ramsey et al. 2005). In order to account for this increase in costs, Miller et al. (2001) noted that that each $1 increase in the cost of feed would need to result in an additional 1 kg increase in calf weaning weight in order to breakeven, and that a “$1 increase in feed cost implied a $2.48 reduction in profit”. Moreover, even though the amount of feed fed did affect costs for these producers studied, they did not always improve production – implying that producers cannot expect better production with higher quality feed (Miller et al. 2001). Further to this point, there is a large opportunity cost for farmers who could instead sell their grains on the market rather than feeding them to their animals, as noted when the market for feed competed with the market for bioethanol (Lutey 2008).

3.2.1.5 Investments and Depreciation

Regarding operating costs, depreciation costs, and capital charges, Miller et al. (2001) found that they were negatively correlated to herd size, but positively correlated to feed costs. As the herd size increases, there might be ways to reduce the needed amount of labour, machinery, etc., on a per animal basis. However, if a herd increases in size, the need for feed also increases. Research from Miller et al. (2001) also noted that “depreciation cost was responsible for 12 percent of the herd-to-herd variation in ‘the return to unpaid labour and management’ in the economic model. Each $1 increase in depreciation cost in the economic equation resulted in a negative $1.19

‘return to unpaid labour and management’” Therefore, the amount and type of machinery used, as well as its rate of depreciation, play a significant role in the variability in the profitability on various farms.

Investments in machinery and other equipment are capital costs to the farm. Each farm must evaluate the appropriate amount of machinery and equipment necessary to sustain itself, compared to its herd or land area. Miller et al. (2001) observed that there is a negative correlation between depreciation and capital costs to herd size. Also, since “larger investments in machinery, equipment and vehicles translate into higher operating costs for repairs, fuel and lube, depreciation, and taxes plus interest on the investment,” purchasing equipment that is too large for a given piece of land, or purchasing other equipment that is inappropriate or inefficient can lead to greater costs and burdens (Ramsey et al. 2005). However, the amount of investment into machinery and equipment does not simply denote the success of a farm. As Dunn (2002) notes, “A cow-calf operation can generate $50,000 of net income with an investment of $1,000,000 to $2,000,000. As an investment opportunity, the business that can generate the highest net income with the lowest investment is the most attractive and competitive.” That is, investments, which provide larger returns to a producer, are more determinant of a productive investment than the total amount invested on a farm.

Economies of size have been considered in Texas with regards to efficient production. Cho et al. (2001) noted that investments in land and large herds might lead to a farm becoming unmanageable, and that farms in the region (with an average of 528 breeding cows) were greater than their optimal size. Wang et al. (2013) pointed out that economies of scale were useful to note when minimizing costs, though that no studies have shown increased productivity with larger herds. However, Wang et al. (2013) noted that the farms that occupied a larger area did, in fact, have greater technical efficiency. Rakipova et al. (2003) noted that while the area of the land devoted to cattle operations was not significant, the method in which it was used did play a role. For example, improved pastureland increased technical efficiency on Louisiana beef farms (Rakipova et al. 2003).

Unlike investments in machinery and equipment, breeding stock as well as structures and land assets have been found to exert a smaller role. While a larger herd does translate into higher operating costs, there are also mixed results on the outcomes of this herd based on their reproductive rates, typical weaning rates, and death rates (Wang et al. 2013).

3.2.1.6 Hired Labour

The cost of labour and the profitability of farm owners are at times separate, though they can also be intertwined. The production function, according to Robinson (1955), overcomes the limitations of simple accounting or financing by using labour hours to develop a product, rather than costs, in order to "find the real productivity of the real investment"(Robinson 1955). However, not all of the investments necessary for a farm are determined by the amount of labour invested. Rather, it can also be determined by factors such as the amount of education or knowledge held by a producer, the amount of land available to a herd, among others.

Miller et al. (2001) found, after using stepwise linear analysis on extensive data that had been collected from beef farms throughout Illinois and Iowa, that hired labour was not a significant factor to determine productive farm management in terms of financial returns to unpaid labour and management. Therefore, combined with the knowledge that few cow-calf farms use hired labour, cost of labour is not a determining factor of profitability.

3.2.1.7 GHG and Beef Economics

Several studies have investigated different farming systems as a method to reduce GHG emissions. Pacini et al. (2004) used a standard linear programming model to compare organic farming to its conventional counterpart under the Common Agricultural Policy of the European Union. They concluded that organic farming systems were more environmentally friendly, and that conventional farms willing to undergo environmentally friendly practices suffered increased opportunity costs (Pacini et al. 2004). In another study centered on production in the Coteaux de Gascogne region of France, Ryschawy et al. (2012) used exhaustive survey information to determine that mixed farms were less likely to contribute to nitrogen pollution due to their high farm land diversification. However, these mixed crop-livestock farms were not uniformly profitable throughout the region. .

Veysset et al. (2010) used a model to assess GHG emissions, non-renewable energy consumption, and the economic performance of five beef production systems in France. These farms ranged from mixed farms to intensive production systems. Their study used a linear programming optimization model in order to assess the success of these five farms between the base year (2006) and the final year (2012). The inputs of the model were based on the structure of each farm, animal performance, selling price for livestock, yield and cost of cash and forage crops, as well as different administrative practices. In order to judge the combination of these activities, these researchers investigated the amount and the types of calving, cropping plans and stocking rates, the quality of forages, annual crop area, feed rations, the quantity and income from each animal and plant, operational costs, and the gross profit margin. Modelling each farm was validated by comparing the data for the five farms to twenty years of monitoring history. As a result, they showed that farms specializing in beef, rather than diversifying into crops as well, faced a decrease from 15 to 20 percent of their income. This study also demonstrated that these farms were less flexible to adjust their systems. However, this research did not address sequestrations through the use of grasslands and forage crops.

More recently, Veysset et al. (2014) noted that most research regarding GHG emissions and suckler cattle, or cow-calf farms, have used farm models rather than specific on-farm information. In order to compile information that could accurately reflect local beef production systems, data from farms that exist in an area that is not suitable for crops were used. Data were collected for two years (2010 and 2011) from 59 farms regarding "structure, herd performances, unit margins of the individual activity centers (cattle, crops), and all the economic results and ratios." Though many of these farms had crops as well as beef enterprise, approximately 84 percent of the utilized agricultural farm area was suitable for forages. Of this land, 98 percent was grassland. These researchers still noted a great diversity among cattle farmers in the central region of France. They found that productivity in terms of average weight gain and technical performances was correlated to lower net GHG emissions, and that farms that specialized in beef production tended to have lower net GHG emissions per kilogram of live animal weight (kgLW). However, net GHG emissions were positively correlated with the stocking rate on each farm. That is, as more animals were fed on a smaller area of pasture, emissions also increased[18].

[18] This result is possibly due to the smaller area of land that would have grown legumes or other plants that could sequester GHG emissions. However, the specific causes were not noted in the study.

Smeaton et al. (2011) studied the relationship between GHG emissions and production, as well as nitrogen leaching in New Zealand. This study used a model based on information from monitored dairy and sheep/beef farms that represented regional average farms. An iterative process to determine the impacts of changes (which included different combinations of stocking rates and the use of nitrogen fertilizer), compared 18 dairy and 14 sheep/beef farming systems. The GHG model, OVERSEER, did not include sequestration calculations from pastures and other forage areas (Ministry for Primary Industries 2013). There were indications that producers with high profitability were able to achieve low GHG emissions. Higher profits and lower GHG emissions were related to a lower stocking rate in conjunction with a higher per-head performance, a higher birthing rate, a restrained use of nitrogen fertilizer, lower replacement rates, and a maximum ratio of weaned heifers to replacement heifers (Smeaton et al. 2011). However, the goal of high profits with low GHG emissions was difficult to achieve, as it required best practices, significant investments, and/or they were simply difficult to achieve (Smeaton et al. 2011).

In order to understand the economic value of best management practices linked to lower GHG emissions, Swift and Bittman (2006) used the Integrated Farm System Model. This model was designed to evaluate production systems in North America that would be monetarily and time prohibitive to research extensively. Notably, this model included economic returns and information to calculate GHG emissions (Swift and Bittman 2006). In addition, only two diets for lactating cows were considered, and inputted into this model. Swift and Bittman (2006) evaluated six best management practices: cover cropping, sand bedding, covered manure storage, manure injection applications, and milk production quantities. When using these practices, revenues dropped somewhat, though not by a significant amount. All of them yielded between 95 to 99 percent of their current economic returns except milk production, which only yielded 74 percent of its average economic return (Swift and Bittman 2006).

Governments can have a negative or positive effect on profitability and greenhouse gas reduction. Neufeldt and Schäfer (2008) noted several policy instruments used by governments, and evaluated their effect on GHG reduction, as well as on the financial toll on governments. In order to study the effects of emission taxes, emission caps, a nitrogen fertilizer tax, and livestock extensification on GHG emissions and farmers' income, they used a GIS-based process-oriented agroecosystem coupled with the Economic Farm Emission Model, which accounted for typical farming systems in Germany. Due to the large variety of circumstances in the area, only the average farming systems were included. They found that both emissions tax and an emissions cap have their benefits (in the form of a reduction of GHG emissions between eight to twelve percent) but as a result it increased costs (in the form of a large financial disbursement). Though these two methods were preferable for better producers, who would incur fewer costs while also creating an efficient GHG reduction system, they would also result in high administrative costs. The options without a high administrative costs, such as livestock extensification and nitrogen fertilizer taxes, were deemed less economically efficient. Reducing the size of herds was deemed a poor option, as it would economically impair producers when commodity prices were high (Neufeldt and Schäfer 2008).

Productivity on beef farms, and its relationship with GHG emissions, was estimated by Wang et al. (2013), as they investigated 42 ranches in the Texas Rolling plains over a 16 year period using Beef Cow-Calf Standardized Performance Analysis. The goal of this research was "to determine the factors that affect the production output of cow-calf enterprises and to measure the technical efficiency of cow-calf herds in the region" (Wang et al. 2013). The secondary goal of the study was to determine whether technically efficient producers were also more efficient in terms of their GHG emissions (Wang et al. 2013). Average age at weaning, protein supplements, machinery assets, and improved pasture were indicative of productive farms (Wang et al. 2013). With regards to GHG emissions, Wang et al. (2013) showed that as technical efficiency increased, the amount of GHG emissions emitted per pound weaned on the farm decreased. Farms with less technical efficiency used more fertilizer, and had lower weaning weights. Farms with greater technical efficiency were able to sequester GHGs, due to lower stocking rates (Wang et al. 2013).

3.2.2 Studies of the Canadian Beef Economy

3.2.2.1 Profits

According to Millang (2003), using AgriProfits Survey information, profitability on Saskatchewan and Alberta cow-calf farms is most closely related to total production costs, the value of production (or the number of pounds weaned per cow wintered), and the total labour hours per cow. More specifically, as operating expenses increased, profitability decreased. The factors that were found least likely to reflect the profitability on farms were: death loss of calves, their weight per day of age, and the weaning rate of calves (Millang 2003).

3.2.2.2 Costs

The beef industry in Saskatchewan has been shown to display economies of size. Leung et al. (1991) developed an econometric model based on the overall performance of the total cost of beef cattle farms. In this analysis, the authors noted that an increase in the price of feed, labour, and capital corresponded to the total cost of production for cow-calf producers, while the price of purchased cattle and land had less correspondence to the total cost of production (Leung et al. 1991). The breakeven point for cow-calf producers in Saskatchewan at that time was equivalent to 434 head of feeder calves sold per annum (Leung et al. 1991).

Brown et al. (1991) noted several different sources of costs on beef farms in Saskatchewan. Feed costs, whether purchased or home grown, were noted to have the largest economic cost. Notably, the smallest farms had the highest feed costs[19], even though they used their own produced feed[20] (Brown et al. 1991). The total amount of labour costs on cow-calf farms decreased as the size of the farm increased, whether the labour was hired, owner/management, or family labour. These decreases were also seen for smaller part-time farms. Fuel costs, interest payments, and depreciation were also significant production costs which decreased on farms as they grew larger (Brown et al. 1991).

Further on hired labour, larger farms with a feedlot and a substantial amount of land might need to hire labour, while a smaller farm with less land and/or animals will need less. According to Statistics Canada (2012d), in 2010 only one third of all farms, which includes beef as well as crop and other livestock producers, reported hiring outside labour. The farms that required the most labour in Canada were large livestock farms, which hired year round workers, and fruit, tree nut, and potato farms, which required only seasonal workers (Statistics Canada 2012d).

[19] Smaller farms might have higher feed costs due to the absence in economics of size.

[20] Feed costs were larger on smaller farms, though they might have stockpiled their feed for future use, or to sell it from the farm (Brown et al. 1991).

3.2.2.3 GHG and Beef Economics

In Canada, a Federal-Provincial-Territorial initiative through the Alberta's Department of Agriculture and Rural Development commissioned a study regarding the environmental impact of beef production, in conjunction with its economic impacts (Conestoga-Rovers & Associates 2010). It used a Life Cycle Analysis to determine the environment footprint, which included GHG emissions, as well as the potential to adopt GHG reduction practices. The study analyzed yearling-fed systems (which were fed hay after they were weaned) as well as calf-fed systems (which were fed grains after they were weaned). Calf-fed systems were found to have lower GHG emissions. This study did not focus on grass-fed cattle, though it did include a variety of forage and cereal grain feeds. While the study did consider cradle-to-gate expenditures that included cows, replacement heifers, and bulls, it did not consider various best management practices or administrative strategies within this portion of the cattle herd, such as different feeding practices, birthing periods and dates, and so on. Researchers also noted that Canadian-specific emissions studies were warranted for more specific approximations in each region (Conestoga-Rovers & Associates 2010).

Expanding upon feeding scenarios selected by Beauchemin et al. (2011), Modongo (2014) evaluated economics of several methods to reduce GHG emissions on an Alberta mixed farm. Some of the scenarios, such as using distiller's dried grain for feed, only decreased GHG emissions by 1 percent whereas another scenario, feeding canola seed, decreased GHG emissions by 8 percent. If all of the recommendations to reduce GHG emissions on farms were used, emissions would be reduced by up to 17 percent on cow-calf farms. Modongo (2014) showed that six of the eleven scenarios could improve both economic and environmental indicators on this farm. These methods included:

i. the provision of corn distillers dried grains in the finishing ration;
ii. the provision of corn distillers dried grains in the breeding stock ration;
iii. the provision of canola seed in the finishing ration;
iv. the provision of canola seed in the breeding stock ration;
v. increased weaning rates; and
vi. the improved quality of hay.

However, the research was unable to address the cumulative effect of all, or a variety of different scenarios if adopted simultaneously. It also assumed that risk levels remained unchanged throughout the 8 year production model. Therefore, changes in grain production and herd size did not alter throughout these years.

3.2.3 Studies of the Manitoban Beef Economy

3.2.3.1 Management Practices

While there have been some studies conducted specifically to understand the economics of Manitoba beef production (Johnson 1969), many of the studies were conducted prior to 1990. Since then studies regarding beef production in the province have evaluated more specific areas in the province's beef industry. Bessant (2000) investigated Manitoba beef operators' decision to work part time off-farm. Fryza (2013) analyzed the economic profitability and risks of resting several different types of pastures for farmers, and found that non-rested alfalfa-grass pastures were able to generate the greatest returns for producers. Khakbazan et al. (2014) analyzed the timing of calving seasons in conjunction with post-weaning feeding practices. They found that late season calving (from May to July), in conjunction with a rapid average daily weight gain for the backgrounding stage of 1 kg per day, gained more productivity than other systems which used early calving seasons (March to April), slow average daily weight gain (0.7 kg average daily weight gain), or both. However, the authors also noted that these outcomes were directed towards producers who focused exclusively on beef livestock, as producers with crops would need to contend with seeding during a late calving season (Khakbazan et al. 2014).

Another study by Small and McCaughey (1999) was conducted to understand beef production in Manitoba. It noted that beef production was generally a smaller portion of revenue on farms. However, farms with large herds, and located in the northwest and Interlake regions of the province, were noted to contribute a greater percentage of the farm income. Approximately 76 percent of the total farm income consisted of revenue from the farm's beef operations (Small and McCaughey 1999). Most cow-calf producers used native pastures during the warm season, and then hay and straw forages during the cold season (Small and McCaughey 1999). Few farms used silage, swath grazing, greenfeed, or stockpiled pastures to feed their animals during the longer cold season (Small and McCaughey 1999). The authors also reported a long calving season (greater than 90 days), which started early in February for 60 percent of their respondents (Small and McCaughey 1999).

3.2.3.2 GHG and Beef Economics

While studies in sections 3.2.1.7 and 3.2.2.3 have improved the beef industry's knowledge of GHGs in relation to its economic viability, there are several areas that need to be addressed. There have been only a small amount of studies since 1990 on Manitoba's beef industry, and as a result, less is known about the factors which create profitability for the province's beef producers. As noted in Figure 2.3, most beef operations in the province focus on cow-calf herds, as opposed to backgrounding or finishing their calves. Therefore the Manitoba beef production industry can gain more from the knowledge related to GHG emissions relative to profitability on cow-calf farms, as it can creates the most impact for provincial producers.

3.3 Farm Budgeting

As suggested in Section 3.2.1.7, Ryschawy et al. (2012) have noted that farms can consist of several different enterprises, which can increase or decrease overall costs. Partial budgeting considers variable and fixed costs in a portion of the farm, while the whole farm budgeting considers variable and fixed costs, as well as all revenue sources on an entire farm.

3.3.1 Partial budgeting – profit under a set of conditions

Partial budgeting is a tool used to compare production alternatives in order to understand positive and negative results of proposed changes (Lessley et al. 1991). These results come in the form of additional income, reduced costs, reduced income, and additional costs (Lessley et al. 1991). The production practices in question are usually some aspects of an enterprise that are not fixed in the short run (Alimi and Manyong 2000), which can therefore change in a set period of time (Dalsted and Gutierrez 2000). Partial budgets are ideal for considerations regarding the adoption of a new technology, leasing or buying machinery, modifying production practices, and making capital improvements (Roth and Hyde 2002). In other words, such techniques should be applied when there are no spill-over effect on other enterprises on a farm.

3.3.2 Whole Farm Budgeting

Whole farm budgeting is a different approach in the context of operations of a farm. All costs, whether fixed or variable, are considered in this evaluation. Revenues from all enterprises, which include marketing and yield projections are also assessed. Enterprise combinations can affect production decisions, which have a major impact on the farm profitability. Therefore, this approach necessitates understanding the number of acres for each type of crop, the amount of various livestock, investments in infrastructure and land, as well as labour (Kadlec 1985).

3.3.3 Partial vs Whole Farm Budgeting

Whereas partial budgets consider only the changes in an enterprise, whole or complete budgets note all changes on the farm in order to improve the profitability of the entire farm (Herbst and Erickson 1996).

3.4 Economic Modelling

Bioeconomics is an attempt to "link economic theories to biological laws," though with the caveat that researchers also consider whether "biological laws be considered at the same level as economic theory, or… biological laws be considered as constraints according to economic theory" (Arfini 2012). There are several different purposes and outcomes for bioeconomic models. Predictive models are used in order to forecast future behavior (Brown 2000). Postdictive models seek analyze data in order to understand patterns and behavior after-the-fact (Schoemaker 1982). Descriptive models allow for a characterization of the situation that it studies (Brown 2000). Prescriptive models are used to provide direction for management decisions in order to achieve normative goals (Brown 2000).

3.4.1 Bioeconomic models

King et al. (1993) explain bioeconomic models as "a mathematical representation of a biological system which describes biological processes and predicts the effects of management decisions on those processes." These models can be used to understand and theorize the outcome of new innovations or management practices, to predict the effects of a new policy, and to also reflect their usefulness or possible complications for other researchers (Janssen and van Ittersum

2007). Bioeconomic models can be divided into two groups: mechanistic models (or mathematical programming models) and empirical or systems models (or simulation models) (Janssen et al. 2010). Empirical models can be iconic, analogue, or symbolic (Wright 1971).

While many of these models are limited to the allocation of inputs among various enterprises, as well as on making the choice of what to produce, decisions extend past these to marketing behavior, non-production activities, consumption choices, migration decisions, population growth, etc. (Brown 2000). Therefore, an integrated modeling choice is desirable (Brown 2000). These models occur at a variety of scales. Swinton and Black (2000) note sub-organism, organism, communities of organisms, and aggregates of communities as different sizes of bioeconomic models. Of these scales, farms are noted as the aggregates of organisms, as they commonly undergo a variety of tasks within the enterprise (Swinton and Black 2000).

3.4.2 Bioeconomic Farm Modelling

There are several methods to understand the relation between production and investment decisions, which then result in farm growth. Simulations, dynamic programming, and multi-period linear programming methods are used to determine how farmers make decisions that will impact a farm's organization and expansion (Boehlje and White 1969). A conceptual farm firm growth model emphasizes the maximization of discounted disposable income and net worth subject to production capacity, investment capacity, and borrowing capacity (Boehlje and White 1969). These decisions are essential to understand since a farm is affected by weather, prices, pests, and diseases, among other factors

Bioeconomic farm models enable decision makers to link biophysical processes to economic factors, such as production possibilities (Janssen and van Ittersum 2007). However, they have also drawn criticism. Many of these models are never reused, as the specificity involved in location, climate, and soil type are important to these models (Janssen et al. 2010). However, these factors vary among even smaller countries in Europe (Janssen et al. 2010). Farm models, such as Holos in Canada (which is discussed further in Section 3.4.6) or MIDAS in Australia, account for changes in soil type and climate within these two countries (Kingwell and Pannell 1987).

3.4.3 Mathematical Programming

Mathematical programming enables researchers to "address the multivariate and highly interlinked nature of the agricultural sector… and brings detailed micro-level data bases to bear in the analysis of such policy issues as pricing, employment, investment decisions, comparative advantage, and risk analysis" (Hazell and Norton 1986). Data regarding the farming sector allows researchers to optimize the model for profitability. These models are usually normative, necessitating several tests to calibrate and validate a model.

Linear programming was originally intended to be used for normative farm planning, which assumes full knowledge of production, and was able to assume that technology was reflected or specified as the Leontief production function (Howitt 1995). This programming takes into consideration the constrained optimization procedure to match the real circumstances of farm producers. It accounts for a number of different activities and restraints simultaneously, uses sensitivity analysis to assess changing parameters, and is used for short and long-term evaluations (Janssen and van Ittersum 2007). Models such as these also need to account for a variety of different factors. Vast models like MIDAS, which considers a whole-farm analysis in the eastern grain belt of Australia, and has a number of constraints and data points, allows for the model to be reused by a number of different researchers (Kingwell and Pannell 1987).

3.4.4 Multiple Criteria Decision Making

Multiple criteria decision making (MCDM) has been formulated on the understanding that profit maximization is not the only goal of the entrepreneur. MCDM can optimize one goal, which is not necessarily profitability, while holding other objectives as constraints. Alternatively, the model can "optimize farm profit, while taking the other objectives as externalities of the maximization of profit" (Janssen and van Ittersum 2007). These objectives could be derived from socio-economic, environmental, or biophysical concerns.

3.4.5 Simulation Modelling

Simulation modelling generates experimental information using numerical manipulations of data gathered in a system (Oriade and Dillon 1997). This modelling has benefitted from increased computer power over the past several decades. However, this type of modelling is not often validated to ensure its results are valid and reproducible (Oriade and Dillon 1997). Kragt (2012) notes that simpler accounting-style modelling is unable to use dynamic processes through environmental changes, feedback loops, and changes in land use decisions. Zander and Kächele (1999) note that simulation models allow for interactive environments, which can be either static or dynamic, and also include environmental goals.

3.4.6 Biophysical Models

Biophysical models search for mathematical or physical patterns in life forms in order to understand deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), medical technologies, and methods to manipulate chemicals. An example of a biophysical model is Holos, which was developed by Agriculture and Agri-Food Canada (Agriculture and Agri-Food Canada 2009). The model was originally based on Canadian academic papers, and it has since been updated to ensure current international standards, such as the Global Warming Potential for GHGs, and to consider new research regarding emissions from agricultural sources (Agriculture and Agri-Food Canada 2009). The model considers ecodistricts, soil textures, and soil types as standard descriptions necessary for a given farm. Holos accounts for tillage practices in the present year, as well as in previous years. Reduced, intensive, or no-till practice options are provided for producers to choose from. Annual and perennial crops areas are recorded, as are tree plantings, fallow areas, and grasslands. Within these areas, yields, irrigation, herbicide and fertilizer rates are noted. Within the beef enterprise, the average weight and number of cows, calves, bulls, as well as backgrounded and finished cattle are recorded. Their diets can consider general values, falling within low, medium, or high energy, or they can become more specific to include dry matter and crude protein levels. Manure management systems are also recorded. In addition to beef animals, dairy, swine, sheep, poultry, as well as more exotic animals, such as llamas and bison, are considered in a similar manner (Agriculture and Agri-Food Canada 2009). However, while the whole-farm model Holos is able to estimate GHG emissions, and allow producers to adjust their management practices to understand impacts on GHG emissions, it does not include profitability. As farmers are often restricted by their financial outcome, it is an essential element.

3.4.7 Model Selection

Due to the objectives set out in Section 1.4, and the review of alternative methodologies, the whole farm budgeting technique was selected in this study. This study associates common practices which might be motivated by sociological attributes and economic realities, rather than modeling an ideal farm or investigating future obstacles or economic systems. A static approximation of cow-calf farms in Manitoba also enables the utilization of the Holos farm to evaluate current levels of GHG emissions and corresponding profitability on select Manitoba farms.

This whole farm budget model used in this study is the reflection of the decisions made in a firm that are affected by a biophysical system. It allows the whole farm, as well as the enterprises throughout the farm, to be evaluated in detail, without speculating on future decisions.

3.5 Trade-off Analysis

Trade-offs involve sacrificing one good, experience, or circumstance in order to gain a different good, experience, or circumstance. Trade-off Analysis allows for decision makers to evaluate and summarize different options using trade-off curves, particularly when the options involve a multi-disciplinary approach (Weersink et al. 2002). While the information involved in these curves usually focuses on financial implications, these models can take into consideration a number of socio-economic and environmental concerns. These concerns arise as one aspect, like productivity in a farm, might affect other dimensions such as environmental contamination, risk, or even available leisure time (Antle et al. 1998). The system also allows for different weights to be placed on the dimensions studied. While environmental concerns may be of great concern to one decision maker, profitability might be the first necessity to another (Weersink et al. 2002). Creating a win-win situation for both is optimal.

