ECONOMICS OF GREENHOUSE GAS MITIGATION SCENARIOS

IN BEEF PRODUCTION

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ABSTRACT

Animal agriculture plays a vital role in the provision of food for the world population; however, in the wake of global warming and greenhouse gas (GHG) emissions, the industry has been under scrutiny as one of the net emitters causing global warming. The same scrutiny applies to beef production in western Canada. The objective of this study is to evaluate the economic impact of GHG mitigation practices (GHGMP) for beef operations, and in the process identify economic and environmental sustainable scenarios. This study was an extension to a study by Beauchemin et al (2011) who studied the mitigation of GHG emissions from beef production in western Canada

A beef simulation model was developed to measure the impacts of adopting GHGMPs on the profitability of a mixed farm in Vulcan County, Southern Alberta. Feed for the herd was produced on the farm, and calves were born and finished on the farm. Whole farm gross margin was used as a profitability measure of the farm over a period of 9 years, which is a full beef production cycle. Eleven GHGMPs were examined and compared to the baseline scenario. These scenarios were adopted from Beauchemin et al (2011), and included dietary modifications (change in use of forages, use of canola seed, and corn distillers grains, and improvement in quality of forage), and improvement in animal husbandry (increased weaning rates, and increased longevity of breeding stock).

Simulation results showed a discounted whole farm gross margin of $11.38 per acre for the baseline scenario. Feed costs accounted for 47.1 percent of total costs of beef production. The change in whole farm gross margin per acre from implementation of different GHGMPs ranged from an increase of 4 percent to a decrease of 5 percent. Six scenarios were identified as 'win-win' scenarios as they improved both environment and economics of the farm. The profit of these scenarios ranged from $238.11 to $30.31 per tonne of GHG reductions expressed in carbon dioxide equivalent). The loss from the other scenarios capable of reducing GHG emissions range from $92.06 to $582.46 per tonne GHG reduced. Based on these results, it was concluded that western Canadian beef producers can adopt sustainable GHGMPs without substantial changing the structure of their operations. Scenarios that improved both the environment and the economics of the farm were: Scenario 7: use of corn distillers dried grain (CDDG) in finishing ration; Scenario 4: use of canola seed in finishing ration; Scenario 8: use of CDDG in breeding stock ration;

Scenario 10: increased calve weaning rate (85% to 90%); Scenario 5: use of canola seed in breeding stock ration; and Scenario 9: improved hay for breeding stock.

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Chapter 1

INTRODUCTION

1.1 Background

Agriculture is an important industry that feeds the growing world population, and plays a vital role in the socio-economic wellbeing of world communities, especially in rural areas. In Canada, the industry employs 2.1 million people and accounts for 8 percent of the total gross domestic product (GDP) (AAFC 2013). The performance of primary agriculture is influenced by several factors such as availability of land, weather/environmental conditions, management, and other input resources.

The interaction of agriculture and the environment has been under scrutiny in the wake of global warming and climate change discussions. On one hand, climatic conditions significantly influence performance of agricultural production systems, and on the other hand agricultural activities affect climate change through the release of GHG emissions that contribute to climate change and global warming.

To illustrate the impact of climate change on agriculture, Mooney and Arthur (1990) have shown that an increase in average temperature of the earth can lead to 20 to 30 percent reduction in yield of major annual crops in Manitoba. Nardone et al (2010) have argued that hot environments can impair animal production (growth, weight, and quality), reproductive performance, metabolic and health status, and immune response. Furthermore, climate change may also increase frequency of natural disasters, such as droughts, hurricanes, flooding, and widespread retreat of glaciers (Van Aalst 2006). Although climate change is caused by both natural process and human activities, scientific studies have shown that recent warming can be largely attributed to human activities (Environment Canada 2013). McAlpine et al (2009) have argued that global climate change, deforestation, dwindling water resources, desertification and loss of biodiversity are all symptoms of human-accelerated environmental change.

Animal agriculture has been estimated to be responsible for 8-10.8% of global GHG emissions, and livestock emissions are projected to grow by 30% from 2002 to 2020 (O'Mara 2011). With the world population projected to grow to 9.1 billion people by 2050 and meat production required to grow by over 200 million tonnes to meet increasing demand (FAO 2009), GHG emissions from livestock production will increase in the future. In Canada, livestock production is the main driver of agricultural GHG emissions with an estimated 60 percent share of all Canadian agricultural emissions (Environment Canada 2013). It is well established that among food items, beef carries the highest global warming potential per kg of food produced (Nguyen et al 2010), and therefore attempts to reduce GHG emissions from primary agriculture have been focused on beef production systems. Beef production emissions in Canada are a main concern for western Canada because that is home to more than 80 percent of all Canadian beef animals, with Alberta carrying about 40 percent of the total Canadian beef animals (Statistics Canada 2012).

The main GHG emissions from beef production are methane and nitrous oxide which are produced mainly from the animals' gut during digestion, and also from manure handling and storage. A study in Alberta determined that enteric fermentation[1] accounts for more than 50 percent of emissions from beef operations (AARD 2010a). Canadian emissions of methane have continued to rise over the years with an increase of 26 percent between 1990 and 2011 (Environment Canada 2013).

Canada, as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), is faced with a challenge to reduce its GHG emission levels to 15 percent lower than the 2005 levels by 2020 (Environment Canada 2013). Beef production, being a main contributor to GHG emissions is perhaps one of the areas that needs attention to achieve emissions target. Scientific research has focused on investigation of efficient beef production systems that reduce GHG emissions in western beef operations (AAF 2007a; Beauchemin et al 2010, 2011; Bonesmo et al 2013; Nguyen et al 2010). These studies have identified the following strategies as a potential for mitigation of GHG emissions from beef operations in western Canada:

1. Increasing percentage of weaned calves;
2. Feeding higher quality of feed and balanced rations;
3. Feeding additives and supplements (ionophores and lipids);
4. Early application of manure and avoiding stockpiling of manure; and
5. Avoiding overgrazing and more use of hay and pasture than annual crops.

[1] Enteric fermentation is the process in which livestock produce methane through digestion; more pronounced in ruminant livestock (cattle, buffalo, sheep, and goats).

Despite these findings to reduce GHG emissions, their adoption by Canadian beef farmers has been reported to be very low (MacKay 2010). It has been found that environmental issues alone do not influence adoption of best management practices, but instead a combination of biophysical and economic characteristics of a strategy plays an important role (Samarawickrema and Belcher 2005). A study done at the George Morris Center (2007) found that one of the greatest barriers to adoption of environmental friendly practices in Canadian farms is lack of information on economic viability of such practices.

The adoption of GHG mitigation practices changes the resource allocation of beef operations which could affect cost and returns to beef operations. Mitigation practices that affect the feed rations of animals will lead to changes in land allocation to annual crops, hay and pasture, and will eventually affect the cost of beef production. Western beef producers are already faced with the challenge of improving the profitability of their operations with feed costs accounting for more than 60 percent of total production costs (Kaliel 2004). Feed rations are also vital to the growth and development of animals, which affect how long it takes for an animal to attain mature weight and the quality of the meat produced. Because beef producers are price takers, keeping costs of production low and producing heavy quality animals is vital to run profitable enterprises.

Management practices, that expand the animal herd (i.e. increasing weaning rates), require more land to produce feed for additional animals, which means that there are opportunity costs associated with removing that land from alternative uses. However, there is also more animal product produced which means more revenues from animal production, and more pounds of meat means fixed costs are spread over more pounds of production. It is, therefore, vital to understand the whole farm economic impacts of GHG mitigation scenarios in order to determine the full impact of such practices on the profitability of the farm.

1.2 Problem Statement

Beef production is an important economic sector in western Canada; however, the industry's GHG emissions pose a threat to Canada's objective of reducing GHG emission levels. Scientific research has identified ways to help mitigate GHG emissions from western beef production systems but the economic viability of those strategies has not been well researched.

Farmers are more likely to adopt management practices that lead to a “win-win” situation--that is they lead to positive environmental and economic benefits. Beef production in western Canada operates in tight profit margins (Saskatchewan Forage Council 2011), and is very sensitive to changes in management decisions. It is, therefore, vital to understand how GHG mitigation scenarios impact producer welfare of these farmers.

There are two approaches that have been used in modelling similar decision problems at the farm level--Mathematical Programming models (Hediger 2006; Wilton et al 1974) and Simulation models (Koeckhoven 2008; BIOCAP Canada 2006). Mathematical programming is more suited to problems with a specified criterion and input constraints, whereas simulation models take a systems approach that involves the construction of a model that encompasses the relevant variables and relationships that characterize a real system. The latter approach allows for experiments and determining effects following alternative management practices (Yudi 2012; Babb and French 1963). Simulation modelling was found to be more suited for this study, and a whole farm simulation model was developed for the analysis.

1.3 Objective and Scope of the Study

Introduction of new management scenarios to a farm directly affects either the costs or/and revenues of the farm, thereby, affecting profitability of the whole farm operation. This study attempts to measure the economic impacts of implementing GHG mitigation scenarios to a western beef operation, and also identify economically and environmentally sustainable scenarios. Eleven GHG mitigation scenarios, adopted from Beauchemin et al (2011), were evaluated for a beef farm with 120 cows, 4 bulls and their progeny, located in Vulcan County, Southern Alberta. These scenarios included:

1. Increased use of forage in growing cattle (scenario 1);
2. Extended grain finishing of beef cattle (scenario 2);
3. Feeding canola seed to different phases of cattle production:
    - Canola seed in backgrounding ration (scenario 3),
    - Canola seen in finishing ration (scenario 4),
    - Canola seed in breeding stock ration (scenario 5);

4. Feeding corn distiller dried grains (CDDG) to different phases of cattle production:
    - CDDG in backgrounding ration (scenario 6),
    - CDDG in finishing ration (scenario 7),
    - CDDG in breeding stock ration (scenario 8);
5. Improved forage quality for breeding stock (scenario 9);
6. Increased number of calves weaned (scenario 10); and
7. Increased longevity of breeding stock (scenario 11).

1.4 Organization of Thesis

The remainder of this thesis is organized into 6 chapters. Chapter 2 is an overview of beef production in western Canada followed by a literature review in Chapter 3. Chapter 4 discusses the study area and the characteristics of the study farm of this study together with the model used for analysis. The GHG mitigation scenarios are described in Chapter 5 followed by the results of the analysis in Chapter 6, and the final chapter is devoted to a discussion of study findings and implications for future research in this area.

Chapter 2

OVERVIEW OF BEEF PRODUCTION IN WESTERN CANADA

2.1 Introduction

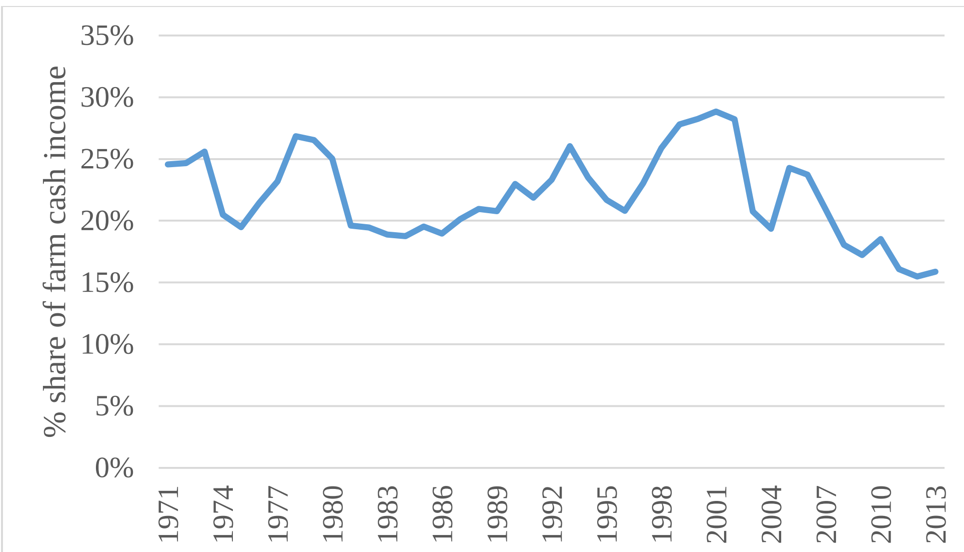
Canadian beef production is dominant in western provinces, with more than 85 per cent of Canadian beef cows located in British Columbia, Alberta, Saskatchewan, and Manitoba (CCA, 2011). Alberta leads the nation in beef production with an estimated 40.7 percent of the total 3.9 million Canadian beef cows (Statistics Canada 2014a). All of Eastern Canada accounts for only 13 percent of all Canadian beef cows as of January 2014 (Statistics Canada 2014a). These statistical numbers support the claim by Grier (2005) that the Canadian beef industry is western based.

This chapter reviews beef production in western Canada; it begins with an overview in section 2.2 of the economic contribution of beef production to Canada and the western provinces, and the influence of international trade on the industry. Section 2.3 contains a review of the farm level structure, and section 2.4, a discussion of profitability of beef operations. Finally, section 2.5 summarizes the chapter.

2.2 Economic Contribution of Beef Production

Beef production is a very important industry to the national and provincial economies of Canada. The cattle sector contributed a total of $13.2 billion to national domestic product and it is directly or indirectly associated with creating 228,811 fulltime equivalent jobs in Canada (Kulshreshtha et al 2012). Western Canada with its large beef numbers contributed a big portion of this national figure with an estimated $8.86 billion gross domestic product and total employment of 127,677 fulltime jobs (Kulshreshtha et al 2012).

Beef production has, for a long time, been an important part of farming in western Canadian provinces. Figure 2.1 shows the trends of cash receipts from cattle and calves as a percentage of total farm cash receipts in western Canada. The average contribution to farm cash receipts in this region for period 1971 to 2013 was 22 percent. The trend shows a slight decrease in contributions to total farm cash receipts over the years. Table 2.1 shows the levels of cash receipts from cattle and calves in Canada, Western provinces, and Eastern Canada. The separate contributions of cattle and calves is different between provinces. This is because of the regional differences in resources between provinces. Saskatchewan has vast pastureland to support cow-calf operations but has no federally-inspected slaughtering facilities to process/slaughter finished cattle in the province, therefore feeders are sent out to other provinces, particularly to Alberta. Alberta slaughters at least 80 percent of all the cattle in western Canada (Kulshreshtha et al 2012). This signifies the importance of interprovincial trade to the industry.



Source: Statistics Canada (2014b). CANSIM Table 002-0001

Figure 2.1 Contribution of cattle and calves to total farm cash income of western Canadian provinces, 1971-2013

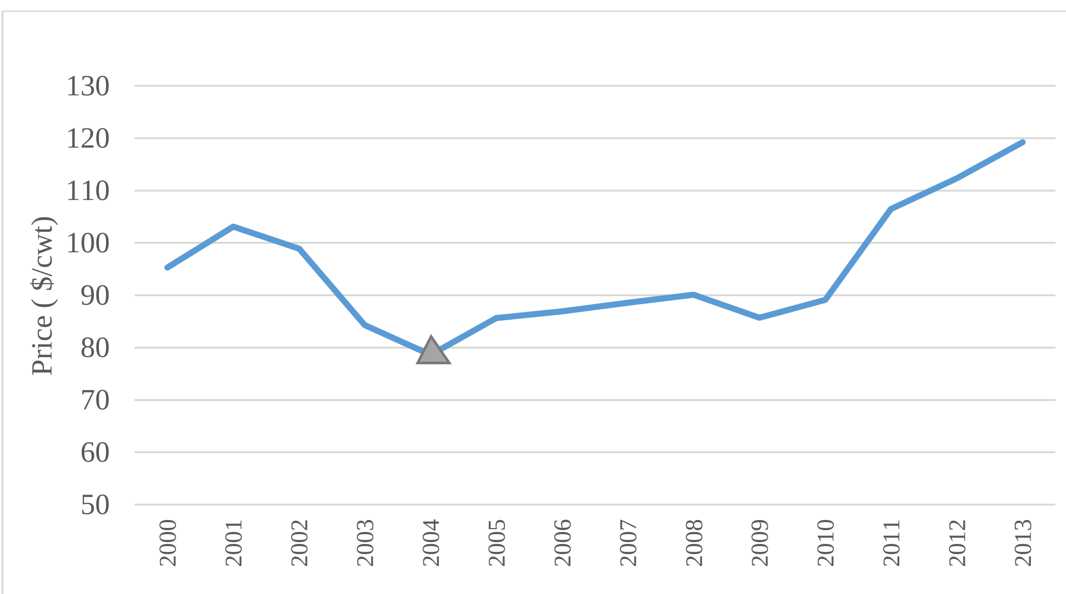
International trade also plays a major role in the Canadian beef industry. Canadians consume only half of the total beef produced in Canada and the other half lands in foreign markets. The United States is a major export market of Canadian beef with an estimated 72.8% of all 2012 beef and veal exports, with the rest going to Hong Kong, Mexico, Japan, China, Egypt, Republic of Korea, Macao, Angola, and Saudi Arabia (AAFC 2014a).

Table 2.1 Farm cash receipts from cattle and calves in Canada, by Canadian provinces, 2013

Geographical Region	Farm Cash Receipts From Cattle and Calves $(*1000)	Percentage of Total Farm Cash Receipts (%)	Percentage of Cattle And Calves Cash Receipts From Cattle (%)	Percentage of Cattle And Calves Cash Receipts from Calves (%)	Percentage of Canadian Total Cattle and Calves Farm Cash Receipts (%)
Canada	6,803.74	13	88	12	100
Manitoba	487.63	9	84	16	7
Saskatchewan	1,186.25	10	71	29	17
Alberta	3,278.70	30	99	1	48
British Colombia	207.73	8	70	30	3
Eastern Canada	1,643.42	7	83	17	24

Source: Statistics Canada (2014b). CANSIM Table 002-0001

Due to this heavy reliance on foreign markets, Canadian beef prices are very sensitive to events in these foreign markets. Figure 2.2 shows the prices of fed steers in Alberta for the period 2000 to 2013. From the price trends in the figure, in the last decade the lowest price was observed in 2004 at $78.63/cwt, which was the time when the US banned Canadian beef and cattle imports.



▲ - marks the lowest Alberta steer price in the last decade, observed in 2004 when the US banned Canadian beef in response to bovine spongiform encephalopathy (BSE) outbreak in Canada

Data source: AAFC (2014b)

Figure 2.2 Alberta weighted average prices of steers, 2000-2013

In mid-2003 there was an outbreak of bovine spongiform encephalopathy (BSE) in Canada, which led to the US closing its borders to Canadian beef and cattle. This caused excess supply of beef and cattle in Canada driving prices down, which was heavily felt in 2004. An estimated $2.5 billion loss in cattle and calf value of exports over the 2002 to 2003 period, resulting in an overall cost of $5.7 billion and 75,000 jobs to the Canadian economy (Mitura and Di Pietro 2004).

Upon opening its borders the US introduced Country of Origin Labelling (COOL) which came into effect in 2008. The US COOL legislation requires meat products to be labelled as to where animals were born, raised and slaughtered. The added costs of labelling meant Canadian beef products have a competitive disadvantage to US beef products in the US market. Carlberg et al (2009) argued that even though COOL costs in the supply chain lowered everyone's profit levels, primary producers bear the brunt of the costs. This might be because primary producers are price takers, which makes it easy for costs to be passed onto them through lower price offered for their cattle and calves.

Persistent drought in the US that has ravaged most of California has seen cattle numbers in the US drop to lowest levels since 1951; the USDA has forecasted a 5.3 percent fall in beef output for 2014 raising retail prices by 3.5 percent from 2013 prices (Bloomberg 2014). Canadian beef markets are priced off US futures so price changes in the US are also realized in Canada. The changes in the US are very evident in Canadian beef prices as shown by the rally of Canadian beef prices from 2011 through 2013 (see Figure 2.2). The early months of 2014 have also shown continued rise in cattle prices with steers averaging $150.95 per hundredweight in the first week of May 2014 (The Western Producer 2014).

Another key component of Canadian beef prices is the US-Canadian currency exchange rate. A strong Canadian dollar means American slaughtering plants need more US dollars to buy Canadian Cattle which eventually lowers Canadian exports. As a major importer of Canadian beef, reduced US demand causes excess supply in Canada, thereby driving prices down.

2.3 Beef Production--Farm Level Structure

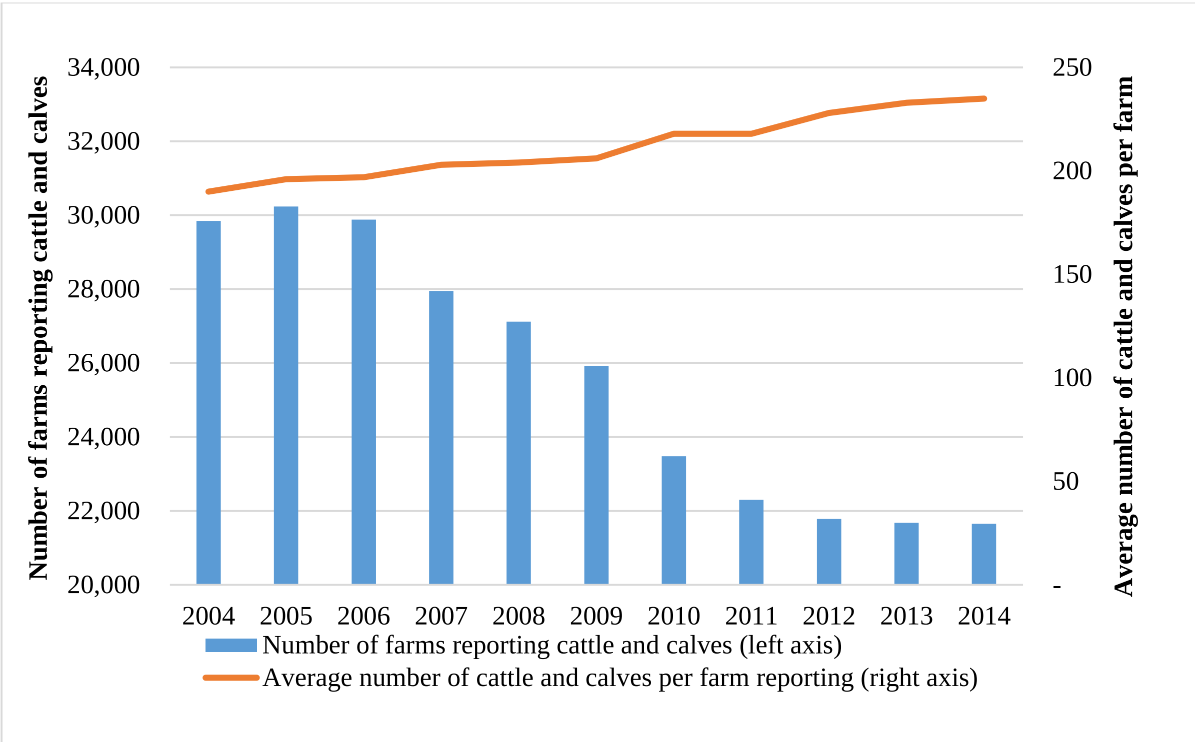
According to Canfax Research Services (2011c) the distribution or dynamics of beef numbers in Canada is driven by feed availability and feed costs. Livestock production in western Canada is supported by the abundance of fresh water and rangeland. Often the land used for grazing by cattle is not well suited to other types of agriculture; cattle production allows this area to be used productively (Canada Beef Inc 2013). The large number of beef cattle in the western provinces is due to the fact that it is home to 96 per cent of the 26 million hectares of Canadian rangeland used for livestock production, 82% of the nation's cultivated pasture, and 64% of the nation's forage crop area (McCartney and Horton 1997).

The Canadian cattle industry has been consolidating over the years, with farm operations getting larger but declining in numbers. Between the years 2004 and 2014, Canadian farm operations reporting cattle and calves decreased by 29 percent, whereas in the same period, the average number of cattle and calves per farm increased by 18 per cent (Statistics Canada 2014c). Similarly, Alberta has seen a decrease of 27 percent in the number of farms reporting cattle and calves while the number of cattle and calves per farm increased by 24 percent (Figure 2.3). As of January 2014, the average number of cattle and calves per farm was 235 and 148 for Alberta and Canada, respectively.

There are five major cattle breeds on Canadian beef farms including Angus, Hereford, Charolais, Simmental and Limousin (AARD 2013); however, there are other breeds which appear in small numbers. According to AARD (2013), there are about two dozen beef breeds represented across Alberta. The major breeds are described as late maturing, fast growing and generally heavier muscled (Canada Beef Inc 2013). There are three stages common in raising beef cattle in western Canada as explained in the next section.