Trade-off analysis is completed in combination with other analysis methods. Brown et al. (2001) used multi-criteria analysis to understand the complete framework involved in managing concerns related to marine protected areas. The criteria involved in this analysis involved economic, social, and ecological concerns that impact decision making for policy makers in the Buccoo Reef Marine Park. This analysis determined that trade-offs, which included the viewpoints of the stakeholders, created a more effective solution to pollution and long term sustainability issues (Brown et al. 2001).

Stoorvogel et al. (2004a) used an econometric model in order to understand economic and environmental goals in land use in Northern Ecuador, which focused on pesticide leaching associated with the growth of potatoes, rather than forage for sheep. Simulations with regards to erosion, soil depth, soil type, and potential productivity affected economic choices, and thus changes in land management. These simulations were used to understand the impacts of management decisions.

3.6 Summary

As there are a large variety of variables in any farm, this chapter explored deterministic indicators for profitability which included an attentiveness to breakeven points which take into account feed costs, depreciation values and farm investments, as well as high weaning weights of calves. This chapter also reviewed the uses of partial and whole farm budgets. For the purposes of this study, a whole farm budget is considered to more accurately determine all costs (variable and fixed) to determine farm level profitability. As Ryschawy et al. (2012) noted, it is difficult to generalize all mixed farms, as they vary greatly. Therefore, this study notes the factors between each study farm with regards to their beef enterprise, as well as their non-beef enterprise.

Dynamic bioeconomic models allow for optimization of costs or profitability on farms. However, they do not analyze the conditions already present among a variety of beef producers. In order to understand the trade-offs between profitability and GHG emissions on Manitoba cow-calf farms, a single year whole farm budget model has been chosen, which is used both for the Holos program to estimate GHG emissions and whole farm budgeting to estimate profitability.

CHAPTER 4 THEORETICAL MODEL

4.1 Introduction

The objective of this chapter is to describe the theory behind the approach used in this study. Since the study is being cast in a positive, as against a normative, framework, Section 4.2 provides an overview of positive economics. Farm level decision making can be explained with the help of choice model, which is described in Section 4.3. Methods of analyzing production and profitability as motivations of producers in managerial economics is noted in Section 4.4. Finally, trade-off analysis that could be used to select the best management practices is described in Section 4.5, which is followed by a summary of the chapter in Section 4.6.

4.2 Positive Economics

Positive economics describes the status of phenomena and its causal relationships, without the inclusion of economic value judgements. It endeavours to clearly state economic circumstances which can be validated (Boundless 2014). Friedman (2007) described positive economics as "a system of generalizations that can be used to make correct predictions about the consequences of any change in circumstances. Its performance is to be judged by the precision, scope, and conformity with experience of the predictions it yields." This study endeavours to understand and describe current conditions on Manitoba beef farms, rather than to prescribe any solutions related to their profitability or their GHG emissions.

4.3 Rational Choice Theory

Choices, whether economic, psychological, sociological, etc., are made with a number of variables. The process determining available options with regards to these variables, and choosing the preferred option according to a consistent criterion is known as rational choice theory (Levin and Milgrom 2004). This section outlines utility maximization as a process to determine available options, and risk as a variable which limits options.

4.3.1 Utility Theory

Utility theory is a method in which an individual's preferences can be structured to show a level of satisfaction (Miller and Fishe 1995). A mathematical function is used to understand the relation between the quality and quantity belonging to a person, as well as any services a person might consume, and the utility one receives from these goods and services (Mahanty 1980). Preferences can be ranked using ordinal utility, (a qualitative method, which often uses ranking), or cardinal utility (a quantitative method, which necessitates a numerical value). The Utility Function is noted thusly:

$$\boldsymbol{U = u(X_{1,} X_{2,} X_3, \dots, X_n)} \tag{4.1}$$

where U is the total utility received for consuming goods X_1, X_2, X_3,…X_n and u represents the goods that were consumed and satisfaction of doing so (Miller and Fishe 1995)[21].

The consumption of goods and services by an individual is constrained by the level of means by which the individual is able to purchase the desired goods and services. A budget constraint equation, as seen below in Equation 4.2, shows the income available to purchase goods and services, and the costs of these goods and services must be in balance:

$$\boldsymbol{M = P_1 X_1 + P_2 X_2 + \cdots + P_n X_n} \tag{4.2}$$

where, M is the income of an individual or firm[22], P_i is the price of the i^{th} ($i=1,\dots,n$) good or service, X_i is the quantity of a good or service, and n denotes the number of goods or services. The equation shows that only a limited amount of goods and services can be purchased, given a level of income, M (Sher and Pinola 1981). Since the goal of the consumer is to maximize utility while satisfying the budget constraint, choices must be made between goods and services (Pashigian 1995).

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[21] Assumptions of the Utility Theory include (i) Complete Ordering; (ii) Transitivity; (iii) Non-satiation or Greed; (iv) Absence of Lexicographic Ordering; and (v) Absence of Externalities.

[22] The utility function applies to the consumer and the producer. The producer is also a consumer of goods and services which are inputs in production.

Although utility is then maximized subject to a budget constraint, there are other factors. Budgets, prices, and income are explicit parameters, while tastes are implicit parameters. The quality of protein in forages or feed grain are implicit parameters which affect the utility of a producer, and the purchase of feed for the cattle on the farm. Risk, as discussed in the next section, is also a constraint for a producer (Kadlec 1985).

4.3.2 Risk

Decisions in order to create realized positive profits differ in terms of expected level of net profit and its variance. The latter being a measure of amount of risk involved in choosing a method of production. While one decision might have a low expected mean net profit, it might have a small variance. Another might have a higher expected mean net profit, with a large variance (Alchian 1950).

Over the course of several years, a whole farm model would expect to experience variations in weather, input costs, output prices, diseases, pests, and crop yields. Imperfect foresight and the inability of humans to solve complex problems with a host of variables ensures that the goal of profit maximization is rarely gained (Alchian 1950). Kadlec (1985) notes that there are several different sources of uncertainty in agricultural production:

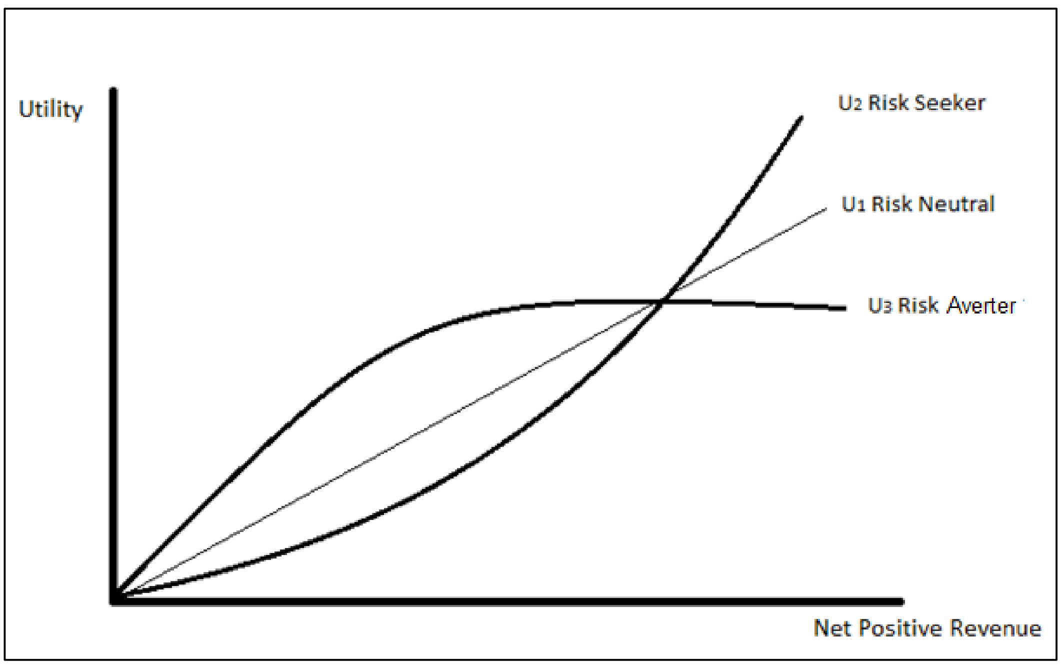
1) Production Uncertainty;
2) Price Uncertainty;
3) Obsolescence, or the investment in a technology that soon becomes unnecessary due to newer, more efficient technology;
4) Political and social uncertainty;
5) Human uncertainty, or changes in goals, health, or behavior;
6) Financial uncertainty;
7) Mechanical uncertainty; and
8) Casualty loss uncertainty, or the damage of buildings, machinery, livestock, or crops.

Rather than profit maximization, consistent by realized positive profits through relative efficiency is the actual goal of firms (Alchian 1950), these goals are determined by the acceptable level of risk in a firm. The expected mean average profit of a firm might be high, though it might also have a large variance. Firms will select a level of net positive profits with their level of acceptable profit variance (Alchian 1950).

The choices involved selecting a profit with regards to profit variance are as follows:

1) Maximize expected income;
2) Select the farm organization with the highest possible income;
3) Select the farm organization that minimizes maximum losses; and
4) Select the organization with the highest expected income but with a selected level of minimum income (Kadlec 1985).

In Figure 4.1, three attitudes towards risk are shown: risk seeker, risk neutral, and risk averter. An individual who is risk neutral (U_1) shows that utility increases as net positive revenue increases in a linearly pattern. Risk seeking behavior (U_2), which is a convex function, notes that as utility increases, net positive revenue increases at an increasing rate. The risk averter (U_3), whose net positive revenue increases as utility stagnates, shows that decisions to increase profit through risky behavior is not ideal (paraphrased from Miller and Fishe 1995).



Source: Miller and Fishe (1995)

Figure 4.1 Utility Subject to Risk

While there is a degree of risk in the agriculture sector and to a larger degree in the beef industry, producers often undergo measures to reduce their costs in order to increase profitability. However, these changes might still result in low or negative profitability due to drought or poor growing conditions. While severe drought and variability in cattle prices are noted as the primary risk factors, extreme cold and diseases are noted as less important (Hall et al. 2003). As a method to prevent the most damaging effects of a severe drought or low cattle prices, producers often understock their pastures or store forages to ensure long term profitability. A producer is able to divert risk by growing an excess amount of feed. According to Pope and Shumway (1984), planning for poor weather conditions and low forage production results in a diversified forage system and small herd sizes, rather than expecting average yields for their forage crops. Institutional methods, such as livestock insurance, could also be used to reduce risk.

Risks can also be generated by surplus goods and resources which could be utilized on the production site, rather than selling them to another business, or from purchasing them when needed. The costs for creating these inputs might not be recuperated, as the quality of feed can degrade with time. Nevertheless, according to Pope and Shumway (1984), it is more expedient to grow more feed than necessary during average yielding years to prepare for years with poorer yields or revenues. Purchasing feed in poorer years was more inconvenient and costly compared to producing and storing it on-farm.

4.4 Measuring Economic Performance of a Firm

The theory of the firm originated from the concern of the internal organization of firms (Crew 1975). Archibald (2008) has noted that there is little agreement among economists as to the explicit scope and purpose of the ‘theory of the firm’. While it is generally agreed upon that its purpose is to “investigate the behavior of firms as it affects allocation and distribution,” some economists would surmise that firms are profit maximizing agents, while others inquire further as to whether or not this is true, as there might be other goals and needs within firms (Archibald 2008). Adam Smith assumed that firms strived to maximize profits, while Coase determined that firms exist in order to reduce transaction costs through internal resource allocations (Crew 1975). That is, economic performance in a firm can be measured using several methods, profitability being one of them. Profitability in a firm necessitates the understanding of its components, namely revenues and costs, leading to the firm's profit. The form of the revenue function incorporates production within a firm, as it confers the type of goods produced by it.

Profitability is highly dependent on the production level of a firm. As conventional cow-calf farmers are price takers, understanding the production system and farm-level decisions are essential. To analyze the process of production decisions, an understanding of prices, technical expectations, the production plan, and the time span of the production plan is needed (Schultz 1939). This section discusses production of a firm, assumptions to analyze profitability, and development of revenue and costs in a business.

4.4.1 Profit Analysis

Profit, or net revenue, is the amount of revenue leftover after all costs within a firm have been paid. Its equation form is shown in Equation 4.3:

$$\boldsymbol{Profit = Total\ Revenue - Total\ Cost} \tag{4.3}$$

A further understanding of what constitutes revenues and costs is described in Section 4.4.2 and 4.4.4, respectively.

Profit analysis has been developed from cost accounting. There is also a parallel analysis, breakeven analysis, which has also been developed from cost accounting to consider the relationship between costs, production volumes, and revenues. Cost accounting considers the cost of products and processes, in order to record proper amounts for financial purposes. Breakeven analysis is used to understand the point at which costs equal revenues, or the point in which there is no profit for the farm, but also no deficit. A margin of safety is also calculated, in order to account for potential risks. Understanding profit on farms uses both cost accounting and breakeven analysis to determine the amount of profits possible on a farm; that is, the amount in which revenue is greater than the costs on a farm.

There are several assumptions associated with profit analysis conducted for a short run period:

i. Sales prices cannot vary;
ii. Variable cost per unit cannot vary;

iii. Total fixed costs cannot vary;
iv. Sales mixes cannot vary; and
v. The number of units sold must equal the amount of units produced (Ready Ratios 2011)

These assumptions are meant for short term analysis, rather than a long term analysis which accounts for the entire cycle of production. For a beef farm, wherein feed supplies can be stored beyond a single year to reduce risk, the last assumption does not consistently apply. That is, the amount of feed produced over the course of a year is not equal to the amount sold or used on the farm, as some of it might be saved for future years when feed production is low (due to poor weather conditions, pests, diseases, or a combination of all of these natural occurrences), as discussed further in Section 4.3.2. Saving feed for future years has an opportunity cost, as the benefit of a more immediate profit by way of selling the remaining feed is postponed in order to save the feed in order to decrease risk on the farm.[23] .

In this study, the sales mixes do vary between farms. In order to understand varying management practices on each farm, it should be noted that a number of factors on these farms differ, which also leads to average weight variations within the herd. However, grain produced outside the beef enterprise is assumed to be homogenous.

4.4.2 Revenue

Revenue is the result of any income made through a business transaction. Total revenue is the price of the goods sold by a firm, multiplied by the amount of goods sold, as noted in Equation 4.4:

$$\boldsymbol{Total\ Reveue} = \sum_{i=1}^{n}(\boldsymbol{P} * \boldsymbol{Q})_{\boldsymbol{1}} + \cdots + (\boldsymbol{P} * \boldsymbol{Q})_{\boldsymbol{n}} \ \boldsymbol{or}\ \sum_{i=1}^{n}(\boldsymbol{P_i} * \boldsymbol{Q_i}) \tag{4.4}$$

where, P_i is the price of the ith good sold, Q_i is the quantity of the i^{th} good sold by the firm, and n denotes the total number of goods sold by the firm.

Revenues also vary from firm to firm. These causes of variation, according to Lehfeldt (1925) are:

[23] However, postponing the use of the remaining feed to a time period when it might be more valuable or useful, could degrade the quality of the feed.

a) Differences in permanent natural resources. On farms, these differences are noted among the fertility of soils and the climate of the area. Areas with poor natural resources will have a corresponding low rental rate for land.
b) Differences in efficiency of a firm. Lower efficiency might be due to the amount of skilled labour available, the education of the manager, etc. Costs also vary according to the extraneous rise or fall of prices of goods bought by the firm.
c) Accidental. These differences, particularly in farming, are due to unpredictable weather, disease or the threat of disease within a crop or herd of livestock, etc. However there are also favourable incidences which lead to positive outcomes, such as lower supply of a product due to unfavourable conditions in other competitive areas of the world. Differences made due to accidental conditions, whether positive or negative, are normally moderated over the course of several years, as weather conditions are rarely permanent, and markets and laws can shift to overcome production difficulties.

Time spans used for profit analysis are based on the technical conditions and the "period of time that it is expected will elapse before subsequent changes are likely to occur which will necessitate altering the production plan" (Schultz 1939). As growing beef animals engulfs at least three years from the birth of a heifer to the sale of its first calf, the production plan is considerably longer than that of a grain-only farm, or that of a pork or poultry farm. As a result, generating revenue in cow-calf farms involves a long time span for production.

4.4.3 Production

Production theory notes the process of turning inputs into outputs. Through this process, value is added to inputs through capital, management skills, and labour, over a period of time, which depends on the product. Such a process is conceptualized as a production function, which is shown in Equation 4.5:

$$\boldsymbol{Q} = \boldsymbol{f}(\boldsymbol{y_1}, \boldsymbol{y_2}, \dots, \boldsymbol{y_n}) \qquad (4.5)$$

where, Q is the total output of the final product, and y_1, y_2,…, y_n are the inputs. Inputs can be fixed (buildings, structures, and machinery) or variable (labour and feed costs).

4.4.4 Cost

The type of costs can vary between those that can change depending on the amount of goods produced, called variable costs, and those that remain consistent regardless of the good produced in the short term, called fixed costs. Fixed costs denote long term contractual agreement payments, as well as purchases of assets with a long durable life span. These fixed costs can vary over time, though they are longer in comparison with the time denoted with variable costs. Variable costs could change within a day, a month, or even a year (Miller and Fishe 1995).

The total cost consists of the total variable cost and the total fixed cost. In order to understand the cost with respect to the amount of production in a firm, the total cost is divided by the quantity of output to yield the average cost. This is shown in Equation 4.6.

$$\boldsymbol{ATC = \frac{TFC}{Q} + \frac{TVC}{Q}} \tag{4.6}$$

where, *ATC* is the average total cost, *TFC* is the total fixed cost, and *TVC* is the total variable cost (Miller and Fishe 1995), and *Q* as noted above.

There are a number of ways in which a firm can choose its costs, whether fixed or variable. The neoclassical view notes that firms minimize their costs in order to increase their profits. Differing levels of inputs could be determined by several other factors. Schultz (1939) determined that there are several methods a farmer could choose inputs:

i. Substitute the output of one product for another;
ii. Substitute the inputs for each other; or
iii. A combination of both (i) and (ii)

Substitution of one output for another occurs when a profit analysis reveals that one activity is less profitable than another. Input substitution occurs when a firm is able to find a different input or technology that would produce the same or similar results, at a lower cost. Fixed costs, such as land, buildings, and infrastructure, are expensive and difficult to purchase within a short-time span. Variable costs, such as different types of minerals for cattle and sprays for crops, can be changed relatively quickly. However, some variable costs, such as changing from an alfalfa crop to a barley crop, necessitates changes in fixed costs, as well, as the technology for this change also requires a change or addition in machinery. Therefore, the third option, as stated above, is a combination of both a substitution of the outputs and the inputs.

Firms often choose not only the type of output, but the number of outputs. On a farm, the growth of a grain crop or a legume crop might alone seem profitable, while the complimentary growth of both crops on a farm can be more successful. Economies of scope notes that numerous outputs can lower input costs and investments. Economies of scope occur when a firm is able to save costs by producing more than one output, as shown in Equation 4.7:

$$\boldsymbol{C(Q_1, Q_2) < [C(0, Q_2) + C(Q_1, 0)]} \tag{4.7}$$

where, C is the cost, and Q_1 and Q_2 are the level of outputs. It shows that the cost of producing both outputs is less than the sum of cost of producing either of them separately. Economies of scope occur when there is a specialization of managerial tasks, when the production uses similar or the same production inputs, when production uses the same equipment, or when technological production can increase the output within the firm, etc. (Miller and Fishe 1995).

Costs can decrease due to complimentary or supplementary production. That is, the production of one good increases the quantity of another. In terms of crop production, the cost of fertilizer is decreased or even unnecessary if cattle manure from feeding areas is spread on the land. A similar relationship can be noted between grain crops and legume rotations, as legumes deposit nitrogen into the soil through their root system. (Herbst and Erickson 1996)

The cost of inputs is also determined by the final output produced by a supplying firm, or the aggregate of firms. If the production from firms are high, the cost of an input is likely to be comparatively low. If the production from firms are low, the cost of an input is likely to be comparatively high (Miller and Fishe 1995).

4.5 Trade-off Analysis

Unlike opportunity costs, which is the return a resource could earn when put to its best alternative use, trade-off analysis determines the use of resources or objectives with respect to other indicators, such as increases in environmental degradation or financial risk exposures (Kadlec 1985). Considering resources, the scarcity of goods and the costs involved in those goods creates a choice between one good rather than another (Stoorvogel et al. 2004a). Regarding objectives, choosing one goal might provide an obstacle to achieving a separate goal within a firm.

Trade-off analysis is a method to evaluate a plethora of stimuli that affect outcomes, in order to provide information to decision makers (Stoorvogel et al. 2004a). It expands on economic models by considering managerial decisions that are affected by crop or animal growth models (for agricultural systems), in addition to financial concerns. However, there are a number of possible outcomes, including a win-win scenario in which one positive outcome coincides with another positive outcome (Stoorvogel et al. 2004a). Therefore, the ultimate goal for this method of analysis is to "understand the joint distributions and the implied interactions among the selected indicators" (Stoorvogel et al. 2004b). These joint distributions can be analyzed as two-dimensional graphs, known as trade-off curves.

Trade-off analysis occurs in conjunction with different types of economic analysis, with regards to econometric evaluations, linear programming evaluations, etc. Variations and different methodological approaches also occur in the bio-physical modelling in this analysis. However, Stoorvogel et al. (2004b) necessitate the identification of sustainability criteria, as well as the geographical information, in order to acquire reliable information.

4.6 Summary

The theory required for this study includes an understanding of positive economics as a qualitative means to study current events and a rational choice theory to understand the variables involved in decision making. Expanding upon this, utility theory and risk variables were explained. Production assessments in a firm were described as part of the theory of the firm. Finally, trade-off analysis was described as a method to compare firms using two criteria – economic returns and GHG emissions.

The next chapter describes the tools used to investigate each farm, as well as the method of gathering information on each farm.

CHAPTER 5 STUDY METHODOLOGY

5.1 Introduction

The objective of this chapter is to explain the methods used to gather, organize, and evaluate data from beef farms in Manitoba. Section 5.2 discusses the geographical area in which this study is based. As the primary data used in this study were obtained from a third party, Section 5.3 discusses the survey methodology used, and Section 5.4 describes the subsequent methodology for selecting the study farms. Section 5.5 discusses the determination of profitability on the study farm, followed by the methods used for estimating total family income in Section 5.6, whole farm level profitability in Section 5.7, the beef enterprise level profitability in Section 5.8, and the non-beef enterprise level profitability in Section 5.9. Section 5.10 reviews GHG estimations obtained by using the Holos model. A comparison of GHG emissions with profitability on study farms using trade-off analysis is presented in Section 5.11, followed by a description of sensitivity analysis with respect to beef cattle prices in Section 5.12. Assumptions made in this analysis are listed in Section 5.13, followed by a summary of the chapter Section 5.14.

5.2 Geographical Area

In this study, the geographical location of Manitoba, as opposed to Canada as a whole, was chosen for two reasons. First, this limited the amount of financial parameters of the study, while also reducing variability. Variations generally exist in tax laws and structures, government policies and assistance packages, fixed and variable costs, and similar average reported prices for each source of revenue on a farm in various parts of Canada. The provinces also differ accordingly to their respective weather disasters (such as floods or tornados) for their regions. Using a limited region excludes financial benefits or disadvantages that might occur within given jurisdiction, and brings more homogeneity among the sample cases. Second, as noted in Section 2.4, the land and terrain in Manitoba are suited for cow-calf operations rather than for backgrounding and finishing operations, which rely on feedlots.[24] This geography might have influenced the type of cattle

[24] The land and terrain in Saskatchewan and Alberta are also suitable for cow-calf operations. However, in this study only one province was selected for further analysis.

operations in Manitoba, which has the third largest number of beef cows, and thus cow-calf operations, in Canada (Honey 2012b).

5.3 Survey information

The data analyzed in this study were obtained from a survey of Canadian beef producers. Data were collected for their operations of 2011 in 2012.[25] Its intent was to understand "feeding strategies, forage and pasture management, animal management, and manure management practices for different types of beef practices across Canada (Ipsos Forward Research 2012).

The above survey was undertaken using the telephone method by Ipsos Forward Research. Beef producers were randomly selected using the Ipsos Forward Research's existing database, as well as from provincial beef associations and the Canadian Cattlemen's Association. There were 1,005 respondents with complete data from their surveys.

These producers were then asked to fill a mail-out survey. One of the intents of the survey was to understand the distribution of cattle farms across Canada. Instructions in the survey provided no minimum or maximum number of cattle for each farm, in order for the information to represent all small, medium, as well as large, farms (Alemu et al. 2015; Sheppard et al. 2015). Respondents were asked to describe their beef operation in 2011, including the conditions for all cattle on the premises, whether owned, boarded, or custom fed during the year.

The survey was divided into nine sections:

1) General farm operation information – size, type, estimated revenue;
2) Cattle feed management;
3) Grazing during the warm season (May to October);
4) Grazing during the cold season (November to April);
5) Seasonal feeding areas;
6) Feeding in barns or feedlots;

[25] The survey was entitled "2012 Beef Producer Feeding and Management Practices Survey." It was developed on behalf of researchers from the University of Manitoba, Alberta Agriculture and Rural Development, the BC Ministry of Agriculture, Manitoba Agriculture Food and Rural Initiatives, and Agriculture and Agri-Food Canada. This survey was supported financially by the Beef Cattle Research Council.

7) Manure handling, storage and application;
8) Use of shelterbelts; and
9) Farmer/producer information and preferences (Ipsos Forward Research, 2012).

Following the survey, data were scrutinized by independent individual experts associated with the larger study[26], and any inconsistent information provided by respondents was removed (Alemu et al., 2015). This process included reviewing each of the surveys to ensure answers from different parts of the survey were internally consistent with each other. For example, if respondents indicated that they had no backgrounding cattle, then all questions referring to feeding these animals should be blank. If such was not the case, the questionnaire was declared inconsistent, and removed from the study sample (Alemu, 2014).

While the survey was reviewed by experts from animal, plant, and soil sciences prior to its distribution to producers, experts with agricultural economics expertise were not included in this review process. As such, some pertinent information in this survey regarding financial behavior was not available and therefore, was assumed. Gathering new information from producers was not considered a valid option.

5.4 Cluster Development

In order to stratify farms using different beef production practices in Canada into homogenous groups, principle component analysis and cluster analysis were utilized. For Canada as a whole, there were 1,009 respondents to the survey, but 4 were rejected either due to inconsistent or incomplete data, or due to the fact that they were too large, and thus considered as outliers. The remaining 1,005 responses were first evaluated based on 41 variables, which were ascertained from responses in the survey. The principal component analysis was employed to reduce the dimensionality of the data, or the number of diagnostic variables (Alemu et al. 2015). This resulted in 16 principal components with eigenvalues, or weights, greater than 1, which

[26] The larger survey was undertaken under the auspices of "Beneficial Management Practices for Greenhouse Gas Mitigation from Agroecosystems, with Emphasis on Cow-Calf Non-confinement Production Systems in Western Canada", a project funded by the Agricultural Greenhouse Gas Program. Overall funding was received by the University of Saskatchewan.

explained 68 percent of total variability (Alemu et al. 2015). This was followed by the use of cluster analysis. The end product of these analyses was creation of eight clusters (Alemu et al. 2015). The following general titles were given to describe each cluster in Canada (Alemu et al., 2015):

Cluster 1 – Small scale, part-time cow-calf operation;
Cluster 2 – Diversified cow-calf through feedlot operation;
Cluster 3 – Large backgrounding and finishing operations;
Cluster 4 – Diversified cow-calf operation;
Cluster 5 – Extensive cow-calf backgrounding operation;
Cluster 6 – Large cow-calf backgrounding;
Cluster 7 – Crop-beef mixed operation; and
Cluster 8 – Large Commercial Finishing (Alemu et al. 2015).

Of the eight clusters found for Canada as a whole, only six of these had any members in Manitoba. No farms in Manitoba were found in either Cluster Five or Cluster Eight. In addition, not all of these six Manitoba clusters were of an appropriate size for further analysis, since there was only one respondent in both of these Clusters. Due to privacy concerns, these clusters and their corresponding farm were excluded from this study. Thus, this study is based on beef cattle farms belonging to Clusters One, Four, Six, and Seven. The distribution of farms across Canada and in Manitoba are noted in Table 5.1.

Table 5.1 Cluster Distribution of Manitoba and Canadian Beef Cattle Farms, 2011

Clusters	Cluster One	Cluster Two	Cluster Three	Cluster Four	Cluster Five	Cluster Six	Cluster Seven	Cluster Eight	Total
Manitoba	29	1	1	12	0	28	39	0	110
Canada	372	77	11	114	21	185	223	2	1,005

Source: Alemu et al. (2015)

Although each farm within a cluster could have been analyzed in detail, given the fact that all cluster farms were similar, only one representative farm was selected from each of the four Manitoban clusters. Furthermore, this decision was taken in light of time and resource constraints faced by the study. The centroid cluster farm was chosen as the representative farm for each cluster.

The groups were based on distinctive attributes from the entire cluster, as described by Alemu et al. (2015). The following sections describe the averages[27] from these clusters.

5.4.1 Cluster 1: Small Scale, Part-Time Cow-Calf Operation

This group of beef producers had the highest concentration in Canada, and the second-highest in Manitoba, at a total of 29 out of 108 farms or 27 percent of the total number. These farms were categorized as small cattle businesses. This was a result of the smaller amount of land managed for feed production, as well as the lower amount of total gross sales from beef production. These operations were largely cow-calf producers with an average of 56 beef cows and 8 replacement heifers, though several farms also reported backgrounding animals as well. Feed was produced from an average of 458 acres of land. Of this area, 55 percent was devoted to forage/silage production, whereas the remaining area was used to produce grain needed for feeding the animals. These producers also recorded the highest amount of off-farm income, as an average of 43 percent additional of their total income was obtained from activities not related to the farm business [data obtained from Alemu et al. (2015)].

5.4.2 Cluster 4[28]: Diversified Cow-Calf Operation

In the Canadian survey, only eleven percent of Canadian beef farms were found in this cluster, with a similar proportion for Manitoba (eleven out of 108 or ten percent of farms). This diverse group of cattle and crop producers (mainly in the cow-calf area) also engaged in off-farm employment and other similar activities. There were an average of 81 beef cows in the herd for this cluster. Pastureland was used for feeding during the warm season, followed by bale or processed forage grazing in seasonal feeding areas during the cold season. Members of this group largely did not depend on purchased animal feed. On-farm revenue was largely generated by the

[27] The averages described in this chapter differ from the description of the centroid farm described in Chapter Six. Average characteristics of a farm are not observed in reality. Rather, these are averages generated from the entire cluster. Centroids, however, are those farms which are responses from a single farm within a cluster that is closest to the center of the cluster. While averages might describe a general trend, they do not describe specific farm practices. Centroid cluster farm does account for actual practices within a farm.

[28] The centroid from Cluster 4 was discarded in favour of the next closest farm, as the responses in the survey were not consistent, and therefore portrayed uncertain information.

sale of cattle (43 percent), followed by sales of grain, forage, or other farm animals (21 percent). Off-farm activity generated an additional 36 percent of the family's total income (Alemu et al. 2015).

5.4.3 Cluster 6: Large Cow-Calf Backgrounding

This cluster comprised 18 percent of the total beef farms in Canada, though the amount was notably larger in Manitoba. There were 27 of 110 farms (or 25 percent of total Manitoba surveyed farms) that fell into this category. These farms, as the name suggests, are largely comprised of cow-calf producers who also background their animals before selling them, with an average of 186 beef cows on these farms. Some producers in this cluster also purchased additional weaned calves in order to increase the number of calves on the farm for backgrounding. An average of 1,788 acres of land was used to produce feed, which was divided into pastureland (63.6 percent), forage/silage production (32.9 percent), and grain production (3.5 percent). The majority of the pastureland was native (743 acres), while the rest was tame pastureland (394 acres). For the majority of these farms, cattle were on pastureland for the warm season, and then fed through winter grazing in the early part of the cold season before moving into a seasonal feeding area. The producers only generated an additional 23 percent more total family income through off-farm work (Alemu et al. 2015).

5.4.4 Cluster 7: Crop-beef Mixed Operation

There were 39 crop-beef mixed farms in Manitoba. Although these operations comprised 22 percent of the total farms in Canada, the proportion in Manitoba was higher than that noted for Canada (35 percent of total Manitoba farms as against only 22 percent for Canada). The farms from this cluster were the most heavily involved in crop production, as 73 percent of the total gross farm sales came from the sales of crops. There was an average of 76 beef cows in their herds, which led to only 23 percent of total gross farm sales. There was an average of 832 acres to produce feed, of which 6.4 percent was devoted to grain production, 46.0 percent was devoted to forage and silage, while 46.8 was devoted to pastureland. Most of the pastureland was native (257 acres), while the rest, 132 acres, was tame pastureland (Alemu et al. 2015).

5.5 Method of Analyzing Economic Profitability

The calculation for profitability level for each k^{th} (1, …, 4) was completed using Equation 5.1:

$$\boldsymbol{Profit_k = Revenue_k - Cost_k} \qquad (k = 1, \ldots, 4) \qquad (5.1)$$

where, *k* is the designated farm in the four clusters.

To make level of profitability comparable, all four farms were evaluated based on the total weight of all cattle sold as shown in Equation 5.2.

$$\boldsymbol{Total\,Weight_k} = \sum(\boldsymbol{A_t * AW_t})_k \qquad (k = 1, \ldots, 4) \qquad (5.2)$$

where, *A* is the type of animal sold, *t* denotes the type of animal (1 = steers, 2 = heifers, and 3 = cull cows), and *AW* is the average weight of each type of animal (cwt). The resulting live weights of animals sold by producers in each cluster farm are noted in Table A.1 The profits, revenues, and costs were then compared to the total weight sold on a farm, in order to understand the ramifications of economy of scale and weaning weights.

The following sections describe the total family income in Section 5.6, followed by profitability at the whole farm level in Section 5.7, and then the same at the beef enterprise level in Section 5.8.

Family income describes not only the profits from the farm, but also revenue generated from off-farm through work on a neighbouring farm, work in a nearby community, or additional income from off-farm investments or savings. Therefore, the financial wellbeing of a producer and his/her family is determined by farm level plus off-farm income. In order to determine the amount of income each family generated through non-farm sources, the survey asked respondents to report their off-farm income based on the percentage of total farm income. Equation 5.3 describes how family income was estimated.

$$\boldsymbol{Family\,Income_k = [TFI * OFI]_k + [TFI]_k} \qquad (k = 1, \ldots, 4) \qquad (5.3)$$

where, k denotes each study farm, *TFI* is the whole farm income, and *OFI* is the proportion of off-farm income (in percentage) reported by each farm.

5.7 Whole Farm Profitability

The whole farm profit estimation uses all costs and revenues reported in the survey. It includes not only the beef enterprise, but also any other enterprise on a farm, such as sales of excess feed or non-feed grain crops.

5.7.1 Revenue

Equation 5.4 reports the method used to determine revenue on each farm:

$$\boldsymbol{Revenue_k} = \left[\sum[\boldsymbol{PC_t} * \boldsymbol{AW_t}/\mathbf{100}] * (\mathbf{1} - \boldsymbol{DL})\right] + \sum\left[\boldsymbol{RGF_y} * \boldsymbol{PF_y}\right] + [\boldsymbol{NBEG} * \boldsymbol{PG}]\Big]_{\boldsymbol{k}} \quad (\text{k} = 1, \ldots, 4) \qquad (5.4)$$

The first segment in the summation indicates revenue generated from cattle sold. It is based on *PC*, which is the price of each animal per hundred weight, in Canadian dollars, t denotes the type of animal sold (1=steer, 2=heifer, 3=cull cow), and *AW* is the average weight of each type of animal (cwt). In order to account for the death loss, *DL* representing the percentage of cattle that have died before the sale of the cull cows or weaned calves was used. It was estimated that the death loss was 2.37 percent. The death loss rate noted in Equation 5.4 was obtained by dividing the total deaths and condemnations by the number of cattle in the ending inventory for Manitoba in 2012 (Statistics Canada 2012c). These animals were assumed to have died on the farm just prior to their sale of the rest of the calves. Therefore, the death loss was calculated by removing 2.37 percent of the revenue that otherwise would have been created. The birthing rate, which was not reported in the survey, was assumed to be 100 percent for all the study farms.

The next segment indicates revenue generated from either remaining feed or non-feed barley grown on a farm.[29] The term *RGF* represents the remaining grown feed (metric tonnes), leftover after the producers have fed their cattle multiplied by the average market price of the feed, *PF* (CAD). There were two farms that grew crops in their non-beef enterprises. *NBEG* represents

[29] While the survey did ask if crops were grown for non-feed use, it did not further question what type of crop was grown. It was then assumed that all non-feed crops were barley.

the non-beef enterprise grain, multiplied by the price of the non-beef enterprise grain, *PG*, while *y* denotes the type of feed (1=oat grain, 2=oat greenfeed, 3=alfalfa-brome forages).[30] The prices of both cull cows and calves were obtained from Agriculture and Agri-Food Canada (2008) for the year 2011. Prices for forages and barley were obtained from Honey (2012a)[31].

Survey producers reported to weights of the calves, but not for the cull cows. Therefore, it was assumed that these animals were fully grown, and that their average weight was 1400 lbs. The food quality grades of the cull cows were set according to the averages set out by Canada Beef Inc (2007)[32]. Using these proportions, seven percent of the graded meat was assumed to be of grade D1, another 59 percent were assumed to be of grade D2, 31 percent was assumed to be of grade D3, and three percent of the cull cow meat was assumed to be of grade D4 (Canada Beef Inc 2007). Since D4 meat prices are not reported, these animals were valued using Grade D3 prices (Canada Beef Inc 2007).

As yields from crops change from year to year, producers cannot accurately predict the amount of feed necessary for their herd. In 2011, the yield for forage and grain crops created an excess of feed for each crop. In order to account for this feed, a linear programming method was used to determine appropriate diets for cows, heifers, and bulls on a month-to-month basis. The diet was limited to periods when the herds were bale grazing or in a feeding area, as the nutritional regiment cannot be determined while on the pasture. Estimation was done using Equations 5.5 to 5.8.

$$\boldsymbol{Min\ C_{kj} = \sum c_{jy} f e_{jy}} \tag{5.5}$$

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[30] The leftover feed was calculated since producers often grow more feed than necessary in an average year, in order to prepare for years when growing conditions are not ideal due to droughts, floods, or harm caused by weather, pests, or diseases. It could also be sold at a high price to other farms during these periods to increase profitability, if the producer has enough feed for their own operations. In this study it was assumed to be first fed to the livestock on farm.

[31] The difference between the value in Honey's report and that of Agriculture and Agri-Food Canada (2011b) were dramatic, though the only available price on the latter document was for Montreal feed (Agriculture and Agri-Food Canada 2011c). Therefore, local prices were used. Greenfeed oats were also assumed to have the same prices as forage hay.

[32] Only 29 percent of mature beef is usually graded, though for the purposes of understanding the price of all of these animals, it was assumed that all of the cull cows were graded.

Subject to:

$$\boldsymbol{TDN_n \leq TDN_a} \quad (5.6)$$

$$\boldsymbol{CP_n \leq CP_a} \quad (5.7)$$

$$\boldsymbol{Y_n \leq Y_a} \quad (5.8)$$

where, *C* is the total cost of feeding j^{th} animal type, *c* is the cost per tonne of the y^{th} feed, *fe* is the nutritional content of the y^{th} feed, *y* denotes the type of the feed (y is 1=oat grain, 2=oat greenfeed, 3=alfalfa-brome forages) and *j* denotes the feed for the type of animal (1=bull, 2=cow, 3=replacement heifer). While there are three different types of feed, the alfalfa brome forage mix differs on each farm based on the amount of alfalfa grown in the forage mix. The amount of total digestible nutrients or crude protein necessary is denoted by *n*, while the amount available in each type of feed is denoted by *a*. The *TDN* represents the total digestible nutrients in each type of feed, *CP* represents the crude protein available in each type of feed, and, and *Y* represents the amount of energy in the feed. The linear programming model maximized *TDN*, *CP*, and *Y*, under the realization of minimal costs for feed.

The feeding program is based on requirements developed by the Subcommittee on Beef Cattle Nutrition (2000), which is also used by the popular Canadian beef nutrition program, CowBytes. The measures to determine nutrition were limited to total digestible nutrients (TDN) and crude protein (CP). Though rations can be determined using the addition of a number of other variables, such as energy content and dry matter, this model was limited to the variables already set in the Holos program.[33] The nutritional content of the feed grown for each farm was gathered from research by Stanton (2014), which is shown in Table 5.2.

While a survey question did ask for the nutritional content of feed, none of the respondents indicated that they tested their feed. In addition, TDN and CP values given in Stanton's research are within the range of values those provided by Alemu (2014), who created feed nutrition assumptions to determine greenhouse gas farms.

[33] The outputs of the Holos program can be seen in Tables A.2 to A.5 in the appendix. [Change numbers to A.3 to 6]

Table 5.2 Nutrition Contents of Feeds in Selected Manitoba Crops		
Feed	**TDN (%)**	**CP (%)**
Perennial Forage >50 legumes	64.0	18.5
Perennial Forage 25-49% legumes	62.0	12.0
Perennial Forage >10% legumes	61.5	11.0
Protein Supplement	n/a*	20.0
Greenfeed Oats	59.0	9.0
Oat Grain	74.0	13.0

* Protein Supplements are meant only to supply protein to cattle. Therefore, there is no dry matter in the supplement.

5.7.2 Costs

Costs for the study farms were estimated using Equation 5.9 as a sum of variable and fixed costs.

$$\boldsymbol{Costs_k = [Variable + Fixed]_k} \qquad (k = 1, \ldots, 4) \qquad (5.9)$$

where, *Variable* represents variable costs, and *Fixed* represents fixed costs.

Variable costs were represented by Equation 5.10:

$$\boldsymbol{Variable_k = \left[\sum F_y\right]_k + O_k + \left[\sum Cr_y\right]_k} \qquad (k=1,\ldots,4) \qquad (5.10)$$

where, *F* represents feed costs, and *y* denotes the type of feed (where 1=oat grain, 2=oat greenfeed, and 3=alfalfa-brome forage, 4= minerals, and 5= creep feed). Feed for the cattle herd was purchased at market prices, provided by the Manitoba Agricultural Services Corporation (2011). The cost of producing feed deemed unnecessary for the beef enterprise, as outlined in section 5.7.1, was designated non-feed Crops, *Cr*. This is further described in section 5.9. The *O* represents operating costs, which includes straw, veterinary medicine and supplies, breeding costs, utilities, marketing and transportation, manure removal, operating costs, and other miscellaneous costs. Further description of these costs is presented in sections 5.7.2.1 and 5.7.2.2.

Fixed costs are shown in Equation 5.11:

$$\boldsymbol{Fixed_k = I_k + D_k} \qquad (k=1, ,\ldots, 4) \qquad (5.11)$$

where, *I* pertains to annualized interest cost, which is the amount producers would pay on loans to purchase machinery and structures, and, *D*, represents depreciation, the annualized cost of structures and machinery. A description of each of these categories is presented in Section 5.7.2.3.

5.7.2.1 Feed Costs

The cost of purchased feed was calculated using Equation 5.12:

$$\boldsymbol{F_k} = \left[\sum \boldsymbol{PF_y} * \boldsymbol{AM_y}\right]_{\boldsymbol{k}} \qquad (k = 1, \ldots, 4) \qquad (5.12)$$

where, *PF* denotes the price of the feed per pound, and *AM* denotes the amount of feed purchased in pounds, and *y* denotes the type of feed purchased, *y* denotes the type of the feed or mineral, where 1=oat grain, 2=oat greenfeed, 3=alfalfa-brome forages 4=creep feed and 5=mineral.

Creep feed is used to provide supplemental nutrition to unweaned calves. It can increase the weight of these calves, and prepare them for solid food in feedlots. Its cost is over the June to December period, when new calves would typically start eating this feed. The type of creep feed can range from a lower side of the spectrum, which includes grain screenings, to those on the higher side of the spectrum, to contain a high protein and energy content feed, typically a combination of grains, molasses, and even oil into pellets. The type of feed chosen for this study was one for which average costs were reported (Armstrong, 2014). Costs for minerals were provided by Manitoba Agriculture Food and Rural Initiatives (2011b), and verified by the figures from the Alberta Agriculture and Rural Development (2014).

With regards to pastureland, taxes per acre ($4.35) (Manitoba Agriculture Food and Rural Initiatives 2010) and seeding costs ($11.35, when accounting for the inflation between 2011 and 2014) (Saskatchewan Ministry of Agriculture 2014) were used. However, seeding costs were only calculated on tame pastureland, once every ten years. The costs for other inputs for the pasture, which included the posts, wire, and fencing nails, as well as windbreak fences, handling facilities, and well and pressure systems for pastures are described as part of fixed costs in Section 5.7.2.3.

5.7.2.2 Other Operating Costs

As noted in Equation 5.10, other operating costs are a part of variable costs within a farm. These costs were estimated using Equation 5.13:

$$\boldsymbol{O_k} = [\boldsymbol{St} + \boldsymbol{VM} + \boldsymbol{B} + \boldsymbol{U} + \boldsymbol{MT} + \boldsymbol{MR} + \boldsymbol{MS}]_{\boldsymbol{k}} \quad (k = 1, \ldots, 4) \qquad (5.13)$$

where, *St* is the straw provided to cattle during the cold season, *VM* is the veterinary medicine and supplies, *B* is the breeding costs, *U* is the utilities, *MT* is the marketing and transportation costs, *MR* is the cost of manure removal, and *MS* represents other miscellaneous costs.

Though straw can generally be produced from a farm growing its own feed, the survey did not inquire about this information. Since all of these farms are located in an area likely to have a great deal of snow cover (leading to higher yields of grain and straw), straw was assumed to have been used to create bedding for cattle after a snow storm. The cost of straw used in the study was standardized at $30 per cow based on estimates provided by Manitoba Agriculture Food and Rural Initiatives (2011b).

Veterinary medicine and supply costs were also based on data obtained from Manitoba Agriculture Food and Rural Initiatives (2011b). Costs included medicine for infectious bovine rhinotracheitis, parasitic control, and scour prevention for cows. Calves were provided a vaccine for blackleg. In addition, a budget for two veterinarian visits was included for each farm with a $0.75/km charge for 80 kilometers, which included the fees for the veterinarian.

A number of costs were included under breeding costs. With regards to bulls, a breeding soundness test was provided to each bull for a cost of $50/bull in order to appraise the structural soundness of the animal, its reproductive system, and the semen quality. These costs were greater than those noted by Bellamy et al. (2000), who proposed this cost at $45.80 per bull. Bellamy et al. (2000) costs were based on Saskatchewan prices during 2000, and in this study the prices for 2011 and for Manitoba were used to provide more accuracy and timeliness. These costs were similar to those noted by Whitley (2008). Health management costs to develop rations were also estimated at $10 per bull (Manitoba Agriculture Food and Rural Initiatives 2011b).

Utility costs were estimated at $11.00 per cow, and miscellaneous costs were estimated at $6.67 per cow (Manitoba Agriculture Food and Rural Initiatives 2011b). These costs are also similar to the costs provided by the Western Beef Development Center in 2005 (Highmoor 2005).

Marketing and transportation costs refer to those costs that are associated with transporting calves and cull cows to auction markets. There are also levies, which are gathered by the Manitoba

Cattle Producers Association ($3 per animal sold), and the Manitoba Cattle Enhancement Council ($2 per animal sold) (Manitoba Agriculture Food and Rural Initiatives 2011b). Commission and Insurance costs, which pertain to the cost of selling an animal in an auction and insuring that the animal arrives safely, was estimated at $17 per head (Manitoba Agriculture Food and Rural Initiatives 2011b). Trucking costs were $1.60 per cwt live weight for each animal sold (Manitoba Agriculture Food and Rural Initiatives 2011b).

Manure removal costs varied from farm to farm as shown by the survey data. This cost depended on the amount of land available to spread manure. In this study, at most, half of the land for each farm was used to spread manure. Consultation with Larson (2014) indicated that these initial costs of manure removal were high. Therefore, more reflective figures using the Manure Transportation Calculator were used (Montgomery 2011). These costs were based on the number of cows in the herd, the accumulated days spent in their feeding area, distance of the application area from the feeding area, and the spreadable area size. The number of days in the feeding area were reported in the survey, which are 181 days for Cluster One farm and Cluster Six farm, 31 days for Cluster Four farm and 89 days for Cluster Seven farm. These assessments were used for estimated manure removal costs.

While the survey did indicate the field in which manure was spread, the precise area chosen to spread manure was not reported. Therefore, the size of the spreadable area was taken as the default value of 45 acres. Twenty five percent of this land was either pastureland or crop land. The survey requested each farm surveyed to indicate where they spread their manure, thus adjusting the area of land where manure was spread, if the total area was less than 45 acres. The cost of manure spreading increased in relation to amount of land used for manure spreading. The distance to the spreading area was set at one kilometre, in order to keep this approximation uniform among the study farms.

Only one farm, Cluster Four farm, indicated that it used composting to manage its manure. In order to estimate costs for composting, BC’s Ministry of Agriculture and Food (Ministry of Agriculture Food and Fisheries 1996) was consulted, as Manitoba data were not available. The costs were estimated using a passive windrow machine, which was purchased. The fixed cost of composting included depreciation and interest costs, which were added to the fixed costs of machinery. A basic windrow machine ($40,000) and a deluxe windrow machine ($190,000) were considered. The basic windrow machine was used on the premise that economies of scale would yield lower costs (Ministry of Agriculture Food and Fisheries 1996).

Two of the study farms also grew crops, in addition to raising beef cattle. Costs were calculated in a similar manner as noted above with regards to feed production. The survey results did not reveal which crop was planted. As a result, it was assumed that both farms produced barley, at a cost of $11.75/acre to seed (Manitoba Agriculture Food and Rural Initiatives 2010). The cost of fuel was determined using Equation 5.19. Since both of the farms used identical machinery and practices to grow barley, a fuel cost of $14.15 was estimated for each farm. Land tax cost of $4.35 per acre was used for all farms (Manitoba Agriculture Food and Rural Initiatives 2010). However, Cluster Seven farm owned its machinery, as it grew barley on 640 acres, whereas Cluster Four farm grew barley only on 160 acres, and therefore was presumed to have rented machinery. Therefore, Cluster Seven farm had machinery repair costs, while Cluster Four farm had machinery rental costs. As none of the feed crops used herbicides, these crops were also assumed to be grown without them. Similarly, it was assumed that no crop insurance was used.

Operating interest cost was calculated at 3.52 percent of all variable costs per year (Statistics Canada 2014b). This figure was used to determine the opportunity costs for which this money could have otherwise been used, or the cost of borrowing this money in 2011.

5.7.2.3 Fixed Costs

The fixed costs, noted in Equation 5.11, were related to the costs of structures and machinery necessary to complete farm work. These costs were divided into two types: interest and depreciation.

Interest costs were calculated for structures, machinery, and livestock using Equation 5.14:

$$\boldsymbol{I_k} = \sum[\boldsymbol{BWS} + \boldsymbol{BS} + \boldsymbol{M}]_{\boldsymbol{k}} * \mathbf{3.52}\% \qquad (k = 1, \ldots, 4)\ (5.14)$$

where, *BWS* is the value of structures and water systems, *BS* is the value of breeding stock, and *M* is the value of machinery. The interest costs were calculated as 3.52 percent,[34] as it was the average rate for a one year loan in 2011 (Statistics Canada 2014b). These values are shown in Table 5.3.

Machinery was assumed to be rented if the farm size (in terms of crop land) was less than 400 acres. Depreciation varied from farm to farm based on the types of structures and machinery owned. The machinery on each farm varied due to growing decisions. Each farm grew similar, but different types of crops. Some feeds, such as greenfeed, do not require a swather or combine, and therefore the need for this equipment was eliminated.