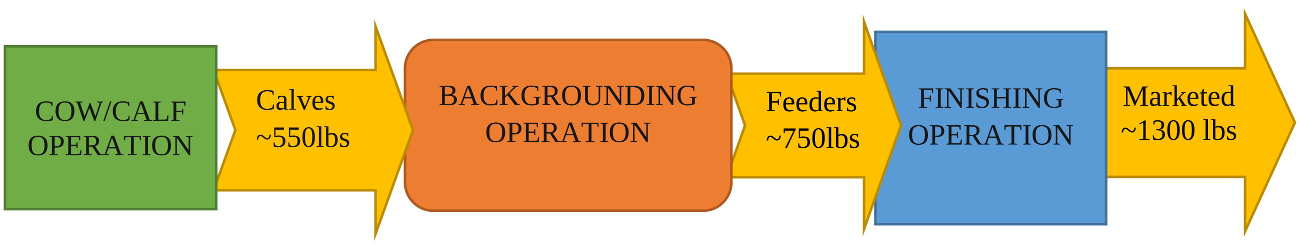
2.3.1 Stages in Beef Production

The common stages in raising beef animals in western Canada include: cow-calf, backgrounding, and finishing phase. Feed availability has an influence in the selection of a stage by farmer to raise animals. Beef farms with sufficient feed and management may retain their calves and feed until finished; however, one-stage (specialty) operations exist across the region. Figure 2.4 shows the stages a calf goes through from being born on a cow-calf operation to finishing operations prior to slaughter.



Data source: Statistics Canada (2014c). CANSIM Table 003-0099

Figure 2.3 Cattle and calves statistics, number of farms reporting and average number of cattle and calves per farm (semi-annual), January 2004 to January 2014.



~ weight of animal leaving the stage

Figure 2.4 Stages of beef production in western Canada

2.3.1.1 Cow-Calf Operations

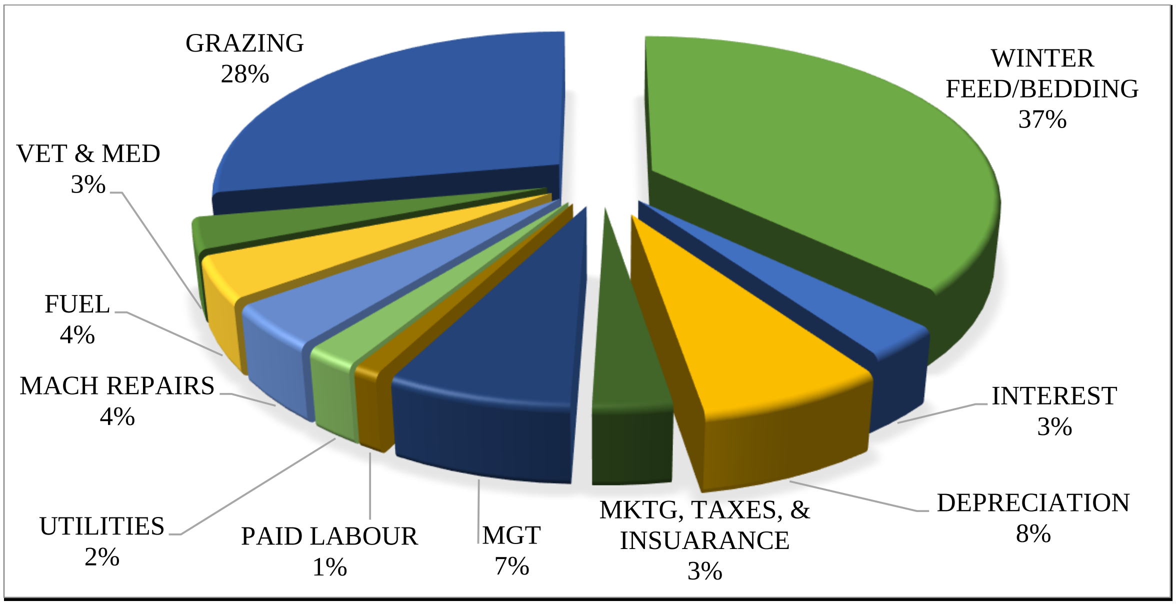
A cow-calf operation is the starting point for commercial beef production where breeding takes place. Traditionally, cows are bred in the summer and birth occurs the following spring. However, because of changing market conditions and increased costs of production, many cattle producers are evaluating different calving systems with suggestions that calving should coincide with peak pasture production and forage quality to meet the nutritional requirement demands of the lactating cow (Girardin et al 2009). Heifers produce first calf at 2 years old, and would produce one calf per year thereafter (ABP 2013). After calving, the mother cow nurses the calf on pasture until weaning, when calf weight ranges from 350 pounds to 650 pounds depending on age and genetic background (ABP 2013). With grazing being the lowest cost feed option, cow-calf producers try to maximize the amount of time spent grazing forages. According to the Saskatchewan Forage Council (2011), 80 percent of Canada's beef production occurs while animals consume forage. Forage can either be animal self-harvested or mechanical harvested. The systems that use more animal self-harvest (grazing) are more economical because there is less investment in capital and labour. Grazing of pastures is from mid-May to late-October; however, duration varies depending on environmental conditions, including precipitation during the growing season, temperature and snowfall amounts (Saskatchewan Forage Council 2011). Early snowfall can cut the grazing season short, whereas late snowfall increase the number of days animals can self-feed on pastures. Feed[2] costs accounts for more than 60 per cent of a cow-calf operations' annual costs (Larson 2010; Kaliel 2004), as shown in the breakdown of costs in Figure 2.5. It is therefore vital for livestock operators to strategically manage costs of feeding in order to have financially successful cow-calf operations. Maintaining the entire western Canadian cow herd on stockpile forage for one more day in the fall has been estimated to save the western beef industry at least $3.1 million (Saskatchewan Forage Council 2011).

There are differences in soil quality, humidity levels, and temperatures across western Canada, hence a difference in levels of feed availability across the region. Soils are categorized into four soil zones; black, grey-black, dark-brown, and brown soil zones. It is, therefore, important to note that cow-calf profitability is different across western Canada depending on the farm location and the management of that farm.

Revenues for cow-calf operations are generated from the sale of weaned calves and cull cows and bulls; however, some beef operations utilize their feed and management capability to retain their calves through the backgrounding and finishing phase. Cow-calf producers have very minimal influence on cattle price fluctuations and therefore their overall revenue generated

[2] Feed – includes grazing and winter feed

(Saskatchewan Forage Council 2011). It is, therefore, important for farm managers to minimize the costs of production in order to run sound financial operations.



VET & MED – veterinary and medicine, MACH- machinery, MGT- management, MKTG- marketing.

Data source: Larson (2010)

Figure 2.5 Breakdown of cow-calf cost of production

2.3.1.2 Backgrounding Operations

Backgrounding is the process of feeding weaned calves a forage based diet, either in a feedlot or on pasture, increasing their weight to around 700 to 950 pounds (FCC 2012). In this phase, calves are fed to grow slowly at an average daily gain (ADG) of 1.5 to 2.25 lb/day (SAFRR 2003). McCartney et al (2008) recommend growing feeders at a slower rate (1.0 to 1.5lb ADG) over the winter because of the high cost of stored feed and cost of yardage associated with feeding.

Backgrounding operations use different kinds of forage, including hay, annual crops, crop residues, or stockpiled pasture. Rations contain 60 to 70 per cent forage (dry matter basis), with the balance comprised of grain or fortified pelleted grain screenings (Saskatchewan Agriculture 2008). Barley swath is commonly used as the main backgrounding forage in western beef operations. Backgrounding steers on barley diets has been found to have higher average daily gain than steers fed wheat diets (Todd et al 2007). Swath grazing forages is an optimal to feed backgrounders because it saves on costs for baling or chopping, hauling, stacking or packing, and feeding (McCartney et al 2008). The average daily gain of animals will depend on management, feed ingredients, genetics and pasture grass production (SAFRR 2003). The farm manager can control the rate at which steers and heifers grow depending on feed costs and market conditions for cattle. If prices of cattle are low, managers can reduce the growth rate of cattle until better prices are realized.

The weight at which the calf enters the backgrounding operation determines the ration to be used to feed it. Small and medium framed animals are of preferable body type for backgrounding operations as they have more efficient use of feed and also meet the feedlot demand of 800 to 900 lbs (SAFRR 2003) by the end of the backgrounding period. Larger framed animals can be placed directly onto a finishing program after weaning with minimal backgrounding (Saskatchewan Agriculture 2008; SAFRR 2003). Table 2.2 shows the rate at which different body framed backgrounding animals can be fed in order to attain desirable finishing weights. According to SAFRR (2003) there are several ways in which cattle can be backgrounded;

I. Calves can be bought in the spring, fed for 30 to 60 days in a feedlot at a low rate of grain, grazed in the summer (summer backgrounded) and sold in the fall or fed to finish.
II. Calves can be retained from the cow herd or can be bought in the fall, wintered in a feedlot at a lower rate of gain, grazed over the summer and sold or fed to finish.
III. Calves can be retained from herd or can be bought in the fall, fed in a feedlot at a low rate of gain (winter backgrounding) and sold in four or six month or fed to finish.

2.3.1.3 Finishing Operations

Finishing is the last phase in beef production that prepares animals for market. About 75 percent of Canadian feedlot cattle are finished in western Canada, with 90 per cent of these (68 per cent of Canada) finished in Alberta (ABP 2013). Feedlot sizes ranges between 200 and 40 000 head (Smith 2011). Saskatchewan and Manitoba send its feeders to be finished in Alberta, Ontario and the United States (Schmitz et al 2003; Grier 2005). Feedlots buy calves from cow-calf and backgrounding operations, and feed them a carefully formulated diet to attain an average daily gain of 3 lbs to 4 lbs (Smith 2011). Weight of feeders entering the feedlot determines the rations used; lighter feeders bought from cow-calf operations as weaned calves are started on a high forage diet with low amounts of grain fed, and progressively moved to a 85-90 per cent of grain ration after a few weeks (Canada Beef Inc 2013). Heavier animals are placed on a high grain diet upon entering the finishing stage. Depending on the body frame of the animal, cattle are usually ready for market at 12 to 24 months of age and weigh between 1,000 to 1,300 pounds (FCC 2012).

Table 2.2 Animal frame size and target sale weight

	Small Frame	**Medium Frame**	**Large Frame**
Purchase Weight	300 - 400 lb.	400 - 500 lb.	500 - 600 lb.
Backgrounding Gain (lb. per day)			
Steers and Heifers	1.50 - 1.75 lb.	1.50 - 2.00 lb.	
Steers			2.25 - 2.70 lb.
Heifers			2.00 - 2.50 lb.
Target Feeder Weight and Destination			
To grass	650 - 700 lb.		
To feedlot	800 - 850 lb.		
Steers and Heifers to feedlot		825 - 875 lb.	825 - 875 lb.
Expected Slaughter Weight			
Steers	1100 lb. +	1150 - 1300 lb. +	1300 - 1525 lb.
Heifers	900 lb. +	950 - 1050 lb. +	1100 - 1200 lb.

Source: Saskatchewan Agriculture (2008)

Feedlots operations sell finished cattle through auctions, meat processing plants or export to other countries, mainly the United States which is the main destination of Canadian beef. Because of a heavy reliance on export markets, international trade plays a major role in the profitability of the beef industry in Canada (Schmitz et al 2003). Canadian beef prices are very responsive to foreign market conditions which makes the industry very susceptible to market volatility risk. When the US closed its borders to Canadian beef and cattle after the discovery of bovine spongiform encephalopathy (BSE) in May 2003 Canadian fed cattle prices declined 65 percent from $108/cwt in April 2003 to $38/cwt in July 2003 (Canfax Research Services, 2009).

2.3.1.4 Cattle Feeds used in Western Beef Operations

Western Canada consists of different ecoregions with different capabilities of crop and pasture production. It is therefore common to find beef producers using different feed rations depending on location and related climate. The commonly used feedstuffs are: grain and forage.

Feed grains include barley, wheat, oats, and corn. Barley is the commonly used feed grain in western Canada (Saskatchewan forage Council 2011). It is because price per unit of energy for barley is less than that of wheat and oats (Agriculture Canada 1992). However, there have been increases in barley prices due to the ethanol industry's demand for grains (McKinnon and Walker 2008). This has been a significant challenge to beef production which has left the industry needing alternative feed products that may be more cost-effective. As the ethanol industry expands in western Canada, the supply of distiller grains (a by-product of ethanol production) has also increased. Wheat and corn distiller grains have been used efficiently and economically for feeding cattle in western Canada (Klopfenstein et al 2008; BCRC 2013).

Forages include mechanical harvested forage and grazed forage. Mechanical or conserved forage includes grass hay, alfalfa hay, alfalfa-grass hay, crop residues/straw and green feed. Native pasture is the lowest cost forage.

2.3.1.5 Pasture Management

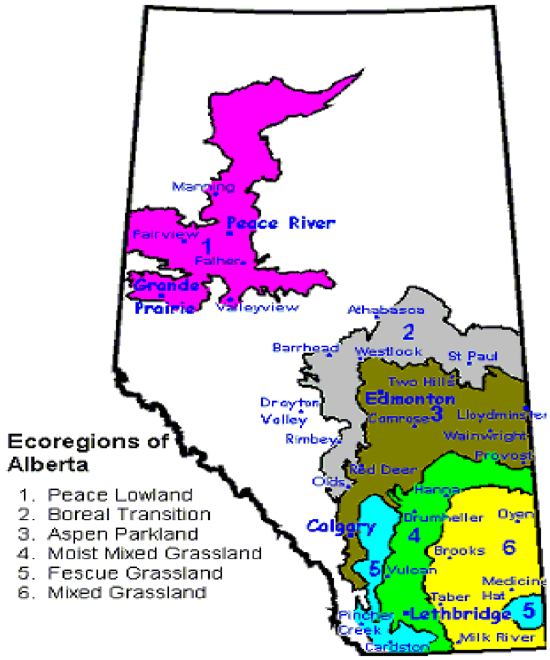
The main types of pasture for beef production are tame or native pasture. Both are very important feed sources in western beef operations. Tame pasture is cultivated land seeded with introduced (non-native) grass and legumes species or cultivars with the multiple purposes of providing livestock grazing forage to improve animal nutrition and health, balance forage supply and demand during low forage production, reduce soil erosion, improve water quality, improve soil quality and health, and provide food and cover for wildlife (Jacobs and Siddoway 2007). These pastures lead to higher productivity gain in beef cattle, but come with increased input costs. Native pastures are natural or wild species. In the beef production cycle, the majority of feeder animals, have gained weight on pasture (grassers or stockers) before being placed in a finishing feedlot (Koeckhovan 2008). However, gain in livestock weights cannot be achieved at the expense of pasture's health. A healthy pasture is described as one that efficiently uses available energy, water, nutrients and mineral resources to produce maximum biomass and provide relatively, high quality source of forage for livestock (ASRD 2007).

To maintain a healthy pasture, beef producers have to determine the carrying capacity of their pastures and stock it accordingly. Carrying capacity is a term used to describe the number of animals that a pasture can support, while still maintaining its productive health. Carrying capacity can be expressed as Animal Unit Month (AUMs), which is the amount of forage required to feed one animal unit per month (ASRD 2004). An animal unit is a 1,000 pound beef cow with or without a calf. According to Bruynooghe and Macdonald (2008), a 1000 pound cow and 1500 pound bull require 26 and 39 pounds of forage dry matter daily, respectively. This translates into 780 pounds of dry matter required to feed a 1000 pound cow per month. After determining the carrying capacity of the land, a producer can decide on the stocking rate; the number of animals that a pasture can support for a given period of time. Balancing livestock demand with forage supply is very important for the sustainability of pasture. As a rule, it is recommended that range be stocked at about 80 per cent of the forage supply or carrying capacity to provide a buffer for periods of low moisture for adequate biomass production (Bruynooghe and Macdonald 2008). The differences in vegetation across western Canada means the carrying capacity is different throughout the region. Pasture in the same ecoregion will have close carrying capacity numbers because of the common characteristics of soil, weather, and vegetation. Alberta has 10 different ecoregions through the province which implies different carrying capacities for the different vegetation (Figure 2.6).

There is no established market for forage in western Canada because many livestock producers use home grown forage or feed bought from neighbours in the vicinity of their farms. Custom grazing rates and pasture rental rates from private and government owned land can be used to estimate the economic values of pasture. In Saskatchewan, government-owned pasture rental rates ranges from $0.40 to $0.55 per cow-calf per day over an average of five months grazing period (SFC 2010). Private rental rates are hard to find, mostly because of contractual agreements; however, an average of $0.75 per day per cow-calf is said to be a reasonable amount (SFC 2010).

2.4 Impacts of GHG Mitigation on Profitability of Beef Operations

Profitability of beef production at the farm gate in western Canada is driven by production costs and market prices. Beef producers have more control over production costs through their management decisions on the farm; they have little influence on market prices, as they are determined by market forces.



Source: AARD 2012b

Figure 2.6 Ecoregions of Alberta showing Vulcan County in the Moist Mixed Grassland.

Profitability of beef farms varies across western Canada and even between operations; Canadian Industry Statistics (2014) figures show that in 2010, 64 percent of commercial beef operations in Alberta recorded positive net profits, whereas 36 percent recorded net losses. A year later (2011), the number of profitable operations fell to 43 percent, with 57 percent of operations reporting a net loss. Profitable Alberta beef operations in 2010 made a net profit of $110.4 thousand, and non-profitable operations averaged a net loss of $89.3 thousand[3] (Canada Industry Statistics 2014). Saskatchewan and Manitoba showed similar figures with profitable farms averaging a net profit of $113.9 and $109.70 thousand, respectively in 2011 (Canadian Industry Statistics 2014).

Larson (2013) points out that the industry has an ever changing marketplace, and the success of producers requires quick responses to changing market conditions while still efficiently producing and marketing a high quality product. With the growth of environmental awareness in consumers, it is upon producers to adjust their operations to incorporate the environmental element

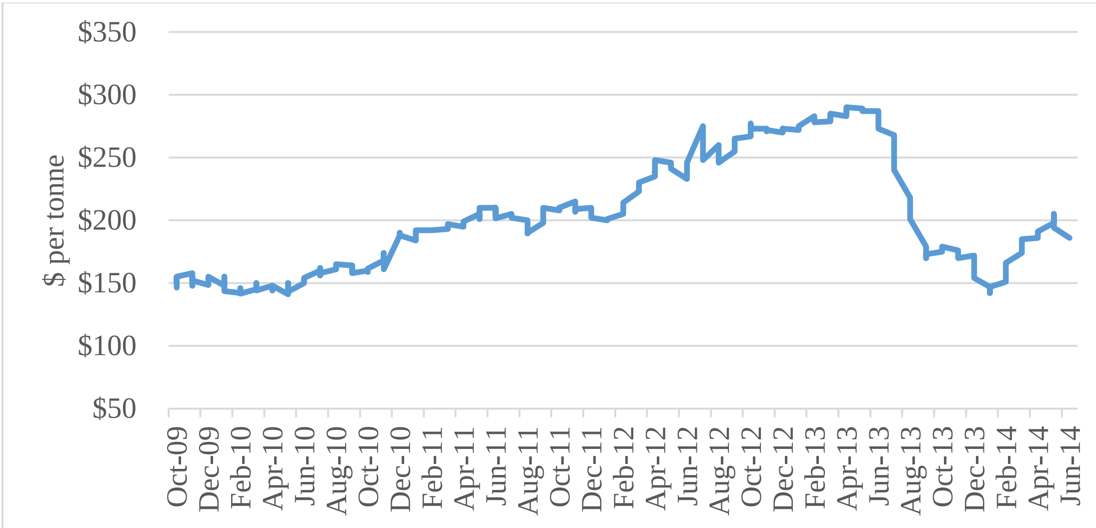
[3] This figures are based on data collected from 2010 and 2011 tax information for farms annual revenues between $30 thousand and $5 million

in their products. This is evident with the prevalence of labels, such as environmental friendly, and natural produced beef. Hobbs et al (2005) did an auction experiment study of beef with different characteristic attributes. The results showed that Canadian consumers are willing to pay a higher price for environmentally friendly produced beef. Adoption of environmentally friendly production practices for beef operations will be more attractive if such they are also economically viable, in other words, they create a 'win-win' outcome.

According to Lardner (2012) profitability of western Canadian beef operations depends on the following items;

1. Low feed costs (Maximizing utilization of pasture, roughage, and crop residue);
2. High percentage calf crop at weaning;
3. Low capital investment per cow:
    - Land,
    - Building,
    - Machinery and equipment;
4. Low labor input; and
5. Favorable market/Prices.

The first item in the above list is feed use, which is of major concern for western beef producers because it is a major driver of profitability and also has high influence on GHG emission from beef operations; feed costs represents more than 60 percent of total annual beef production costs (Larson 2010; Kaliel 2004). Cow-calf operations rely mostly on native or tame pasture, and homegrown forage, whereas, feedlot operations use purchased barley grains as their main feed ingredient. As can be seen in Figure 2.7, barley prices are variable, making it hard for beef feedlots to manage costs. It is, therefore, a challenge for beef producers to control feed related GHG emissions and also run profitable operations.



Source: ACPC (2014)
Figure 2.7 Calgary weekly feed barley prices, 2009-2014.

Conestoga-Rovers and Associates (2011) have identified some economically viable GHG reducing feed management practices that can be used in western beef operations. Their study used a benefit-cost analysis to calculate a net present value of adopting management practices to a representative Alberta beef operation for a period of 10 years between 2001 and 2010. Management practices which were identified to have positive economic impacts to the beef industry included: (i) reducing the number of days from weaning to slaughter by using growth promotants; (ii) eliminating the backgrounding phase for feeder animals; (iii) swath grazing; (iv) use of ionophores in roughage diets; and (v) use of superior residual feed intake genetics for breeding animals. Use of dietary additives has also been found to improve feed efficiency in beef cattle (Wall et al 2010; Conestoga-Rovers and Associates 2010; Beauchemin et al 2011).

A study of Ireland suckler beef production systems by Clarke et al (2012) found that increasing the stocking intensity by increasing fertilizer nitrogen application rates increased the carcass output and profitability with only modest increase in GHG emissions. Similar results have been observed in Colorado state where intensive grazing with improved pastures by breeding cows reduced herd GHG and GHG/ kg live weight by 13 percent while increasing profits by $48 per ton of GHG saved (Johnson et al 2003a). The same study also found that moving weaned calves directly into finishing feedlot without the backgrounding phase decreased GHG/ kg live weight sold by 4% and also increased profits, this finding is similar to that found in Alberta beef where moving weaned calves directly to the finishing lot also reduced GHG emissions and increased total farm profits of the region by $56.12 million (Conestoga-Rovers and Associates 2010). The economics and GHG emission of using forage in beef diets needs careful examination, because low quality forages results in reduced which can elongate the production period (leading further to increasing economic costs of non-feed items), and also increases GHG emissions from cow herds, as observed in Beauchemin et al (2011).

Breeding selection has also been identified as crucial in long-term environmental and economic benefits in livestock production. Wall et al (2010) argued that genetic improvement is a very cost effective technology, producing permanent and cumulative changes in performance. Selection of larger but faster growing breeds can help reduce the time between weaning and slaughter, leading to less feed energy intake per unit of body weight produced and higher finishing weights (Rotz 2013).

Other studies have also looked at the rate of culling breeding cows as a way of economically reducing GHG from beef operations. Frequent culling of breeding cows can have a negative impact on profitability of beef operations, as it can be costly to raise replacement heifers, and if more heifers are required, reductions in the number of marketable heifers, which in turn implies lower returns (Canfax Research Services 2011c). A study of Colorado dairy systems found that reducing culling by 10 percentage units decreased herd GHG emissions and increased profits per herd primarily by reducing replacement costs (Johnson et al. 2003b). Rogers (1972) found that 10 years of age is the last year annual returns from a cow in the herd exceed the equivalent annual net return from replacements in Central Washington, US. Oishi et al (2013) found similar results in Japan; Japanese cows have optimal net revenues at 9 years of age, but minimal GHG emissions in the 10th year. These studies suggest an optimal culling rate for both economic and environmental performance of beef cattle of at 9 to 10 years of age; however, culling can be done for other reasons, other than economic and environmental performance.