Table 5.3 Annual Machinery Depreciation Calculations on Manitoba Farms

Machinery	Annual Depreciation Value	Original Value	Percent Remaining Value after Use	Years of Use
Miscellaneous Machinery	$400.00	$10,000	20	20
Tractor, 268 hp	$9,866.67	$185,000	20	15
Tractor, 160 hp	$4,800.00	$120,000	20	20
Air seeder 25-30 ft.	$3,200.00	$60,000	20	15
Swather, 18 - 24 ft.	$1,066.67	$20,000.00	20	15
Combine	$8,000.00	$150,000.00	20	15
Baler 4X6	$1,440.00	$27,000	20	15
Tractor and Feed Wagon	$1,400.00	$35,000	20	20
Stock Trailer, 20 ft. gooseneck	$906.67	$17,000	20	15
Truck	$3,150.00	$35,000	10	10
Haybine 12ft	$1,546.67	$29,000.00	20	15
Bale Wagon	$800.00	$20,000.00	20	20
Front end loader	$500.00	$12,500.00	20	20
Composter	$2,000.00	$50,000.00	20	20

Source: Manitoba Agriculture Food and Rural Initiatives (2005)

The rate of depreciation and the value remaining after use for the machinery, as shown in Table 5.3, was provided by Manitoba Agriculture Food and Rural Initiatives (2011) while the cost of each piece of machinery was obtained from Manitoba Agriculture Food and Rural Initiatives (2005). Though the costs for 2011 were available, the prices for grain increased after 2005, which

[34] Interest costs and operating interest costs were both determined to be those for a one year loan in this analysis.

increased the price of machinery. Thus, it was less likely that producers who rely on livestock production purchased newer equipment in 2011. As shown in Table 5.5, the salvage value and the depreciation rate varied between each piece of machinery. Each farm used different machinery, based on their crops, as discussed further in Chapter Six.

There were several sources of expenditures with regards to structures and infrastructure. Costs to fence pastureland or a feeding area varied from farm to farm, based on the area that each farm indicated. Other costs regarding the structures and water systems were the same on each farm.

The cost of pastureland consisted mostly from fencing. These costs included posts ($956.16 per ¼ mile), braces ($139.80 per ¼ mile), gates ($86.01 per ¼ mile), wire ($759.64 per ¼ mile), staples ($17.94 per ¼ mile), the use of a tractor ($268.94 per ¼ mile), and a post pounder ($176.10 per ¼ mile) (Agriculture Knowledge Centre, 2013). The useful life of the fence was assumed to be 20 years (Agriculture Knowledge Centre 2013). Native pastureland, tamed pastureland, and seasonal feeding areas were assumed to be in different locations, with no shared fence line were used. All farms with pastureland had divided their land into fenced-off sections, called paddocks.

The total area of pastureland for each study farm was reported, but the perimeter of each paddock was not. Therefore, assumptions were necessary. The geometric division of a pasture affects the amount of fencing necessary. Therefore, the exact fencing cost might vary from those actually found on each farm.

Structures and water systems were assumed to have a useful life of 20 years with no salvage value. The structures included a portable wind break ($450), feed troughs ($500), handling facilities ($10,000), calving facilities ($12,500), water troughs ($6,000), pasture watering system ($3,000), pasture water source ($3,000), gates ($1,450), round bale feeders ($2,400), a well and pressure system ($8,000), and power poles ($2,400). All of these data were obtained from Manitoba Agriculture Food and Rural Initiatives (2011b).

5.8 Beef Enterprise Profitability

In order to understand the profitability of the beef enterprise on each study farm, the costs and revenues relating only to the cattle herd were separated out of whole farm analysis. The beef enterprise takes into account only the costs associated with caring for the beef herd, and the revenues from the weaned calves and cull cows. The beef enterprise does not include revenues from sales of excess feed, or any off-farm income.

Estimated total profitability of the beef enterprise is the difference between revenue and its costs, as shown in equation 5.15:

$$\boldsymbol{Beef\ Enterprise\ Profit_k = BER_k - BEC_k} \qquad (k = 1, \ldots, 4) \qquad (5.15)$$

where, *BER* is the beef enterprise revenue, and *BEC* is the beef enterprise costs.

Equation, 5.16, represents the direct costs of the beef enterprise.

$$\boldsymbol{BEC_k = [F + Op]_k} \qquad (k = 1, \ldots, 4) \quad (5.16)$$

where, *F* is the feed purchased for the cattle, as outlined in section 5.7.2.1; *Op* is the operating costs for the beef enterprise on the farm.

The equation 5.17 was used to estimate revenue solely from the beef enterprise.

$$\boldsymbol{BER_k = \{\sum[PC_t * (AW_t/100)] * (1 - DL)\}_k} \qquad (k = 1, \ldots, 4) \qquad (5.17)$$

where, *PC* is the price of each animal per hundred weight, and *AW* is the average weight in cwt; and t denotes the type of animal sold (1=steer, 2=heifer, 3=cull cow); *DL* is the deadweight loss, or percent of the herd that had perished before the sale date.

5.9 Non-Beef Enterprise Profitability

The costs of on-farm produced grain and forages were determined by cost of production expenditures[35] (from seeding to harvest).

The cost to produce crops was calculated using Equation 5.18.

$$\boldsymbol{Pr_k = \left[\sum\left(S_y + FL_y + MR_y + LT_y\right) * A_y\right]_k} \qquad (k = 1, \ldots, 4) \qquad (5.18)$$

where, *S* is the cost of the seed and its treatment, *FL* is the cost of fuel, *MR* is the cost of machinery repairs, and *LT* is the cost of land taxes, and *y* denotes the type of feed produced, (where 1=oat

[35] These costs were based on estimates from Manitoba Agriculture, Food, and Rural Initiatives (2011b), unless otherwise noted.

grain, 2=oat greenfeed, and 3=alfalfa-brome forage). All of these costs were calculated on a per acre basis first, and then multiplied by the reported number of acres, *A*, used in order to obtain total cost. As most of the farms had the ability to feed their animals different types of feed, the cost of all feeds were summed.

The cost of alfalfa seed was collected from Wong and Yoder (2012). The forage crop, which consists partially of alfalfa, was planted at a rate of 16 pounds per acre, every three years. This differs from pastureland, which is planted every ten years. The amount of alfalfa seed compared to grass seed changed from farm to farm[36]. Therefore, the cost of seed increased when more alfalfa was seeded. While the specific type of perennial forage, other than alfalfa, was not named, sweet brome was assumed to be planted due to its suitability for forage production. The cost of alfalfa seed was $22.24 per acre, while the cost of brome grass seed was $13.44 per acre.[37] Forage crop costs thus differed, due to the proportion of alfalfa in each forage crop. It was assumed that each of the farms rotated their crops every three years, and thus the prices per acre were divided by three.

The cost of fertilizer was not included in feed production costs, as none of the study farms reported its use. The use of herbicide and fungicide was also not included, as none of the crops would normally need to use these products (Kowalchuk 2014).

The amount of fuel used was calculated using the same formula utilized in Holos. Using standards from the American Society of Agriculture and Biological Engineers, Smith (2014) devised the equation as shown in Equation 5.19 for fuel costs:

$$\boldsymbol{Fuel_k(l/hr) = [0.73 * 0.305(PTO\ HP) * MACH * 1.15]_k} \quad (k = 1, \ldots, 4) \qquad (5.19)$$

where, *MACH* is the power of the tractor or combine. The value 0.73 is the conversion factor for gasoline to diesel, while 0.305 is the litres per hour of gasoline per kW of Power Take Off Horse

[36] The cost of alfalfa seed is more expensive than the cost of brome grass seed. The nutritional value of alfalfa, as noted in Table 5.2, also differs from brome grass. Therefore, the amount of alfalfa in the forage crop within each cluster farm was evaluated, as shown in Section 6.3.

[37] The website for this information no longer exists. Costs for alfalfa seed were $13.30 per acre according to Manitoba Agriculture Food and Rural Initiatives (2015b). However, these prices are based on 2015 rates, and not 2011 rates.

Power (*PTO HP*). The amount of fuel per hour was then multiplied by the amount of acres that each service (seeding, baling, combining, and swathing) completed in one hour. The value 1.15 adds 15 percent of the value in order to include oil and lubricants. These figures were provided by the Manitoba Agriculture Food and Rural Initiatives (2012). The price of fuel was derived from Statistics Canada (2012a).

After determining the amount of fuel used per acre, it was multiplied by the cost of fuel, at $1.05 CAD. The average cost of fuel throughout 2011 in Winnipeg was $1.12 CAD, determined by Statistics Canada (2012a). As agriculture production is not subject to fuel taxes, this average was reduced by 6.3 percent.

The machinery used to seed, swath, harvest and/or bale the crop was either owned or rented by the producers. Farms with less than 400 acres were deemed too small to necessitate ownership of machinery. Therefore, rental rates were used in these cases, which are shown in Table 5.4. If the total area of crop land exceeded 400 acres, then it was assumed that the farm purchased, rather than rented, its farm equipment. The initial cost of machinery was obtained from 2005 costs, which approximated the period of time before machinery prices rose as a response to higher grain prices.[38] These costs were used, as it is unlikely that all machinery was purchased in 2011, particularly if machinery costs were high and cattle prices were low. The repair costs were provided by Manitoba Agriculture Food and Rural Initiatives (2012).

Table 5.4 Machinery Rental Costs (Per Acre) used in the Study

Machinery	Rental Cost
Air seeder 25-30 ft.	$14.09
Swather, 18 - 24 ft.	$12.11
Combine	$14.81
Baler 4X6	$3.82
Haybine 12ft	$4.99

Source: Manitoba Agriculture Food and Rural Initiatives (2005)

[38] This assumption was made with the assistance of Kathy Larson, of the Western Beef Development Centre. Some producers might have purchased machinery before the increase in prices. However, the increase in the price of machinery might have coincided with the increase in crop prices. Due to a lack of information regarding the price of machinery, an assumption was made that the machinery purchase decisions were made in 2005.

Since only 13 percent of forage producers choose to insure their crops (Wilcox 2014), in this study, none of the crops, either grain or forage, were assumed to be insured. Since all of the farms seem to grow more feed than needed to meet the nutritional requirements of their herd, it was assumed that their form of insurance is provided by the stockpile of feed produced in previous years (Wilcox 2014).

Land taxes data were obtained from Manitoba cost of production information produced by Manitoba Agriculture Food and Rural Initiatives (2011b). These were based on an informal survey of rural municipalities in the province (Arnott 2014). While these taxes could vary from municipality to municipality, in this study it was assumed that all taxes were the same, and based on the area of crop, forage, and pastureland on the farm.

5.10 Greenhouse gas estimation

In this study, GHG emissions for the study farms were estimated using the Holos model, described in Section 3.4.6. These estimates were made by researchers from the University of Manitoba using results from the survey for each study farm. Although the survey did ask producers to provide specific information pertaining to activities responsible for GHG emissions and carbon sequestration, the answers, in some cases, were incomplete.[39]

Estimates from the University of Manitoba were modified in order to reflect the lack of fertilizer use, as described in the survey, and also the lack of herbicide use, which was noted in Section 5.9. Since the Holos model uses a standard application rate for various inputs, in this study, coefficients were changed for lack of fertilizer and herbicide use, based on the results of the survey. The GHG model allows specific dry matter and crude protein inputs from CowBytes, noted in Section 4.3.3. As such, theses inputs were changed to reflect the exact nutritional contents of each herd's diet. The specific types of GHGs are reported in Section 5.11, and specified in detail for each farm in Tables A.2 to A.5, in Appendix A.

[39] For example, not all producers tested their manure or their feed to inspect their contents, and therefore precise details could not be integrated into the Holos model. Instead, the default values for Holos were used.

5.11 Trade-off Analysis

In this study, profitability was compared by dividing net revenue (profits), by the total live weight of animals sold on each farm. The GHG emissions were calculated as shown below in Equation 5.20:

$$\boldsymbol{GHGE_k} = [\boldsymbol{LUC} + \boldsymbol{CS} + \boldsymbol{B}]_{\boldsymbol{k}} \qquad (k = 1, \ldots, 4) \qquad (5.20)$$

where, *GHGE* is GHG emissions, *LUC* is GHG emissions from land use change, *CS* represents the amount of GHGs emitted through crops and soil, and *B* represents the amount of GHGs emitted from beef production on a farm. The *LUC* includes change[40] in practices, such as tillage, fallow, perennial crops, and seeded or tame pastureland, which typically sequester CO_2. The *CS* or Crops/Soils represents all emissions from crops and soils, such as the production of oats, barley, forages, and the application of manure to crop fields. Crops/Soils based GHGs emissions are through direct and indirect N_2O, as well as CO_2. The *B* represents all enteric fermentation from cows, calves, heifers, and bulls, as well as direct and indirect N_2O emissions through stored and non-stored manure.

GHGE from the beef enterprise and the whole farm were then compared to the total weight from each farm. In order to explain variability in profitability or losses in conjunction with net GHG emissions or sequestrations, several factors were studied. These factors included weaning weights, the size of herds, and variable and fixed costs.

5.12 Sensitivity Analysis

To reduce uncertainty in the beef enterprise and the whole farm, a range of prices for cattle were employed. It included low, average, and high prices for weaned steers and heifers, as well as D1 and D2 grades for beef cows.[41] These prices are reported in Table A.6 in Appendix A. The low prices were the lowest recorded prices in Manitoba, during 2011. The high prices were the highest

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[40] The aforementioned survey asked participants if they had changed their tillage and/or fallow practices from 2010 to 2011. However, none of the four study farms indicated any change in these practices. As a result, Tables A.2 through A.5 do not note emission changes from tillage or fallow practices.

[41] See Table A.1 in Appendix A for more details on the prices of cattle in Manitoba, 2011.

recorded price in Manitoba during 2011 for a given type of animal (Agriculture and Agri-Food Canada 2008).

In order to measure the range of net revenue for the beef enterprise, revenues were adjusted using low, average, and high prices from weaned calves and cull cows. This led to the understanding of price variability as a factor affecting profitability.

5.13 Assumptions

Although this study was based on the actual quantities of feed, the area of land, and the total weight of live animals sold, some assumptions were necessary.

First, while the quantity of feed is important, the quality of feed is equally important. Though this research was able to incorporate this quality in terms of the amount of alfalfa in its forage, other aspects of feed quality, which result in good feed for the cattle, were not incorporated. Similarly for grains, in the absence of this information, it was assumed that each farm received good growing conditions and uniform grades.

Second, while average, low, and high prices were recorded by Statistic Canada, more information regarding the condition of animals from each farm would provide a better indication as to the prices each farm received. If the calves sold were both small, healthy, and vaccinated, they might draw a higher price than those that are large, unhealthy, and unvaccinated. In addition, these farms might have been stock cattle breeders, which are able to gain higher prices for their cattle based on their purebred traits from breeds such as Charolaise, Angus, or Hereford. The assumption of a uniform breed might make some study farms less viable in the results. That is, methods to add value to these cattle through vertical integration have not been noted. None of the farms were assumed to have added value to their beef enterprise through a vaccination program, through specific breeds, or through other methods regarding vertical integration.

Third, the results from the Holos model do have their limitations. While this study has noted the final results, the average results differ by 37.5 percent, in either a positive or negative manner. Table 5.5 below notes the specific uncertainty for each of the GHG emissions or sequestrations.

Table 5.5 Uncertainty of GHG calculations using the Holos Model	
Emission category	**Uncertainty**
Soil/land use change CO_2	+/- 40%
Crops/soils N_2O - direct	+/- 60%
Tree planting CO_2	+/- 20%
Enteric CH_4	+/- 20%
Manure CH_4	+/- 20%
Manure N_2O - direct	+/- 40%
Indirect N_2O - crops/soils and manure	+/- 60%
Energy use CO_2	+/- 40%

Source: Agriculture and Agri-Food Canada (2009)

Fourth, pasture costs might be greater from one farm to the next, and the carrying capacity on each farm might vary. A stocking rate, or the Animal Unit Months (AUM) per acre, can be used to analyze the quality of each farm's pastureland. However, the circumstance of this land is unknown, and therefore each study farm with a pasture was presumed to be in the same condition.

Fifth, replacement heifers were assumed to replace the same number of cull cows on the farm. That is, a farm with 30 replacement heifers were assumed to have 30 cull cows. A farm might have, instead, decided to increase the size of its herd. As a result, the revenue from cull cows might be overestimated for the study period.

5.14 Summary

This chapter described the survey methodology employed to select farms used in this study, as well as the methods employed to analyze their costs, revenues, and overall profitability. It also described procedures for estimating profitability at three levels: (i) the beef enterprise, (ii) the whole farm, and (iii) the family income. The GHG estimations from Holos model were described, along with the method employed to compare profitability to GHG emissions on each farm and the factors used to evaluate the trade-offs between high profitability and low GHG emissions.

CHAPTER 6 RESULTS

6.1 Introduction

Using the methodology described in Chapter Five, this chapter presents the results from the analysis of four types of beef operations in Manitoba. It reports their individual feeding costs, operating costs, depreciation and interest costs, revenues, profits, and GHG emissions or sequestrations. Trade-off analysis is undertaken to illustrate the effect of different uses of land, production of feeds, and the ramification of higher weaning weights through a comparison of their GHG emissions and respective profitability. This chapter describes three levels of farm profitability in Section 6.2. Subsequently, individual farms' results are reported in Section 6.3. Emission levels for GHGs for each farm is reported in Section 6.4, followed by a presentation of trade-offs between profitability and GHG emissions in Section 6.5. Section 6.6 summarizes the results of farm level profitability and GHG emissions, along with those based on the trade-off analysis.

6.2 Levels of Examination of Economics of Cluster Farms

Mixed farms depend on different enterprises for their profitability, including income from non-farm sources. In order to compare the four study farms at an equal footing, beef enterprise economics has been analyzed in this study first for the beef enterprise level, and then extending it to the whole farm and the total family income levels. It should be noted that each of these three levels are cumulative – family income include all farm income and off-farm income, whereas whole farm income includes beef enterprise level income. Beef enterprise income is solely from the activities directly related to beef cattle.

Beef enterprise production included the cost of feed (which is often produced on the farm, but sometimes purchased if available supply is not adequate), other operating costs which pertain to raising cattle, and depreciation and interest costs for structures and other infrastructure required to maintain cattle. The profitability analysis for the beef enterprise was obtained exclusively from the sale of cattle.

Whole farm production included all enterprises on the farm. This included the beef enterprise plus costs and revenues from growing feed and non-feed crops not required for the beef enterprise. Revenues for excess feed were determined using 2011 prices. However, in this study all stored feed was considered sold at 2011 market prices. It is conceivable that these prices could increase in the future (depending upon forces of demand and supply), or may even decline (if the quality of feed deteriorates significantly in the future). A comparison of our study farms' cost of production is presented in Appendix B (Table B.1). Each of these farms used different feeds and/or crops on their farms. A comparison of the total acres on these farms to the total weight of cattle sold is found in Appendix B (Figure B.1).

Family net income included the amount of income obtained from off-farm employment or investments. Only two farms reported such an income. These incomes assist farms to sustain short-term problems, such as high costs and/or low revenues, or to help them achieve their long term goals, such as retirement.

6.3 Economic Results by Cluster Farms

6.3.1 Cluster One Farm: Small Scale, Part-Time Cow-Calf Operation

The centroid in this cluster is a small cow-calf operation with 26 cows, three replacement heifers and one bull. Within this cluster of 27 farms, it had the fourth smallest herd in Manitoba. Among all four farms studied, this farm also had the lowest birth weight, at 70 pounds, and weaning weight, at 500 pounds.

6.3.1.1 Land Use

This farm had the smallest amount of land dedicated to feed grains among the four Manitoba study farms. This area was devoted to oats for grain feed on 17 acres. There were 330 acres of forage, of which 30 percent was alfalfa. It did have the smallest amount of total pastureland, at 150 acres, as shown in Table 6.1. All of the pastureland was native, rather than tame pasture.

Results from linear programming (see Section 5.7.1) showed that only 16 percent of the forage was used to feed the herd over the year. In addition, oats were not used for beef cattle. As such, all 17 acres of oats as well as 277 acres of forage were considered to be a part of the non-beef enterprise. Therefore, the designated costs and associated revenues with this portion of the crops are also considered part of the non-beef enterprise, relevant only at the whole farm level. The herd used pasture grazing between May and October. For the remainder of the year, bales produced using the forage crop were grazed on 75 acres of land, which was assumed to have been a part of the pastureland.[42]

Table 6.1 Land Use (Acres) of Cluster One Farm, Manitoba, 2011			
Type of Land Use	**Beef**	**Non-Beef**	**Total**
Feed Oats - Grain	-	17	17
Forage	53	277	330
Native Pasture	150	-	150
Total	**203**	**294**	**497**

Off-farm income was used by 56 percent of the farms in this cluster, in addition to their farm income. This farm also supplemented its income with off-farm income, which comprised approximately 20 percent of the total income.

6.3.1.2 Farm Assets

Machinery to seed and harvest forage, such as a tractor, seeder, or a baler, were not included in depreciation and interest costs (seen in Table B.1) because this farm was deemed too small to necessitate owning this equipment. As noted in Table 6.1, there were only 17 acres of oats reported, and 330 acres of forage. Therefore, it was assumed that this farm rented all its farm machinery. This reflects the overall lower values noted below in Table 6.2. Additional details on the depreciation and interest from this farm can be seen in Tables B.2 and B.3.

Table 6.2 Annual Value of Assets, Depreciation and Interest Costs for Cluster One Farm, Manitoba, 2011			
Assets	**Value**	**Depreciation**	**Interest**
Machinery	$194,500.00	$9,756.67	$6,846.40
Structures	$66,580.79	$3,329.04	$2,343.64
Livestock	$27,724.37		$975.90
Total	**$288,805.16**	**$13,085.71**	**$10,165.94**

[42] This farm indicated that it had two paddocks. As the total pasture area was 150 acres, it was assumed that bale grazing occurred on one of the paddocks, which would be half of the pastureland, or 75 acres.

6.3.1.3 Whole Farm Level Costs

The cost of all enterprises, as explained in Chapter 5, on Cluster One Farm were estimated for both the beef and non-beef enterprises (see Table 6.3). A large portion (74 percent) of the total costs were incurred for the beef enterprise. Since non-beef enterprise consisted only of the seed and other inputs allocated to the surplus feed not fed to the cattle, this was expected. The interest and depreciation on machinery were totally charged to the beef industry, as all of the machinery that would have been necessary for the non-beef enterprise would have been rented.

Table 6.3 Annual Beef and Non-beef Enterprise Costs for Cluster One Farm, Manitoba, 2011

Cost Items[1,2]	Beef	Non-Beef	Total
Oats		$1,463.99	$1,463.99
Forages	$5,156.50	$9,915.00	$15,071.50
Pasture	$652.50	-	$652.50
Straw	$870.00	-	$870.00
Veterinary Medicine and Supplies	$376.36	-	$376.36
Breeding Costs	$60.00	-	$60.00
Utilities	$330.00	-	$330.00
Marketing and Transportation	$947.70	-	$947.70
Manure Removal	$902.00	-	$902.00
Miscellaneous	$200.10	-	$200.10
Operating Interest	$334.23	$400.54	$734.77
Depreciation	$13,085.71	-	$13,085.71
Interest	$10,165.94	-	$10,165.94
Total Cost	**$33,081.04**	**$11,779.54**	**$44,860.57**

[1]Forages, oats, and pasture costs are included in the feed costs for the beef enterprise.
[2]Rental costs are included in oat and forage production.

Combined interest and depreciation costs were the highest cost item on this farm, comprising 70 percent of the beef enterprise costs, and 52 percent of the whole farm costs. Input costs for feed included the cost of seed, fuel, machinery rentals, and land taxes. Including the cost of the pasture of this farm, feed and crops costs comprised 18 percent of the costs for the beef enterprise.

6.3.1.4 Beef Enterprise Economics

The total cost on a PPS[43] (Per Pound Sold) basis was $2.08 when considering only the beef enterprise cost items of this farm. Figure 6.1 shows the PPS cost for major items of the beef enterprises. Major item of cost for this farm were the fixed costs (depreciation and interest) which were 70 percent of the total cost. Approximately 12 percent of the total costs were operating costs, while the remaining 18 percent were the feed costs[44].

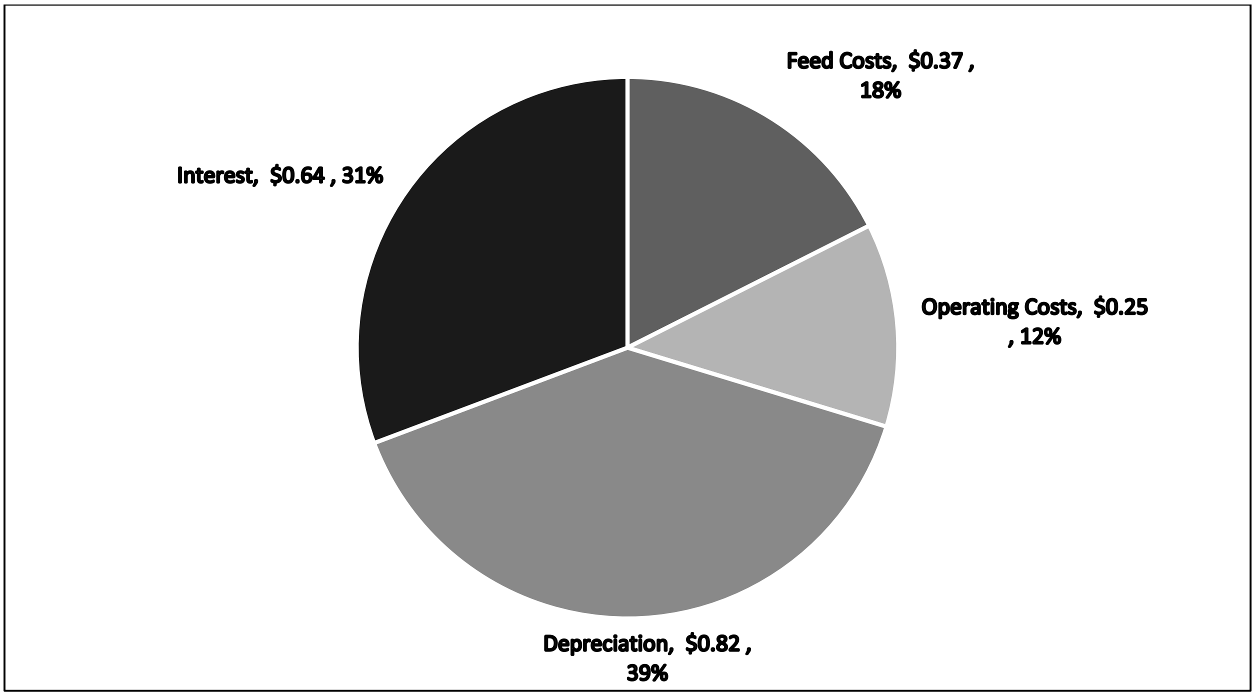


Figure 6.1 Distribution of Cluster One Farm Annual Beef Enterprise Costs on a PPS Basis by Major Cost Types, Manitoba, 2011

Since all of the 150 acres of pasture were native pastures, rather than tame, only property taxes and interest payments for the machinery were included for this land. The cost of seed was excluded as native pasturelands are not seeded or otherwise maintained, apart from fences. The forage for this farm consisted of only 30 percent alfalfa. This decreased the costs for seed by 27 percent, when compared to a field that was seeded completely with alfalfa.