Manure management is another component of beef production that has received scrutiny in terms of environmental impacts. Traditionally, manure was applied to nearby fields but the intensification of livestock meant that land application was unsustainable. Composting has been suggested as the best alternative to direct land application (Hao et al 2001); however, only 15 percent of feedlots in Alberta compost their manure with the rest of the feedlots assumed to be transporting manure off site for land application (Conestoga-Rovers and Associates 2011). The cost of a composting system depends on the size and the sophistication of the system. Composting systems with windrow turning machines are more expensive than passive composting because of the capital investments involved (BCMAFF 1996). Forced aeration and turning reduces methane emissions compared to stockpiling of manure; however, it has been found that emissions from fuel used for turning in active compost significantly increases overall GHG emissions compared to passive composting (Hao et al 2001). Conestoga-Rovers and Associates (2011) have found that 100 percent adoption of windrow composting would cost the Alberta beef sector a total net annual income of $322.35 million. However, this system presents the best alternative to the use of existing farm equipment to turn compost, which has an estimated annual cost of $413.76 million.

2.5 Summary

Beef production plays a vital role in the economy of western Canada, especially in the province of Alberta. International and interprovincial trade facilitate the movements of animals at different stages and supports the continuous operation of the industry. Profitability of beef farms varies across western Canada, and is dependent on feed costs and cattle market prices. Feed management plays a vital role in emission levels of beef operations. Studies on beef production and GHG emissions have identified mitigation strategies that can be profitable if adopted by beef operations; however, very few of the studies have focused on western Canadian beef farms. The next chapter is a literature review on GHG emissions from Canadian beef operations, and the methods used in evaluating profitability of mitigation strategies in beef operations.

Chapter 3

LITERATURE REVIEW

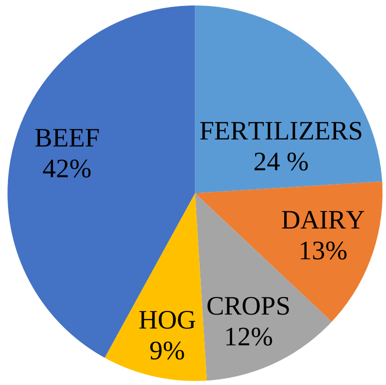
3.1 Introduction

This chapter reviews work of other researchers in the field of livestock production and GHG emissions in order to understand the source and solutions of GHG emissions from animal production. Particular emphasis is placed on GHG emissions from beef operations and the position of western Canada. Mitigation strategies to curb emissions are also reviewed, followed by a description of models used in the evaluation of economics of mitigation scenarios.

3.2 Beef Production and Greenhouse Gas Emissions

Livestock production is associated with several environmental problems. Early livestock grazing research focused on forage and physical watershed characteristics, with concerns of watershed runoff and erosion (Meehan and Platts 1978). However, there are many other environmental issues associated with livestock production including: land degradation, loss of biodiversity, water pollution, and climate change (FAO 2006). According to FAO (2006), 70 per cent of previously Amazon forested land in Latin America is now occupied by pastures, with feedcrops covering a large part of the remainder. The 20^{th} century has seen more emphasis on GHG emissions from different sectors of national economies. Animal agriculture is a huge player in GHG emissions with an estimated 8 - 10.8 percent of global GHG emissions and a projected growth of 30 percent between 2002 and 2020 (O'Mara 2011).

Animal agriculture in Canada has shown a similar trend; 64 percent of total Canadian agricultural GHG emissions come directly from animal production as shown in Figure 3.1. From the figure, it is evident that beef production is a big player in GHG emissions, accounting for 42 percent of total Canadian agricultural emissions. GHG emissions from beef production are higher in western Canada than in eastern Canada simply because the majority of the nation's beef animals are in western Canada.



Source: CCA (2013b)
Figure 3.1 Breakdown of GHG Emissions from Canadian Agriculture.

A study by Verge et al (2008) has shown that beef production in western Canada produces about 83% of total Canadian beef GHG emissions. It is, therefore, evident that western provinces need more attention in the process of reducing Canadian GHG emissions from animal agriculture. A life cycle analysis of a beef farm in southern Alberta was found to produce total emissions of 5.45 million kg carbon dioxide equivalent (Beauchemin et al 2010). Of this total, 68 percent was methane gas, 27 percent nitrous oxide, and 5 percent carbon dioxide. Methane emissions were a result of enteric fermentation and manure storage (Verge et al 2008; Beauchemin and McGinn 2008). Most of the methane gas from beef production is enteric methane, with only 10 percent estimated to be from manure (Beauchemin and McGinn 2008). Nitrous oxide is produced from manure handling and storage (CCA 2013a). When manure decomposes in the presence of oxygen, carbon dioxide is produced (CCA 2013a); other carbon dioxide sources on the farm are: farm fieldwork, hauling by farm-owned trucks, electricity use, heating (including grain drying), and manufacture and supply of both farm machinery and synthetic fertilizer (Verge et al 2008).

It has been determined that 40 per cent of total agricultural emissions in Canada come directly from methane emissions (AAFC 2012). Johnson and Johnson (1995) have argued that methane emissions receive special attention because of methane's potential to affect climate directly with its interaction with long-wave infrared energy and indirectly through atmospheric oxidation reaction that produces carbon dioxide, a potent GHG which contributes to climate change and global warming.

International governments had cooperatively come together on the agenda of climate change with efforts to reduce GHG emissions under the 1998 Kyoto protocol, and the recent Copenhagen accord (CACC 2010). Under the Kyoto Protocol, Canada had committed to reduce GHG emissions by 6% below the 1990 levels by 2012 (Ellis et al 2009). Now under the recent agreement the plan is to reduce GHG emissions by 15 percent below the 2005 levels by 2020. In order to achieve this objective, Canada has incorporated agricultural environmental issues in its agricultural policy, which includes federal-provincial cost sharing programs aimed at producing ecological good and services in agricultural production (Schmidt et al 2012). Support for Best Management Practices (BMP) has been one of the environmental pillars which has received federal and provincial funding, and the program has been in existence for many years and have provided incentives to farmers to maintain and enhance environmental farm practices (Schmidt et al 2012). Despite Canada's commitments, emissions of methane and nitrous oxide have continued to rise, with an estimated 20% increase between 1990 and 2002 (Basarab et al 2005). Ellis et al (2009) have identified methane production from ruminants as an area that agriculture sector can contribute to reducing overall GHG emissions.

The levels of GHG emissions from a farm depend on the management practices of that particular farm. CCA (2013a) has identified three management practices in beef production associated with the levels of GHG emissions: grazing, feeding, and manure management strategies. These management practices are discussed in detail in section 3.3.

3.3 Greenhouse Gas Mitigation Practices (GHGMP) in Beef Operations

Several researchers have identified management practices that reduce GHG emissions from beef operations (Beauchemin et al 2011; Beauchemin and McGinn 2005; Pelletier et al 2010, Boadi et al 2002; and DeRamus et al 2003). Most of these researchers have concluded that beef producers can reduce GHG emissions by managing the diet of animals, manure storage and application, and through land management. DeRamus et al (2003) have argued that traditional production systems are generally inefficient in converting plant biomass into animal protein. In support of this argument, the authors demonstrated that controlled rotational grazing systems have the potential to reduce GHG emissions by 22 per cent compared to traditional continuous grazing systems. The type of production system used for beef production also determines the levels of emissions produced from beef farms. The cow-calf beef production system, common in Canadian beef operations, has been found to produce 80 per cent of total GHG emissions from beef operations, compared to a mere 20 per cent from feedlot systems (Beauchemin et al 2011). A similar study in the US also found cow-calf production to emit more methane and nitrous oxide than feedlot cattle (Phetteplace et al 2001).

As previously stated, most methane gas from beef production is emitted though enteric fermentation, which results from the inefficiency of ruminants to convert feeds into milk or weight gain (CCA 2003). Studies have shown that additives, such as crushed oil seeds (Beauchemin et al 2011), can be used as part of animal diets to reduce methane emission levels, thus increasing the efficiency of feed use in animals. The choice of the type of feeds is also vital in beef production emissions. Beauchemin and McGinn (2005) have shown that producers can reduce the amount of GHG emissions from their farms by selection of the type of feeds used. These authors found that corn diets fed to beef cattle in Alberta, during the backgrounding and finishing phase, resulted in less emissions compared to barley grain diets.

Managing manure storage and application to cropland is also an important part of dealing with GHG emissions. The amount and timing of manure application to cropland is vital. Over application of manure and commercial nitrogen fertilizers results in excess nitrogen accumulation, and results in release of nitrogen as nitrous oxide, a GHG (CCA 2003). Application of manure in the spring when crops can use them is effective in GHG mitigation (Kulshreshtha et al 2001, CCA 2003a). The type of manure storage used for feedlot raised cattle is also an issue in GHG emissions. Kulshreshtha et al (2001) have shown that covering manure tanks during storage helps reduce GHG emissions from liquid manure.

A very comprehensive study of a beef farm in southern Alberta by Beauchemin et al (2011) has shown that different management strategies that include dietary supplements, land management, timing of moving calves from pasture to feedlot to market has the potential to reduce total farm GHG emissions by 8 percent, and if some strategies are combined reduction may be up to 17 percent of total beef production GHG emissions.

Besides the economic factors, there are other factors that affect the adoption of environmental management practices. A study of Canadian farms has pointed to the importance of information availability to be very crucial in adoption of environmental friendly practices

(Jayasinghe and Weersink 2004). A similar study in the US has shown that government involvement in educating farmers about new management practices has a positive influence on adoption of environmental management practices on beef operations (Kim et al 2005). Diversification of the farm has also been found to be strongly correlated with adoption of environmental management practices in beef (Jayasinghe and Weersink 2004; Kim et al 2005). Operations with both livestock and crop production will more likely adopt environmentally friendly management practices as compared to operations that specialize in either crop or livestock production (Jayasinghe and Weersink 2004; Kim et al 2005). Other factors that have a positive influence on the adoption of environmental friendly management practices in beef operations are: large farm size, high household and cattle income, presence of purebred cattle on the farm, and having a family member to take over the farm when the operator retires (Kim et al 2005). These factors show that the closer the operator is personally attached to the farm, there is more willingness to improve/maintain the farm for a longer period through the adoption of environmental friendly management practices.

3.4 Modelling Economic Impacts of Adopting GHGMPs

Decision making in the farm is a complex process that is influenced by the environment in which the farm operates. Olson (2004) described the farm environment as having four main components: resources, markets, institutions, and technology. Farmers are faced with the problem of how to use the resources (land, labour, capital, and entrepreneurial ability) available to them under the restrictions of policy and technology that are ever changing. Mixed farms have further complications in that enterprises within the same farm compete for limited available resources, such as land and capital. Environmental problems also enter the decision process of the farmer as different management practices have different environmental and economic impacts. Because of this complexity in the farm business, there have been models developed to help farmers run their operations with less complication while using their resources efficiently.

In analyzing the farm economics of different management practices, two common approaches have been widely used in agriculture: mathematical programming and simulation models. These two approaches have dominated in Canadian agriculture (Klein and Narayanan 1992). It is, however, important to note that farm models do not replace managers as decision makers but provide information to facilitate their management function (Babb and French 1963). The following two sub-sections will explore the strengths and weaknesses of these techniques.

3.4.1 Mathematical Programming

Mathematical programming (MP) models are tools that are used to allocate resources into production according to a specified criterion. In the context of a production economics problem, the objective may be to maximize profit or minimize cost subject to a set of constraints that represent technology and availability of limited resources (Koeckhoven 2008). In a profit maximization problem, MP allocates resources to activities of the farm that leads to the highest profit. McCorkle (1955) has suggested the uses of MP as resource allocation among alternative lines of production, optimal levels of inputs, optimal resource use through time and selection of alternatives, and cost minimization for a given level of output.

MP models have been widely applied to analyze management practices of different farm enterprises such as livestock, grasslands, and croplands (Hediger 2006). Wilton et al (1974) used MP to analyze the nutrient requirements for cows, replacement heifers, feedlot heifers and steers in an Ontario integrated beef production enterprise. The Model of Integrated Dryland Agricultural System (MIDAS), developed in Australia, has also proved the power of MP in economic analysis of farm level enterprises. The MIDAS model takes into account the joint emphasis of economics and environmental impacts in allocation of resources to alternative enterprises, rotational selection, selection of machine size and pattern of use, and determination of impact of limited farm finance on optimal farm strategy (Pannell 1996). Furthermore, MP has been used in the analysis of various other agricultural problems, i.e., water policy analysis (Bartolini 2007), and carbon sequestration and GHG emissions (Hediger 2006).

Despite its acceptability and implementation in farm level analysis, MP models have received considerable criticism in the literature. The first being its single objective function; i.e., optimization. Hazell and Norton (1986) pointed out that production may be restricted by the need to observe sound husbandry practices, farmer's desire to be self-sufficient or by desire to avoid undue risk. Furthermore, Cros et al (2004) have argued that usually there is no universal optimal solution to a particular management problem, because efficiency of a solution depends on the specific constraints and subjective judgment of the farmer. This criticism is very applicable to the present study concerning the reduction of GHG emissions. It is possible that some farmers will adopt GHG mitigation practices based on their beliefs and values for the environment; therefore it may not be appropriate to impose a profit optimization function for such farmers. In support of this claim, Willock et al (1999) have argued that the normative theory that farmers maximize profit fails to account for behavior of individuals. It is evident that MP will choose enterprises that lead to maximizing profits or minimizing costs, thereby pushing out enterprises that do not fall in those categories.

Linear programming (LP) is one of the mathematical programming tools that has been widely used in analyzing the economics of farm level management strategies. This technique has also been criticized for its assumptions. Wheeler and Russell (1977) criticized the linearity and divisibility assumptions of LP arguing that linearity of input to output irrespective of activity does not capture the economics of scale, and diminishing marginal returns that occur in farms. Divisibility is found to be a problem when dealing with indivisible inputs or capital. An example is an LP solution that shows a fraction of a cow or land, Wheeler and Russell (1977) argue that the problem with divisibility stems from fixed costs which cannot be adjusted to make up for fractional inputs. Wilton et al (1974) also criticizes LP arguing that technical coefficients might not be known and must be estimated.

3.4.2 Simulation Modelling

Klein and Narayanan (1992) have described an ideal type of farm model as one that pertains as a whole farm and is multi-period, recursive, and dynamic in value, and captures the producer's behaviour as positive and in a more realistic manner. The approach of the simulation model suits this definition better than the MP. Yudi (2012) described simulation as a modelling approach that gains understanding regarding how the interaction of parts of the system give rise to the behavior of the systems as a whole. It involves building a model that runs over time based on defined rules and interactions within the system model, which allows for experiments and determining effect following alternative management practices (Babb and French 1963). Yudi (2012) commends simulation modelling for its depth and flexibility of evaluation.

There are studies that have used simulation modelling to analyze the farm level economic impacts of introducing different management practices in livestock production systems. Koeckhoven (2008) used simulation modelling to study the economic impacts of adopting beef farm management practices that enhance water conservation and natural habitat in southern Alberta. This study proved the power of simulation modelling by its ability to incorporate the stochastic elements of weather, prices and yields. A very interesting simulation model called Integrated Farm Simulation Model (IFSM) has been developed for Canadian crop and livestock production systems (BIOCAP Canada 2006). IFSM allows for the evaluation and comparison of alternative agronomic, feeding, manure storage and disposal strategies in terms of production, profitability and nutrient cycling. The model has been used to evaluate best management practices designed to reduce GHG emissions from dairy farms in Coastal British Colombia. Studies for the US beef production system have also used simulation models to evaluate profitability of cattle production systems under different management practices (Halter and Dean 1965). Simulation has proven very applicable to all agricultural production systems with its applicability to both livestock and crop production systems.

3.5 Environmental-Economic Trade-off Analysis (TOA)

The concept of trade-off derives from the idea that resources are scarce; that is to obtain more of one good, some amount of another good will have to be given up (Stoorvogel et al 2004). A farmer who continuously grazes cows on one piece of land without maintaining the land risks total loss of the farm business, because with time the land's nutritive value is lost and it cannot provide enough feed for the cattle. This demonstrates the trade-off between the income generated from the farm and the nutritive value of the land. Macleod and McIvor (2008) have argued that the reliance on production economics to inform resource use decisions on rangeland enterprises might not be appropriate, given a second feature of livestock production that has an ecological aspect. Trade-off analysis recognizes that complex interactions between environmental and economic indicators are a key aspect of production systems, and quantifies the inter-relationship of these interactions as a joint distribution (Stoorvogel et al 2004). Trade-off curves are used to represent the joint distribution of indicators (Stoorvogel et al 2004; Vos et al 2003). The curve is a two-dimensional graph that shows the relationship between the two indicators; thus it can be used to measure the change in one indicator given a change in the other (Vos et al 2003). With adoption of GHGMP, this curve can help farmers decide what management practices to implement in their farms given the level of economic returns and the levels of GHG emissions from those management practices.

There are instances in which decision makers take into consideration more than two indicators (i.e. environmental, economic, and social) in their management decisions. In this situation a Multi Criteria Approach (MCA) is adopted to the tradeoff analysis (Klemmer 2010). MCA offers opportunities to present the trade-offs and to rank different priorities and criteria in a systematic manner that does not specify an overall single value framework by applying weights to the different indicators under consideration (Brown et al 2001).

The TOA is often used by ecological economists to determine solutions for land use, evaluating production, and measuring environmental impacts (Klemmer 2010). Pradel et al (2006) used TOA to analyze the trade-off between economic and methane emissions of genetically modified dairy cows in Cajamarca, Peru. This study indicated some win-win outcomes using this type of analysis. The genetically modified cows were found to reduce GHG emissions by 20 percent when compared to local breeds, and also generated more than double the income. Stoorvogel et al (2004) argued that even win-win outcomes must come at the expense of some other desirable attribute, such as the willingness to let go of the local breeds, and the tools used to train local producers on the management of the new breed.

The cost effectiveness of alternative manure management systems for livestock operations has been analyzed using TOA to measure the tradeoffs between pollutants (environmental indicator) and the economic returns to the producers (Vos et al 2003). TOA has also been used to analyze the economics and environmental tradeoffs of converting conventional agriculture to organic production in Canadian Prairie Provinces (Klemmer 2010).

The TOA is a good tool in analyzing the impacts of making a change in a farm, especially when such a change may impact more than one decision variable simultaneously. Introducing GHGMP in beef operations will impact the levels of economic returns and the levels of GHG emissions. It is, therefore, important to provide information on how such a management practices will affect environmental and economic outcomes of beef operations in order to help producers make informed decisions on whether or not to adopt the management practices.

3.6 Summary

This chapter borrowed from the literature to argue the case that there is a problem of GHG emissions from Canadian beef operations, especially in western Canada, which is home to the majority of the country's beef herds. Beef operations emit GHGs, consisting of methane, nitrous oxide and carbon dioxide. Several mitigation strategies applicable to western beef farms were identified. Models of farm management decisions were also reviewed with particular focus on mathematical programming and simulation modelling. Both mathematical programming and simulation have proved to be very important tools in farm management. MP proves to be more of a resource allocation tool, whereas simulation is suited to analyzing more realistic behavior of the farm under different management strategies. The question of "if we introduce GHGMP to the farm what happens to economic returns" is more suited to the simulation approach in which the farm system is allowed to feel the shock of the change and re-adjust to a different economic state without trying to force maximum economic returns like the MP does. Tradeoff analysis of environmental and economic outcomes was also reviewed. This will help identify sustainable GHGMPs. The following chapter will borrow some material from this chapter to explain the model developed for the mitigation scenarios evaluated in this study, and will also explain the study area and study farm.

Chapter 4

STUDY METHODOLOGY

4.1 Introduction

This chapter explains the development and operationalization of the model built to evaluate the impacts of GHGMPs on the study farm. The main components of the study farm included: a beef herd, annual cropping, and pasture production. Feed requirements of the beef herd were the linkage between these components. It was postulated that implementation of a GHGMP to this farm would change the resource allocation affecting all three components of the farm in a systematic manner. The literature reviewed in Chapter 3 suggested that simulation modelling is the best approach for capturing the behavior of a system with shock and response patterns. Therefore, a whole farm simulation model was developed for this study. In order to understand the model, the discussion of timeline and dynamics of the beef herd is presented in section 4.2, followed by section 4.3 with an explanation of the profitability measure of the farm and the concept of discounting, and finally, an overview of the study area and study farm characteristics are presented in section 4.4.

4.2 Timeline and Dynamics of the Beef herd

The beef farm was simulated for a period of 9 years, which is a full production cycle of the beef herd. In the 9 years, there are 3 crucial stages that the breeding stock[4] goes through: the development period, production period, and finally the culling stage, which marks the end of the beef cycle. These stages[5] are shown in Figure 4.1. Calves are raised to finish in the farm through the three development-period system common in western Canadian beef operations (cow-calf, backgrounding, and finishing). The breeding stock was brought into the farm as young heifers and bull calves.

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[4] Breeding stock is the Cows and Bulls that are kept in the farm for reproduction.
[5] Stage – is a period of 1 year running from May to April; except stage 1 which is 151 days from mid-November to April.

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	Stage 9	Stage 10
Cows	Development	Development *First Breeding*	Production Period	Production Period	Production Period	Production Period	Production Period	Production Period	*Cows Culled*	
Bulls	Development	Development *First breeding*	Production Period	Production Period	Production Period	Production Period	Production Period	*Bulls Culled*		
Calves			Calf crop 1	Calf crop 2	Calf crop 3	Calf crop 4	Calf crop 5	Calf crop 6	Calf crop 7	

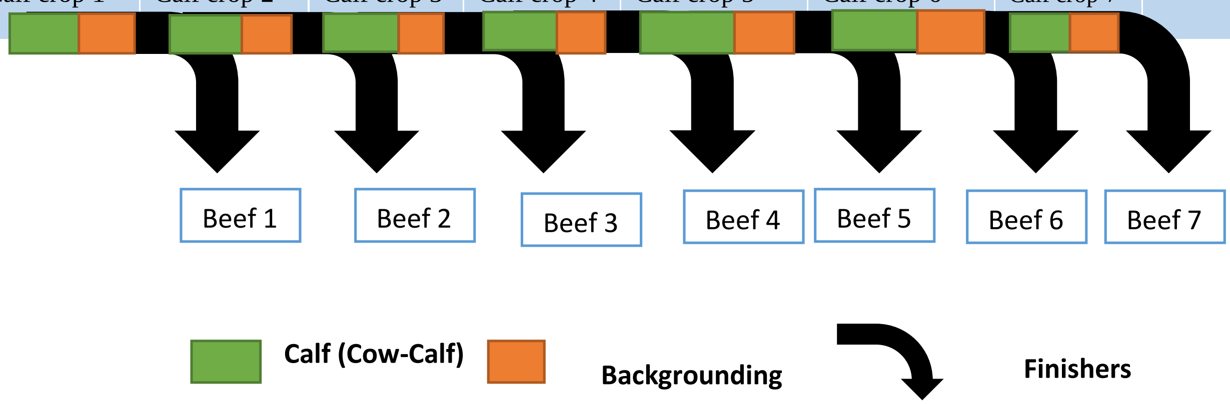


Figure 4.1 Timeline of the beef herd

Stage 1 is the entry point of the breeding stock to the farm. In this stage the breeding stock is developed to be ready for their first breeding. A backgrounding diet[6] was used in this stage. From stage 2 to stage 9 the breeding stock grazed pasture in the summer, and were fed mixed alfalfa-grass hay in the winter. The first breeding occurred in stage 2 and calves from that breeding were born in stage 3. Cows gave birth in every stage until stage 9 and then they were culled. Bulls were culled[7] after the final breeding in stage 8. In every stage there are three components (beef herd, crop production, and pasture production) in the farm which are shown in Figure 4.2.