[43] PPS was calculated adding the total weight sold on the farm (shown in Table A.6), and then using it as the denominator in a fraction. This enables a comparison from farm to farm. [Check table no.]

[44] Table B.1 notes the operating costs within the farm on a PPS basis.

The gross revenue from the sale of cattle was $18,986.76 or $1.19 on a PPS basis, of which $16,344.99 (86 percent) was from the sale of weaned steers and heifers, while $ 2,641.76 (14 percent) was from the sale of cull cows. As a result of higher costs and slightly lower revenues for the beef enterprise, the farm suffered a net loss of $14,094.28 ($0.89 on a PPS basis) under average prices.

6.3.1.5 Non-Beef Enterprise Economics

Although this farm created revenue from the sales of weaned calves and cull cows, it was more successful at creating profitability from its non-beef enterprise. Linear programming, which evaluated the use of feed on the farm throughout 2011, determined that there were reserves of forage within the year that could be carried forward beyond 2011. As noted earlier, these reserves were valued in this study using 2011 prices. None of the oats were deemed necessary for the beef enterprise, along with 84 percent of the forages. All unused feed, therefore, were stored in inventory for sales or future use in future years. This led to an inventory worth $3,406.03 from 18.41 tonnes of oats, and $267,784.06 from 396.92 tonnes of forages, for a total of $31,190.09.

6.3.1.6 Whole Farm Revenue

Although this farm described itself primarily as a cow-calf beef farm, Table 6.4 shows that the revenues from the beef enterprise were lower than that from the non-beef enterprise. Forage sales provided 55 percent of gross revenue, while oat sales provided 7 percent of total gross revenue values. The sale of weaned calves and cull cows comprised of only 38 percent of total gross revenue.

Table 6.4 Cluster One Farm Annual Gross Revenue at Whole Farm Level, 2011

Source of Revenue	**Beef**	**Non-beef**	**Total**
Oats		$3,406.03	$3,406.03
Forage		$27,784.06	$27,784.06
Cattle	$18,986.76	-	$18,986.76
Gross Revenue	**$18,986.76**	**$31,190.09**	**$50,176.85**

6.3.1.7 Family and Whole Farm Income

This farm reported that 20 percent of its net revenue was generated off of the farm, which equals $1,063.26. The non-beef enterprise generated a net gain of $19,410.55, while the beef enterprise generated a net loss of $14,094.28. As a result, the total income, given costs and revenues from the beef and non-beef enterprise, as well as off-farm income, was $6,379.53 (Table 6.5).

Table 6.5 Cluster One Farm Annual Net Revenue, Manitoba, 2011	
Source	**Value**
Beef Enterprise	-$14,094.28
Non-Beef Enterprise	$19,410.55
Off-farm Income	$1,063.26
Total Income	**$6,379.53**

6.3.1.8 Sensitivity to Price[45]

The sensitivity analysis with respect to cattle prices showed that the revenue for the beef prices could vary by $7,502.73 between low and high beef cattle prices (Table 6.6). This translated into $0.98 on a PPS basis under low beef cattle price levels, $1.19 on a PPS basis under average beef cattle levels, and $1.46 on a PPS basis for high beef cattle price levels.

Table 6.6 Cluster One Farm Annual Gross Revenue Sensitivity to Price, 2011			
Scenario	**Calves**	**Cows**	**Total**
Low	$ 13,429.01	$ 2,121.85	$15,550.85
Average	$ 16,344.99	$ 2,641.76	$18,986.75
High	$ 19,906.76	$ 3,347.40	$23,254.16

As noted in Table 6.7, this resulted in a loss in net revenue from the beef enterprise of $17,530.18 ($1.10 on a PPS basis) for low prices, $14,094.28 ($0.89 on a PPS basis) for average prices, and $9,826.88 ($0.62 on a PPS basis) for high prices. Thus on this farm, regardless of beef cattle prices, the beef enterprise does not make any profit. The non-beef enterprise, as well as the off-farm income, do result in overall profitability for this farm, in all three scenarios.

[45] As this study focused on profitability and GHG emissions from the beef enterprise, a sensitivity analysis was conducted only on the sale of cattle, and not the sale of barley or cattle feed.

Table 6.7 Cluster One Family Income Sensitivity to Price				
Level	**Beef Enterprise**	**Non-Beef Enterprise**	**Off Farm Income**	**Family Income**
Average	-$14,094.28	$19,410.55	$1,063.26	$6,379.53
Low	-$17,530.19	$19,410.55	$376.07	$2,256.44
High	-$9,826.88	$19,410.55	$1,916.74	$11,500.41

6.3.2 Cluster Four Farm:[46] Diversified cow-calf operation

This farm was largely a beef farm, though it also grew crops. In fact, it was the only study farm which sold forages during 2011, reporting that 15 percent of its whole farm revenue was generated from this source. It had 120 cows, five bulls, and 30 replacement heifers. It had the second smallest cow herd among all farms in this cluster in Manitoba. The birth weight of 90 pounds matched farms in Cluster Six and Cluster Seven, while its weaning weight (650 pounds) was the highest recorded among all four study farms. This larger weaning rate on this farm was observed despite its late birthing dates compared to Cluster Seven farm. It reported that its calving occurred between March and April, while Cluster Seven farm's calving period occurred between February and March.

This farm also sold barley, which was done only by three out of seven non-centroid Cluster Four farms in Manitoba.

6.3.2.1 Land Use

The Cluster Four farm had the largest area under pastures, as it rotated its cattle through four paddocks on a total of 1,030 acres of native and tame pastureland (Table 6.8). This pastureland was divided into 830 acres of tame pastureland, while the remaining 200 acres were native pastureland. An additional 360 acres were planted with a forage crop comprising of 50 percent alfalfa. In addition, 30 acres of oats for grain feed were also planted on this farm. This producer bale grazed their animals between November and January, then placed them in a feeding area between February and May. This producer then used pasture grazing between June and October.

[46] The centroid from Cluster 4 was discarded due to inconsistent responses from this farm. It was felt that information provided could be unrealistic. It was replaced by the next closest farm.

Table 6.8 Land Use (Acres) of Cluster Four Farm, Manitoba, 2011			
Type of Land Use	**Beef**	**Non-Beef**	**Total**
Feed Oats	-	30.0	30.0
Barley	-	160.0	60.0
Forage	118.8	241.2	360.0
Native Pasture	200.0	-	200.0
Tame Pasture	830.0	-	830.0
Total	1,148.8	431.2	1,580.0

6.3.2.2 Farm Assets

Though this farm did grow non-feed barley, the amount of land devoted to it, in addition to the land used to grow oats and forage, was too small to necessitate the purchase of machinery. Therefore, only a stock trailer, a truck and a composter were assumed to have been purchased on this farm. This, in turn, resulted in low depreciation and interest costs for machinery. Estimated value of assets is shown in Table 6.9.

While the cost of fencing was different from farm to farm, the cost of structures were not. The amount of fencing differed according to the size of pastureland noted by each farm. As noted in Table B.2 and Table B.3 in the appendix, the same buildings and structures were necessary for all farms.

Table 6.9 Annual Value of Assets, Depreciation and Interest Costs on Cluster Four Farm, Manitoba, 2011			
Assets	**Value**	**Depreciation**	**Interest**
Machinery	$112,000.00	$11,756.67	$8,606.40
Structures	$70,983.38	$3,549.17	$2,498.61
Livestock	$143,131.70	-	$5,038.24
Total	**$326,115.08**	**$15,305.84**	**$16,143.25**

6.3.2.3 Whole Farm Level Costs

In Table 6.10, costs of the beef and non-beef enterprise on this farm are reported. The cost of growing oats, alfalfa, and barley on a PPS basis are noted in Table B.1 in the Appendix. This farm grew a forage crop of which 50 percent of the seed mix was alfalfa. This resulted in a cost of $5.95 per acre over and above the cost of brome grass

Table 6.10 Annual Beef and Non-beef Enterprise Costs for Cluster Four Farm, Manitoba, 2011			
Cost Items[1,2]	**Beef**	**Non-Beef**	**Total**
Oats	-	$ 2,469.06	$ 2,469.06
Barley	-	$ 11,466.70	$ 11,466.70
Forages	$ 32,775.23	$ 14,164.27	$ 46,939.50
Salt and Minerals	$ 1,903.22	-	$ 1,903.22
Pasture	$ 13,901.00	-	$ 13,901.00
Straw	$ 4,500.00	-	$ 4,500.00
Veterinary Medicine and Supplies	$ 1,437.00	-	$ 1,437.00
Breeding Costs	$ 300.00	-	$ 300.00
Utilities	$ 1,705.00	-	$ 1,705.00
Marketing and Transportation	$ 5,423.45	-	$ 5,423.45
Manure Removal	$ 612.60	-	$ 612.60
Miscellaneous	$ 1,033.85	-	$ 1,033.85
Operating Interest	$ 2,238.42	$989.12	$ 3,227.54
Depreciation	$ 15,305.84	-	$ 15,305.84
Interest	$ 16,143.25	-	$ 16,143.25
Total Cost	**$ 97,278.85**	**$ 29,089.15**	**$ 126,368.00**

[1]Forages, oats, and pasture costs are included in the feed costs for the beef enterprise.
[2]Rental costs are included in oat and forage production.

As mentioned in the previous section, this farm was not exclusively a beef enterprise operation. During 2011, it grew grain (which was assumed to be barley) not utilized for cattle feed, but instead it was sold in the marketplace. Besides the sale of barley, the linear programming model solution resulted in 67 percent of forages not required for the beef enterprise, and thus available for sale also. None of the oats grown were deemed necessary for raising beef cattle, and therefore were placed in the non-beef enterprise.

Depreciation and interest costs related to structures and pasture fences were necessary for the beef enterprise. On account of a small area under various crops, all machinery was assumed to have been rented. This resulted in no depreciation or interest costs for machinery that was required for crop production. Instead, only a tractor with a front end loader, a stock trailer, a truck, and other miscellaneous machinery, as well as a composter, were purchased to tend to the needs of the herd.

6.3.2.4 Beef Enterprise Economics

In addition to the forages fed to the cattle, Cluster Four farm purchased commercial protein as well as minerals to supplement feed for the herd. This farm used tame pastureland, in addition to native pastureland, which added a cost of $11.39 per acre for seed. This increased the cost of pastureland by 44 percent.

Unlike the other study farms, Cluster Four farm opted to compost its manure. This manure was removed only once per year from its feeding area, and then composted, and stored. The storage method was not indicated, and therefore it was assumed to have been stored as a pile outdoors. Therefore, depreciation and interest costs for this farm increased due to the possession of a manure composter.

The total costs for the beef enterprise for this farm were $0.95 on a PPS basis. As noted in Figure 6.2, feed costs comprised 50 percent of total costs, operating costs comprised 18 percent of all costs, and depreciation costs comprised 16 percent, while interest comprised 17 percent of total costs.

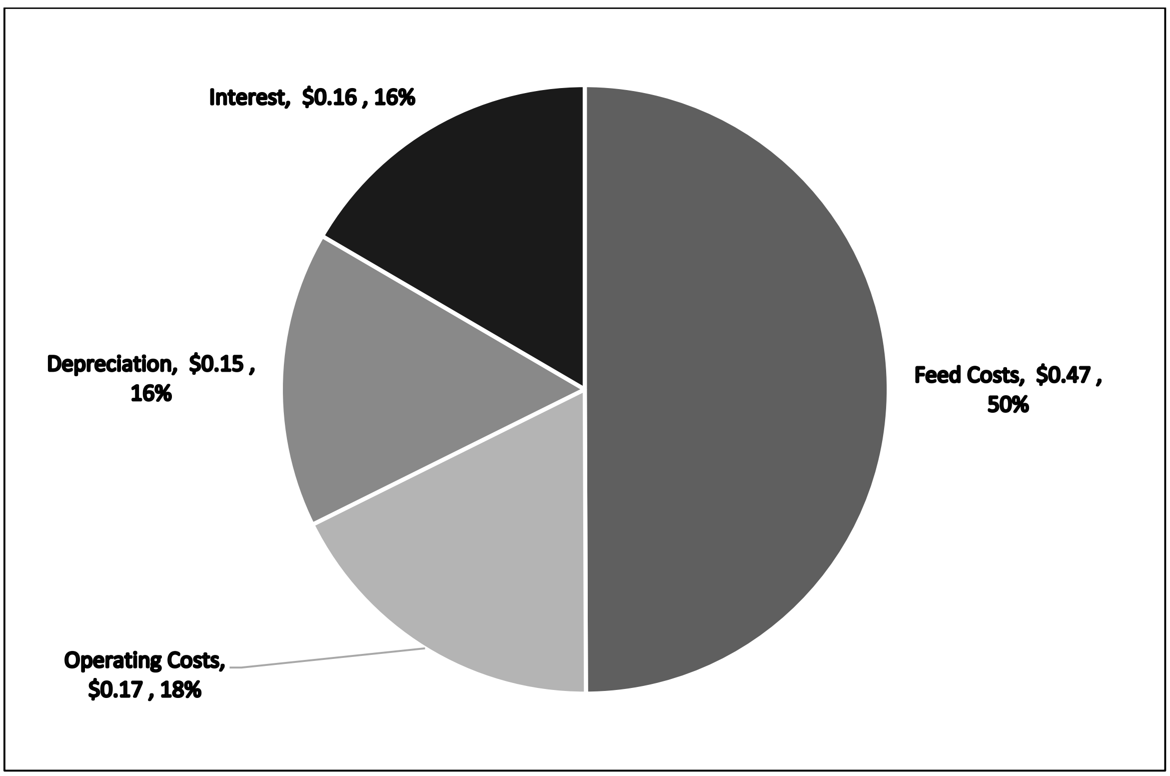


Figure 6.2 Distribution of Cluster Four Farm Annual Beef Enterprise Costs on a PPS basis, by Major Cost types, Manitoba, 2011

The revenue generated from the sale of weaned steers and heifers was estimated at $75,785.88, while cull cows generated a total of $26,417.64. Therefore, the total revenue generated by the sale of cattle was $102,203.52. After the above mentioned costs are paid, the average net profit was $4,924.66 or $0.05 on a PPS basis.

6.3.2.5 Non-Beef Enterprise Economics

Unlike Cluster One farm, this farm indicated in the survey that it sold a portion of its feed, rather than storing it. This reportedly increased its revenue by 15 percent[47]. However, the quantity of feed sold is unknown, as a portion of excess feed might also have been stored. The survey did not ask producers about the quantity of feed remaining after the year had ended.

Rather than one cut of its forage crop, this farm harvested its forages three times throughout the year. This increased the yield by 2.37 times compared to forage crops with only one cut, resulting in 35 percent higher total costs for forages. This increase in cost was due to the rental and fuel use of a mower/conditional and round baler three times a year, rather than once. However, compared to a farm that cut its forages only once, the cost per tonne of forages decreased as no additional seed costs or land taxes were necessary. That is, the fixed costs were lower per tonne of forages due to higher yields resulting from three cuts of forages.

Cluster Four farm made more revenue from the non-beef enterprise than the beef enterprise. The non-beef enterprise sold (or stored) 195.8 tonnes of barley not utilized as feed, valued at $33,000.64, in addition to 953.27 tonnes of forage valued at $66,728.86, and 32.49 tonnes of oats valued at $6,010.64. The total gross revenue from sales (or in storage) for the non-beef enterprise on this farm equaled $105,740.14.

6.3.2.6 Whole Farm Revenue

The majority of the revenue from this farm originated from the non-beef enterprise. The sale of forage created 32 percent of gross revenue on the farm, while the sale of barley and oats created 16 and 3 percent of total revenue, respectively. As noted in Table 6.11, the total gross revenue for the Cluster Four farm was $207,943.66.

[47] The amount of revenue reported from the sale of feed differs from the amount of feed sold in this study. The discrepancy might be that the farm did not value the inventory change. [Needs elaboration]

Table 6.11 Cluster Four Farm Annual Gross Revenue, Manitoba, 2011			
Source of Revenue	**Beef**	**Non-Beef**	**Total**
Oats	-	$ 6,010.64	$ 6,010.64
Barley	-	$ 33,000.64	$ 33,000.64
Forage	-	$ 66,728.86	$ 66,728.86
Cattle	$ 102,203.52	-	$ 102,203.52
Gross Revenue	**$ 102,203.52**	**$ 105,740.14**	**$ 207,943.66**

6.3.2.7 Family and Whole Farm Income

This farm reported that it had increased its family income through off farm sources. It had contributed 40 percent more income, based on its farm revenue. Off-farm income then totals $32,630.26of the net family income, as noted in Table 6.12.

The whole farm net total income differs from the whole farm revenue, as the costs to raise beef cattle were greater than that to produce barley, forages, or oats.

Table 6.12 Cluster Four Farm Annual Net Revenue, Manitoba, 2011	
Source	**Value**
Beef Enterprise	$ 4,924.67
Non-Beef Enterprise	$76,650.99
Off-Farm Income	$32,630.26
Total Income	**$114,205.92**

6.3.2.8 Sensitivity to price

Using low, average, and high prices for weaned calves and cull cows, as reported by Agriculture and Agri-Food Canada (2008), sensitivity analysis for the farm was undertaken. Results are shown in Table 6.13. If the market prices were high for all cull cows and weaned calves, revenues were exceeded by 20 percent of those under average prices. Thus the range of gross revenue could be from $84,995 to $121,619 per annum.

Table 6.13 Cluster Four Farm Annual Gross Revenue Sensitivity to Price, Manitoba, 2011			
Scenario	**Calves**	**Cows**	**Total**
Low	$ 63,776.80	$ 21,218.47	$ 84,995.27
Average	$ 75,785.88	$ 26,417.64	$ 102,203.52
High	$ 88,145.25	$ 33,474.05	$ 121,619.29

Table 6.14 notes the profitability of this farm's beef enterprise, non-beef enterprise, off farm income, and family income given average, low, and high prices for cattle. Cluster four family income ranged from $90,114.38 to $141,338.00 due to its large herd size, which would affect the prices more substantially than Cluster One farm. The beef enterprise was not able to create profitability in the low revenue scenario. However, it was able to do so if average or high revenues were considered. In all three scenarios, the farm was able to make a profit when considering the beef enterprise, the non-beef enterprise, as well as off farm income.

Table 6.14 Cluster Four Family Income Sensitivity to Price				
Level	**Beef Enterprise**	**Non-Beef Enterprise**	**Off Farm Income**	**Family Income**
Average	$ 4,924.67	$ 76,650.99	$ 32,630.26	$114,205.92
Low	$ (12,283.58)	$ 76,650.99	$ 25,746.96	$ 90,114.38
High	$ 24,340.44	$ 76,650.99	$ 40,396.57	$141,388.00

6.3.3 Cluster Six Farm: Large cow-calf farm[48]

As noted in Section 5.4.1, this study farm did not background any cattle. It did have, however, the largest herd (in the 80th percentile) among the 28 farms in Manitoba Cluster Six. On this farm, there were 145 cows, eight bulls and 17 replacement heifers. The birth weight of the calves was 90 pounds, while the weaning weight was 600 pounds. The calving period was between March and April.

[48] While the average farm introduced in Section 5.4.3 also includes a backgrounding operation in its title, the centroid for this farm did not include this addition. Therefore, the term "backgrounding" was removed from the title.

The linear programming model (as described in Section 5.7.1) determined that only 27 percent of the forage was left unused, while none of the greenfeed oats were needed. As there were no other grains grown on the farm, the non-beef enterprise consisted only of these unused feeds.

6.3.3.1 Land Use

Uniquely, this farm did not report any pastureland. Instead, all of the land reported was devoted to forage production in either alfalfa-brome grass or oat greenfeed, as shown in Table 6.15. This producer also purchased creep feed for the calves, and salt and minerals for the entire herd. The farm sustained its herd on bale grazing throughout the year, including during the warm months of the year when pasture grazing is a general practice in Manitoba. Eighty percent of its forage crop consisted of alfalfa, which is the highest percentage of alfalfa among all other study farms.

Table 6.15 Land Use (Acres) of Cluster Six Farm, Manitoba, 2011

Type of Land Use	**Beef**	**Non-Beef**	**Total**
Feed Oats	-	650.00	650.00
Forage	472.37	177.63	650.00
Total	**472.37**	**827.63**	**1,300.00**

Since all of the greenfeed oats and 27 percent of the forages were deemed not needed for the beef enterprise, 472.37 acres, or 36 percent of the total land area, was allocated to the non-beef enterprise.

6.3.3.2 Farm Assets

As the farm had more than 400 acres in both oats and forage, it was assumed that this farm owned all of its machinery, rather than renting them. However, all costs involved in machinery ownership (which include interest, depreciation, and repair costs) were somewhat mitigated, as the oats crop was not grain, but instead used as a greenfeed. This production process did not necessitate a combine or swather. Instead, it used the same equipment necessary to seed and harvest a forage crop, thereby lowering costs relative to that for oat grain. The resulting costs are reported in Table

6.16. While this farm did not own any pastureland, it was assumed that only one of the fields was fenced.[49]

Table 6.16 Annual Value of Assets, Depreciation and Interest Costs on Cluster Six Farm in Manitoba, 2011			
Assets	**Value**	**Depreciation**	**Interest**
Machinery	$495,500.00	$25,810.00	$17,441.60
Structures	$70,465.48	$3,523.27	$2,480.38
Livestock	$158,657.47	-	$5,584.74

6.3.3.3 Whole Farm Level Costs

The operating costs, which included the feed costs, are noted below in Table 6.17. These costs were created through the growth of oat greenfeed, a forage crop, as well as those incurred while tending to a herd of cattle. As noted previously in Subsection 6.3.3.1, none of the greenfeed oats were needed for this farm's beef enterprise, while 27 percent of the forages were similarly considered as such. This resulted in 73 percent of the acres as a part of the non-beef enterprise. For this reason, a proportionate amount of depreciation and interest costs were allocated for the non-beef enterprise.

6.3.3.4 Beef Enterprise Economics

Costs for the beef enterprise differed between Cluster Six farms and all other farms because this farm had land large enough to necessitate owning all of the equipment and machinery necessary to harvest forage crops. Although this eliminated the need to rent machinery, this cost increased from two sources: (i) machinery repairs were then included in the production of its forages, and (ii) depreciation and interest costs were also higher those from Clusters One and Four farms, due to the ownership of machinery.

As noted in Section 6.3.3.1, this farm did not utilize any pastureland for the beef herd. Instead, it relied solely on bale grazing throughout the year. The cost for purchasing forages is typically higher than tending to native pastureland, as forages required seeding at least every four

[49] Both of the crops, oats and forage, were produced on 650 acres. One of these areas were used to bale graze animals. As they are both the same area, it was assumed unnecessary to determine which crop area was fenced.

to five years, which in turn requires the use of fuel, machinery repairs, and seed, in addition to the land taxes and fencing related costs.

Table 6.17 Annual Beef and Non-beef Enterprise Costs for Cluster Six Farm, Manitoba 2011			
Cost Items[1]	**Beef**	**Non-Beef**	**Total**
Greenfeed Oats	-	$ 32,662.92	$ 32,662.92
Forages	$ 54,988.70	$ 4,231.32	$ 15,483.77
Salt and Minerals	$ 2,620.32	-	$ 2,620.32
Creep Feed	$ 13,200.00	-	$ 13,200.00
Straw	$ 4,860.00	-	$ 4,860.00
Veterinary Medicine and Supplies	$ 1,399.64	-	$ 1,399.64
Breeding Costs	$ 480.00	-	$ 480.00
Utilities	$ 1,870.00	-	$ 1,870.00
Marketing and Transportation	$ 5,616.80	-	$ 5,616.80
Manure Removal	$ 923.00	-	$ 923.00
Miscellaneous	$ 1,133.90	-	$ 1,133.90
Operating Interest	$ 3,065.65	$ 1.299.68	$ 1,412.41
Depreciation	$ 9,141.34	$ 16,688.66	$ 29,333.27
Interest	$ 5,528.57	$ 11,913.03	$ 25,506.73
Total Cost	**$ 116,416.33**	**$ 66,774.60**	**$ 183,190.93**

[1]Forage costs are included in the feed costs for the beef enterprise.

The linear programming model to determine the nutritional requirements for this farm indicated that only the forage and grass was necessary.

The total costs for Cluster Six farm's beef enterprise were $1.14 on a PPS basis. Figure 6.3 shows that feed costs are the largest fraction of the total beef enterprise costs, at 61 percent. Depreciation and interest costs were 11 percent and 12 percent, respectively. The remaining costs were operating costs at 16 percent of total beef enterprise costs.

In order to increase the weaning weights of its calves, or to supplement their nutritional needs, this beef producer supplied its calves with creep feed. This, in addition to the cost of salt and mineral supplements, increased total feed costs of this farm.