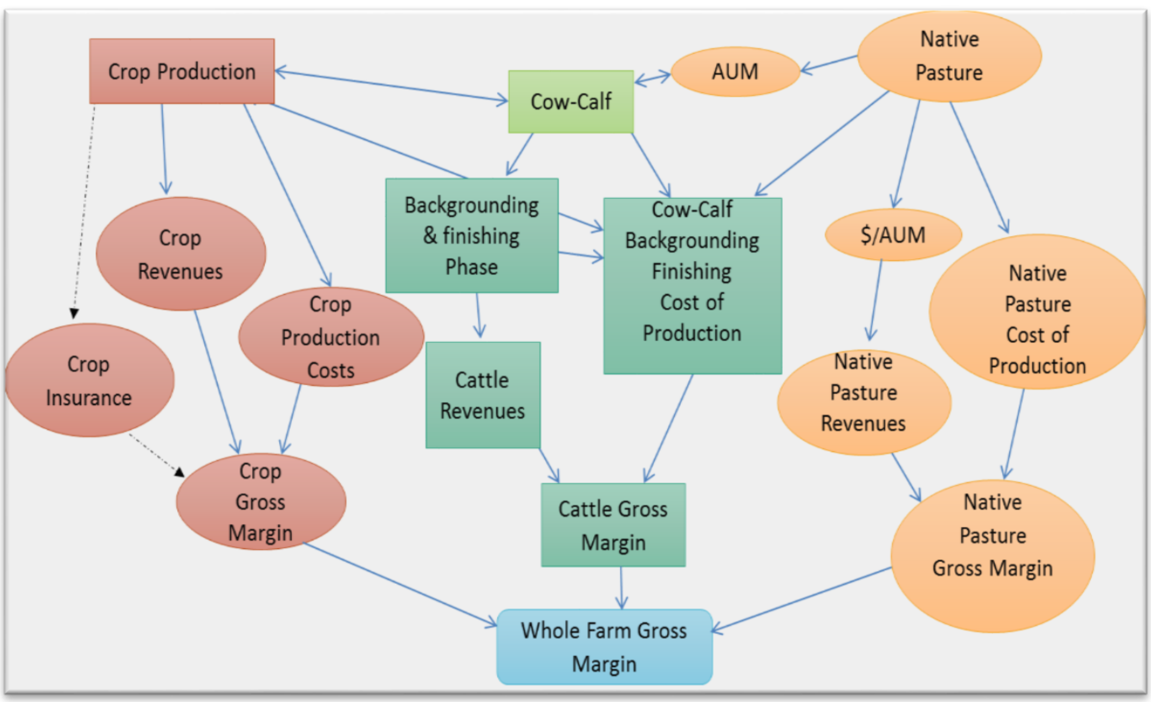


Figure 4.2 Components and linkages of the farm model

The linkages within the farm were developed from industry coefficient data and economic variables. Feed requirements of cattle links the beef herd to native pasture and crop production.

[6] Backgrounding diet ration consists of 40 percent dry matter barley grain and 60 percent dry matter barley silage.

[7] Bulls are culled and replaced regularly in western beef operations but here they were assumed to go through the whole production cycle without culling in order to keep consistence with GHG emissions.

The following section (4.3) explains the methodology used for measuring profits of the farm; which will also clarify the components and linkages of Figure 4.2.

4.3 Profitability Measure of the Farm

As has already been mentioned, the model was developed to analyze profitability of the whole farm over the entire beef production cycle under different GHGMPs. Profitability of the farm was measured using gross margin value, which is simply calculated from subtracting variable costs from revenues. Since the farm spans for a period of more than one year, the present values of costs and revenues were calculated to account for the time value of money. Present value of cash received from future transactions is calculated as:

$$\text{Present Value of } C = \frac{C}{(1+r)^t} \qquad (4.1)$$

where, C is the future value of money to be discounted, r is the discount rate (see section 4.4) and t is the number of years from the present date to the time C is realized. Profitability of the whole farm is the summation of present value gross margin of the beef herd, crop production and native pasture, and adding other revenues (i.e. insurance receipts) as shown in equation 4.2:

$$\text{PVWFGM}_k = \sum_{e=1}^{3}(\text{PVGM}_{ekt}) + \text{PVOR}_{kt} \qquad (4.2)$$

where, PVWFGM_k is the present value of whole farm gross margin under management practice k. e is the enterprise (where e =1, 2, 3, refer to beef herd, crop production, and native pasture rented out, respectively), PVGM_e is the present value gross margin of individual enterprise e, and PVOR is the present value of other revenues (in this study it is revenues from insurance receipts and from aftermath grazing assumed to be rented out). From equation 4.2, the PVGM of each enterprise can be further broken down into costs and returns of that enterprise as follows:

$$PVGM_{e=1,k} = \sum_{t=1}^{n}(PVBR_{kt} - PVBC_{kt}) \qquad (4.3)$$

$$PVBR_{kt} = \sum_{t=1}^{n} \frac{W_{ikt} * P_i}{(1+r)^t} \qquad (4.4)$$

$$PVBC_{kt} = \sum_{t=1}^{n} \frac{\left(FC_{cc,t} + FC_{fd,t} + OVC_{cc,t} + OVC_{fd,t}\right)_k}{(1+r)^t} \quad (4.5)$$

where, t is the time in years from $1 \ldots . n$ (n = 9 for the full production beef cycle*),* $PVBR$ is the present value of beef revenues from animal sales, $PVBC$ is the present value of beef production costs, W *is* the live weight of animals sold, i is the type of animal sold where i =1, 2, 3, 4, being steers, heifers, cull cows, and cull bulls, respectively. FC_{cc} is the cost of cow-calf feed*,* FC_{fd} is the cost of feedlot feed*,* OVC_{cc} and OVC_{fd} are other variable costs associated with the cow-calf and feedlot operations, respectively.

After all the feed has been produced, unused land is put into a cash crop, which generates revenues for the farm but also incurs costs of production. The following equations describe how present value gross margin from the cash crop was determined:

$$L_{cs} = TL_a - L_f \quad (4.6)$$

$$PVGM_{e=2,k} = \sum_{t=1}^{n} \left(R_{cs,k,t} - C_{cs,k,t}\right) \quad (4.7)$$

$$R_{cs,k,t} = \sum_{t=1}^{n} \left(\frac{Q_{cs,kt} * P_{cs}}{(1+r)^t}\right) \quad (4.8)$$

$$C_{cs,k,t} = \sum_{t=1}^{n} \left(\frac{L_{cs,kt} * VC_{cs}}{(1+r)^t}\right) \quad (4.9)$$

where, L_{cs} is the land under the cash crop in acres, TL_a is the total annual cropping land of the farm, L_f is the land under feed production, R_{cs} is the present value of revenues from sales of the cash crop, C_{cs} is the present value of cash crop production costs, Q_{cs} is the quantity of cash crop produced in tonnes, P_{cs} is the cash crop price per tonne, and VC_{cs} is the cash crop variable cost per acre.

After satisfying the grazing needs of the animals, all unused native pastureland is put up for rent to other beef producers. Pasture land was converted to Animal Unit Months (AUM), which is a standard way of dealing with pasture use. To convert pastureland into AUMs the stocking rate (AUMs/acre) of the area is required and equation (4.10) was used to convert pastureland to AUMs:

$$AUM_T = L_p * S_p \quad (4.10)$$

where, AUM_T is the total available animal unit months of the farm, L_p is the total pastureland available, and S_p is the stocking rate of the pasture. Thus, AUMs rented out is the total available AUMs less AUMs for animal feed:

$$AUM_R = AUM_T - AUM_F \quad (4.11)$$

where, AUM_R is the total AUMs available to be rented out, and AUM_F is the total AUMs used to feed the beef herd of the farm. The present value gross margin of rented out pasture can now be determined as shown in equation (4.12):

$$PVGM_{e=3,k} = \sum_{t=1}^{n} (R_{pt} - C_{pt}) \quad (4.12)$$

where,

$$R_{pkt} = \sum_{t=1}^{n} \left(\frac{AUM_{Rkt} * J}{(1+r)^t} \right) \quad (4.13)$$

$$C_{pkt} = \sum_{t=1}^{n} \left(\frac{L_{Rkt} * VC_p}{(1+r)^t} \right) \quad (4.14)$$

where, R_p is the revenues received from rented out pasture, C_p is the pasture cost of production, J is the rental rate (\$/AUM) of pasture. L_R is total pastureland rented out, VC_p is per acre pastureland variable cost (\$/acre) of production.

The final component of whole farm gross margin value is the present value of other revenues. Insurance costs and aftermath grazing was the sources of revenue under this category. The level of revenues from insurance and aftermath grazing depends on how much land has been put under each crop and the total amount of pastureland the farm owns. Equation (4.15) shows the calculation of revenues in this category;

$$PVOR_{kt} = \sum_{t=1}^{n} \left(\frac{L_{jt} * N_j + L_{jt} * A_j}{(1+r)^t} \right) \quad (4.15)$$

where, L_j is land under crop j (in this study the j = 1, 2, 3, 4 if feed barley, barley silage, mixed hay, native pasture, respectively), N_j is the compensation rate for crop, and A_j is the rental rate of the aftermath grazing rented out.

From the equations of the individual components of the farm above (equation 4.3 to 4.15), present value whole farm gross margin (equation 4.2) can be rewritten as:

$$\mathrm{PVWFGM}_k = \overbrace{\sum_{t=1}^{n}\left(\frac{W_{ikt} * P_i - \left(FC_{cc,t} + FC_{fd,t} + OVC_{cc,t} + OVC_{fd,t}\right)_k}{(1+r)^t}\right)}^{\text{Beef gross margin}} + \overbrace{\sum_{t=1}^{n}\left(\frac{Q_{cs,kt} * P_{cs} - L_{cs,kt} * VC_{cs}}{(1+r)^t}\right)}^{\text{Cash crop gross margin}} +$$

$$\underbrace{\sum_{t=1}^{n}\left(\frac{AUM_{Rkt} * J - L_{Rkt} * VC_p}{(1+r)^t}\right)}_{\text{Rented-out native pasture gross margin}} + \underbrace{\sum_{t=1}^{n}\left(\frac{L_{jkt} * N_j + L_{jkt} * A_j}{(1+r)^t}\right)}_{\text{Other revenues}} \qquad (4.16)$$

4.4 Present Value of Future Stream

Time value of money has to be considered when dealing with investments that span a long period of time. A dollar received in the future does not have the same value as a dollar received today. The difference in time value of money is represented by a discount rate or an interest rate, which is typically equal to a return that could have been earned in financial markets with a comparable risk profile (Conestoga-Rovers and Associates 2011).

Koeckhoven (2008) used Capital Market Line method to determine the appropriate discount rate for a mixed farm in Alberta and found a value of 7.5 percent but decided to use 10 percent for the analysis citing previous literature. Conestoga-Rovers and Associates (2011) argued that over a long period of time, any discount rate greater than zero will place minimal to zero value on an event in the distant future. In that report, a discount rate of 5 percent was used for the analysis of the economic impacts of different GHGMPs on a beef farm in Alberta, which is close to the 4.66 percent interest rates charged on farm loans by the Agricultural Financial Services Corporation in Alberta (AFSC 2014).

A discount rate of 5 percent was used in this study following previous studies of beef operations and the interest rate charged on farm loans as discussed above. However, sensitivity analysis was conducted at discount rate of 3 percent and 7 percent to determine the impact of discount rates on farm level profitability of adoption of GHGMPs.

4.5 Study Area

The farm used in this study is located in Vulcan County[8], Southern Alberta (Figure 4.3). The County has a population of 6,900 and agriculture is the largest economic industry employing 52 percent of the labour force (City-Data 2013). Agriculture encompasses about 81.5 percent of the total County area (Vulcan County Statistics 2014).

Source: Generated through Google Maps
Figure 4.3 Map of Canada showing the location of Vulcan County

The County is characterized by three different soil zones: brown, dark brown, and thin black soil zones, with majority of the County being in dark brown soil cover. According to Malmberg and Andrews (2005), the area gets a mean annual precipitation that varies from approximately 390 mm to 450 mm. Majority of the precipitation occurs between May and

[8] Vulcan County was used following Beauchemin et al (2011) in order to have consistence with GHG emission analysis.

September, and there is sufficient growing degree days to grow most cereals and oilseeds (Malmberg and Andrews 2005).

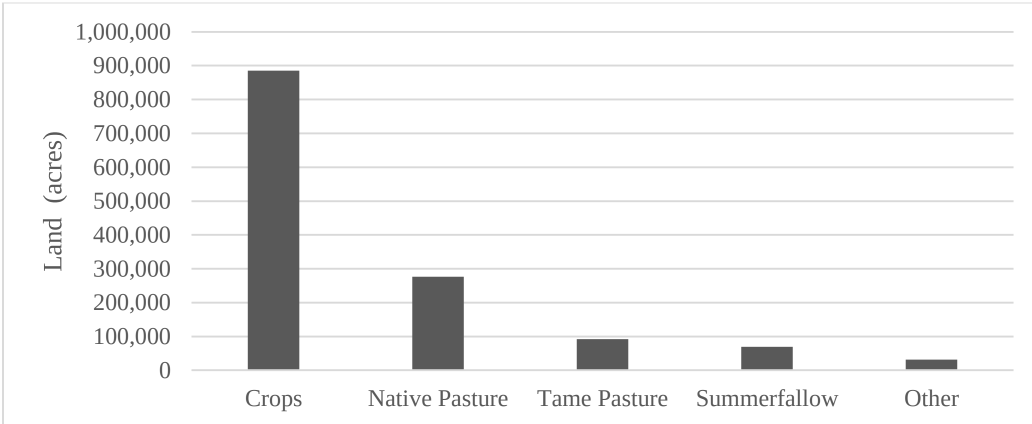
In 2011, there were a total of 603 farms in the Vulcan County, of which 355 reported having grain and oilseed farming, and 105 reported beef cattle ranching and farming, including feedlots (Statistics Canada 2011). There is a wide range of farm sizes (Table 4.1) across the County. More than 50 percent of the farms have at least 1000 acres of farmland. Annual crops occupy the biggest portion of agricultural land as shown in Figure 4.4, with pasture occupying the second largest land area. A small portion of land is in summerfallow, and other uses such as Christmas trees, woodlands, and wetlands.

Table 4.1 Farmland area of Vulcan County Farms

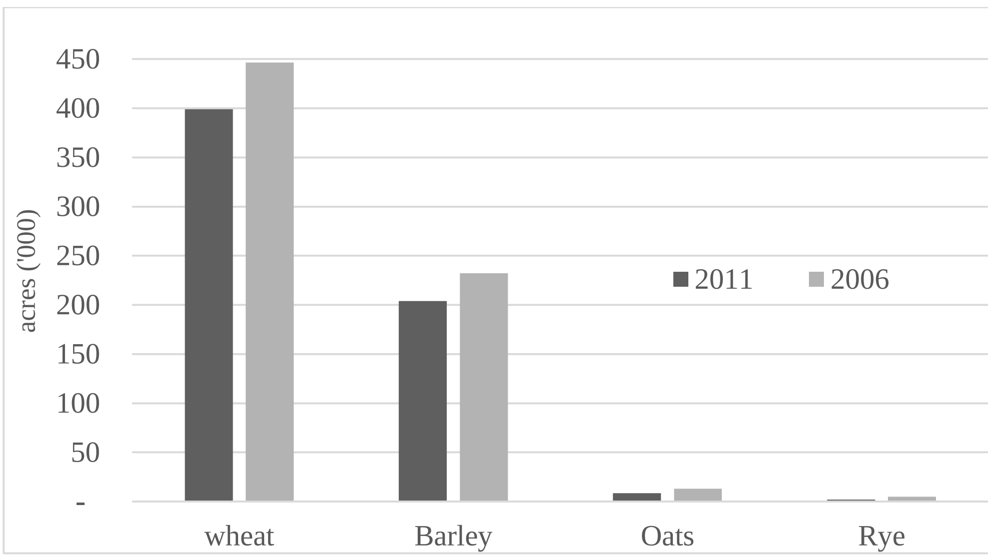
Total Farm Area	**Number of farms**	**Percentage of Total**
under 10 acres	11	2%
10 to 69 acres	35	6%
70 to 129 acres	15	2%
130 to 179 acres	50	8%
180 to 239 acres	9	1%
240 to 399 acres	57	9%
400 to 559 acres	34	6%
560 to 759 acres	31	5%
760 to 1,119 acres	49	8%
1,120 to 1,599 acres	63	10%
1,600 to 2,239 acres	64	11%
2,240 to 2,879 acres	47	8%
2,880 to 3,519 acres	28	5%
3,520 acres and over	110	18%

Source: Statistics Canada (2011

The area of major crops grown in the area is shown in Figure 4.5. In 2011, the main crop grown in the area was wheat (399,210 acres) followed by barley, oats and rye at 203,846; 8,452; 1,951 acres, respectively (Statistics Canada 2011). Most of the wheat grown is spring wheat (at 83 percent of total wheat) with the rest being durum wheat and winter wheat at 14 and 3 percent, respectively.



Source: Statistics Canada (2011)
Figure 4.4 Farmland use in Vulcan County, 2011.



Source: Statistics Canada (2011)
Figure 4.5 Acreage of major crops seeded in Agricultural Census Division # 5

Pasture and crop land availability supports livestock production. The dominant livestock is cattle production reported in 277 farms with a total of 197,851 cattle and calves[9]. This represents, 3.9 percent of the total cattle and calves reported in Alberta; southern Alberta represents about 28 percent of Alberta's total cattle and calves (Statistics Canada 2011). Beef production is characterized by three different phases at the farm level: cow-calf, backgrounding/feeders, and

[9] Total cattle and calves includes "Calves under 1 year," "Steers 1 year and over," "Heifers for slaughter or feeding," "Heifers for beef herd replacement," "Heifers for dairy herd replacement," "Beef cows," "Dairy cows" and "Bulls 1 year and over."

finishing operations. Table 4.2 shows the number of cattle and calves reported in Vulcan County farms.

Table 4.2 Number of Cattle and Calves as of May 2011 in Vulcan County, Alberta, and Canada

	Vulcan County	**Alberta**	**Canada**
Calves, under 1 year			
farms reporting	232	19,154	75,108
number	24,744	1,594,068	4,080,233
Steers, 1 year and over			
farms reporting	93	7,387	27,979
number	69,056	819,409	1,498,894
Heifers for slaughter or feeding			
farms reporting	55	4,910	19,693
number	71,438	684,470	1,100,968
Heifers for beef herd replacement			
farms reporting	95	10,623	34,272
number	2,638	264,372	602,701
Beef cows			
farms reporting	224	18,618	61,425
number	26,112	1,530,391	3,849,368
Bulls, 1 year and over			
farms reporting	198	16,457	55,326
number	1,333	90,813	225,022
Total cattle and calves (53)			
farms reporting	277	21,888	85890
number	197,851	5,104,605	12,789,965

Source: Statistics Canada (2011)

In the County, a total of 24,744 calves under 1 year old, 71,438 heifers for slaughter or feeding, 69,056 steers 1 year and over, and 2,638 heifers for beef herd replacement were reported. On average, Vulcan County has large beef herds with an average of 117 beef cows per farm compared to Alberta and Canada with 82 and 63 beef cows per farm, respectively. The number of bulls averaged 7 per farm, which suggests each bull service about 17 cows. However, this number could be a small number considering that some beef producers raise bulls to sell, and there is also use of artificial insemination[10].

Dairy production represents a very small part of cattle production in this area, with only 2 farms reported having dairy cattle and milk production in the 2011 census data. Other livestock

[10] The rule of thumb is that 1 bull services between 25 to 30 cows (Larson 2011)

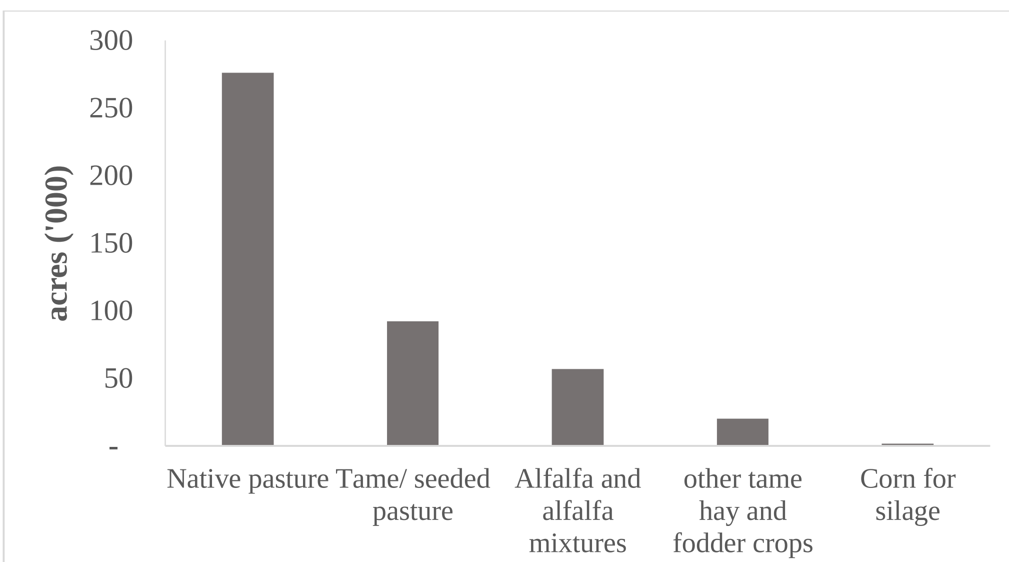
farms reported in the County include: pigs, sheep, goats, horses, llamas, and alpacas (Table 4.3). Pig production is also a big livestock industry in the County.

Table 4.3 Livestock numbers on farms in Vulcan County

Type of Farm Enterprise	Farms reporting	Number of Animals
Cattle and Calves	277	197,851
Pigs	21	57,764
Sheep and Lambs	20	4,388
Horses and Ponies	159	1,314
Goats	12	363
Llamas and Alpacas	13	195

Source: Statistics Canada (2011)

One of the key factors resulting in dominance of western Canada in cattle production is the abundance of native pasture land, which primarily supports cow-calf operations. The total native pasture land in western Canada is 47.4 million acres compared to only 2.6 million acres in Eastern Canada (Kulshreshtha et al 2012). The County of Vulcan also has an abundance of native pasture (276,110 acres), and farmers also grow tame pasture, alfalfa and alfalfa mixtures, tame hay and fodder crops, and corn for silage (Figure 4.6).



Source: Statistic Canada (2011)

Figure 4.6 Pasture and forage production ('000 acres) in Vulcan County

4.6 Study Farm and Simulation Model

The study farm was a proxy for a mixed farm in Vulcan County. Thus it can be seen as a 'synthetic farm' for a region representing salient features of the region. To keep consistency with the findings of GHG emission levels of the study farm, information of the resources and activities of the farm (i.e. farmland area, crop and pasture production, beef herd dynamics, feed requirements) was adopted from Beauchemin et al (2011). In addition to this information, industry data and expert information was also used to build the study farm.

The study farm has a total land area of 5,765 acres. This puts the farm in the largest farm category representing 18 percent of the farms in Vulcan County as shown in Table 4.1. The farmland was assumed to be owned, which is a reasonable assumption since 95 percent of all farms in the region were reported as owned according to the 2011 agriculture census data (Statistics Canada 2011). Beef production was assumed to be the main business activity of the farm; however, some of the land in the farm is used for crop and pasture production for livestock feeds. This therefore makes this farm a "mixed farm". The annual cropping part of the farm is 724 acres and is used for the production of grains and hay, and the remaining 5,041 acres is under native pasture for livestock grazing. The land area under any annual crop is determined by livestock feed requirements. If there is extra land left after all animal feed requirements are fulfilled the land was put into a cash crop to boost the revenues of the farm.

Beef cattle have different nutritional needs at different stages, and also have different feed intake capacity. For this reason, all cattle were divided into different classes: breeding cows and bulls, calves, backgrounding (feeders), and finishing. The breeding stock fed on native pasture in the summer and on harvested mixed hay in the winter. Calves relied on milk from nursing cows in the early stages after birth and gradually shifted to feeding on forage. Feeders and finishing cattle were fed on silage and grains at different formulations, following Beauchemin et al (2011).

4.6.1 Annual Crop Production

The annual crops grown in the farm were barley grain and silage, and hay. Hay was used as a winter feed for the breeding stock, whereas barley grain and silage were used as feedlot feed for marketed beef animals.

4.6.1.1 Feed Grain Production

Grains are a high energy feed required for feedlot animals as they need to gain more weight in a short time prior to being sent to the market. The two main grains grown in Vulcan County are wheat and barley. Barley is primarily used as an energy and protein source in beef cattle diets (Anderson et al 2012). The medium textured dark brown soil of the study farm is very suited to barley production. Surveys in the Alberta region have shown that 75 percent of the top producers were growing their barley on medium textured soils compared to forty-five percent of the low income producers (AARD 2011a). Barley is seeded in the early spring and harvested in late summer. Early seeded barley tends to have a yield advantage in Alberta because the crop can capitalize on early spring moisture, longer spring days and slightly cooler temperatures before the hottest part of the summer; therefore, moisture use is optimized resulting in higher crop yields (AARD 2008).