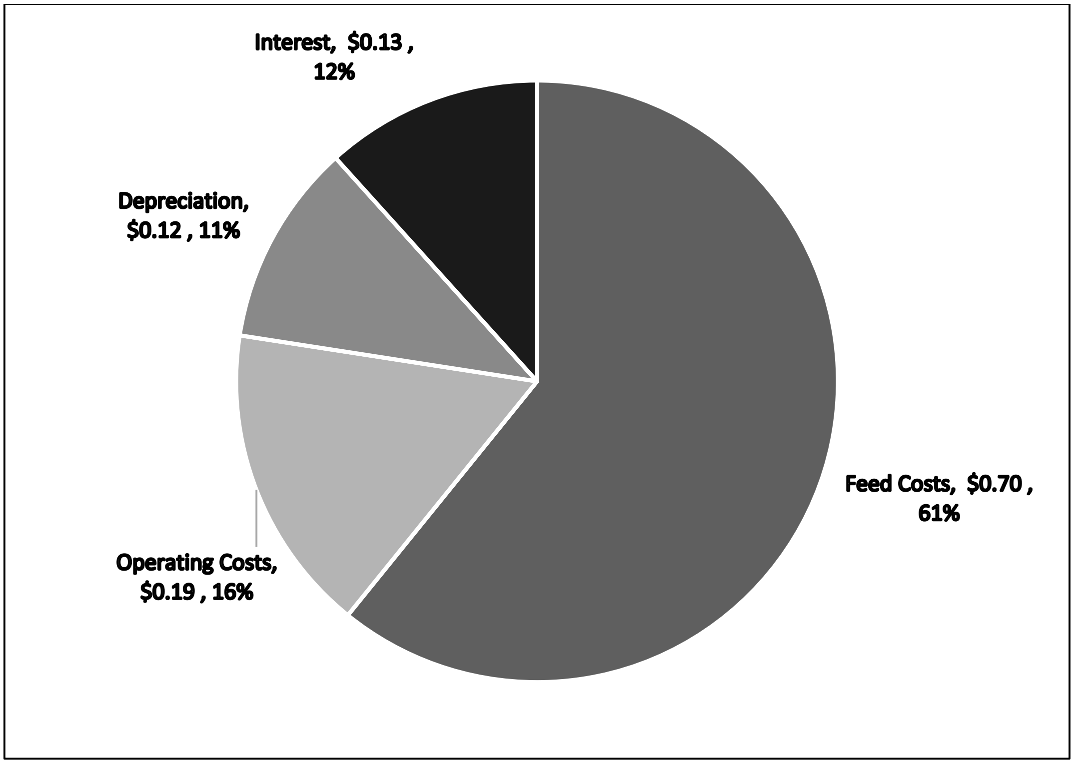


Figure 6.3 Distribution of Cluster Six Farm Annual Beef Enterprise Total Costs on a PPS basis by Major Cost Types, Manitoba, 2011

Revenue from the sale of weaned steers and heifers generated $102,346.59, while the sale of cull cows generated another $14,970.00. Therefore, the total annual revenue generated from the sale of cattle on this farm was $117,316.59, or $1.15 on a PPS basis. However, on account of high cost so beef enterprise, there was a profit of only $900.26 or $0.01 on a PPS basis.

6.3.3.5 Non-Beef Enterprise Economics

Although the response form the producer showed no sales revenue for non-beef enterprise, the linear programming model estimated that 27 percent of the alfalfa was unused, while none of the oat greenfeed was used. Like Cluster One farm, this farm indicated that it did not sell any of its feed. However, it was valued using 2011 market prices for possible future use. Thus, 295.40 tonnes of forages were assumed to be in inventory, valued at $20,677.71. There was also 835.90 tonnes of greenfeed oats stored, valued at $58,512.93. The total revenue for the non-beef enterprise was estimated at $79,190.64.

6.3.3.6 Whole Farm Revenue

As noted in Table 6.18, Cluster Six farm gained more gross revenue through the beef enterprise than through the non-beef enterprise (through the value of stored feed). The non-beef enterprise comprised only of the feed not required (after satisfying nutritional requirements of the herd). Total revenue of the farm at the whole farm level was estimated at $196,507.23 of which 60 percent was contributed by the beef enterprise, while the remaining 40 percent was contributed by the non-beef enterprise

Table 6.18 Cluster Six Farm Annual Gross Revenue, Manitoba, 2011

Source of Revenue	Beef	Non-beef	Total
Oats	-	$ 58,512.93	$ 58,512.93
Forage	-	$ 20,677.71	$ 20,677.71
Cattle	$ 117,316.59	-	$ 117,316.59
Gross Revenue	**$ 117,316.59**	**$79,190.64**	**$ 196,507.23**

6.3.3.7 Family and Whole Farm Income

This farm did not report any income from an outside source. Therefore, no additional revenue inputs and net profitability changes were noted. The beef enterprise was able to create a positive net revenue of $900.26 and the farm as a whole created $13,316.30, as shown in Table 6.19.

Table 6.19 Cluster Six Farm Annual Net Revenue, Manitoba, 2011

Source	Value
Beef Enterprise	$ 900.96
Non-Beef Enterprise	$ 12,416.04
Total Income	$ 13,316.30

6.3.3.8 Sensitivity to price

Sensitivity analysis with respect to beef cattle prices resulted in change in gross revenue for the beef enterprise. Table 6.20 notes the sensitivity of prices for net revenue from weaned calf and cull cow sales. Prices for the cattle in the high scenario were $41,811.92 or 30 percent greater than prices for cattle in the low scenario.

Table 6.20 Cluster Six Farm Annual Gross Revenue Sensitivity to Price			
Scenario	**Calves**	**Cows**	**Total**
Low	$ 86,014.47	$ 12,023.80	$ 98,038.27
Average	$ 102,346.59	$ 14,970.00	$ 117,316.59
High	$ 120,881.56	$ 18,968.63	$ 139,850.19

Regarding the beef enterprise, under low beef cattle prices as these caused in a loss of $18,378.06, or a loss $0.18 on a PPS basis (Table 6.21). Average revenues generated a profit of $900.26 or $0.01 on a PPS basis, as against under high beef prices where profits of $23,433.86 or $0.23 on a PPS basis could be realized.

Table 6.21 Cluster Six Family Income Sensitivity to Price				
Level	**Beef Enterprise**	**Non-Beef Enterprise**	**Off-Farm Income**	**Family Income**
Average	$900.26	$40,997.72	0	$41,897.98
Low	-$18,378.06	$40,997.72	0	$22,619.67
High	$23,433.86	$40,997.72	0	$64,431.58

However, due to the non-beef enterprise, Cluster Six farm showed a positive family income for average, low, and high beef revenues.

6.3.4 Cluster Seven Farm: Crop-beef mixed operation

This centroid farm from the Cluster Seven was the second smallest farm within the Manitoba Cluster seven. It had only 55 cows, three bulls and seven replacement heifers. All other farms in this province's cluster group had more than 175 head of cattle. However, almost all of the other farms in this cluster also had revenue from non-beef sources. This farm was not an exception, as it grew a non-feed grain crop, in addition to its beef enterprise, for sales.

The average birth weight for calves on this farm was 90 lbs. The average weaning weight was 600 lbs. Cows on this farm began calving in February, and finished in March.

6.3.4.1 Land Use

Table 6.22 notes the land area under various uses. The total area of the farm was 1,840 acres. Of this total, 746.9 acres were required for the beef enterprise, while the remaining 703.14 acres were allocated to non-beef enterprises. Cluster Seven farm did not grow, nor did it intend to grow, any feed grain for its animals. Instead, it grew only forages. The linear programming model found that only 63 percent of the forages grown on this farm was needed for the beef enterprise. The forage consisted of 20 percent alfalfa, while the remaining 80 percent was assumed to be brome grass. This forage crop was harvested once during the year.

Table 6.22 Land Use (Acres) of Cluster Seven Farm, Manitoba, 2011

Type of Land Use	Beef	Non-beef	Total
Barley	-	640.0	640.0
Forage	106.9	63.1	170.0
Pasture	640.0	-	640.0
Total	746.9	703.1	1,840.0

Cluster Seven farm also relied on 640 acres of native pastureland, which was broken into three paddocks. All of the pastureland was native, rather than tame.

6.3.4.2 Farm Assets

Table 6.23 shows the depreciation and interest costs, as well as the values of farm assets (machinery, structures, and livestock) on the Cluster Seven farm. Since the land used for meeting the needs of the beef enterprise was not larger than 400 acres, machinery to grow forage, which included a haybine and a baler, was rented rather than owned. On the other hand, there were 640 acres of barley grown under the non-beef enterprise. Therefore, an air seeder, a large 260 HP tractor as well as a smaller 150 HP tractor, and a combine were assumed to be owned by the producer. Since an air seeder and 268 hp tractor is necessary for both operations, the rental of this machinery for the beef enterprise was unnecessary; instead, this machinery was assumed to be owned. As a result, depreciation and interest costs were higher on this farm, but the rental costs for machinery were lower.

Livestock was a comparatively small portion of total capital value on this farm, relative to machinery. The fixed costs of the beef enterprise, such as the structures (which include fencing and cattle handling systems (as described in Section 5.7.2.3)), are necessary for the beef enterprise.

Yet, the cost for structures for the beef enterprise were of a lower value than the fixed assets in the form of machinery required for the non-beef enterprise.

Table 6.23 Annual Value of Assets, Depreciation and Interest Costs on Cluster Seven Farm, Manitoba, 2011			
Assets	**Value**	**Depreciation**	**Interest**
Machinery	$ 609,500.00	$ 31,890.00	$ 21,454.40
Structures	$ 2,578.26	$ 3,662.30	$ 2,578.26
Livestock	$ 60,624.01	-	$ 2,133.97

6.3.4.3 Whole Farm Level Costs

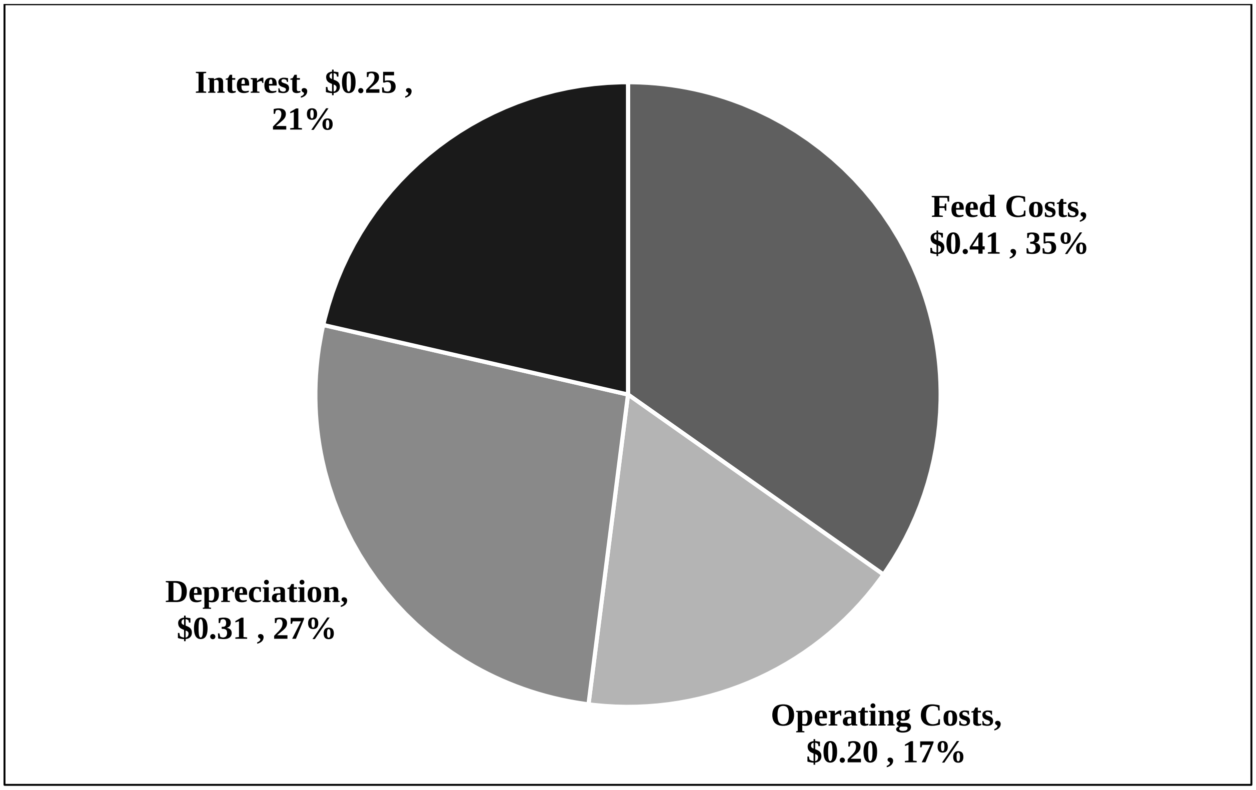
Table 6.24 notes the operating costs of the whole farm. It also includes the cost to grow barley (which is a part of the non-beef enterprise), which increased the operating costs for this farm. Also, as noted in Section 6.3.4.2, this crop was large enough to necessitate the ownership of machinery, rather than utilizing rentals. This decreased rental rates both for the beef and non-beef enterprises. However, it increased depreciation, interest, and machinery repair costs.

Table 6.24 Annual Beef and Non-beef Enterprise Costs for Cluster Seven Farm, Manitoba 2011			
Cost Items[1]	**Beef**	**Non-beef**	**Total**
Barley	-	$ 32,286.77	$ 32,286.77
Forages	$ 11,251.81	$ 3,321.88	$ 14,573.68
Salt and Minerals	$ 1,903.22	-	$ 1,903.22
Pasture	$ 2,784.00	-	$ 2,784.00
Straw	$ 1,860.00	-	$ 1,860.00
Veterinary Medicine and Supplies	$ 844.42	-	$ 844.42
Breeding Costs	$ 180.00	-	$ 180.00
Utilities	$ 715.00	-	$ 715.00
Marketing and Transportation	$ 2,155.40	-	$ 2,155.40
Manure Removal	$ 902.00	-	$ 902.00
Miscellaneous	$ 433.55	-	$ 433.55
Operating Interest	$ 810.63	$1,253.42	$ 2,064.06
Depreciation	$ 12,172.21	$ 23,380.10	$ 35,552.30
Interest	$ 9,819.08	$16,347.55	$ 26,166.62
Total Cost	**$ 85,558.96**	**$ 36,862.07**	**$ 122,421.03**

[1]Forages, oats, and pasture costs are included in the feed costs for the beef enterprise.
Note: Rounding errors change the total from costs PPS from $1.15 to $1.16

6.3.4.4 Beef Enterprise Economics

Figure 6.4 shows the share of feed costs, operating costs, depreciation, and interest for the beef enterprise. Feeds contributed 35 percent to the total cost of the farm. The total costs of the beef enterprise amounted to 1.15 on a PPS basis.



*Rounding errors change the total from costs PPS from $1.15 to $1.16

Figure 6.4 Distribution of Cluster Seven Farm Annual Beef Enterprise Costs on a PPS basis, by Major Cost Types, Manitoba, 2011

The feed costs are the cost to buy the forage, at market price, that has been grown on the farm. The costs incurred for the beef enterprise of Cluster Seven farm were greater than the corresponding revenues. As a result, the beef enterprise showed a net loss of $1,398.97 in 2011, or $0.04 on a PPS basis.

6.3.4.5 Non-Beef Enterprise Economics

Similar to Cluster One and Cluster Six farms, Cluster Seven farm indicated that it did not sell any of its feed. Therefore, all remaining feed was stored as inventory for future use. As seen in Table 6.22, the non-beef enterprise generated higher gross revenue than the beef enterprise. This was due to the presumed sale of barley and some of forages. The linear programming method to determine the necessary amount of feed for the herd indicated that 37 percent of the forage crop is not required to maintain the herd, and thus, could be stored for future use. This equalled 81.68 tonnes of forage in inventory, valued at $5.717.57.

The farm also indicated that it grew grain. As the survey did not ask producers on the type of grain grown, researchers in Manitoba, who determined the levels of GHGs from each farm, assumed that it was barley. There were 782.72 tonnes of barley grown on Cluster Seven farm, which was sold for $132,002.56.

6.3.4.6 Whole Farm Revenue

The above noted sale of barley created 73 percent of the gross revenue on Cluster Seven farm, while the inventory of excess forage added another 3 percent to the revenue (Table 6.25). The remaining gross revenue was generated through sales from the beef enterprise. The sale of weaned steers and heifers provided the farm with $38,268.23 in revenue, while the sale of cull cows provided the farm with $6,164.12 in revenues. This contribution was 24 percent of all gross revenues on this farm.

Table 6.25 Cluster Seven Farm Annual Gross Revenue, Manitoba, 2011

Source of Revenue	Beef	Non-beef	Total
Barley	-	$ 132,002.56	$ 132,002.56
Forage	-	$ 5,717.57	$ 5,717.57
Cattle	$ 44,432.35	-	$ 44,432.35
Gross Revenue	**$ 44,432.35**	**$ 137,720.13**	**$ 182,152.48**

6.3.3.7 Family and Whole Farm Income

Since this farm did not report any off-farm income, the family and the whole farm incomes are identical. As noted in Table 6.26, the beef enterprise provided a net loss for Cluster Seven farm. However, due to its barley production and the inventory built-up from excess forages, the farm was able to make a profit of $59,731 in 2011.

Table 6.26 Cluster Seven Farm Annual Net Revenue, Manitoba, 2011	
Source	**Value**
Beef Enterprise	- $ 1,398.97
Non-beef Enterprise	$ 61,130.41
Total Income	$59,731.45

6.3.4.8 Sensitivity to Price

Table 6.27 notes the range of revenue potential for Cluster Seven's beef enterprise. Beef revenues for this farm ranged by $15,896.17, or 30 percent.

Table6.27 Cluster Seven Farm Annual Gross Revenue Sensitivity to Price, Manitoba, 2011			
	Calves	**Cows**	**Total**
Average	$ 38,268.23	$ 6,164.12	$ 44,432.35
Low	$ 32,159.32	$ 4,950.98	$ 37,110.30
High	$ 45,195.86	$ 7,810.61	$ 53,006.47

Table 6.28 shows the differences in revenue at average, low, and high prices for Manitoba in 2011. Average beef revenues resulted in a loss of $1,398.97 or $0.04 on a PPS basis, while low beef revenues showed a loss of $8,721.02 or $0.22 on a PPS basis in Manitoba in 2011. High beef revenues resulted in a profit of $7,175.15 or $0.18 on a PPS basis. This farm did not use any off farm income to supplement its family income. However, due to its profits in its non-beef enterprise, there was profitability for all levels of beef revenue.

Table 6.28 Cluster Seven Family Income Sensitivity to Price				
Level	**Beef Enterprise**	**Non-Beef Enterprise**	**Off Farm Income**	**Family Income**
Average	-$1,398.97	$61,130.41	0	$59,731.45
Low	-$8,721.01	$61,130.41	0	$52,409.40
High	$7,175.15	$61,130.41	0	$68,305.57

6.4 Greenhouse Gases

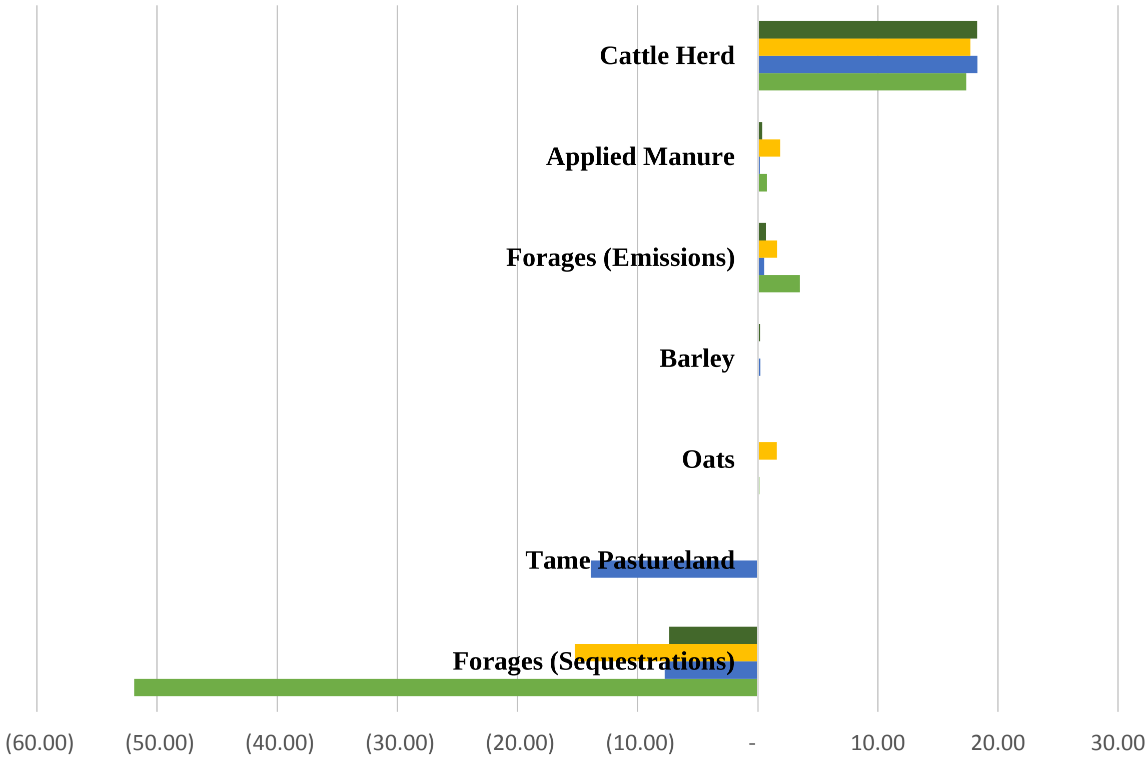
This section presents details of GHG emissions from each of the study farms at two levels - the whole farm and the beef enterprise level. Both total GHG emissions and those on a PPS (per pound sold) basis are included in this discussion. More details on these emissions are presented in Appendix A. It should be noted that these GHG emissions were calculated by Aklilu Alemu from the University of Manitoba. Some modifications were made to these level for fertilizer and herbicide use. While these emissions were initially included in the Holos calculation, each farm indicated that they did not use fertilizer on their perennial or annual crops. The use of herbicides for any crop was also excluded.

As noted earlier, the whole farm includes the beef enterprise, as well as farming activities beyond raising the cow-calf herd. The beef enterprise shows the amount of CH_4 and N_2O emitted. Methane is a product of enteric fermentation by cows, bulls, replacement heifers, and calves, as well to a lesser extent through storage of manure. Applied manure to crop fields or manure storage lead to emissions of N_2O and CO_2Crops such as forages, barley, and oats release CO_2 and N_2O through seeding, harvest, and baling operations, as fuels are required to run machinery. Finally, GHGs were sequestered in the form of CO_2 through the area devoted to perennial crops and tame pastureland.

6.4.1 Whole Farm GHG Emissions

Figure 6.5 shows the GHG emissions and carbon sequestrations from each cluster farm. Cattle are the most significant GHG emitters on each farm, whereas major sources of carbon sequestration are forages and tame pastureland, However, each of these farms grew different areas of forages, while Cluster Four farm was the only farm to use tame pastureland.

Cluster One farm sequestered a significant amount of GHGs through devoting area to perennial crops. As discussed in Section 6.3.1, most of these forages were not needed for the beef enterprise, but instead were kept in inventory for future year uses. Since its GHG emissions from the production of unused oat feed were minimal, the total amount of additional GHG emissions was also minimal. As a result, Cluster One farm sequestered 30.17 lbs CO_2e of GHG on a PPS basis, as noted in Table 6.29. The total amounts of GHG emissions are noted in Tables A.2 to A.5.



	Forages (Sequestrations)	Tame Pastureland	Oats	Barley	Forages (Emissions)	Applied Manure	Cattle Herd
Cluster 7	(7.36)	-	-	0.21	0.68	0.37	18.25
Cluster 6	(15.23)	-	1.59	-	1.60	1.88	17.71
Cluster 4	(7.75)	(13.91)	0.04	0.21	0.54	0.18	18.30
Cluster 1	(51.91)	-	0.16	-	3.49	0.75	17.35

lbs CO_2e of GHG on a PPS basis

Source: Based on data provided by Alemu (2014) for the study farms and proftitability data presented earlier

Figure 6.5 Whole Farm GHG Emissions (lbs. CO_2e) on a PPS basis, Manitoba, 2011

Cluster One farm sequestered a significant amount of GHGs through devoting area to perennial crops. As discussed in Section 6.3.1, most of these forages were not needed for the beef enterprise, but instead were kept in inventory for future year uses. Since its GHG emissions from the production of unused oat feed were minimal, the total amount of additional GHG emissions was also minimal. As a result, Cluster One farm sequestered 30.17 lbs CO_2e of GHG on a PPS basis, as noted in Table 6.29. The total amounts of GHG emissions are noted in Tables A.2 to A.5.

Table 6.29 Total Annual GHG Emissions (lbs of CO_2e on PPS basis) on the Whole Farm and Beef Enterprise, Manitoba, 2011		
Study Farms	**Whole Farm**	**Beef Enterprise**
Cluster One	-30.17	10.51
Cluster Four	-2.38	2.20
Cluster Six	7.54	9.68
Cluster Seven	12.16	14.43

Source: Constructed using GHG data from Alemu (2014)

Cluster Four farm sequestered GHGs through its forage crop production, as well as through some area under tame pasture. It was the only farm to have utilized tame pastureland in this study. This farm did have more replacement heifers than any other farm, and therefore, it had a greater amount of GHG emissions than any other study farm from raising cattle. Among all farms, Cluster four farm emitted the least amount from its crops and sequestered the most from its tame pastureland and forages. As a result, the cumulative effect was that the farm sequestered 3.25 lbs CO_2e of GHG on a PPS basis.