Crop rotation is an important management practice in western Canada. Crop rotations help the soil with a supply of nitrogen and organic matter, improve tilth, and conserve plant nutrients (Crisostomo et al 1993). Farms in Vulcan County uses different cropping systems with different rotations; farms in the northern and western part of the County have adopted a two or three year cereal rotation followed with a year of pulse and oilseeds, in the southern part of the County rotations include specialty crops, and in the eastern part rotations are very diverse (Malmberg and Andrews 2005). In the study model there is no specification on the sequence of what crop was grown over the years. Like Koeckhoven (2008), it is implicitly assumed that a crop rotation is implemented using feed barley, barley silage, and alfalfa-grass hay. The yields of the crops are therefore independent of what crop was grown in the previous year.

The yield of barley for the farm was set at the 2010 yield level of 51.36 bushels per acre reported in the Agriprofit benchmark reports from AARD (2011b). This yield is an average of all feed barley yields grown on owned land in southern Alberta. It is however important to note that yields can be different from one farm to the other depending on soil characteristics and other farm management practices such as crop rotations and fertilizer uses. Studies in Alberta have shown barley yield increases when additional units of nitrogen and phosphorus are applied (AARD

2011a). The amount of nitrogen and phosphorus fertilizers appropriate for this farm are 0.42 and 0.25 kilograms per acre, respectively as recommended for the region (Beauchemin et al 2010).

4.6.1.2 Hay Production

Hay is a forage that can be produced from different crops; in western Canada there is prevalence of legumes (i.e. alfalfa, clover) and/or grasses (i.e. timothy, wheat grass, and brome) used for hay production. Mixing legumes and grasses has been found to improve the yields and the nutritional value of forage (Sleugh et al 2000; Ball et al 2001). Sleugh et al (2000) found that yield, crude protein and in vitro dry matter digestibility of monoculture grasses was lower than those of legume-grass mixtures or of the monoculture legume. The inclusion of legume as a hay crop is also very beneficiary for the soil because of its soil nitrogen fixing characteristic, which saves the farmer on nitrogen fertilizer cost.

In crop rotations, grain yields have been found to increase when preceded by a legume crop (Beckman 1996). Alfalfa is the most widely grown forage legume in Canada (AAFC 2014c). Following recommended practices, the study farm produced alfalfa-grass hay, and the crop was cut and allowed to field dry to about 15 percent moisture level under natural sunlight and wind conditions (AAFC 2014c). The yields of hay were set at the 2010 levels of 1.58 tonne per acre, based on the average of yields from owned cropland in southern Alberta (AARD 2011b). As hay can be kept for longer periods with little loss of nutrients when protected from weather (Lacefield et al 1999), farmers tend to produce more than they need so that they can carry over some to the next production year, which helps them in case of a drought. In western Canada most of the hay used for beef production is farm-grown but farmers can also buy hay from their neighbours. There is also online tools such as the AARD’s Hay and Pasture Directory which has hay, straw and pasture listings from all over Alberta (AARD 2014). Hay is an important part of the diet for breeding beef cattle because of their low requirements of energy, protein and fiber (Beckman 1996). In the study farm hay was used as the winter feed source for the breeding stock.

4.6.1.3 Silage Production

Silage is a high moisture feed made from the preservation of green forage crops through acidification and fermentation (AARD 2012a). A forage crop is harvested and chopped into pieces and packed in silage piles or silos to remove oxygen which enables the feed to be stored for a long period of time without losing its feed quality (Koeckhoven 2008). Annual crops, such as cereals, grasses, and legumes, can be used for silage production. Crops that have been damaged by hail, insects or frost can also be harvested for silage. Barley is commonly used for silage in western Canada. According to a 2012 survey of Alberta farmers, 70 percent of the total 2.45 million tonnes of silage produced in the province was barley silage with oats, and other mixed grains constituting 17 and 0.08 percent of the total, respectively (AARD 2012a). Barley silage is preferred because of its high quality compared to other cereals, as it is very high yielding in the dark brown soil zone (SMA 2013). The yield of barley silage used for the study farm is 7.33 tonnes per acre, which is an average of all silages produced from owned land within the dark brown soil zone in southern Alberta (AARD 2010b). High rates of fertilizer, especially nitrogen, are required for high silage yields (SMA 2013). For optimum feed quality barley has to maintain a moisture content of 63 percent. This high quantity of moisture makes it costlier to keep silage than hay; however the nutritional value is higher for silage, and there is less field loss with silage because the crop is harvested at an earlier stage.

4.6.2 Native Pasture Production

Native pasture, also referred to as rangeland, is the vegetation that is indigenous to a region and is being grazed or has a potential to be grazed, as opposed to tame pasture, which includes vegetation species that have been introduced to a region. The native pasture of the study farm is classified as the Wheat Grass and Needle and Thread community (Classification MGA21) from the Lethbridge and Vulcan Plains of the mixed grass prairies. This vegetation is found in the ecoregion of the “Moist mixed grassland” as per the subdivision classifications of rangelands in Alberta (see Figure 2.6). Western and northern wheat grass is the dominant vegetation; however, under heavy to very heavy grazing, needle and thread, blue gama and pasture sage will increase in abundance (Adams et al 2013). The recommended ecologically sustainable stocking rate for the area is 0.28 AUM/acre (Adams et al 2013). The month of May has been found to be a good date to start grazing mixed prairie grass for maximum beef production (Schellenberg et al 1999). Pasture is grazed for a 6 month period from May to October. In the pasture, cows are exposed to bulls and breeding takes place. It is also a place where cows nurse their calves until they are weaned into backgrounding or finishing. Native pasture is the cheapest way of feeding animals as there are no major costs of producing it.

4.6.3 Livestock Inventory and Feed Requirements

The amount of feed required is dependent on livestock needs. Because cattle have different nutritional requirements, the herd was divided into four classes: breeding (cows and bulls), calves, backgrounding, and finishing cattle. Table 4.4 below shows the cattle numbers and some basic farm management information of the study farm.

4.6.3.1 Breeding Cattle and Feed Requirements

Breeding cattle consists of cows and bulls that are used for reproduction. The breeding stock was brought into the farm as weaned heifers and bull calves[11]. The decision to buy the breeding stock at this stage was taken with advice from Larson (2014), who advised that western beef producers sell weaned calves in mid-November, which is the starting point for the farm. The breeding stock was kept in the farm to produce 7 calves which are fed and finished in the farm.

Upon arrival to the farm, the breeding stock was fed a formulated diet to make sure they were ready for their first breeding. The diets used in this study followed rations in Beauchemin et al (2011), to bring comparability with their GHG emissions. A high forage diet containing 60 percent barley silage and 40 percent barley grain was used to develop the breeding stock, readying them for their first breeding. The heifers were bred at 15 months of age and gave birth to their first calf as two year olds. This follows studies of Canadian beef breeds on age and reproduction patterns (Canadian Agriculture Museum 2013). Laster et al (1972) found that 70 percent of straight bred and 86.9 percent of crossbreeds reach puberty by 15 months of age. For this study, breeding was assumed to happen in June when animals are out in the pasture. A total of 4 bulls are kept in

[11] Bulls were kept for the entire production period, but it is common for bulls to be replaced after every 2 years. This assumptions did not affect the marginal effects of scenarios evaluated.

the farm for breeding, one bull services 30 cows. This decisions was taken based on a report by Hamilton (2009), which indicated that bulls can service between 15 to 40 cows.

Table 4.4 Cattle numbers and basic farm management of the study farm

Breeding Cattle	**Value**
Cows	120
Bulls	4
Management	
Weaning rate	85%
Heifer replacement	15%
Backgrounding death loss	3%
Finishing death loss	1%
Animal weights	
Feeder finishing weight	1,334 lbs
Mature cow weight	1,323 lbs
Mature bull weight	1,808 lbs

Source: Beauchemin et al (2011)

The breeding stock relied on native pasture for 6 months of the year and on alfalfa-grass hay for the other 6 months. The amount of pastureland required to feed the livestock was determined from total animal unit months (AUM) and the stocking rate.

Table 4.5 Animal Units Equivalent based on metabolic weight

Animal live weight (*lbs*)	**Animal unit equivalent(AUE)**
600	0.682
650	0.724
850	0.885
900	0.924
950	0.962
1,000	1
1,100	1.074
1,200	1.147
1,800	1.554
1,900	1.618
2,000	1.682

Source: AAF (2007b)

To calculate the AUMs, animal weights were converted to animal unit equivalents (AUE) which is a comparison to a 1000 pound cow with or without a calf consuming 26 lbs dry matter of forage daily. Values shown in Table 4.5 were used for the conversion of animal weights to AUE (AAF 2007b).

From the AUE and the stocking rate the amount of pastureland was determined using equations (4.17) and (4.18).

$$AUM_F = \sum_{g=1}^{2} \left(\mathrm{B}_g * \mathrm{AAUE}_g * m\right) \qquad (4.17)$$

$$l_{PF} = AUM_F \div S_p \qquad (4.18)$$

where in equation 4.17, AUM_F is the total number of animal unit months of the herd, 'B' is the number of animals entering pasture and g = 1, 2 for cows and bulls, respectively. AAUE is the average animal unit equivalents of the animals entering pasture, and m is the number of months animals spend on pasture. In equation 4.18, l_{PF} is native pastureland for feed, and S_p is the stocking rate of the pasture in the farm.

An assumption was made that cows have the same weight throughout the production cycle, as do bulls.

4.6.3.2 Weaning and Death Loss

Weaning is the separation of suckling calves from cows. Calves were separated from cows in September towards the end of pasture grazing at a body weight of 529 pounds; however, weaning weights can vary within the herd. Not all calves that are born survive through the cow-calf operation; some calves die at birth, and others die later due to disease or predation. A weaning rate[12] of 85 percent was used as representative of western Canada (Beauchemin et al 2010). At that rate, it meant of the 120 calves born, only 102 calves were weaned into the backgrounding operation. The death loss in the feedlot operation was also included at 3 and 1 percent for

[12] Weaning rate = number of calves weaned / number of females exposed to breeding.

backgrounding and finishing, respectively (Beauchemin et al 2010). The total number of beef cattle going to the market was estimated at 98 for the study farm.

4.6.3.3 Cull Cow and Cow Replacement

Cows can be culled for various reasons but the most common one is to remove unproductive cows from the herd. Cows that are not pregnant at the end of breeding or whose calf do not survive through to weaning were removed from the herd. Up to 20 per cent of Alberta's cow herds are culled annually for various reasons which include: cows that experienced calving difficulty, whose calves do poorly, or have physical weakness (i.e. cancer eye, lump jaw, broken udders) (AAMS 2000). Culling can also be done as a response to market signals, if cull cow marketings are low, the price of culls goes up, which provides an incentive to increase culling rates and replace culled cows with younger animals with better genetics to improve reproductive efficiency (Canfax Research Services 2011a). Culling rate[13] in this study was set to 15 per cent to correspond with the number of cows that did not wean a calf. Cows were culled after pregnancy check and sold in September. Cow prices are usually high between March and September when the supply of cull cows is lower and the demand for hamburger, the primary use of cow meat, is higher (AAMS 2000).

Culled cows have to be replaced to maintain the herd size. In western Canada, it is common for beef producers to retain weaned heifers and raise them as replacements for the culled cows (Larson 2011). The decision of whether to buy or raise replacements depends on many different factors, including availability of feeds, labour, facilities, conception rates, genetic choice, and market prices (Cleere 2006). Replacements were brought into the breeding herd just before breeding in June so that they can be exposed to bulls. The cost of replacements was set at \$1056/head (Larson 2011). Final culling of cows was done at the end of a cow's reproduction period that is the time when the cow can no longer produce a calf. In the model it was assumed to be after the 7th calf crop was weaned. The breeding cows were then sold.

13 Culling rate was set equal to replacement rate which means the death loss of breeding cows was set to zero. This assumption was made in order to keep consistence with Beauchemin et al (2011); however a death loss of 1 percent is commonly used in western Canada.

4.6.3.4 Feeder Cattle and Feed Requirements

After calves were weaned, they were moved to a feedlot where they were fed rations formulated to provide a consistent and controlled body gain. Feedlot rations were adopted from Beauchemin et al (2011). In the backgrounding phase, animals were fed a high forage diet containing 60 percent barley silage and 40 percent processed barley grain, resulting in an average daily body gain of 2.2 lbs[14]. The main objective of backgrounding is to ensure that cattle develop stronger frames and muscles to carry the heavy weight gain+ in the finishing phase. The diet was fed for 110 days after which cattle transitioned to the finishing phase, where they were fed a high energy diet. The high energy finishing diet contained 90 percent processed barley grain and 10 percent barley silage, resulting in daily body gain of 3.2 lbs. The finishing phase takes 170 days and cattle are shipped to the market.

The feed required by feedlot animals was produced on the farm. Total amount of feed had to be determined to find the total area of crop to be produced. The daily dry matter intake (DMI) was determined based on the nutritional requirements of growing and finishing cattle table in NRC (2000). The total dry matter[15] of barley grain and silage required for the entire period animals are in the feedlot was determined. The feed was then converted to 'wet basis' which is the state of the crop when it is harvested. Equations (4.19) and (4.20) were used to find total feed and land area requirements.

$$\text{Feed Requirement (DMI)} = \sum_{j=1}^{2} \left(\mathrm{DDMI}_j * \mathrm{DF}_j * \mathrm{F}\right) \qquad (4.19)$$

where, DDMI is the dry matter intake per animal per day, DF is the number of days the animal is on feed, and F is the total number of feeders going into operation j = 1 for backgrounding and 2 for finishing. For example, if there is a total of 100 feeders going into the backgrounding phase with each animal feeding on 10 pounds dry matter intake per day of high forage diet for a period of 110 days, then the feed requirements of the period is;

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[14] Heifers and steers were assumed to have the same average daily gain; however, under normal conditions steers gain better than heifers.
[15] Dry matter is the state of feed when moisture has been removed.

$$\text{Feed requirements for 100 feeders} = 10*110*100 = 110,000 \text{ lbs dry matter} \qquad (4.20)$$

Since this is a backgrounding ration, it was 60 percent barley silage (66, 000 lbs) and 40 percent barley grain (44, 000 lbs).

Adjustment was also made for feeding and harvesting wastage. Harvesting losses were assumed to be 12 percent for silage and 3 percent for grain, while feeding wastage was assumed to be 5 percent for silage and 0 percent for grain (Rotz and Muck 1994). After adjustments for harvesting and feed losses, the amount of feed was converted to "wet basis" which is the state of the crop when it is harvested.

$$\text{Feed Wet Basis} = \text{Adjusted Feed Requirement} \div \%\ \text{DMC}^{16} \qquad (4.21)$$

To illustrate the conversion of dry matter to wet basis, let us consider the above example. As determined in equation 4.20, the 100 backgrounding cattle will need 66, 000 lbs dry matter of barley silage. Adjusting it for harvesting (12 percent) and feeding (5 percent) losses: it results in 78,947 lbs of silage required (as shown in equation 4.22 and 4.23)

i. Adjusting for Feeding Loss

$$\text{Adjusted Barley Silage Required}_{\text{Feeding}} = 66\,000 \div (1\text{-}5\%) = 69{,}474 \text{ lbs} \qquad (4.22)$$

ii. Adjusting for Harvesting Loss

$$\text{Adjusted Barley Silage Required}_{\text{Harvesting}} = 69{,}474 \div (1\text{-}12\%) = 78{,}947 \text{ lbs} \qquad (4.23)$$

After adjusting for feeding and harvesting losses, it is converted into 'wet basis' to meet the feed requirements. The dry matter content of feeds is different; a copy of dry matter content for western feeds was obtained from Yaremcio (2013). Barley silage and grain has a dry matter content of 37 and 89 percent, respective. Therefore the wet basis for barley silage in the example above was 213,370 lbs (as shown in equation 4.24).

16 DMC stands for dry matter content of feed, which is the mass of feed when dried.

$$\text{Barley silage 'wet basis'} = 78\ 947 \div 0.37 = 213{,}370 \text{ lbs} \quad (4.24)$$

The amount of crop to be produced in wet basis was used to determine the amount of land required to produce that crop. Land required was calculated from the total crop and yields of crop as shown in equation 4.25.

$$\text{Land Required} = \text{Total Crop "wet basis"} \div \text{Crop Yield} \quad (4.25)$$

Yields for the farm were obtained from an average of yields for the owned land of the dark brown soil in Alberta as reported in the Agriprofits benchmark reports (AARD 2010b). Barley silage is reported to have a yield of 7.33 tonnes per acre which is equivalent to 16, 160 pounds per acre. From the example above the land required to produce barley silage is 13.2 acres (as shown in equation 4.26)

$$\text{Land required for barley silage} = 213\ 370 \text{ lbs} \div 16\ 160 \text{ lbs/acre} = 13.2 \text{ acres} \quad (4.26)$$

It was assumed that all feeds required for the year were produced during the year, prior to the time it is required (i.e. summer/fall harvest for fall/winter feeding).

4.6.4 Cost of Annual Cropping and Native Pasture Production

The farm incurred the costs of producing annual crops, native pasture, and maintaining the beef herd. The cost of production data for barley grain and silage, and alfalfa-grass were obtained from Agriprofit benchmarks (AARD 2010b). These costs included seeding, fertilizers, chemicals, insurance, fuel, machinery and building repairs, custom and specialized labour, unpaid labour and interest charges. They were representative of a farm in the dark brown soil zone in southern Alberta. These data are collected by a survey of voluntary farmers in the region who specify the input costs of their production over the year. Table 4.6 shows the costs of production data for annual crop and native pasture used in the model.

Table 4.6 Cost of production in Southern Alberta: annual crops and native pasture

Variable	Feed Barley $/acre	Barley Silage $/acre	Alfalfa/grass Hay $/acre	Native Pasture $/acre	Canola $/acre
1. Seed & Seed Cleaning	6.42	12.00	-	-	37.92
2. Fertilizer	25.20	4.21	0.86	-	39.35
3. Chemicals	12.83	12.11	-	0.01	23.23
4. Hail / Crop Insurance	9.59	9.04	4.73	0.45	31.09
5. Fuel	15.83	7.35	1.89	0.26	12.12
6. Repairs - Machine	10.36	4.68	3.67	0.15	10.22
7. Repairs - Buildings	1.57	0.52	0.69	0.23	0.86
8. Utilities & Miscellaneous	6.12	4.69	1.91	0.13	7.82
9. Custom Work & Specialized Labour	6.92	9.31	5.58	-	2.21
10. Paid Labour & Benefits	1.08	4.81	0.55	0.21	2.07
11. Unpaid Labour	8.81	2.02	6.05	0.26	7.63
12.Operating Interest Paid@6.5%	3.40	2.30	0.84	0.06	5.67

Source: AARD Development (2010b)

Note that investment costs were omitted from this table. This is because only variable costs were used in the model to avoid overestimation of costs as the enterprises shared farm machinery and equipment. The final decision was to drop fixed costs all together because there was no data available on a mixed farm of the study farm size, and that decision did not affect profitability impact of any GHGMP evaluated.

4.6.4.1 Crop Insurance

Crop insurance is an important part of the farm since it covers against risk of lost production due to low yields caused by natural disasters. Alberta Agriculture Financial Services Corporation offers two types of insurance to Alberta crop farmers: production based insurance and area based insurance. The production based insurance is used for most of the annual crops, such as barley and wheat grain whereas the area based insurance is for silage/green feed and corn. Production based insurance is purely based on the farmers historical yields and offers farmers a choice to cover 50, 60, 70, or 80 percent of their average historical yields based on the last 5 years of production. If the yield is lower than the expected yields as per the farmers' insurance policy, a payment is triggered. The area based policy used for silage is based on the geographical location of the farm and it is only available at 80 percent coverage. This policy can be determined based on the average production losses of all farms in proximity or on the level of moisture received at a weather station that the farm is close to. In this study an insurance premium for the different crops grown was on a per acre cost basis based on what farmers in southern Alberta pay for insurance (Table 4.6).

4.4.4.2 Cow-Calf and Feedlot Cost of Production

Beef herd cost of production (COP) is divided into two parts: Cow-calf costs and Feedlot costs. The costs of the cow-calf phase are the costs of the breeding operation which include the cost of maintaining the herdsire(s) and breeding females to insure productive continuity of the farm. The costs of raising replacement cows is also part of the breeding operation. Table 4.7 shows a detailed breakdown of the total costs of production for the cow-calf operation and the feedlot operation (backgrounding + finishing) used in the model.

The main component of both the cow-calf and feedlot operation is the feed costs. Feed costs is the link between livestock and crop/pasture production. The cow-calf incurred costs of pasture and hay production, and the feedlot incurred costs of barley grain and silage. The other costs of cow-calf operations are the other variable costs with corresponding values in Table 4.7. Fixed costs[17] are also incurred in this phase of the farm but due to lack of prorating[18] they are omitted from this table.

The Feedlot costs includes both the costs of backgrounding and finishing. The decision to combine the two was based on the data reported by Canfax Research Services (2011b). This combination implies that the producer will incur the same costs in the feedlot regardless of their development stage, except for feed costs, which were separate. The yardage costs included the costs of fuel, machinery and building repairs, utilities and miscellaneous, and custom work.

[17] Fixed costs are the costs of building and machinery invested in the farm.
[18] Prorating is the allocation of costs according to how they are incurred (i.e. how much depreciation is incurred by the use of a truck in feeding animals).

Table 4.7 Beef herd costs of production (COP): cow-calf and feedlot

COW-CALF COP		FEEDLOT COP	
Feed Costs	**Cost**	**Feed Costs**	**Cost**
1.pasture	A*	1.barley grain	C*
2.mixed hay	B*	2.barley silage	D*
Other Variable costs	$/Cow	**Other Variable costs**	$/Feeder
3.bedding	2.04	3.backgrounding death loss	20.83
4.veterinary medicine and supplies	15.35	4.finishing death loss	9.63
5.fuel, oil and lube	9.33	5.vet and medicine	21.71
6.repairs-machinery and building	14.81	6.interest	14.04
7.herd Replacement @ 15 %	158.40	7.labour paid and unpaid	35.56
8.utilities	11.15	8.yardage costs(less labour)	24.64
9.marketing and transportation	2.48	9.marketing	2.00
10.custom work and specialized labour	5.07		
11.interest	14.15		
12.paid labour and benefits	18.09		
13.breeding costs	25.47		
14.unpaid labour & benefits	20.81		
Total Other Variable Costs	297.15		128.41

*indicates the cost of producing animal feed.

Sources: AARD (2012b), Canfax Research Services (2011b)

The yardage costs were adjusted to remove the fixed cost. Highmoor (2005) provided details on the components of yardage costs which were used in the study to adjust yardage costs to only include variable costs. Table 4.7 shows the adjusted values of yardage costs. In the backgrounding development stage of the feeders, a 3 percent death loss was assumed and the cost ($20.83/hd) that corresponds with the loss is included as shown in Table 4.7. Similarly, there is a 1 percent death loss in the finishing phase, which was also included in the total cost.

4.6.5 Revenues for the Farm

The primary source of revenues for the beef herd was from sales of finished steers and heifers. The ratio of finished animals was assumed to be 1:1 for steers and heifers. Revenues were simply calculated as prices multiplied by animal weights. Prices were obtained from the 2010 statistics yearbook prepared by AARD (2011b).The other revenue sources of the beef herd were from sales of culled cows and bulls. Culled cows were assumed to be of grade D2[19] category of the Canadian grading system of cull cow carcasses as described in OMAFRA (2005). Other cows were culled at the end of all production cycles. All four bulls were sold as soon as they sired the last calf crop in stage 8. Market prices of all animals are shown in Table 4.8. The other sources of revenues to the farm included: sales of forage[20], insurance receipts, rented out pastureland, and rented out stubble land. It is common for producers to rest land for recovery or leave straw on the field for incorporation back into the soil. In this study it was assumed land was at full production in every stage, this makes it easier for comparability since scenarios affected cropland and native pasture allocation. Every year all the cropland that was left idle after producing all feed for the animals was put towards alfalfa grass hay production which was sold as a cash crop. Hay was sold at $61.09 per tonne (AARD 2010b).

Table 4.8 Market prices of beef cattle in Alberta

2010 livestock prices	$/100 lbs Live weight
Steers 900+	102.4
Heifers 800+	99.97
Cull cows D2	54.25
Cull bull	65.59

Source: AARD (2011b)

After harvest, the stubble left on the field was rented out to other livestock producers at grazing rates shown in Table 4.9. All unused native pasture was also rented out to other beef producers from the area at a rental rate of $22.49/ AUM. The final source of revenues was from insurance receipts. The data from AARD (2010) shows that of all the crops grown in the farm, in 2010 only barley silage producers received insurance payment of $5.14 per acre grown.

Table 4.9 Annual crop aftermath grazing rates

Aftermath Grazing rates	$/acre
Feed Barley	$10.99
Barley Silage	$2.72
Alfalfa/grass Hay	$2.43

Source: AARD (2010b)

[19] D2 cull cows have medium to excellent muscling with less than 15 mm of white to yellow back fat (OMAFRA 2005).

[20] Producers normally carry over their forage into the next year in order to buffer the risk of droughts. In this study it was assumed the producer had perfect knowledge and sold forage annually. Hay was also treated as an annual crop, and establishment year was not accounted for, since this did not affect the marginal effect of scenarios.

4.7 Summary

This chapter described the simulation model used to evaluate the impacts of GHGMPs on profitability of the study farm. A timeline of the farm was drawn and described to help visualize the biophysical activities of the farm which attributes to the economic costs and returns of the study farm. The beef herd is the main activity of the farm supported by annual cropping and native pasture for feed production. The ten stages of the beef herd was categorized into three main stages: development, production, and culling. During the 9 year production cycle, 7 calf crops were born, raised and marketed. Profitability of the farm is described as the difference between present value of farm revenues and variable costs over the entire period of the farm. A discount rate of 5 percent is assumed following a review of literature.

The chapter also covers an overview of agriculture in Vulcan County. The beef herd size and farmland area of the study farm were drawn from Beauchemin et al (2011). Those numbers were confirmed to be consistent with the average of the region according to the 2011 agricultural census data.

Chapter 5

GREENHOUSE GAS MITIGATION SCENARIOS

5.1 Introduction

This chapter explains the different GHGMP scenarios evaluated in this study. The scenarios are categorized into two types: feed management, and animal husbandry management scenarios. These scenarios were adopted from Beauchemin et al (2011). For this reason, the discussion in this chapter borrows material from that study. Simulated profits of the farm reflects the changes in the total costs and revenues of the farm due to changes brought about by implementing GHGMP scenarios relative to the baseline scenario.

5.2 Baseline Scenario

The baseline scenario is representative of the farm in Vulcan County under the current management practices of the region as described in Chapter 4. The performance of the other scenarios is measured in terms of the incremental impact they have on the whole farm present value gross margin (section 4.3), which is the profitability measure used. Thus, a scenario leading to an increase in profitability of the farm is an economically desirable scenario to undertake.

5.3 Feed Management Mitigation Strategies

The scenarios in this category include changes in the timing of feedlotting, and modification of feed rations. The first two scenarios look at the impacts of changes in the timing of backgrounding and finishing of marketed beef animals (Table 5.1), and the other seven scenarios looks at modifications of feed rations (Table 5.2). In Table 5.2, the shaded area is the diet that's changed brought about by implementing a ration changing mitigation scenario. The scenarios are described in sub-sections that follow.

Table 5.1 Duration of feeding during backgrounding and finishing of market beef calves

Scenario	Stage	Location	Days	ADG(lbs/d)
Baseline	Backgrounding	Feedlot	110	2.2
	Finishing	Feedlot	170	3.3
Increased use of forage for growing cattle (**Scenario 1**)	Backgrounding	Feedlot	150	1.54
	Backgrounding	Pasture	120	1.54
	Finishing	Feedlot	120	3.52
Extended grain finishing of cattle **(Scenario 2**)	Backgrounding	Feedlot	40	2.2
	Finishing	Feedlot	210	3.3

ADG = Average daily gain

Source: Beauchemin et al (2011)

Table 5.2 Dietary composition for dietary mitigation scenarios

	Baseline	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
		Canola Seed			**Corn Distillers Grains**			**Forage Quality**
Backgrounding Ingredients, g/kg DM								
Barley grain	400	301	400	400	50	400	400	400
Barley silage	600	600	600	600	600	600	600	600
Canola seed	0	99	0	0	0	0	0	0
Distillers dried grain	0	0	0	0	350	0	0	0
CP, g/kg DM	125	133	125	125	188	125	125	125
DC	0.7	0.744	0.7	0.7	0.711	0.7	0.7	0.7
Days	110	110	110	110	110	110	110	110
Finishing Ingredients, g/kg DM								
Barley grain	900	900	801	900	900	550	900	900
Barley silage	100	100	100	100	100	100	100	100
Canola seed	0	0	99	0	0	0	0	0
Distillers dried grain	0	0	0	0	0	350	0	0
CP, g/kg DM	120	120	129	120	120	184	120	120
DC	0.81	0.81	0.849	0.81	0.81	0.816	0.81	0.81
Days	170	170	170	170	170	170	170	170
Breeding stock Ingredients, g/kg DM								
Legume-grass hay	1000	1000	1000	900		1000	800	1000
Canola seed	0	0	0	100		0	0	0
Distillers dried Grain	0	0	0	0		0	200	0
CP, g/kg DM	120	120	120	129		120	156	140
DC	0.55	0.55	0.55	0.618		0.55	0.61	0.6

DM, dry matter; CP, crude protein; DC[21], digestibility coefficient. The ingredients of feed is measured in g/kg, which shows the portion of an ingredient in the whole ration. An example of reading these diets is: the backgrounding diet of the baseline has 400 g/kg barley grain, which means per kg of backgrounding ration there is 400 grams barley grain. The shaded area is the ration modified to reflect the scenario under evaluation.

Source: Beauchemin et al (2011)

[21] DC is the digestibility coefficient defined as the portion of feed or nutrient which is not recovered in faeces, i.e., the portion which has been absorbed by the animal (Paulraj and Easerson 1982).

5.3.1 Increased Use of Forage in Growing Cattle (Scenario 1)

There is an emerging growth in demand for grass produced beef over the traditional grain produced beef in North America (Kelly 2012). This demand is driven by the fact that consumers believe grass fed "naturally produced" beef is healthier, and safer for the environment than grain fed beef, since the latter involves fertilizers and growth hormones. Producing beef using grass is attainable; however, it comes with added costs of keeping cattle in the farm for longer periods as rate of weight gain is slower. Berthoaume et al (2006) found that grass fed cattle produce lower weight as compared to grain-fed beef, which suggests that grass-fed beef might have to capture a premium price to be competitive with grain-fed beef. However, these practices have an impact on GHG. Beauchemin et al (2011) found that increased use of forage in growing cattle increases GHG emissions by 6.5 percent; however, other reports suggest that feeding cattle on high quality forage can reduce the production of methane gas, and also reduces manure emissions as manure is more widely distributed on pastures (CFBI 2008). There is very little done on the economic impacts of increased use of forages in growing cattle for western Canada. A study in the aspen parkland of western Canada found that backgrounding calves on Italian ryegrass pastures was less costly compared to the conventional backgrounding system (McCartney et al 2008). Their findings suggest that backgrounding on forage reduces the associated costs of yardage and stored feed. Despite this finding, there is still a lack of information on the whole farm economic impacts of increased use of forage in growing cattle.

For this scenario, growing cattle[22] were fed in a two stage backgrounding system that included a high forage diet as formulated in the baseline scenario followed by native pasture before being transitioned into the finishing phase. A high forage diet is fed for 150 days followed by 120 days of native pasture (see Table 5.1). The use of more forage added 110[23] days between weaning and selling finished cattle compared to the baseline scenario. The additional costs of this scenario included the 120 days on native pasture and the additional 40 days (110 days baseline vs 150 days under this scenario) that animals were fed on a high forage diet (backgrounding diet). However, there are also cost savings in the finishing phase as the number of days in the finishing stage was reduced from 170 days to 120 days. With this intensive use of forage, there is an expected need

[22] Growing cattle also referred as backgrounders.
[23] Weaning to finish in scenario 2 is 390 days compared to baseline's 280 days, which is 110 days difference.

for more land used in native pasture and barley silage to supply required feed for backgrounding animals.

5.3.2 Extended Grain Finishing Cattle (Scenario 2)

Compared to the baseline, this scenario increased the number of days animals spent in the finishing stage by 40 days and reduced the number of days spent in the backgrounding stage by 70 days. The increase in the number of days in the finishing phase meant the animals gained more weight in a shorter period of time (due to higher ADG), making them ready for the market earlier than in the baseline scenario. Shortening the number of days in the feedlot by using grains has been found to reduce GHG emissions of feedlots (Beauchemin et al 2011, Petellier et al. 2010). In western Canada, Beauchemin et al (2011) found that shortening the backgrounding phase and extending grain finishing has a potential to decrease whole farm GHG intensity by 2 percent compared to the conventional western Canada beef finishing systems. In a production system where grains are bought from the market, the economics of this scenario will be dependent on grain market prices. If grain prices are low compared to other feed inputs, a grain intensive system could be economically favorable. Lewis et al (1990) supports this claim in their study comparing extensive and intensive beef production systems and showing that overall cost of gain in animals is low for extensive systems than intensive system, except when the price of corn was low in relation to other feed inputs.

The grain was grown on the farm, making the price independent of market forces. However, a sensitivity analysis was done to determine the responsiveness of farm profitability to changes in grain costs/prices. The reduced number of days in the feedlot has a potential of feedlot cost savings compared to the baseline scenario; however, extended grain finishing has been found to produce low body weight animals (Lewis et al 1990; Beauchemin et al 2011) which could potentially lead to lost revenues. The overall economic implication of this scenario is dependent on the cost savings of having animals in the finishing stage for fewer days, and lost revenues due to lower market weights compared to the baseline scenario.

5.3.3 Feeding Canola Seed (Scenario 3 to 5)

Dietary supplementation of ruminant feed rations with lipids to reduce GHG emissions has received considerable amount of scientific study. In review of methane mitigation strategies, Hook et al (2010) have suggested several feed sources (i.e., oils, fatty acids, tallow, and seeds) can be used as lipid supplements in diets to reduce GHG emissions. Beauchemin et al (2009) compared the mitigation potential of sunflower, flax, or canola in dairy cows and found that canola seed offered a means of mitigating methane without negatively affecting diet digestibility of feed. Use of canola seeds as a supplement in rations used in a beef operation in western Canada was found to lower GHG intensity by 11 percent if included in the feedlot and cow calf diets (Beauchemin et al 2011). In this study, the economics of supplementing feed diets with canola seed was evaluated by incorporating crushed canola seed in rations of the backgrounding (scenario 3), finishing (scenario 4) and breeding stock (scenario 5). Canola seed was produced on the farm as per the requirements of animals. The requirements of land for the other crops substituted by canola seed was reduced; i.e., substituting canola for mixed hay in the breeding stock diet meant there is less hay required to feed the breeding stock as canola enters the ration. Similarly, reductions were needed for barley grain and silage in feedlot diets. The inventory of crops produced from the farm was determined in the model as rations changed. Data on the variety of canola used as feed in western Canada was not available; therefore, an average of the two varieties (roundup ready and liberty link) of canola produced in the region was used.

Canola seed crushing was assumed to be done on the farm using a roller mill. The cost of crushing canola was set at $0.005 per bushel canola crushed (Possberg 2014). This cost covers the operational costs of the roller mill[24].

5.3.3.1 Feeding Canola Seed to Backgrounding Cattle (Scenario 3)

In the backgrounding phase of marketed beef, canola seed was used to replace some barley grain in the ration. The ration of this scenario was formulated to contain 301, 600, and 99 g/kg dry matter barley grain, barley silage and canola seed, respectively. Introducing canola to the ration increased the digestibility of the feed from the baseline digestibility coefficient of 0.7 to 0.744

[24] It was assumed that the use of the roller mill will not require any additional labour.

(Beauchemin et al 2011). This increase in digestibility coefficient meant animals were able to turn more feed into body weight gain as compared to the baseline scenario. As a result, less dry matter intake was required to achieve the 2.2 lbs daily gain of backgrounding animals. In this scenario finishing weights were the same as in the baseline. Profitability change was a result of a change in the feeding costs as the number of backgrounding days remained the same as those in the baseline scenario, meaning the costs of non-feed items stayed the same.

5.3.3.2 Feeding Canola Seed to Finishing Cattle (Scenario 4)

The finishing ration was reformulated to contain 801, 100, and 99 g/kg dry matter of barley grain, barley silage and canola seed, respectively. Digestibility of the diet improved from a digestibility coefficient of 0.81 to 0.849 (Beauchemin et al 2011). This meant animals ate less dry matter to achieve the 3.3 lbs daily gain. The finishing weights of the animals did not change. Therefore profitability change was determined by the costs of producing the canola needed and the savings from substituted barley grains and reduction in the total dry matter consumed by animals.

5.3.3.3 Feeding Canola Seed to Breeding Cattle (Scenario 5)

In this scenario canola seed was incorporated in the winter ration for breeding stock. Canola seed replaced some of the legume-grass mixed hay, with the new ration containing 900 and 100 g/kg of mixed grass hay and canola seed, respectively. Inclusion of canola seed improved the nutritive value of the ration by increasing the protein and energy levels (see Table 5.2).The digestibility coefficient of the diet improved from 0.55 to 0.618 (Beauchemin et al 2011). The dry matter intake was adjusted to reflect the improved digestibility of the feed. Land requirements for the amount of canola needed was determined from the total dry matter required by all the breeding animals for the winter period. The impact on profitability of the farm came from the costs of producing the required canola seed and the savings from substituted alfalfa grass hay. Revenues from sales of beef animals were unchanged as this scenario did not affect the weights of animals going into the market.

5.3.4 Feeding Corn Distillers Dried Grains (CDDG) (Scenario 6 to 8)

The surge of the ethanol industry increased the demand for grains, limiting availability of feed grains and driving grain prices up; however, in the process of biofuel production a by-product is produced that can be incorporated in feed rations and potentially reduce feed costs. In Canada, ethanol is produced using wheat in the west and corn in the east. According to Boaitey and Brown (2011) the economic value of distiller by-product in feed ration varies depending on the price and nutritional value of other nutrients. Incorporation of CDDGs in beef rations has a potential of a win-win situation for the environment and the profitability of beef operations. Beauchemin et al (2011) found that incorporating CDDGs into beef rations has the potential to reduce GHG emissions by 2 percent over the entire feedlot cycle and by 6 percent from the cow-calf herd. On the economic aspect, Boaitey and Brown (2011) have found CDDGs can substitute a high proportion of barley grains in backgrounding and finishing rations, thereby reducing the costs of feeds.

In this study, to evaluate the impact of CDDGs on the profitability of the study farm, CDDG were incorporated in backgrounding (scenario 6), finishing (scenario 7), and breeding stock rations (scenario 8). Detailed explanation of these scenarios follows.

Since CDDGs are not available in western Canada, this study assumed CDDGs are imported from Lawrenceburg, Indiana in the United States as noted in Boaitey and Brown (2011). Shipping costs were included as part of the total price for the product. The total cost of CDDG was set at $197.29/tonne[25]. The cost of moving CDDGs from Lawrenceburg was estimated at $58/ tonne which consists of $50/tonne from Lawrenceburg to Lethbridge (Boaitey and Brown 2011) and $8/tonne between Lethbridge and Vulcan County (SAAEP 2008). Since CDDG are purchased and not grown on farm, land is freed up from the reduction of feed requirements of grains and hay from the farm that CDDG offsets. This land was put towards the cash crop production to generate revenues for the farm.

[25] Cost of CDDG include the cost of the product ($139.29/tonne) and the moving costs ($58/tonne).

5.3.4.1 Feeding CDDG to Backgrounding Cattle (Scenario 6)

In the backgrounding stage, a portion (35 percent) of barley grain CDDGs was replaced with CDDGs. The new feed ration contained 50, 600, and 350 g/kg dry matter of barley grain, silage and corn DDG, respectively. This improved the digestibility of the diet from 0.7 to 0.711 (Beauchemin et al 2011), and resulted in a reduced consumption of the modified ration to obtain the same body weight gain as the baseline backgrounding ration. However, profitability of this scenario depends on the competitiveness of the price of CDDG compared to the costs of producing barley grain in the farm.

5.3.4.2 Feeding CDDG to Finishing Cattle (Scenario 7)

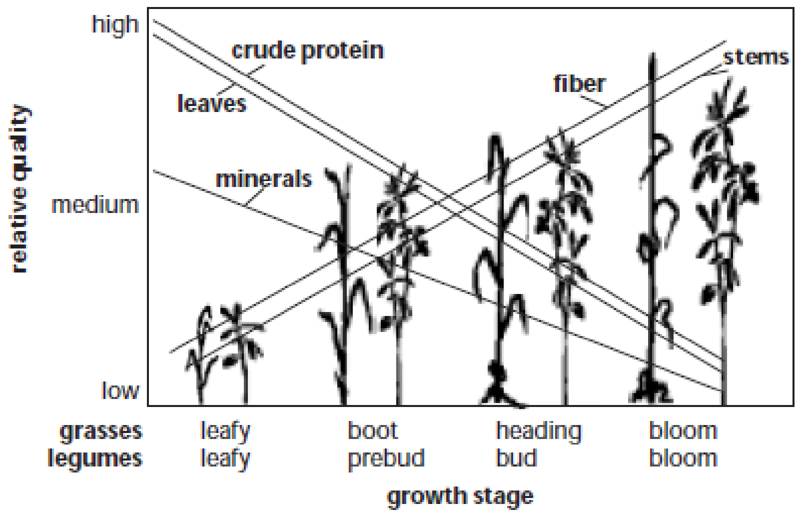
In the finishing diet, a portion (10 percent) of barley grain was replaced with CDDGs. The new ration contains 550, 100, 350 g/kg dry matter of barley grain, barley silage, and CDDG, respectively. Digestibility coefficient of the ration increased from 0.81 to 0.816 (Beauchemin et al 2011). This meant that animals consumed less dry matter and achieved the same body weight gain as in the baseline scenario.

5.3.4.3 Feeding CDDG to Breeding Cattle (Scenario 8)

In the breeding stock diet, a portion (20 percent) of alfalfa-grass hay was replaced with CDDGs. The ration was reformulated to contain 200 g/kg of CDDG and 800 g/kg alfalfa-grass hay. Digestibility of the diet increased from 0.55 to 0.61 (Beauchemin et al 2011). There was a huge improvement in the energy value by using CDDG in the breeding stock compared to the feedlot rations. The dry matter requirements of the breeding stock were adjusted to reflect the increased energy levels of the new ration.

5.3.5 Improved Forage Quality for Breeding Cattle (Scenario 9)

Forage quality is reflected in the nutritional value of the forage to the animal. The quality of forage can be determined by different factors that include forage species, temperature, maturity stage, and the leaf to stem ratio (Ball et al 2001). In this scenario forage quality was measured by digestible energy in the forage (Beauchemin 2014). As a forage plant matures and gets a higher ratio of stem to leaf material, fiber content increase and digestibility decreases (Filley 2013). Figure 5.1 shows the decrease in forage nutritional value as the plant grows until the bloom stage.



Source: Ball et al (2001)

Figure 5.1 Effect of plant maturity on forage quality

Under the baseline scenario, hay was assumed to be of medium quality with a digestible energy coefficient of 0.55, whereas in this scenario, hay was cut at an early stage to have a digestible energy coefficient of 0.60 (Beauchemin et al 2011). The amount of alfalfa grass hay to be fed the breeding stock under these different hay quality situations was obtained from Beauchemin (2014) as shown in the Table 5.3.

Animals were fed to obtain the same energy as in the baseline scenario; therefore less dry matter intake of the good quality hay was required to meet animal nutritional requirements. As Table 5.3 shows, the breeding stock would consume approximately 13 percent less dry matter of early cut hay compared to late cut hay. Early cutting hay also reduces yields. In this study a yield decrease of 10 percent was used as recommended by Beauchemin et al (2011). The decrease in yield would suggest a need for more land to produce enough animal feed, but since dry matter intake of animals also decreased, the overall impact was less land required for producing animal feed as will be seen in the results in Chapter 6.

Table 5.3 Dry matter intake of hay cut at an early stage versus late stage

Cattle class	Late Cut Hay Dry matter intake (kg) at DE= 0.55	Early Cut Hay Dry matter intake (kg) at DE=0.60	Percentage change
Dry cow (4 months)	12.02	10.47	12.9
Lactating cow (2 months)	18.18	15.84	12.9
Bull	15.35	13.38	12.8

Source: Beauchemin (2014)

5.4 Animal Husbandry Mitigation Strategies

These strategies in this section are related to management of the beef herd in order to improve production and productivity of the breeding stock. Two scenarios are analyzed in this category: increasing the weaning rate (scenario 10) and increasing the longevity of the breeding stock in the farm by one additional production year (scenario 11). The scenarios are described with more detail in the following sub-sections.

5.4.1 Increased Number of Calves Weaned (Scenario 10)

The weaning rate of the farm was set at 85 percent in the baseline scenario consistent with the overall average number used in Alberta, Saskatchewan, and Manitoba operations (Beauchemin et al 2011). Weaning rates can be improved with management of the herd. Bailey (1990) has shown that dam breed and timing of birth plays a pivotal role on the variation of number of weaned calves. Beauchemin et al (2011) also argued that a high calf crop could be increased by increased conception rate, fewer abortions and increased number of live births. A higher weaning rate means more beef is produced with same amount of emissions, so emissions per pound of beef produced is reduced. Beauchemin et al (2011) found that an increase in weaning from 85 percent to 90 percent in western Canada decreases the GHG intensity by 4 percent, mainly as a result of additional meat produced. Increasing the number of weaned calves will increase the costs of beef operation with more requirements for feed, labour, and other operational expenses; however, revenues from additional beef produced could offset those costs. In this study, this scenario attempt to measure the profitability response of increasing the weaning rate from 85 percent to 90 percent for western beef operations. This increase in weaning rate will also mean that less breeding cows are culled as there are more calves weaned rendering less unproductive cows. The number of weaned calves increased from 102 in baseline scenario to 108 calves under this scenario.

5.4.2 Increased Longevity of the Breeding Stock (Scenario 11)

Surveys of western Canadian farmers have found that 50-60 percent of commercial cows are in their 3rd to 9th gestation (Beauchemin et al 2011). In a study of GHG emissions from beef operations Beachaumin et al (2011) decided that a farm representative of southern Alberta will cull breeding cows after 7 production cycles. In this scenario the impact of having the breeding stock in the farm for 1 additional production cycle was evaluated. The farm remains in the same state as the baseline scenario such that there is no additional resources employed but just an additional production cycle to make it 8 production cycles. The breeding cows were sold after weaning the 8th calf crop. The additional cost of this scenario was the costs of keeping the breeding stock for an additional production cycle and raising the calves until finish, whilst there was also added revenues from selling an additional batch of finished market animals.

5.5 Summary

Eleven mitigation scenarios were discussed in this chapter, with at least one scenario for every stage of beef production. Of the eleven scenarios, nine are feed related and two are animal husbandry management related. The impact on profitability of the farm from these strategies will depend on how they affect the costs and returns of the farm. The following chapter will discuss the results from the evaluation of these strategies in a farm located in Vulcan County, using the model developed in Chapter 4.

Chapter 6

RESULTS

6.1 Introduction

Economics of the baseline and eleven GHMPs, as described in Chapter 5 were evaluated using the study model reported in Chapter 4. In this chapter, results obtained from the simulation of baseline and GHGMPs are reported. The resource allocation and profitability of the farm under different scenarios were compared to the baseline scenario. The latter was assumed to be representative of the conventional system of beef producers in Vulcan County, Southern Alberta. Profitability of the farm was estimated for a 9 year period, which is a complete beef cycle. Simulated present value gross margin (discounted revenues less discounted variable costs) was used as a profitability measure and basis of performance evaluation.

Two categories of scenarios were evaluated: feed management scenarios, and animal husbandry management scenarios. In order to show a comparison with the baseline scenario the results of these scenarios are presented in section 6.2, 6.3, and 6.4, which reports the results of baseline, feed management, and animal husbandry management scenarios, respectively. Environmental-Economic trade-off analysis results are reported in section 6.5, and a sensitivity analysis is performed in section 6.6. Lastly, a summary of results is presented in section 6.7.