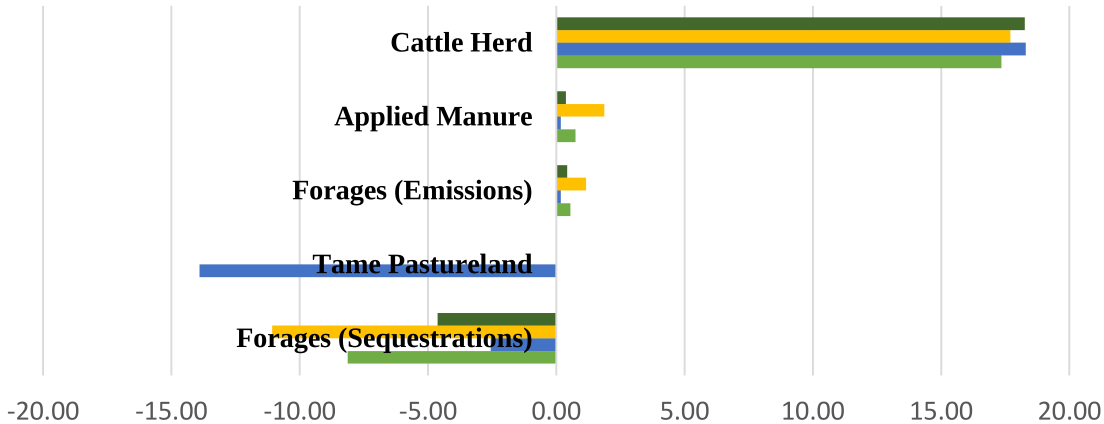
Cluster Six sequestered the second lowest amount of emissions among the four farms. This is in spite of the fact that it had the largest proportion of alfalfa in its forage area. Alfalfa is known to sequester nitrogen in the soil. However, the emission of GHGs from oat production on this farm was higher than other study farms, due to the larger area devoted to it. There was no tame pastureland, or any other pastureland on this farm. As a result, the farm was an overall emitter, at 7.54 lbs CO_2e of GHG on a PPS basis.

Cluster Seven farm generated a total of 12.16 lbs CO_2e of GHG on a PPS basis. Its emissions from barley, forages, and applied manure were less than those from every other study farm, except the Cluster Four farm. It also had the second highest emissions from its cow-calf herd, though the range of such emissions for all four farms was much smaller than that from crops and soils. The largest determining factor regarding its emissions was small forage crop. This farm also sequestered the least emissions from its forage, as it had only 170 acres under forages. As a result, it had the highest GHG emissions among the four farms.

Table 6.25 describes the total GHG emissions from each farm separated for the whole farm and the beef enterprise. The next section describes the differences between the emissions for the beef enterprise and the whole farm separately.

6.4.2 Beef Enterprise GHG Emissions

When examining the beef enterprise of all four study farms, the Holos model indicated that each farm emitted, rather than sequestered, GHGs. Results are shown in Figure 6.6.



	Forages (Sequestrations)	Tame Pastureland	Forages (Emissions)	Applied Manure	Cattle Herd
Cluster 7	-4.63	0.00	0.43	0.37	18.25
Cluster 6	-11.07	0.00	1.17	1.88	17.71
Cluster 4	-2.55	-13.91	0.18	0.18	18.30
Cluster 1	-8.13	0.00	0.55	0.75	17.35

lbs CO2e of GHG on a PPS basis

Source: Based on data provided by Alemu (2014) for study farms and proftitability data presented earlier

Figure 6.6 Beef Enterprise GHG Emissions (lbs CO_2e) per a PPS Basis, Manitoba, 2011

While the amount of emissions within various Cattle Herd sources varies little, by only 0.95 lbs CO_2e on a PPS basis, the amount of emissions within the applied manure and forage crops differ more significantly, by 1.7 lbs CO_2e on a PPS basis and 0.99 lbs CO_2e on a PPS basis, respectively. The variability in GHG emissions through tame pastureland and forage sequestration was estimated to be more significant. Only one farm (Cluster Four farm) had tame pastureland, which created a large discrepancy between this farm and the other study farms that did not employ this practice. The difference between the highest level in sequestration and the lowest level of sequestration was 8.52 lbs CO_2e on a PPS basis, which was greater than the range for other sources of GHG s. Therefore, the farm with the largest levels of GHG emissions through applied manure and forage crops was not the largest GHG emitter through its beef enterprise.

Cluster One farm emitted the least amount of GHGs from its herd, though it also emitted the second largest GHG emissions through its applied manure on land used for feed and forages. Cluster One farm emitted a total of 10.51 lbs CO_2e of GHG on a PPS basis from its beef enterprise. This was the second largest amount of GHGs emitted among the four study farms.

Cluster Four farm sequestered the least amount of GHGs through its forage crop, and emitted the most from its cow-calf herd. The most significant factor with regards to its emissions, however, was its use of tame pastureland. Due to the fact that it had 830 acres in tame pastureland, a feature that no other farm had, its overall emissions through the beef enterprise was only 2.20 lbs CO_2e of GHG on a PPS basis.

Cluster Six emitted the second lowest amount of GHGs, at 9.68 lbs CO_2e of GHG on a PPS basis. It sequestered the greatest amount of GHGs from its forage crop, which had the greatest percentage of alfalfa among the four study farms. However, through its high emissions from manure application and its forage crop, it emitted more through crops and soils than any other farm in this study.

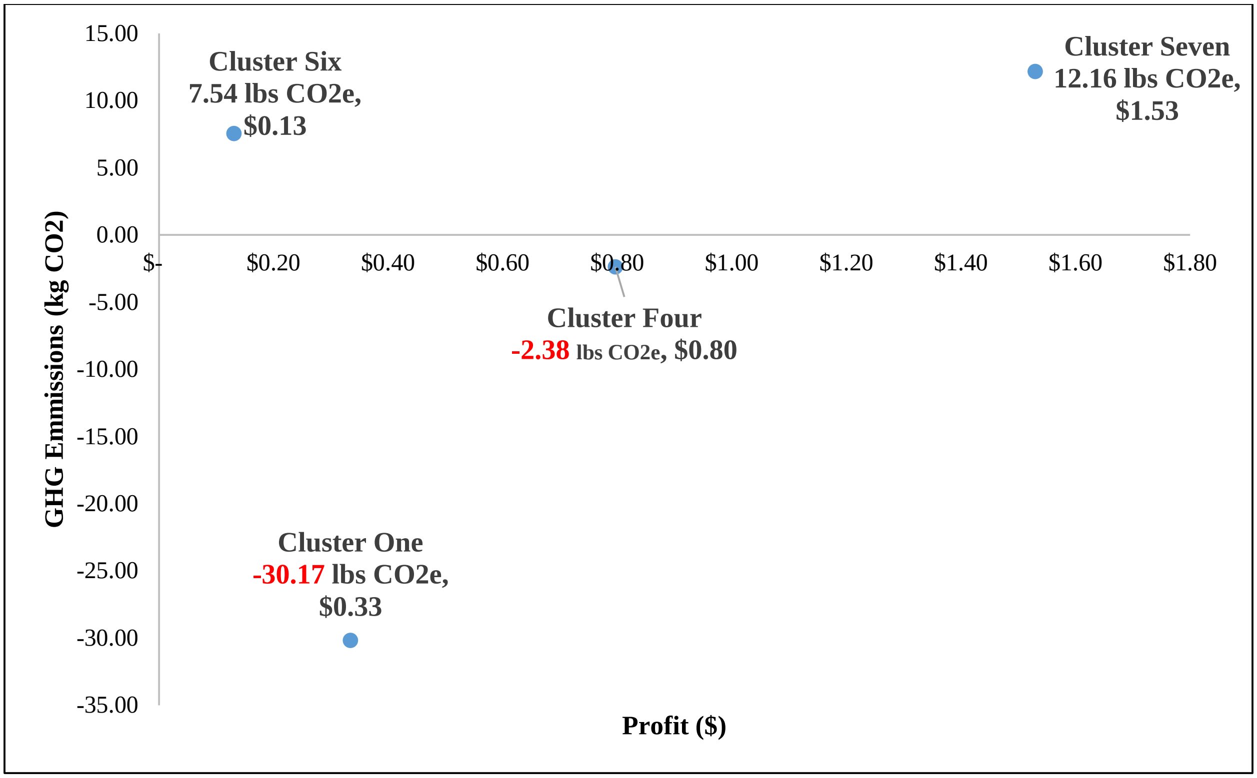
Cluster Seven sequestered the least amount of GHGs through its perennial crop area. It also emitted the second highest amount of GHGs from its herd. As a result, it had the highest emissions from all four farms, at 14.43 lbs CO_2e of GHG on a PPS basis.

6.5 Trade-off Analysis

6.5.1 Whole Farm Level Trade-off Analysis

The analysis of the whole farm notes that all of the study farms were profitable, as shown in Figure 6.7.

Of the four farms, two of them (Cluster One farm and Cluster Four farm), were also able to sequester GHGs. However, Cluster Seven farm, which had the highest level of profitability, was also the farm with the highest level of GHG emissions. Cluster Six farm had the lowest profitability, and the second highest GHG emissions (Figure 6.7).



Source: Constructed using GHG data from Alemu (2014) and proftitability data presented earlier

Figure 6.7 Trade-off Analysis between Whole Farm Profitability and GHG (in CO_2e) Emissions on a PPS basis

Each of the farms grew forage crops, which sequestered GHGs. However, there was a range of costs to grow forages. Variable costs to grow forages on Cluster Seven farm were higher than any other farm, at $36.89 per tonne, while the variable cost to grow forages on Cluster One farm were only $24.98 per tonne. The variable costs to grow forages on Cluster Six farm and Cluster Four farm were lower, at only $14.32 per tonne and $14.86 per tonne, respectively. However, Cluster One grew more feed on a PPS basis than any other farm, as noted in Table 6.30. Therefore, it incurred more costs, compared to Cluster Four and Cluster Six farm, and also grew more than any other farm.

Table 6.30 Forage Grown on Farms on a PPS Basis

Cluster	Forage in tonnes
Cluster One	0.029611125
Cluster Four	0.013879015
Cluster Six	0.010630065
Cluster Seven	0.006208257

All the study farms added to their inventory from the current level of forage production. Cluster One farm and Cluster Four farm grew oats for grain, while Cluster Six farm grew oats and used it as greenfeed, which was all placed into their respective inventory. This increased the revenue noted in Table 6.31. The value of this inventory was based on the 2011 market prices. In 2011, the average price of tame forage was $70 per tonne (Manitoba Agricultural Services Corporation 2011). This price was lower than 2010 and 2012 prices, which both recorded an average price of $75 per tonne. Therefore, the revenues which affect Figure 6.8 below might change if the inventory was kept until they reached higher values, and if the quality of the feed diminished only marginally. If the quality of the feed degraded substantially, monetary value would also decrease, as the value of the feed could decrease between 25 to 40 percent (Lemus 2009).

Table 6.31 Annual Whole Farm Costs, Gross Revenues, and Profit on a PPS Basis

Farms	Costs	Revenues	Profit
Cluster One	$2.82	$3.16	$0.33
Cluster Four	$1.23	$2.73	$0.80
Cluster Six	$1.80	$1.93	$0.13
Cluster Seven	$3.14	$4.66	$1.53

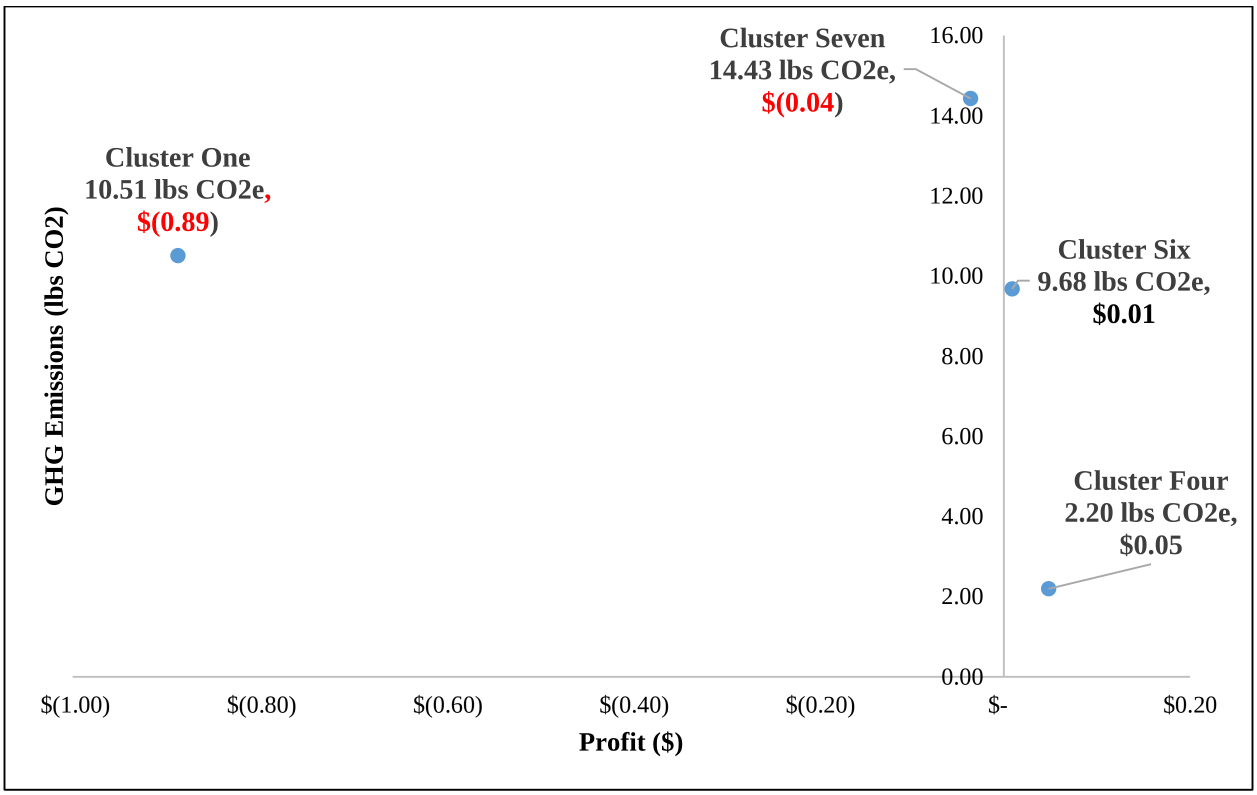
During 2011, Cluster Four farm harvested its forage three times, rather than once. By doing so, it increased fuel costs on a per acre basis, from $5.99 to $17.26. However, it also increased its yield by 2.37 times the amount it would have yielded with only one cut. As noted in subsection 6.3.2.4, while it cost Cluster One farm $24.98 per tonne to produce forages, it cost Cluster Four farm $14.86 per tonne to produce its forages. Cluster One farm sequestered a greater amount of GHGs through its forage production, but Cluster Four farm decreased its overall costs, on a per tonne basis, by using less land to produce more forage.

The farms with the greatest revenues were not necessarily the farms with the greatest overall profitability. As noted in Table 6.27, high costs also reflected on profitability. Cluster One had the second highest revenues, though it also maintained the second highest cost. Cluster Four farm, however, had only 59 percent of the revenues that Cluster Seven maintained, yet only 39 percent of Cluster Seven's costs.

The mixed farms, from Clusters Four and Seven, generated 16 percent and 72 percent of their gross revenue respectively from the sale of barley. The amount of GHG emissions from the production was minimal, at only 1 percent of their total emissions for both farms. Therefore, a large increase in profits on these farms coincided with low GHG emissions due to the growth of barley production.

6.5.2 Beef Enterprise Level Trade-off Analysis

As noted in Figure 6.8, the beef enterprise with a lowest level of GHGs (Cluster Four farm) also had the second highest level of profits. Cluster Six farm had the highest level of profits from its beef enterprise, and the second lowest level of GHG emissions (Figure 6.8). Cluster Seven farm had the highest level of GHG emissions, and had negative net revenue. Cluster One farm lost the most money from its beef enterprise, and had the second highest level of GHG emissions.



Source: Constructed using GHG data from Alemu (2014)

Figure 6.8 Trade-off Analysis between Beef Enterprise Profitability and Beef Enterprise GHG Emissions on a PPS basis

In order to visualize the differences among the farms, Table 6.32 shows the costs and revenues under average prices for the beef enterprise. As noted in Section 6.5.2 and in Table 6.27, high levels of revenue do not necessarily coincide with higher levels of profitability. Instead, Cluster Four farm had the lowest revenues among all four farms, and generated the second highest profitability, on a PPS basis.

Table 6.32 Beef Enterprise Annual Costs, Gross Revenues, and Profit on a PPS Basis			
Farm	**Costs**	**Revenues**	**Profit**
Cluster One	$2.08	$1.19	- $ 0.89
Cluster Four	$0.95	$1.00	$ 0.05
Cluster Six	$1.14	$1.15	$ 0.01
Cluster Seven	$1.17	$1.14	$ 0.04

Cluster One farm recorded one of the lowest revenues relative to the other three farms. This was due to the low weaning weight of the calves, at an average of only 500 pounds. If the average weight were to increase to 600 pounds, the revenue for the beef enterprise would have increased by $0.18 on a PPS basis. However, even with a higher weaning weight, this farm still would have recorded a loss due to its high level of costs.

Cluster Six and Cluster Seven farms had a weaning weight of 600 pounds. Cluster Four farm had a weaning weight of 650 pounds for its calves, which provided the largest level of profit. While the average revenue generated by one 600-pound steer on Cluster Six or Cluster Seven farm was $855.93, the average revenue generated by one 650-pound steer on Cluster Four farm was $891.15.

Some methods to increase weaning weights were unsuccessful. Cluster Six farm used creep feed in order to increase the size of its weaned calves. It is difficult to determine what weight these calves would otherwise have been without the use of creep feed. However, the use of feed was too expensive to compensate for a low weaning weight. If the presumption of an average weight of 550 pounds for weaned calves is made, additional revenue of only $5,334.92 would have been generated. If the use of creep feed had been able to assist calves to reach a weaning weight of 650 pounds, then the producer would have made an additional revenue of $10,089.12 in 2011. However, the cost of the creep feed was $13,200.00. Therefore, the weaning weight of these calves were not large enough to compensate for the high cost of creep feed.

The differences in the revenue are also explained by the number of cull cows in each herd. While Cluster Four did make more profit from its weaned calves, it also had a large percentage of cull cows in its herd. This was due to the assumption that the herd was not growing in size, but instead all replacement heifers were actually replacing older cows. The average revenue from a D1 or D2 cow was $937.90, while the revenue from a 650 pound heifer was $805.22. Therefore, in 2011, cull cattle that were replaced by new heifers generated more income for the Cluster Four farm. However, as cull cows are larger than weaned calves, it generated less revenue on a PPS basis. As such, Cluster Four farm generated the least revenue on a PPS basis.

Costs on each of the study farms were affected by a variety of different factors, including depreciation and interest values, the use of land, and repair costs. The low weaning weight, as well as small herd size, affected Cluster One farm with respect to its depreciation and interest costs. Though it did not own any equipment aside from a stock trailer and truck (for the purpose of transporting cattle), as well as miscellaneous equipment, its level of costs for these two items was greater than that on all other farms, including those from Cluster Six and Cluster Seven, where all of the equipment was owned. Cluster One farm was assumed to have the same amount of structures as other farms, though it had a small herd, because the equipment necessary (a watering system, a water source, etc.) is necessary in a small, medium, and large herd. Therefore, depreciation costs for structures and water systems on this farm were $0.21 on a PPS basis. In comparison, depreciation for structures and watering systems were estimated to be only $0.02 on a PPS basis on both Cluster Four farm and on Cluster Six farm, but $0.09 per PPS on Cluster Seven farm. Therefore, as herd size grew, effect of economies of scale became more apparent. In other words, as a farm becomes larger, greater efficiencies can be achieved through a better use of machinery and equipment.

The Cluster Six farm did not have any pastureland. Pastureland was a more affordable option for the herd on the other cluster farms, which were only $0.07 on a PPS basis on Cluster Seven farm, and $0.04 on a PPS basis on Cluster One farm and $0.14 on a PPS basis on Cluster Four farm, as noted in Appendix B (Table B.1). Cluster Six farm increased its costs by $0.23 compared to the farm with the next highest feed costs, Cluster Four farm. Its total forage costs were $0.54 on a PPS basis, which was the highest forage costs among the four study farms.

Cluster Four farm used tame pastureland in addition to native pastureland, which sequestered 6.31 lbs CO_2e on a PPS basis, and significantly lowered its overall level of GHG emissions from its beef enterprise. However, there was a cost associated with this production technique. Seeding pastureland increased the cost from $4.35 per acre to $15.70 per acre. Its pastureland cost on a PPS basis was $0.14, which was twice the cost on Cluster Seven farm, or 3.5 times higher than Cluster One farm. As a result, the cost of feeding the herd was the second highest, at $0.47 on a PPS basis.

6.6 Summary

This chapter examined four study farms' costs and revenues, and resulting profitability. It also examined GHG emissions and carbon sequestrations. To make results comparable, these values were translated in terms of on a per pound sold basis.

Cluster One farm and Cluster Four farm were able to achieve profitability and sequester GHGs for the beef enterprise. Cluster Four farm, however, created $0.47 more profit, on a PPS basis, than Cluster One farm. Its profitability was due to its larger weaning weight, while its use of tame pastureland lowered GHGs. Farms that were less successful had no tame pastureland, had smaller weaning weights, and machinery and building not commensurate with the size of their operation, resulting in large depreciation and interest costs. Due to the high amounts of CH_4 and N_2O emitted from beef cattle through enteric fermentation or manure, none of the beef enterprises encapsulated by each study farm were able to sequester GHG emissions. With regards to whole farm income, Cluster Four farm was able to gain the most profitability, at $97,890.79 due to its off-farm income, as well as its grain production and successful beef enterprise.

CHAPTER 7 SUMMARY AND CONCLUSION

7.1 Introduction

Canada is the 12th largest beef producer in the world (Cook 2015c). Much of this production is located in Western Canada. Within the region, Manitoba has the third largest beef herd in Canada, with over 1.2 million head of cattle (Canada Beef, 2013). Most of the beef operations in the province (77 percent) are cow-calf operations (Statistics Canada 2015e). The calves are sold to producers within Canada, and also to producers in the United States (Statistics Canada 2012b). Due to the large amount of trade with the United States, Canadian beef producers depend on that country's beef market (Matthews et al. 1999). However, producers in either of these jurisdictions have not witnessed secure, reliable profit margins over the past 15 years (Agriculture and Agri-Food Canada 2008). Most of the income increases for these farms have been as a result of off-farm income, rather than through an increase in revenue from their beef enterprises (Statistics Canada 2014c).

The production of beef and climate conditions are interactive. Agricultural GHG emissions from Canada have increased by 9 Mt CO_2e since 1990 (Environment Canada 2013b), amounting up to 8 percent of Canada's total GHG emissions. Approximately 40 percent of these emissions originate from cattle and sheep herds (Agriculture and Agri-Food Canada 2011b). The percentage of Manitoba's agricultural GHG contribution was higher than that for Canada, at 31 percent of total emissions in 2013 (Manitoba Eco-Network 2014c).

The Canadian government has signalled that carbon emission reduction targets are a priority through its participation in the Copenhagen Accord, and more recently through the Paris Climate Conference. As such, the government had promised to reduce its 2020 emissions by 17 percent from the 2005 levels (Government of Canada 2013). In order to reach these emissions targets, reductions in all major sources of emissions in each sector of the economy has been considered in national plans (Government of Canada 2007).

As GHG emissions from beef cattle production are a significant segment of the agricultural sector, it has been included in Canada's emission reduction strategy. However, as profit is, at times, elusive in the beef industry, increasing costs in order to meet climate change targets might cause resistance to change from the beef cattle industry. Manitoba beef producers have indicated that they are willing to be a part of the Manitoba Government's initiative to address environmental concerns within their Ecological Goods and Services Program. However, they insist that such a program should include carbon sinks that mitigate climate change (Manitoba Beef Producers 2011). The organization also notes that the program should be income neutral, and involve beef producers (Manitoba Beef Producers 2011).

7.2 Summary

Comparison of profitability of beef enterprise and its GHG emissions in Manitoba has not been studied and therefore, requires a fresh investigation. With this in mind, the objective of the study was to analyze profitability on four farms in Manitoba, data for which were obtained from a survey of Canadian beef farms in 2012. These data pertained to feed production, growth and feeding practices, manure handling, and herd related questions. Principle component analysis and cluster analysis were used to classify them into eight clusters based on their common beef farm attributes.

Although all Canadian farms were disaggregated into eight clusters, only four of them were usable for Manitoba. A single farm from each of the four clusters was selected for study. These farms in most cases were centroid farms. Cluster One farm had the smallest herd, with only 26 cows. It also used the least amount of land to grow feed for its herd. Cluster Four farm diversified its operations as it sold a portion of its feed off-farm, and also grew a crop not used for the production of beef cattle. It had 120 cows, and had the largest weaning weight at 650 pounds. It was the only farm to have used tame pastureland, in addition to native pastureland. Cluster Six farm was a large cow-calf operation, with 145 cows. Unlike any of the other farms studied, it did not have any pastureland. Cluster Seven centroid farm had only 55 cows, but achieved diversification through 640 acres of grain production not used for the beef enterprise.

The costs, revenues, and ultimate profitability of each cluster farm was based on their herd qualities, the type of crops grown, and their manure storage and/or application. Each cluster farm was evaluated as a whole farm, which included revenue from the beef enterprise, as well as from non-beef enterprise. The latter category was a result of either production intended for sales or production was higher than that needed by the beef enterprise. Cost of beef enterprise included costs related to production of feed for the herd, operational costs including veterinary services, transportation, and utilities, as well as depreciation and interest costs on machinery and structures. The beef enterprise within each whole farm was also evaluated separately by including only revenue and costs associated with the beef herd (weaned calves and cull cows). The cost of feed was determined at market prices, rather than at the producer's cost to produce the feed on-farm.

GHG emissions were calculated for each farm using the Holos program, which was developed by Agriculture and Agri-Food Canada. Researchers from the University of Manitoba input information on each farm into the Holos program based on the information gathered through the 2012 survey.

Subsequently, profitability from each farm and their corresponding GHG emissions or sequestrations were evaluated. To relate these two terms, the total amounts from each farm were divided by the total live weight of cattle sold by the farm. This further facilitated trade-off analysis between profits and GHG emissions. This became the basis for identify a farm with high profitability and lower GHG emissions.