6.2 Baseline Scenario Simulation Results

6.2.1. Simulation Land Allocation Results

As already discussed in Chapter 4, the beef operation used native pasture and alfalfa hay for the breeding stock, and barley grains and silage for marketed beef animals. The feed requirements for the livestock is different at different stages, hence a different area of land is required for feed production each year. The simulation results of the total amount of land required to produce feed for the herd over the entire lifetime of the breeding stock is shown in Table 6.1. From this table it is very evident that western beef producers require a large area of land under native pasture to support the beef herds, specifically the cow-calf operations. At the peak of production (stage 3 to 7) the farm required 3,908 acres of land for the production of feed. This is the period when the breeding stock have matured and are having calves being fed on the farm. The first two stages and the last two stages required less land; the first two stages corresponds to the time when the breeding stock was being developed for breeding, and the last two stages is when the breeding stock was culled, marking the end of the herd production cycle.

Table 6.1 Land required for production of feed for the beef herd (acres)

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	Stage 9
Feed barley	71.22	-	206.10	206.10	206.10	206.10	206.10	206.10	206.10
Barley silage	45.48	-	32.71	32.71	32.71	32.71	32.71	32.71	32.71
Alfalfa/grass hay	-	278.41	304.33	304.33	304.33	304.33	304.33	291.15	-
Native pasture	-	2,910.65	3,364.64	3,364.58	3,364.58	3,364.58	3,364.58	3,341.86	2,744.03
Total land required	116.70	3,189.06	3,907.78	3,907.72	3,907.72	3,907.72	3,907.72	3,871.82	2,982.84

The total farm area was assumed to be 5,765 acres, with 724 acres in annual cropping and 5041 acres in native pasture. From Table 6.1 it is evident that not all land was used in the production of feed. The amount of land left unused after feed production is shown in Table 6.2. This land was assumed to be used to grow a cash crop, and the unused native pasture was rented out. Alfalfa-grass hay was assumed to be the cash crop beef producers would grow; however, any other crop could also be selected depending on market prices and producers' preference.

Table 6.2 Land used for cash crop and rented-out pasture (acres)

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	Stage 9
Unused cropland	607.32	445.61	180.88	180.88	180.88	180.88	180.88	194.06	485.21
Unused pastureland	5,040.90	2,130.25	1,676.26	1,676.32	1,676.32	1,676.32	1,676.32	1,721.76	2,296.87

6.2.2. Simulated Costs of Production Results

The cost of production is reported in Table 6.3 specifying the direct costs associated with the three different components of the farm: beef herd, marketed forage, and rented out pasture. These costs are only the variable costs, and a 5 percent discount rate was used. Crop and native pasture produced for feeding the herd were included as cost of the beef herd components. The cost of production shows different values in different stages to reflect the variance in the activities of the farm. The cost of beef production was highest in stage 1, which included the costs of purchasing the breeding stock, feed costs, and other variable costs.

Table 6.3 Costs of production: beef herd, marketed forage, and rented-out pasture

Stage in Beef Cycle	Beef herd		Marketed Forage		Rented-Out Pasture	
	Total Variable Costs	Discounted Total Variable Costs	Total Variable Costs	Discounted Total Variable Costs	Total Variable Costs	Discounted Total Variable Costs
Stage 1	$ 110,732.42	$ 105,459.44	$ 16,259.61	$ 15,485.34	$ 8,848.04	$ 8,426.70
Stage 2	$ 25,607.50	$ 23,226.76	$ 11,930.19	$ 10,821.03	$ 3,739.12	$ 3,391.49
Stage 3	$ 84,313.98	$ 72,833.59	$ 4,842.77	$ 4,183.37	$ 2,942.26	$ 2,541.63
Stage 4	$ 84,313.98	$ 69,365.32	$ 4,842.77	$ 3,984.16	$ 2,942.36	$ 2,420.68
Stage 5	$ 84,313.98	$ 66,062.21	$ 4,842.77	$ 3,794.44	$ 2,942.36	$ 2,305.41
Stage 6	$ 84,313.98	$ 62,916.39	$ 4,842.77	$ 3,613.75	$ 2,942.36	$ 2,195.63
Stage 7	$ 84,313.98	$ 59,920.37	$ 4,842.77	$ 3,441.67	$ 3,022.11	$ 2,147.76
Stage 8	$ 82,542.04	$ 55,867.70	$ 5,195.48	$ 3,516.51	$ 3,022.11	$ 2,045.49
Stage 9	$ 47,973.72	$ 30,924.29	$ 12,990.43	$ 8,373.75	$ 4,031.59	$ 2,598.80
Total	**$ 688,425.60**	**$ 546,576.08**	**$ 70,589.56**	**$ 57,214.01**	**$ 34,432.31**	**$ 28,073.60**

The present value of costs for the beef herd (excluding purchases of breeding stock) from stage 1 to stage 9 was $464,433.23, of this cost feed totaled $218,910.54 (see Table 6.9), which is 47 percent of the total costs.

The costs of marketed forage and rented out pasture was dependent on how much land was left after producing animal feed. The first stage of production was the period when less feed was required for animal feed (Table 6.2), hence the high costs of marketed forage and rented out pasture.

6.2.3 Simulated Revenues

The breakdown of total beef produced and beef revenues for the entire production cycle is shown in Table 6.4. Revenues from marketed heifers and steers contributed $660,773.33, which is 84.5 percent of total beef herd revenues. Cull cows and bulls contributed the rest of the beef herd revenues, $118,365.04 and $3,210.19, respectively. The stage by stage revenues of the farm is shown in Table 6.5. The beef herd generated no revenues in the first stage (development stage of the breeding stock) because no animals were sold. In stage 2 and 3, cull cows were sold generating a discounted value of $11,715.96 and $11,158.06, respectively. The first calf crop finished in the farm was sold in stage 4, raising the revenues of the beef herd to a discounted value of $119,383.61. Unlike the cost of production profile with 9 stages, beef revenues had an additional stage (Stage 10) to account for the revenues of animals born in stage 9 and sold a year later. Bulls were sold in stage 8 generating $3,210.19 for the farm, and the breeding cows were culled in stage 9, which shows the highest revenues of the beef herd in the entire production cycle.

Table 6.4 Breakdown of beef produced (lbs) and discounted revenues in the entire production cycle

	Live weight produced ('00) lbs.	Discounted Revenues ($)
Marketed heifers and steers	9,145.26	$ 660,773.33
Cull cows	3,015.92	$ 118,365.04
Cull bulls	72.31	$ 3,210.19
Total	12,233.48	$ 782,348.57

Marketed forage and rented out pasture were also important sources of farm revenues, with a combined discounted value total of $413,561.61, accounting for 33.8 percent of the total farm revenues over the entire production cycle. The other sources of revenues for the farm came from insurance receipts and aftermath grazing as shown in Table 6.6 below. The total of these two accounted for 2.2 percent of total farm revenues in the entire production period. The total discounted revenues of the farm for the entire production cycle was $1,222,506.68 (Table 6.7).

Table 6.5 Discounted revenues of the beef herd, marketed forage and rented-out pasture

	Beef Enterprise		**Marketed Forage**		**Rented-Out Pasture**	
	Revenues	**Discounted Revenues**	**Revenues**	**Discounted Revenues**	**Revenues**	**Discounted Revenues**
Stage 1	$ -	$ -	$ 89,042.83	$ 84,802.69	$ 31,656.66	$ 30,149.20
Stage 2	$ 12,916.85	$ 11,715.96	$ 65,333.51	$ 59,259.42	$ 13,377.89	$ 12,134.14
Stage 3	$ 12,916.85	$ 11,158.06	$ 26,520.56	$ 22,909.46	$ 10,526.86	$ 9,093.49
Stage 4	$ 145,111.52	$ 119,383.61	$ 26,520.56	$ 21,818.53	$ 10,527.22	$ 8,660.77
Stage 5	$ 145,111.52	$ 113,698.67	$ 26,520.56	$ 20,779.55	$ 10,527.22	$ 8,248.35
Stage 6	$ 145,111.52	$ 108,284.45	$ 26,520.56	$ 19,790.05	$ 10,527.22	$ 7,855.57
Stage 7	$ 145,111.52	$ 103,128.05	$ 26,520.56	$ 18,847.67	$ 10,527.22	$ 7,481.50
Stage 8	$ 149,854.44	$ 101,427.38	$ 28,452.13	$ 19,257.52	$ 10,812.57	$ 7,318.37
Stage 9	$ 205,390.15	$ 132,396.32	$ 71,139.74	$ 45,857.31	$ 14,424.28	$ 9,298.02
Stage 10	$ 132,194.67	$ 81,156.06				
Total	**$ 1,093,719.04**	**$ 782,348.57**	**$ 386,571.01**	**$ 313,322.20**	**$ 122,907.11**	**$ 100,239.40**

Table 6.6 Discounted revenues from insurance receipts and aftermath grazing

	Insurance Receipts	Aftermath Grazing	Total other Revenues	Discounted Other Revenues
Stage 1	$ 366.08	$ 2,382.22	$ 2,748.30	$ 2,617.43
Stage 2	$ -	$ 1,759.37	$ 1,759.37	$ 1,595.80
Stage 3	$ 1,059.35	$ 3,533.06	$ 4,592.41	$ 3,967.10
Stage 4	$ 1,059.35	$ 3,533.06	$ 4,592.41	$ 3,778.19
Stage 5	$ 1,059.35	$ 3,533.06	$ 4,592.41	$ 3,598.27
Stage 6	$ 1,059.35	$ 3,093.51	$ 4,152.86	$ 3,098.93
Stage 7	$ 1,059.35	$ 3,093.51	$ 4,152.86	$ 2,951.36
Stage 8	$ 1,059.35	$ 3,061.50	$ 4,120.85	$ 2,789.15
Stage 9	$ 1,059.35	$ 2,354.00	$ 3,413.35	$ 2,200.27
Total	**$ 7,781.52**	**$ 26,343.29**	**$34,124.82**	**$ 26,596.50**

The breakdown of all farm revenues is shown in Table 6.7. Total discounted revenues from animal sales contributed the biggest portion of farm revenues in the entire production cycle, estimated at $782,348.57, which is 64 percent of total farm revenues.

Table 6.7 Farm discounted revenues over the entire production cycle

	Discounted Revenues	Percentage of Total Farm Revenues
Beef Revenues	$ 782,348.57	64.00
Marketed Forage	$ 313,322.20	25.63
Rented Out Pasture	$ 100,239.40	8.20
Other Revenues	$ 26,596.50	2.18
Total	$ 1,222,506.68	100.00

6.2.4 Profitability of Baseline Scenario

Profitability of the study farm was measured separately for the beef herd as a single enterprise and for the whole farm. The present value gross margin for the beef herd in the entire production cycle was $235,772.48. This value is the difference between the total discounted revenues (Table 6.4) and discounted variable costs (Table 6.3). The breakdown of discounted whole farm gross margin is shown in Table 6.8.

Table 6.8 Simulated discounted gross margin of the farm (baseline scenario)

Activity	Discounted Gross Margin
Beef Enterprise	$235,772.48
Forage sales	$256,108.20
Pasture Rented out	$72,165.80
Other revenues	$26,596.50
Whole Farm Gross Margin	**$590,642.98**

Profitability of the farm can also be expressed as per product produced. In this case, profitability of beef produced can be measured from the total beef produced and gross margin of beef. The simulated results for total marketed live weight beef produced (Table 6.5) for the entire production cycle was 914, 526 lbs. Gross margin per pound live weight beef produced was $0.26.

The model results shows that under the baseline scenario, present value of whole farm gross margin was $590,642.98. Given that a total of 51,884.28 acres of land was put into production in the whole production cycle, whole farm gross margin per acre is $11.38.

6.3 Simulation Results for Feed Management Scenarios.

6.3.1 Increased use of Forage in Growing Cattle (Scenario 1)

Simulation results for this scenario are shown in Table 6.9. As expected, increasing the use of forage for feeding means more land is required to produce forage. Land under native pasture for animal grazing in the entire production cycle increased by 9,438.99 acres (36.59 percent) compared to the baseline scenario. Barley silage production also increased by 46.83 acres to reflect feed requirements for the additional 40 days animals spent in the feedlot backgrounding operation. Overall, annual cropland under feed production decreased by 198.67 acres (5.12 percent) compared to the baseline scenario. The annual cropping land freed from production of feed was put into marketed forage, increasing unused cropland by 198.67 acres, compared to the baseline scenario.

Marketed beef animals finished heavier than the baseline (1369.1 lbs vs 1333.8 lbs), increasing total live weights of marketed steers and heifers by 24,203 lbs in the entire production cycle. This is because animals stayed in the farm for a longer period after weaning compared to the baseline scenario. This increase in weights led to $17,487.85 increase in revenues from marketed beef.

Table 6.9 Simulation results for 'Improved forage for growing cattle (Scenario 1)'

	Baseline Scenario	Scenario 1	Change[1]	Percentage change
Land Allocation (acres)				
Annual Cropping land				
barley grain	1,513.91	1,268.41	-245.50	-16.22%
barley silage	274.45	321.28	46.83	17.07%
alfalfa/grass hay	2,091.20	2,091.20	0.00	0.00%
canola	0	0	0.00	0.00%
Total Land for Feed Production	3,879.56	3,680.89	-198.67	-5.12%
unused cropland (Marketed Forage)	2,636.62	2,835.29	198.67	7.53%
Native Pasture land (acres)				
grazed land	25,796.79	35,235.78	9,438.99	36.59%
unused pastureland	19,571.31	10,132.32	-9,438.99	-48.23%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs*)				
finished market cattle	9,145.26	9,387.29	242.03	2.65%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,475.52	242.04	1.98%
Cost of Beef Production*				
feed costs	$218,910.54	$213,992.96	-$4,917.58	-2.25%
other variable costs	$245,522.68	$250,541.39	$5,018.71	2.04%
Total costs	$464,433.23	$464,534.35	$101.12	0.02%
Beef Revenues*				
finished market cattle	$660,773.33	$678,261.19	$17,487.86	2.65%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$799,836.42	$17,487.85	2.24%
Beef Gross Margin*	$235,772.48	$253,159.21	$17,386.73	7.37%
Gross Margin($)/lb marketed beef*	$0.26	$0.27	$0.01	4.61%
other revenues*	$440,158.11	$414,850.43	-$25,307.68	-5.75%
other costs of production*	$85,287.61	$76,853.52	-$8,434.09	-9.89%
other gross margin*	$354,870.50	$337,996.91	-$16,873.59	-4.75%
Whole Farm Gross Margin*	$590,642.98	$591,156.13	$513.15	0.09%
Whole Farm Gross Margin/acre*	$11.38	$11.39	$0.01	0.09%

Change[1]- the difference between values of scenario 1 and baseline scenario,
*****-discounted value,
Other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing).

Substituting forages for grain also generated feed cost savings. Feed costs decreased by $4,917.58 compared to the baseline; however, the costs of other variable costs increased by

$5,018.71 to reflect the additional days the animals stayed in the farm before being sold. The overall costs of beef production increase by $101.12.

The discounted gross margin value of the beef herd was estimated at $253,159.21, which is an increase of 7.37 percent from the baseline scenario. Gross margin per pound of beef produced increased by 4.61 percent from $0.26 to $0.27 per pound of beef produced.

Whole farm profitability of the farm also showed small but positive improvements compared to the baseline scenario. The discounted whole farm gross margin under this scenario was $591,156.13, which is a 0.09 percent increase from the baseline scenario. Profitability per acre of land under production also increased by 0.09 percent.

Increasing the use of forage in growing cattle shows a positive improvement in profitability of the beef herd, and of the farm as a whole.

6.3.2 Extended Grain Finishing Cattle (Scenario 2)

This scenario shortened the time between weaning and sale of market beef animals by 30 days. As part of the scenario, the backgrounding days were decreased from 110 days to 40 days which resulted in a decrease of 97.44 acres (35.5 percent) of land seeded to barley silage (the main ingredient in backgrounding ration). Land seeded to barley grain increased by 102.49 acres in the entire production cycle. This is because the number of days animals spent in the finishing stage were increased by 40 days as part of the scenario, which meant animals consumed more barley grain in the finishing stage. Simulation results of this scenario are shown in Table 6.10 below.

Under this scenario, a decrease in the number of days between weaning and finishing of marketed beef animals resulted in a decrease of $4,101.21 in variable costs; however, feed costs increased by $2,973.54, leading to an overall decrease of $1,127.68 in total variable costs of beef production compared to the baseline.

Table 6.10 Simulation results for 'Extended grain finishing cattle (Scenario 2)'

	Baseline Scenario	Scenario 2	Change[2]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,616.40	102.49	6.77%
barley silage	274.45	177.01	-97.44	-35.50%
alfalfa/grass hay	2,091.20	2,091.20	0.00	0.00%
canola	-	-		
Total Land for Feed Production	3,879.56	3,884.61	5.05	0.13%
unused cropland (marketed forage)	2,636.62	2,631.57	-5.05	-0.19%
Native Pasture land				
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs)*				
finished market cattle	9,145.26	8,993.73	-151.53	-1.66%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,081.95	-151.53	-1.24%
Cost of Beef Production*				
feed costs	$218,910.54	$221,884.08	$2,973.54	1.36%
other variable costs	$245,522.68	$241,421.47	-$4,101.21	-1.67%
Total costs	$464,433.23	$463,305.55	-$1,127.68	-0.24%
Beef Revenues*				
finished market cattle	$660,773.33	$649,824.85	-$10,948.48	-1.66%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$771,400.08	-$10,948.49	-1.40%
			$0.00	
Beef Gross Margin*	$235,772.48	$225,951.67	-$9,820.81	-4.17%
Gross Margin($)/lb marketed beef*	$0.26	$0.25	-$0.01	-2.55%
other revenues*	$440,158.11	$440,639.05	$480.94	0.11%
other costs of production*	$85,287.61	$85,186.18	-$101.43	-0.12%
other gross margin*	$354,870.50	$355,452.88	$582.38	0.16%
Whole Farm Gross Margin*	$590,642.98	$581,404.55	-$9,238.43	-1.56%
Whole Farm Gross Margin/acre*	$11.38	$11.21	-$0.17	-1.56%

Change[2]- -the difference between values of scenario 2 and baseline scenario
***-** discounted value,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing).

The shortening of days between weaning and marketing animals also meant animals were marketed with smaller weights (1311.7 lbs vs 1333.8 lbs). The total live weight of marketed beef dropped by 15,153 lbs, lowering revenues of the beef herd from $782,348.57 to $771,400.08. The decrease in costs did not compensate for lost revenues, yielding a decrease in beef gross margin of 2.55 percent from $0.26 to $0.25 per pound of beef produced.

The overall profitability of the farm also decreased from a whole farm perspective, as discounted gross margin was reduced from $11.38 to $11.21 per acre. One therefore, can conclude that extended grain finishing cattle has a negative impact on economic returns of the study farm.

6.3.3 Feeding Canola Seed to Backgrounding Cattle (Scenario 3)

The results for this scenario are shown in Table 6.11. Replacing canola seed for barley grain was a costly feed management practice in the backgrounding stage of marketed beef animals. The data used for this analysis showed that the cost of producing feed barley was $108.13 compared to $180.17 per acre for producing canola. This big difference in production costs might explain the costliness of using canola seed instead of barley grain in backgrounding rations. Even though canola seed has higher energy content compared to barley grain, replacing canola seed for barley grain resulted in $5,150.98 increase in feed costs. The other variable costs increased by $292.02 (0.12 percent), which captures the costs of crushing canola seed. Overall, total variable costs of beef production increased by 1.17 percent compared to the baseline scenario.

Revenues from beef sales did not change as animal weights stayed the same. Thus, profitability of beef dropped under this scenario. Beef gross margin decreased to $230,329.48, which is a 2.31 percent decrease compared to the baseline, due to increases in feed and crushing costs.

A total of 50.96 acres were freed from production of feed barley grain and silage, but canola production required 64.85 acres of land, which meant feed producing land had to be expanded into the cash crop land, reducing revenues from marketed forage. Revenues of non-beef sales were lowered by $1,798.82 in the entire production cycle.

Table 6.11 Simulation results for 'Feeding canola seed to backgrounding cattle (Scenario 3)'

	Baseline Scenario	Scenario 3	Change[3]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,482.81	-31.10	-2.05%
barley silage	274.45	254.59	-19.86	-7.24%
alfalfa/Grass Hay	2,091.20	2,091.20	0.00	0.00%
canola	0	64.85	64.85	0.00%
Total Land for Feed Production	3,879.56	3,893.45	13.89	0.36%
unused cropland (marketed forage)	2,636.62	2,622.73	-13.89	-0.53%
Native Pasture land				
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs)*				
finished market cattle	9,145.26	9,145.26	0.00	0.00%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,233.48	0.00	0.00%
Cost of Beef Production*				
feed costs	$218,910.54	$224,061.53	$5,150.98	2.35%
other variable costs	$245,522.68	$245,814.71	$292.02	0.12%
Total variable costs	$464,433.23	$469,876.23	$5,443.01	1.17%
Beef Revenues*				
finished market cattle	$660,773.33	$660,773.33	$0.00	0.00%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$782,348.57	$0.00	0.00%
Beef Gross Margin*	$235,772.48	$230,329.48	-$5,443.01	-2.31%
Gross Margin($)/lb marketed beef*	$0.26	$0.25	-$0.006	-2.31%
other revenues*	$440,158.11	$438,359.29	-$1,798.82	-0.41%
other costs of production*	$85,287.61	$85,008.81	-$278.81	-0.33%
other gross margin*	$354,870.50	$353,350.48	-$1,520.01	-0.43%
Whole Farm Gross Margin*	$590,642.98	$583,679.96	-$6,963.02	-1.18%
Whole Farm Gross Margin/acre*	$11.38	$11.25	-$0.13	-1.18%

*-discounted value,
Change[3]-the difference between values of scenario 3 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing).

Whole farm gross margin decreased by a discounted value of $6,963.02, which is a 1.18 percent decrease from the baseline. Whole farm discounted gross margin per acre decreased by 1.18 percent.

Replacing canola seed for barley grains in backgrounding diets of marketed animals proved to be a costly scenario for the beef herd and for the farm as a whole.

6.3.4 Feeding Canola Seed to Finishing Cattle (Scenario 4)

Summary results of this scenario are shown in Table 6.12. Including canola seed in the finishing ration improved profitability of the beef herd, increasing discounted beef gross margin by $2,206.88 compared to the baseline scenario. The increase in beef profitability was a result of decreased feed costs associated with including canola seed to finishing rations. Revenues from the herd remained the same as animals were fed to attain the same body weight gain as in the baseline scenario. The model estimated a 1.05 percent decrease in feed costs, with a slight increase (0.04 percent) in other variable costs. Overall, total variable costs of beef production decreased by 0.48 percent. These results are opposite to the previous results when canola seed was used in backgrounding ration. This might be explained by the fact that canola seed is a high energy diet and is best utilized when fed to produce a high daily gain in finishing animals than backgrounding animals which are grown slowly.

Under this scenario, annual cropping land seeded to feed crops decreased by 114.12 acres, freeing this land for production of marketed forage that generated revenues for the whole farm. Revenues from non-beef sales shown in Table 6.12 as ‘other revenues’ increased by a discounted value of $10,100.06 compared to the baseline. Profitability of the whole farm increased by a discounted value of $10,016.16. Whole farm gross margin per acre increased by $0.19 (1.7 percent). Thus, including canola seed in finishing rations is an economically feasible option to the study farm.

6.3.5 Feeding Canola Seed to Breeding Cattle (Scenario 5)

In this scenario, canola seed was used to replace some hay in the winter feed of the breeding stock. Summary results of this scenario are presented in Table 6.13. Feeding canola seed to the breeding stock had a negative impact on profitability of the beef herd.