7.3 Conclusions

Concerning the whole farm, two of the four farms were able to generate profits while also sequestering GHGs. Cluster One farm sequestered 30.18 lbs CO_2e on a PPS basis, while also generating a net return of $0.33 on a PPS basis. Cluster Four farm sequestered less GHGs, at 2.38 lbs CO_2e on a PPS basis, but showed greater profitability, at $0.80 on a PPS basis. Cluster Seven farm created the most profits, $1.53 on a PPS basis, while also emitting the greatest amount of GHGs, 12.16 lbs CO_2e on a PPS basis. Higher profitability on Cluster Seven farm was due to its sale of barley, while Cluster Four farm was also able to increase its profitability due to sales of barley as well, though to a lesser degree. Regarding the beef enterprise on each farm, Cluster Four farm was the most successful farm for both profitability and GHGs. It emitted the least amount of GHGs, 2.20 lbs CO_2e on a PPS basis, while reaching a profit of $0.05 on a PPS basis. Cluster Six farm created the second largest profit, $0.01 on a PPS basis, and the second lowest amount of GHGs, 9.68 lbs CO_2e on a PPS basis. Cluster Seven farm emitted the most GHGs on its farm, 14.43 lbs CO_2e on a PPS basis, and lost $0.04 on a PPS basis. Cluster One created the greatest economic loss, $0.89 on a PPS basis, and emitted the second greatest amount of GHGs, 10.51 lbs CO_2e on a PPS basis.

Profitability and GHG emissions were affected by each farm's size, the weaning weight of its calves, the efficiency with which it produced feed, and each farm's crop choices. Cluster One farm's herd was the smallest among the four farms, and also had the lowest weaning weight (500 lbs). As a result, it had the lowest amount of live weight cattle sold. However, its structures, fencing, and watering systems required costs similar to the other cluster farms. Thus, on a PPS basis, this farm had a higher cost. Although the whole farm recorded the greatest level of sequestrations at the whole farm level among the four study farms, the cost of doing so was prohibitive.

Cluster Four farm had the largest weaning weight, (650 lbs) among the four study farms. It also had the second largest herd, which allowed the farm to utilize the same amount of structures and watering systems that every other farm required, with a greater amount of live weight sold. Cluster Four farm sequestered GHGs through the use of tame pastureland, which resulted in additional cost of $11.35 per acre. While this did increase the cost of its pastureland, it was still a lower cost option than purchasing forages. This farm also harvested its forage crop three times throughout the year, which resulted in 2.37 times more forage than it would have with only one cut. Therefore, the farm was able to reduce its overall forage costs, and create more profitability at the whole farm level. Cluster Four farm also grew 170 acres of barley, which generated 16 percent of its gross revenue for the whole farm.

Cluster Six farm had the largest herd, with a weaning weight of 600 lbs. As a result, there were more cattle to utilize the same structures and water systems than any other farm. This resulted in decreased costs of interest and depreciation on a PPS basis. This farm used creep feed, which increased its feeding costs by $0.13 on a PPS basis. Its forage costs, with respect to its whole farm costs, were the most affordable among the four farms, as a tonne of forage cost only $14.32 to produce.

Cluster Seven farm had the second smallest beef herd, and therefore had a lower amount of live weight cattle sold. As a result, it had the second highest interest and depreciation costs, after Cluster One farm. It also grew less than half the amount of forages than Cluster One farm, but had a herd almost twice as large. Emissions from Cluster Seven farm mostly emanated from the beef herd, rather than its non-beef enterprise. The farm grew the largest amount of barley, which was grown primarily for market sales. This sale increased the farm's gross revenue by 73 percent. Therefore, profitability on this farm came from its non-beef enterprise, while its high GHG emissions came from its beef enterprise.

Profitability and low GHG emissions are possible on Manitoba beef farms. To do so, producers should attend to several management practices on their farms:

1) Increase weaning weights, as there are several benefits: (i) it decreases the amount of GHGs emitted on a PPS basis; (ii) it also decreases the costs on a PPS basis; and (iii) it increases the revenue generated from a calf.
2) Increase the size of herd, as it decreases average fixed cost (depreciation and interest costs).
3) Invest in tame pastureland, when possible, in order to cost-effectively sequester GHGs.
4) Use several cuttings of forage in the warm season, in order to decrease interest and depreciation costs to produce feed, while also increasing the amount of yield per acre of land.

7.4 Limitations and Further Research

Although this study analyzed the four farms using the best set of data available, many assumptions needed to be made. Further research on these aspects of the methodology would benefit development of beef industry in Manitoba.

The quality of feed was assumed to be the same among the four farms. The pastureland was also assumed to have the same carrying capacity. As noted in Section 5.11, the weaning weight of the calves might indicate the quality of the feed and pastureland. However, the weaning weight might also be a result of genetics within the herd. Even though the survey asked producers about the nutritional content of the feed grown on their farms, none of the respondents in this study provided an answer to this question. Determining the precise nutritional content of each feed on the farm would create a more accurate linear programming system to understand the precise amount of feed necessary.

The development of the survey, which included members of the scientific community who were well verse in herd management, did not include an economist. As a result, specific details regarding the costs and revenues were not included. It also excluded whether replacement heifers were used to grow their herds, or solely to replace cull cows. In order to provide greater quality of these results, and to understand more precise management practices, financial and management aspects need to be incorporated.

The levels of uncertainty within the Holos Model ranges between 20 percent for CH_4, and 60 percent for N_2O. However, the Holos Model will continue to improve through continued research, as shown by an annual workshop focused on this goal (Amiro 2015). Therefore, further evaluations of GHG emissions and sequestrations and their comparison profitability will on one side reduce the degree of uncertainty in the GHG estimates, and on the side provide potential solutions to make Manitoba beef industry sustainable.

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APPENDIX A: FURTHER DETAILS ON STUDY METHODOLOGY

Table A.1 Total Live Weight Sold, Manitoba, 2011				
	Cluster One	**Cluster Four**	**Cluster Six**	**Cluster Seven**
# of Steers	13	60	72.5	27.5
Steer Weight/Animal	500 lbs.	650 lbs.	600 lbs.	600 lbs.
# of Heifers	10	30	55.5	20.5
Heifer Weight/Animal	500 lbs.	650 lbs.	600 lbs.	600 lbs.
# of Cull Cows	3	30	17	7
Cull Cow Weight/Animal	1,464 lbs.	1,464 lbs.	1,464 lbs.	1,464 lbs.
Total Live weight	**15,892 lbs.**	**102,420 lbs.**	**101,688 lbs.**	**39,048 lbs.**

Table A.2 Cluster 1 Study Farm Annual GHG Emissions in lbs, Manitoba, 2011

Land Use Change	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Tillage	---	---	---	---	---	0	**0**
Fallow	---	---	---	---	---	0	**0**
Forage	---	---	---	---	---	-374,221	**-374,221**[1]
Seeded / Tame Pastureland	---	---	---	---	---	0	**0**
Land Use Change Sub Totals	---	---	---	---	---	-374,221	**-374,221**
Crops/soils	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Oats	---	---	368	66	701	---	**1,134**[2]
Annual Crop 2	---	---	0	0	0	---	**0**
Forage - mixed	---	---	7,376	1,315	16,468	---	**25,158**
Perennial Crop 2	---	---	0	0	0	---	**0**
Fallow Areas	---	---	0	---	0	---	**0**
Grassland Seeded 1	---	---	0	0	0	---	**0**
Land Applied Manure N	---	---	4,020	1,181	172	---	**5,372**
Mineralized N	---	---	0	0	---	---	**0**
Crops/Soils Sub Totals	---	---	11,763	2,561	17,341	---	**31,665**
Beef	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Cow / Calf - Cows	84,095	2,922	13,471	4,934	0	---	**105,423**
Cow / Calf - Calves	4,000	120	1,702	458	0	---	**6,280**
Stockers and Grassers / Steers	0	0	0	0	0	---	**0**
Stockers and Grassers / Heifers	7,128	246	1,173	433	0	---	**8,980**
Backgrounding Group 1 / Steers	0	0	0	0	0	---	**0**
Finishers Group 1 / Steers	0	0	0	0	0	---	**0**
Bulls	3,435	123	581	224	0	---	**4,363**
Beef Sub Totals	98,659	3,412	16,927	6,049	0	---	**125,046**
Totals	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
	98,659	**3,412**	**28,690**	**8,610**	**17,341**	**-374,221**	**-217,510**
				Uncertainty		+/-	+/- **< 40%**

Rounding in some areas affects total estimates.

[1] Negative results denote GHG sequestrations

[2] Positive results denote GHG emissions

Table A.3 Cluster 4 Study Farm Annual GHG Emissions in lbs, Manitoba, 2011

Land Use Change	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Tillage	---	---	---	---	---	0	**0**
Fallow	---	---	---	---	---	0	**0**
Forage	---	---	---	---	---	-360,069	**-360,069**
Seeded / Tame Pastureland	---	---	---	---	---	-646,000	**-646,000**
Land Use Change Sub Totals	---	---	---	---	---	-1,006,068	**-1,006,068**
Crops/soils	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Oats	---	---	484	92	1,507	---	**2,083**
Barley	---	---	2804	530	6,577	---	**9,911**
Forage - mixed	---	---	6,172	1,167	17,943	---	**25,282**
Perennial Crop 2	---	---	0	0	0	---	**0**
Fallow Areas	---	---	0	---	0	---	**0**
Grassland Seeded 1	---	---	0	0	0	---	**0**
Land Applied Manure N	---	---	6,049	2,053	337	---	**8,440**
Mineralized N	---	---	0	0	---	---	**0**
Crops/Soils Sub Totals	---	---	15,509	3,842	26,364	---	**45,715**
Beef	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Cow / Calf - Cows	407,506	7,878	220,097	21,232	0	---	**656,713**
Cow / Calf - Calves	24,259	482	18,819	2,208	0	---	**45,768**
Stockers and Grassers / Steers	0	0	0	0	0	---	**0**
Stockers and Grassers / Heifers	68,978	1,305	38,270	3,812	0	---	**112,365**
Backgrounding Group 1 / Steers	0	0	0	0	0	---	**0**
Finishers Group 1 / Steers	0	0	0	0	0	---	**0**
Bulls	17,175	269	16,554	1,101	0	---	**35,100**
Beef Sub Totals	517,918	9,934	293,740	28,354	0	---	**849,946**
Totals	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
	517,918	**9,934**	**309,250**	**32,196**	**26,364**	**-1006068**	**-110,407**
				Uncertainty		+/-	**+/- < 40%**

Table A.4 Cluster 6 Study Farm Annual GHG Emissions in lbs, Manitoba, 2011							
Land Use Change	Enteric CH_4 (CO_2e)	Manure CH_4 (CO_2e)	Direct N_2O (CO_2e)	Indirect N_2O (CO_2e)	Energy CO_2 (CO_2e)	CO_2 (CO_2e)	Sub-total (CO_2e)
Tillage	---	---	---	---	---	0	**0**
Fallow	---	---	---	---	---	0	**0**
Forage	---	---	---	---	---	-702,625	**-702,625**
Seeded / Tame Pastureland	---	---	---	---	---	0	**0**
Land Use Change Sub Totals	---	---	---	---	---	-702,625	**-702,625**
Crops/soils	Enteric CH_4 (CO_2e)	Manure CH_4 (CO_2e)	Direct N_2O (CO_2e)	Indirect N_2O (CO_2e)	Energy CO_2 (CO_2e)	CO_2 (CO_2e)	Sub-total (CO_2e)
Oats	---	---	16,319	2,346	54,658	---	**73,323**
Annual Crop 2	---	---	0	0	0	---	**0**
Forage - mixed	---	---	17,095	2,457	54,414	---	**73,966**
Perennial Crop 2	---	---	0	0	0	---	**0**
Fallow Areas	---	---	0	---	0	---	**0**
Grassland Seeded 1	---	---	0	0	0	---	**0**
Land Applied Manure N	---	---	67,796	16,374	2,457	---	**86,627**
Mineralized N	---	---	0	0	---	---	**0**
Crops/Soils Sub Totals	---	---	101,210	21,176	111,529	---	**233,915**
Beef	Enteric CH_4 (CO_2e)	Manure CH_4 (CO_2e)	Direct N_2O (CO_2e)	Indirect N_2O (CO_2e)	Energy CO_2 (CO_2e)	CO_2 (CO_2e)	Sub-total (CO_2e)
Cow / Calf - Cows	44,2547	147,401	66,637	19,991	0	---	**676,577**
Cow / Calf - Calves	30,796	9,528	8,045	2,414	0	---	**50,783**
Stockers and Grassers / Steers	0	0	0	0	0	---	**0**
Stockers and Grassers / Heifers	34,466	11,244	4,449	1,335	0	---	**51,495**
Backgrounding Group 1 / Steers	0	0	0	0	0	---	**0**
Finishers Group 1 / Steers	0	0	0	0	0	---	**0**
Bulls	24,572	8,811	3,390	1,017	0	---	**37,790**
Beef Sub Totals	532,381	176,985	82,521	24,756	0	---	**816,644**
Totals	Enteric CH_4 (CO_2e)	Manure CH_4 (CO_2e)	Direct N_2O (CO_2e)	Indirect N_2O (CO_2e)	Energy CO_2 (CO_2e)	CO_2 (CO_2e)	Sub-total (CO_2e)
	532,381	**176,985**	**183,731**	**45,933**	**111,529**	**-702,625**	**347,934**
				Uncertainty		+/-	**+/- < 40%**

Table A.5 Cluster 7 Study Farm Annual GHG Emissions in lbs, Manitoba, 2011							
Land Use Change	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Tillage	---	---	---	---	---	0	**0**
Fallow	---	---	---	---	---	0	**0**
Forage	---	---	---	---	---	-130,439	**-130,439**
Seeded / Tame Pastureland	---	---	---	---	---	0	**0**
Land Use Change Sub Totals	---	---	---	---	---	-130,439	**-130,439**
Crops/soils	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Barley	---	---	29,392	5,530	80,361	---	**115,283**
Annual Crop 2	---	---	0	0	0	---	**0**
Forage - mixed	---	---	3,058	575	8,480	---	**12,113**
Perennial Crop 2	---	---	0	0	0	---	**0**
Fallow Areas	---	---	0	---	0	---	**0**
Grassland Seeded 1	---	---	0	0	0	---	**0**
Land Applied Manure N	---	---	4,762	1,579	253	---	**6,593**
Mineralized N	---	---	0	0	---	---	**0**
Crops/Soils Sub Totals	---	---	37,211	7,684	89,094	---	**133,989**
Beef	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
Cow / Calf - Cows	188,176	21,937	47,278	8,766	0	---	**266,156**
Cow / Calf - Calves	10,456	1,194	4,851	897	0	---	**17,397**
Stockers and Grassers / Steers	0	0	0	0	0	---	**0**
Stockers and Grassers / Heifers	16,117	3,359	3,626	758	0	---	**23,859**
Backgrounding Group 1 / Steers	0	0	0	0	0	---	**0**
Finishers Group 1 / Steers	0	0	0	0	0	---	**0**
Bulls	10,469	2,366	2,536	543	0	---	**15,914**
Beef Sub Totals	225,217	28,855	58,291	10,964	0	---	**323,326**
Totals	Enteric CH4 (CO2e)	Manure CH4 (CO2e)	Direct N2O (CO2e)	Indirect N2O (CO2e)	Energy CO2 (CO2e)	CO2 (CO2e)	Sub-total (CO2e)
	225,217	**28,855**	**95,502**	**18,647**	**89,094**	**-130439**	**326,876**
				Uncertainty		+/-	**+/- < 40%**

Table A.6 Sales and Weighted Average Prices per 100 lbs for Cows and Weaned Calves in Manitoba, 2011			
Cows	Average	Low	High
D1 and D2 Grades	$ 64.24	$ 52.00	$ 81.00
D3 Grade	$ 57.00	$ 45.00	$ 73.00
Weaned Steers			
-400 lbs	$168.82	$ 136.00	$ 213.00
401-500 lbs	$159.26	$ 130.00	$ 195.00
501-600 lbs	$148.21	$ 124.00	$ 177.00
601-700 lbs	$137.10	$ 115.00	$ 159.00
701-800 lbs	$127.78	$ 110.00	$ 148.00
801-900 lbs	$119.05	$ 98.00	$ 136.00
901+ lbs	$111.93	$ 90.00	$ 126.00
Weaned Heifers			
301-400 lbs	$146.73	$ 115.00	$ 185.00
401-500 lbs	$139.22	$ 110.00	$ 175.00
501-600 lbs	$130.74	$ 110.00	$ 157.00
601-700 lbs	$123.88	$ 105.00	$ 145.00
701-800 lbs	$116.59	$ 100.00	$ 133.00
801-900 lbs	$110.05	$ 92.00	$ 126.00

APPENDIX B: FURTHER DETAILS ON STUDY RESULTS

Table B.1 Whole Farm Annual Costs Per Pound[1], on Study Farms, Manitoba, 2011								
	Cluster One		Cluster Four		Cluster Six		Cluster Seven	
	Beef	**Non-Beef**	**Beef**	**Non--Beef**	**Beef**	**Non-Beef**	**Beef**	**Non-Beef**
Oats		$0.09		$0.02		$0.32		
Forage	$0.32	$0.62	$0.32	$0.14	$0.54	$0.04	$0.29	$0.09
Salt and Minerals			$0.02		$0.03		$0.05	
Pasture	$0.04		$0.14				$0.07	
Additional Feed			$0.00		$0.13			
Feed Costs	**$0.37**	**$0.72**	**$0.47**	**$0.16**	**$0.70**	**$0.36**	**$0.41**	**$0.09**
Straw	$0.05		$0.04		$0.05		$0.05	
Vet Services	$0.02		$0.01		$0.01		$0.02	
Breeding Costs	$0.00		$0.00		$0.00		$0.00	
Utilities	$0.02		$0.02		$0.02		$0.02	
Marketing and Transportation	$0.06		$0.05		$0.06		$0.06	
Manure Removal	$0.06		$0.01		$0.01		$0.02	
Miscellaneous	$0.01		$0.01		$0.01		$0.01	
Non Feed Grain				$0.11				$0.83
Operating Interest	$0.02	$0.03	$0.02	$0.01	$0.03	$0.36	$0.02	$0.03
Other Operating Cost	**$0.25**	**$0.03**	**$0.17**	**$0.12**	**$0.19**	**$0.36**	**$0.20**	**$0.86**
Buildings	$0.21		$0.03		$0.03		$0.09	
Machinery and Equipment	$0.61		$0.11		$0.25		$0.22	
Depreciation	**$0.82**		**$0.15**		**$0.29**		**$0.31**	
Buildings	$0.15		$0.02		$0.02		$0.07	
Machinery and Equipment	$0.43		$0.08		$0.17		$0.13	
Livestock	$0.06		$0.05		$0.05		$0.05	
Interest	**$0.64**		**$0.16**		**$0.25**		**$0.25**	
TOTAL COSTS	**$2.08**	**$0.74**	**$0.95**	**$0.28**	**$1.43**	**$0.73**	**$1.17**	**$0.94**

* Rounding in some areas affects total value.

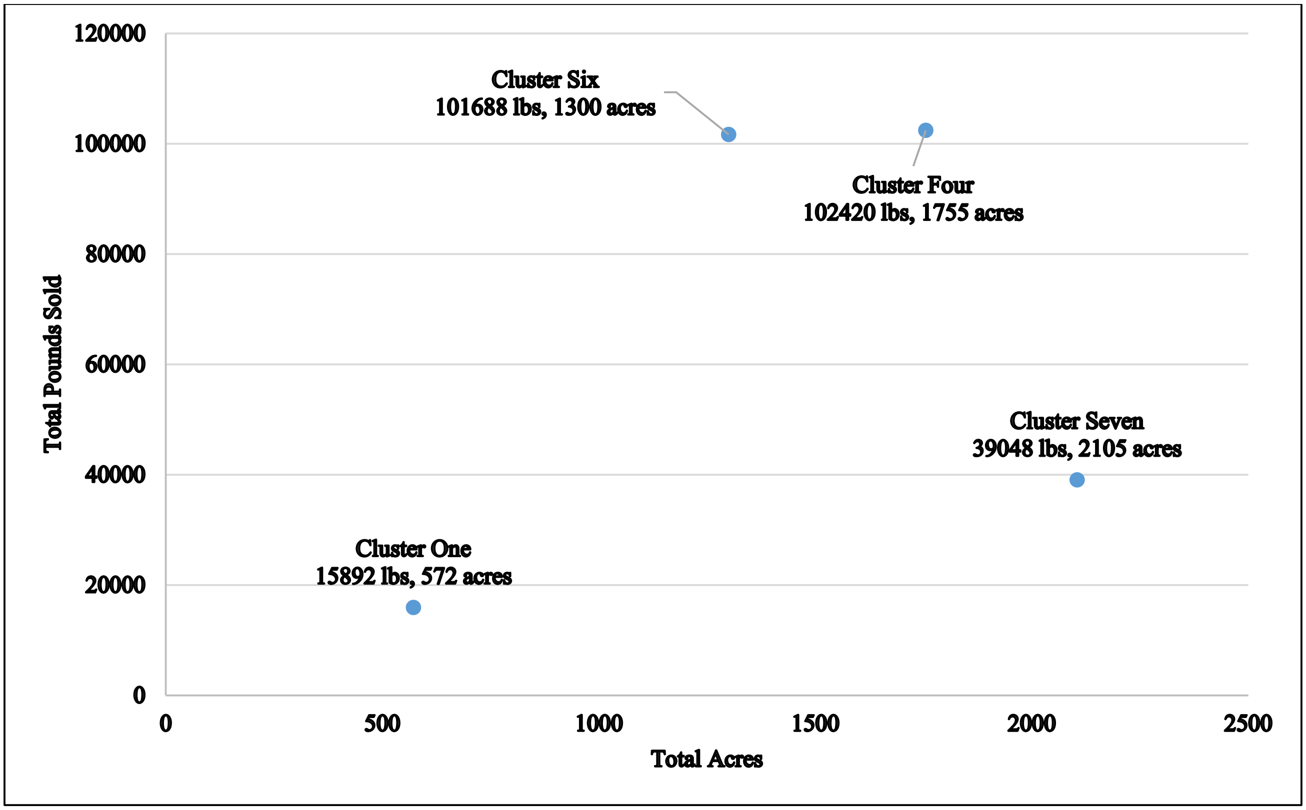

Figure B.1 Total Pounds Sold vs. Total Acres on Study Farms

Table B.2 Annual Depreciation and Interest Costs of Machinery on Study Farms, Manitoba, 2011

	Cluster One		Cluster Four		Cluster Six		Cluster Seven	
	Depreciation	**Interest**	**Depreciation**	**Interest**	**Depreciation**	**Interest**	**Depreciation**	**Interest**
Miscellaneous Machinery	$400.00	$352.00	$400.00	$352.00	$400.00	$352.00	$400.00	$352.00
Tractor, 268 hp	-	-	-	-	$9,866.67	$6,512.00	$9,866.67	$6,512.00
Tractor, 160 hp	$4,800.00	$4,224.00	$4,800.00	$4,224.00	$4,800.00	$4,224.00	$4,800.00	$4,224.00
Air seeder 25-30 ft.	-	-	-	-	$3,200.00	$2,112.00	$3,200.00	$2,112.00
Swather, 18 - 24 ft.	-	-	-	-	-	-	$1,066.67	$704.00
Combine	-	-	-	-	-	-	$8,000.00	$5,280.00
Baler 4X6	-	-	-	-	$1,440.00	$950.40	-	-
Stock Trailer, 20 ft. gooseneck	$906.67	$598.40	$906.67	$598.40	$906.67	$598.40	$906.67	$598.40
Truck	$3,150.00	$1,232.00	$3,150.00	$1,232.00	$3,150.00	$1,232.00	$3,150.00	$1,232.00
Haybine 12ft	-	-	-	-	$1,546.67	$1,020.80	-	-
Front end loader for 150hp tractor	$500.00	$440.00	$500.00	$440.00	$500.00	$440.00	$500.00	$440.00
Composter	-	-	$2,000.00	$1,760.00	-	-	-	-
Machinery Total	**$9,756.67**	**$6,846.40**	**$11,756.67**	**$8,606.40**	**$25,810.00**	**$17,441.60**	**$31,890.00**	**$21,454.40**

Table B.3 Annual Depreciation and Interest Costs of Structures on Study Farms, Manitoba, 2011								
	Cluster One		**Cluster Four**		**Cluster Six**		**Cluster Seven**	
	Depreciation	**Interest**	**Depreciation**	**Interest**	**Depreciation**	**Interest**	**Depreciation**	**Interest**
Pasture Fence	$479.04	$337.24	$699.17	$492.21	$673.27	$473.98	$812.30	$571.86
Portable wind break	$22.50	$15.84	$22.50	$15.84	$22.50	$15.84	$22.50	$15.84
Troughs (2)	$25.00	$17.60	$25.00	$17.60	$25.00	$17.60	$25.00	$17.60
Windbreak Fence	$315.00	$221.76	$315.00	$221.76	$315.00	$221.76	$315.00	$221.76
Handling Facilities	$500.00	$352.00	$500.00	$352.00	$500.00	$352.00	$500.00	$352.00
Calving Facility	$625.00	$440.00	$625.00	$440.00	$625.00	$440.00	$625.00	$440.00
Waterers	$300.00	$211.20	$300.00	$211.20	$300.00	$211.20	$300.00	$211.20
Pasture Watering System	$200.00	$140.80	$200.00	$140.80	$200.00	$140.80	$200.00	$140.80
Pasture Water Source	$150.00	$105.60	$150.00	$105.60	$150.00	$105.60	$150.00	$105.60
Gates	$72.50	$51.04	$72.50	$51.04	$72.50	$51.04	$72.50	$51.04
Round Bale Feeders	$120.00	$84.48	$120.00	$84.48	$120.00	$84.48	$120.00	$84.48
Well and Pressure System	$400.00	$281.60	$400.00	$281.60	$400.00	$281.60	$400.00	$281.60
Hydro (6 poles @ $400)	$120.00	$84.48	$120.00	$84.48	$120.00	$84.48	$120.00	$84.48
Structures Total	**$3,329.04**	**$2,343.64**	**$3,549.17**	**$2,498.61**	**$3,523.27**	**$2,480.38**	**$3,662.30**	**$2,578.26**

Table B.4 Annual Interest Costs for Livestock on Study Farms, Manitoba, 2011				
	Cluster One	**Cluster Four**	**Cluster Six**	**Cluster Seven**
D1 and D2 Cows	$631.89	$3,268.41	$3,529.88	$1,350.94
D3 Cows	$288.83	$1,493.97	$1,613.48	$617.51
Bulls	$55.17	$275.86	$441.38	$165.52
Livestock Total	**$975.90**	**$5,038.24**	**$5,584.74**	**$2,133.97**