Table 6.12 Simulation results for 'Feeding canola seed to finishing cattle (Scenario 4)'

	Baseline Scenario	Scenario 4	Change[4]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,279.46	-234.45	-15.49%
barley silage	274.45	268.83	-5.62	-2.05%
alfalfa/Grass Hay	2,091.20	2,091.20	0.00	0.00%
canola	0	125.95	125.95	0.00%
Total Land for Feed Production	3,879.56	3,765.44	-114.12	-2.94%
unused cropland (marketed forage)	2,636.62	2,750.74	114.12	4.33%
Native Pasture land				
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs*)				
finished market cattle	9,145.26	9,145.26	0.00	0.00%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,233.48	0.00	0.00%
Cost of Beef Production*				
feed costs	$218,910.54	$216,608.28	-$2,302.26	-1.05%
other variable costs	$245,522.68	$245,618.06	$95.38	0.04%
Total costs	$464,433.23	$462,226.34	-$2,206.88	-0.48%
Beef Revenues*				
finished market cattle	$660,773.33	$660,773.33	$0.00	0.00%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$782,348.57	$0.00	0.00%
Beef Gross Margin*	$235,772.48	$237,979.37	$2,206.88	0.94%
Gross Margin($)/lb marketed beef*	$0.26	$0.26	$0.002	0.94%
other revenues*	$440,158.11	$450,258.17	$10,100.06	2.29%
other costs of production*	$85,287.61	$87,578.39	$2,290.78	2.69%
other gross margin*	$354,870.50	$362,679.77	$7,809.28	2.20%
Whole Farm Gross Margin*	$590,642.98	$600,659.14	$10,016.16	1.70%
Whole Farm Gross Margin/acre*	$11.38	$11.58	$0.19	1.70%

*****- discounted value,
Change[4]-the difference between values of scenario 4 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing)

Discounted beef gross margin decreased from a baseline value of $235,772.48 to $219,812.04. This decrease was associated with increases in feed and other variable costs. Feed costs increased by $15,474.50 (7.07 percent), and the other variable costs increased by $485.95 (0.2 percent). This scenario did not affect the dynamics or weight gains of animals, so revenues from animal sales remained unchanged.

Including canola seed in the breeding stock ration replaced a large amount of hay in the ration, leading to 541.87 acres (25.91 percent) of land seeded to hay being freed, and a total of 352.14 acres going into production of marketed forage, which increased whole farm revenues by a discounted value of $40,460.86. Whole farm gross margin increased by a discount value of $17,085.76 compared to the baseline scenario. Whole farm gross margin increased by 2.89 percent.

In conclusion, including canola seed in the breeding stock ration is not profitable to the beef herd as a single enterprise, but to the whole farm when land freed from feed production is put into a profitable cash crop to offset the losses of the beef herd.

6.3.6 Feeding CDDG to Backgrounding Cattle (Scenario 6)

In this scenario, feeding of CDDG was included in the backgrounding ration to replace some barley grain. Simulation results of this scenario are shown in Table 6.14. Since CDDG was bought off-farm, some land was freed. Simulation results showed a decrease of 11.58 acres in annual cropping land seeded to barley grain and silage, with that land going into marketed forage production. Non-beef revenues of the farm increased by $1,188.40; however, the farm experienced a discounted whole farm gross margin loss of $32,353.44 compared to the baseline.

Decrease in discounted whole farm gross margin of this scenario was mainly due to the losses in the beef herd. Revenues of the beef herd stayed the same, while feed costs increased by 32,079.54 (14.65 percent) leading to a decrease in discounted beef gross margin of $33,309.35.

Including CDDG in backgrounding cattle proved costly to the beef herd and the whole farm, meaning producers will lose money if they were to implement this scenario.

Table 6.13 Simulation results for 'Feeding canola seed to breeding cattle (Scenario 5)'

	Baseline Scenario	**Scenario 5**	**Change[5]**	**Percentage change**
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,513.91	0.00	0.00%
barley silage	274.45	274.45	0.00	0.00%
alfalfa/grass hay	2,091.20	1,549.33	-541.87	-25.91%
canola	0	189.73	189.73	0.00%
Total Land for Feed Production	3,879.56	3,527.42	-352.14	-9.08%
unused cropland (marketed forage)	2,636.62	2,988.76	352.14	13.36%
Native Pasture land				
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs)*				
finished market cattle	9,145.26	9,145.26	0.00	0.00%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,233.48	0.00	0.00%
Cost of Beef Production*				
feed Costs	$218,910.54	$234,385.04	$15,474.50	7.07%
other variable costs	$245,522.68	$246,008.63	$485.95	0.20%
Total costs	$464,433.23	$480,393.67	$15,960.45	3.44%
Beef Revenues*				
finished market cattle	$660,773.33	$660,773.33	$0.00	0.00%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$782,348.57	$0.00	0.00%
Beef Gross Margin*	$235,772.48	$219,812.04	-$15,960.45	-6.77%
Gross Margin($)/lb marketed beef*	$0.26	$0.24	-$0.017	-6.77%
other revenues*	$440,158.11	$480,618.97	$40,460.86	9.19%
other costs of production*	$85,287.61	$92,702.27	$7,414.66	8.69%
other gross margin*	$354,870.50	$387,916.70	$33,046.20	9.31%
Whole Farm Gross Margin*	$590,642.98	$607,728.74	$17,085.76	2.89%
Whole Farm Gross Margin/acre*	$11.38	$11.71	$0.33	2.89%

*- discounted value,
Change[5]-the difference between values of scenario 5 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing).

Table 6.14 Simulation results for 'Feeding CDDG to backgrounding cattle (Scenario 6)'

	Baseline Scenario	Scenario 6	Change[6]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,506.85	-7.06	-0.47%
barley silage	274.45	269.93	-4.52	-1.64%
alfalfa/grass hay	2,091.20	2,091.20	0.00	0.00%
canola	0	0	0.00	0.00%
Total Land for Feed Production	3,879.56	3,867.98	-11.58	-0.30%
unused cropland (marketed forage)	2,636.62	2,648.20	11.58	0.44%
			0.00	
Native Pasture land			0.00	
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs)*				
finished market cattle	9,145.26	9,145.26	0.00	0.00%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,233.48	0.00	0.00%
Cost of Beef Production*				
feed costs	$218,910.54	$250,990.08	$32,079.54	14.65%
other variable costs	$245,522.68	$246,752.51	$1,229.83	0.50%
Total costs	$464,433.23	$497,742.58	$33,309.35	7.17%
Beef Revenues*				
finished market cattle	$660,773.33	$660,773.33	$0.00	0.00%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$782,348.57	$0.00	0.00%
Beef Gross Margin*	$235,772.48	$202,463.13	-$33,309.35	-14.13%
Gross Margin($)/lb marketed beef*	$0.26	$0.22	-$0.04	-14.13%
other revenues*	$440,158.11	$441,346.51	$1,188.40	0.27%
other costs of production*	$85,287.61	$85,520.10	$232.49	0.27%
other gross margin*	$354,870.50	$355,826.41	$955.91	0.27%
Whole Farm Gross Margin*	$590,642.98	$558,289.54	-$32,353.44	-5.48%
Whole Farm Gross Margin/acre*	$11.38	$10.76	-$0.62	-5.48%

*- discounted value,
Change[6]-the difference between values of scenario 6 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing).

6.3.7 Feeding CDDG to Finishing Cattle (Scenario 7)

Similar to scenario 6, CDDG was used as feed for feedlot animals but included in the finishing ration only. Simulation results of this scenario are shown in Table 6.15. The use of CDDG freed 466.48 acres of land seeded to feed barley grain, increasing non-beef revenues of the farm by a discounted value of 46,132.45 (10.48 percent) compared to the baseline. The beef herd experienced an economic loss of $26,766.77 in discounted gross margin value, with most of this loss associated with increase in feeding costs, which increased by 11.78 percent.

Despite losses in the beef herd component of the farm, whole farm gross margin increased by a discounted value of $9,984.45. This increase in whole farm profitability came from an increase in discounted gross margin of marketed forage. Discounted whole farm gross margin per acre of the study farm increased by $0.20 compared to the baseline scenario. One therefore, can conclude that including CDDG in finishing rations is economical feasible for the study farm.

6.3.8 Feeding CDDG to Breeding Cattle (Scenario 8)

Under this scenario, CDDG replaced some alfalfa-grass mixed hay in the winter feed of the breeding stock. Results from the simulation model are shown in Table 6.16.

Using CDDG in the breeding stock ration proved to be the most costly scenario of all the CDDG scenarios for the beef herd component of the farm. Discounted beef gross margin decreased by $39,438.31 compared to the baseline, this decrease is directly associated with the ration change, as feed costs increased by a discounted value of $38,945.60, which is 17.79 percent higher than the baseline.

The loss experienced in the beef herd was offset by gains in the other components of the farm. Revenues from marketed forage increased with increase in land freed from feed production. A total of 679.22 acres were freed from feed production and seeded to marketed forage, increasing discounted gross margin of the whole farm by $24,075.15. Per acre gross margin of the whole farm increase by $0.47 compared to the baseline scenario. Like the other two previous CDDG scenarios, this scenario proved to be profitable at the whole farm level, but not for the beef herd components.

Table 6.15 Simulation results for ‘Feeding CDDG to finishing cattle (Scenario 7)’

	Baseline Scenario	Scenario 7	Change[7]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,047.43	-466.48	-30.81%
barley silage	274.45	273.58	-0.87	-0.31%
alfalfa/grass hay	2,091.20	2,091.20	0.00	0.00%
canola	0	0	0.00	0.00%
Total Land for Feed Production	3,879.56	3,412.21	-467.35	-12.05%
unused cropland (marketed forage)	2,636.62	3,103.97	467.35	17.73%
Native Pasture land				
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
			0.00	
Live weight produced (*'00 lbs*)			0.00	
finished market cattle	9,145.26	9,145.26	0.00	0.00%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,233.48	0.00	0.00%
Cost of Beef Production*				
feed Costs	$218,910.54	$244,689.05	$25,778.51	11.78%
other variable costs	$245,522.68	$246,510.95	$988.27	0.40%
Total costs	$464,433.23	$491,200.00	$26,766.77	5.76%
Beef Revenues*				
finished market cattle	$660,773.33	$660,773.33	$0.00	0.00%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$782,348.57	$0.00	0.00%
Beef Gross Margin*	$235,772.48	$209,005.71	-$26,766.77	-11.35%
Gross Margin($)/lb marketed beef*	$0.26	$0.23	-$0.03	-11.35%
other revenues*	$440,158.11	$486,290.67	$46,132.56	10.48%
other costs of production*	$85,287.61	$94,668.95	$9,381.34	11.00%
other gross margin*	$354,870.50	$391,621.72	$36,751.22	10.36%
Whole Farm Gross Margin*	$590,642.98	$600,627.43	$9,984.45	1.69%
Whole Farm Gross Margin/acre*	$11.38	$11.58	$0.20	1.69%

*-discounted value,
Change[7]-the difference between values of scenario 7 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing).

Table 6.16 Simulation results for 'Feeding CDDG to breeding cattle (Scenario 8)'

	Baseline Scenario	Scenario 8	Change[8]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,513.91	0.00	0.00%
barley silage	274.45	274.45	0.00	0.00%
alfalfa/grass hay	2,091.20	1,411.98	-679.22	-32.48%
canola	0	0	0.00	0.00%
Total Land for Feed Production	3,879.56	3,200.34	-679.22	-17.51%
unused cropland (marketed forage)	2,636.62	3,315.84	679.22	25.76%
Native Pasture land				
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs)*				
finished market cattle	9,145.26	9,145.26	0.00	0.00%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,233.48	0.00	0.00%
Cost of Beef Production*				
feed costs	$218,910.54	$257,856.14	$38,945.60	17.79%
other variable costs	$245,522.68	$246,015.40	$492.72	0.20%
Total costs	$464,433.23	$503,871.54	$39,438.31	8.49%
Beef Revenues*				
finished market cattle	$660,773.33	$660,773.33	$0.00	0.00%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$782,348.57	$0.00	0.00%
Beef Gross Margin*	$235,772.48	$196,334.17	-$39,438.31	-16.73%
Gross Margin($)/lb marketed beef*	$0.26	$0.21	-$0.05	-16.73%
other revenues*	$440,158.11	$517,973.26	$77,815.15	17.68%
other costs of production*	$85,287.61	$99,589.30	$14,301.69	16.77%
other gross margin*	$354,870.50	$418,383.96	$63,513.46	17.90%
Whole Farm Gross Margin*	$590,642.98	$614,718.13	$24,075.15	4.08%
Whole Farm Gross Margin/acre*	$11.38	$11.85	$0.47	4.08%

*****-discounted value,
Change[8]-the difference between values of scenario 8 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing)

6.3.9 Improved Forage Quality for Breeding Cattle (Scenario 9)

Cutting hay at an early stage improved nutritional content of the feed, thereby requiring less feed to meet animal's total nutritional requirements. Results of this scenario are shown in Table 6.17. Land seeded to feed hay decreased by 69.71 acres, freeing up this land for marketed forage. Revenues from marketed forage increased by 7,985.96, increasing discounted gross margin value of non-beef production of the farm by 1.84 percent. Consequently, whole farm gross margin increased by a discounted value of $8,004.52, which is a 1.36 percent increment compared to the baseline scenario. Using good quality hay also improved profitability of the beef component of the farm. Discounted beef gross margin increased by $1,486.32 (0.63 percent) compared to the baseline scenario. Feed costs decreased by $1,467.74, and the total cost of beef production decreased by 0.32 percent. Revenues of the beef herd remained unchanged, indicating an increase in profitability of the herd reflected entirely through the cost savings of the scenario.

One therefore, can conclude that using good quality hay in breeding stock improves profitability of the whole farm, and of the individual beef herd component. Producers will be well-off implementing this scenario.

6.4 Simulation Results of Animal Husbandry Management Strategies

6.4.1 Increased number of Calves Weaned (Scenario 10)

Summary results of this scenario are shown in Table 6.18. Increasing the weaning rate had a positive impact on profitability of the beef herd and the whole farm. Increasing the weaning rate from 85 percent to 90 percent meant a total of 105 calves were weaned into the backgrounding lot, and a total of 104 finished feeders were marketed per year (stage 3-stage 10). This increase in finished cattle led to finished market cattle revenue increase of $38,869.02. However, the increase in the number of calves weaned meant the herd needed more feed to meet additional nutritional requirements. Simulation results showed that land towards feed production increased by 216.77 acres (5.59 percent), leading to a $10,109.71 (4.62 percent) increase in feed costs.

Table 6.17 Simulation results for 'Improved forage quality for breeding cattle (Scenario 9)'

	Baseline Scenario	Scenario 9	Change[9]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,513.91	0.00	0.00%
barley silage	274.45	274.45	0.00	0.00%
alfalfa/grass hay	2,091.20	2,021.49	-69.71	-3.33%
canola	0	0	0.00	
Total Land for Feed Production	3,879.56	3,809.85	-69.71	-1.80%
unused cropland (marketed forage)	2,636.62	2,706.33	69.71	2.64%
Native Pasture land			0.00	
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs)*			0.00	
finished market cattle	9,145.26	9,145.26	0.00	0.00%
cull cows	3,015.92	3,015.92	0.00	0.00%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,233.48	0.00	0.00%
Cost of Beef Production*				
feed costs	$218,910.54	$217,442.80	-$1,467.74	-0.67%
other variable costs	$245,522.68	$245,504.11	-$18.57	-0.01%
Total costs	$464,433.23	$462,946.91	-$1,486.32	-0.32%
Beef Revenues*				
finished market cattle	$660,773.33	$660,773.33	$0.00	0.00%
cull cows	$118,365.04	$118,365.04	$0.00	0.00%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$782,348.57	$0.00	0.00%
Beef Gross Margin*	$235,772.48	$237,258.80	$1,486.32	0.63%
Gross Margin($)/lb marketed beef	$0.26	$0.26	$0.002	0.63%
other revenues*	$440,158.11	$448,144.07	$7,985.96	1.81%
other costs of production*	$85,287.61	$86,755.36	$1,467.75	1.72%
other gross margin*	$354,870.50	$361,388.71	$6,518.21	1.84%
Whole Farm Gross Margin*	$590,642.98	$598,647.50	$8,004.52	1.36%
Whole Farm Gross Margin/acre*	$11.38	$11.54	$0.16	1.36%

***-**discounted value,
Change[9]-the difference between values of scenario 9 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing)

Increasing the weaning rate also meant that the number of unproductive breeding cows went down, hence a decrease in the number of breeding cows replaced. This decrease in replacement of breeding cows led to a decrease in the costs associated with buying and raising replacement cows for the beef herd. In response to this, other variable costs of the beef herd decreased by $20,746.56; however, less replacement rate meant revenues from cull cows also diminished. The model estimated a $20,952.09 decrease in cull cow revenues.

The overall impact of this scenario on the beef herd was a $10,636.86 decrease in discounted total cost, and a $17,916.93 increase in discounted revenues, increasing the discounted gross margin of the beef herd by $28,553.79 compared to the baseline.

Increase in land area under feed production to satisfy high animal nutritional requirements meant land was taken from marketed forage, leading to a loss of $23,396.63 in non-beef revenues; however, gains in the beef herd offset this loss. The whole farm gross margin increased from $590,642.98 to $600,265.72, which is a 1.63 percent increment from the baseline scenario. This scenario had a positive impact on profitability of the study farm.

6.4.2 Increased Longevity of the Breeding Stock (Scenario 11)

Prolonging the breeding stock for 1 additional production period had a positive impact on profitability of the beef herd. Results of this scenario are shown in Table 6.19. Beef gross margin increased by $34,017.85 (14.43 percent) from the baseline scenario. However, this number has to be interpreted with caution because of the different lifespan of the farm between this scenario and the baseline. It is therefore appropriate to compare profitability of this scenario to the baseline in terms of change in gross margin per product produced. Discounted gross margin per pound of marketed beef increased by 0.12 percent under this scenario compared to the baseline. This increase in beef profitability suggests that producers can keep the breeding stock to produce 8 calf crops and still have financially successful beef operations.

Whole farm gross margin also showed a positive gain of $54,232.95; however, per acre whole farm gross margin showed a decrease of $0.19, which is 1.74 percent less than the baseline scenario. The fact that transaction of this scenario appear one year later compared to the baseline led to lower gains per acre put into production because of discounting. It therefore, makes this scenario infeasible to the study farm.

Table 6.18 Simulation results for 'Increased number of calves weaned (Scenario 10)'

	Baseline Scenario	Scenario 10	Change[10]	Percentage change
Land Allocation (Acres)				
Annual Cropping land				
barley grain	1,513.91	1,598.78	84.87	5.61%
barley silage	274.45	287.91	13.46	4.91%
alfalfa/grass hay	2,091.20	2,209.63	118.43	5.66%
canola	0	0	0.00	0.00%
Total Land for Feed Production	3,879.56	4,096.33	216.77	5.59%
unused cropland (marketed forage)	2,636.62	2,419.85	-216.77	-8.22%
Native Pasture land				
grazed land	25,796.79	25,796.79	0.00	0.00%
unused pastureland	19,571.31	19,571.31	0.00	0.00%
Total Land Used	51,884.28	51,884.28	0.00	0.00%
Live weight produced (*'00 lbs)*				
finished market cattle	9,145.26	9,683.21	537.95	5.88%
cull cows	3,015.92	2,539.72	-476.20	-15.79%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	12,295.24	61.76	0.50%
Cost of Beef Production*				
feed costs	$218,910.54	$229,020.25	$10,109.71	4.62%
other variable costs	$245,522.68	$224,776.12	-$20,746.56	-8.45%
Total costs	$464,433.23	$453,796.37	-$10,636.86	-2.29%
Beef Revenues*				
finished market cattle	$660,773.33	$699,642.35	$38,869.02	5.88%
cull cows	$118,365.04	$97,412.95	-$20,952.09	-17.70%
cull bulls	$3,210.19	$3,210.19	$0.00	0.00%
Total Revenues	$782,348.57	$800,265.50	$17,916.93	2.29%
Beef Gross Margin*	$235,772.48	$264,326.27	$28,553.79	12.11%
Gross Margin($)/lb marketed beef*	$0.26	$0.27	$0.01	5.88%
other revenues*	$440,158.11	$416,761.48	-$23,396.63	-5.32%
other costs of production*	$85,287.61	$80,822.04	-$4,465.57	-5.24%
other gross margin*	$354,870.50	$335,939.44	-$18,931.06	-5.33%
Whole Farm Gross Margin*	$590,642.98	$600,265.72	$9,622.74	1.63%
Whole Farm Gross Margin/acre*	$11.38	$11.57	$0.19	1.63%

*-discounted value,

Change[10]-the difference between values of scenario 10 and baseline scenario,

other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing).

Table 6.19 Simulation results for 'Increased longevity of the breeding stock (Scenario 11)'

	Baseline Scenario	Scenario 11	Change[11]	Percentage change
Land Allocation (acres)				
Annual Cropping land				
barley grain	1,513.91	1,720.01	206.10	13.61%
barley silage	274.45	307.16	32.71	11.92%
alfalfa/grass hay	2,091.20	2,395.52	304.32	14.55%
Canola	0	0	0.00	0.00%
Total Land for Feed Production	3,879.56	4,422.69	543.13	14.00%
unused cropland (marketed forage)	2,636.62	2,817.51	180.89	6.86%
Native Pasture land				
grazed land	25,796.79	29,161.37	3,364.58	13.04%
unused pastureland	19,571.31	21,247.63	1,676.32	8.57%
Total Land Used	51,884.28	57,649.20	5,764.92	11.11%
Live weight produced (*'00 lbs)*				
finished market cattle	9,145.26	10,451.72	1,306.46	14.29%
cull cows	3,015.92	3,254.01	238.09	7.89%
cull bulls	72.31	72.31	0.00	0.00%
Total weight beef produced	12,233.48	13,778.05	1,544.57	12.63%
Cost of Beef Production*				
feed costs	$218,910.54	$242,984.13	$24,073.59	11.00%
other variable costs	$245,522.68	$274,383.17	$28,860.49	11.75%
Total costs	$464,433.23	$517,367.30	$52,934.07	11.40%
Beef Revenues*				
finished market cattle	$660,773.33	$738,064.82	$77,291.49	11.70%
cull cows	$118,365.04	$124,444.57	$6,079.53	5.14%
cull bulls	$3,210.19	$3,057.33	-$152.86	-4.76%
Total Revenues	$782,348.57	$865,566.72	$83,218.15	10.64%
Beef Gross Margin*	$235,772.48	$269,790.33	$34,017.85	14.43%
Gross Margin($)/lb marketed beef*	$0.26	$0.26	$0.00	0.12%
other revenues*	$440,158.11	$464,852.35	$24,694.24	5.61%
other costs of production*	$85,287.61	$89,766.75	$4,479.14	5.25%
other gross margin*	$354,870.50	$375,085.60	$20,215.10	5.70%
Whole Farm Gross Margin*	$590,642.98	$644,875.93	$54,232.95	9.18%
Whole Farm Gross Margin/acre*	$11.38	$11.19	-$0.19	-1.74%

*-discounted value,
Change[11]-the difference between values of scenario 11 and baseline scenario,
other- refers to the other farm components (forage, rented out pasture, insurance receipts and aftermath grazing)

6.5 Environmental-Economic Trade off Analysis

Various GHGMPs in this study have also been evaluated in terms of their impacts on the levels of GHG emissions by Beauchemin et al (2011). Their environmental results and economic results of this study enables an environmental-economic tradeoff analysis as shown in Figure 6.1 and 6.2. Changes in emission levels of the study farm is plotted against changes of profitability of the beef component of the farm (Figure 6.1), and profitability of the whole farm (Figure 6.2).

The solid shaded scenarios (IV) in the figures shows the scenarios that resulted in a 'win-win' outcome in mitigation of GHG and profitability of the farm. The scenarios in (III) show a 'win-loss' for the environment and profitability of the farm, respectively. The scenarios in (II) shows the scenarios that had a 'loss-win' outcome for the environment and profitability of the farm, respectively.

The trade-off analysis (Figure 6.1) based on profitability of the beef component of the farm places 4 scenarios (4,9,10,11) into the 'win-win' outcome, 6 scenarios (2,3,5,6,7,8) into the 'win-loss' outcome, and only one scenario (1) into the 'loss-win' outcome. The trade-off (Figure 6.2) based on profitability of the whole farm has different placing of the scenarios; 6 scenarios (4, 5, 7, 8, 9, 10) are under the 'win-win' outcome, 4 scenarios are 'win-loss', and one scenario (1) is a 'loss-win'.

Using the beef component of the farm as a profitability measure ignores the resource reallocation of the farm that come with adoption of different mitigation strategies. Take an example of using CDDG which were sourced from off-farm. When CDDG were included in beef rations, they replaced a crop that was assumed to be grown on the farm under the baseline scenario, resulting in freeing up land that could have been used in feed production. Under this situation profitability of the beef herd ignores the freed-up land because it has no relationship to beef production. Whole farm profitability assumes freed up land is put into a cash crop generating revenues for the farm. It is therefore most appropriate to use the whole farm economic outcomes when doing tradeoff analysis under this situation.

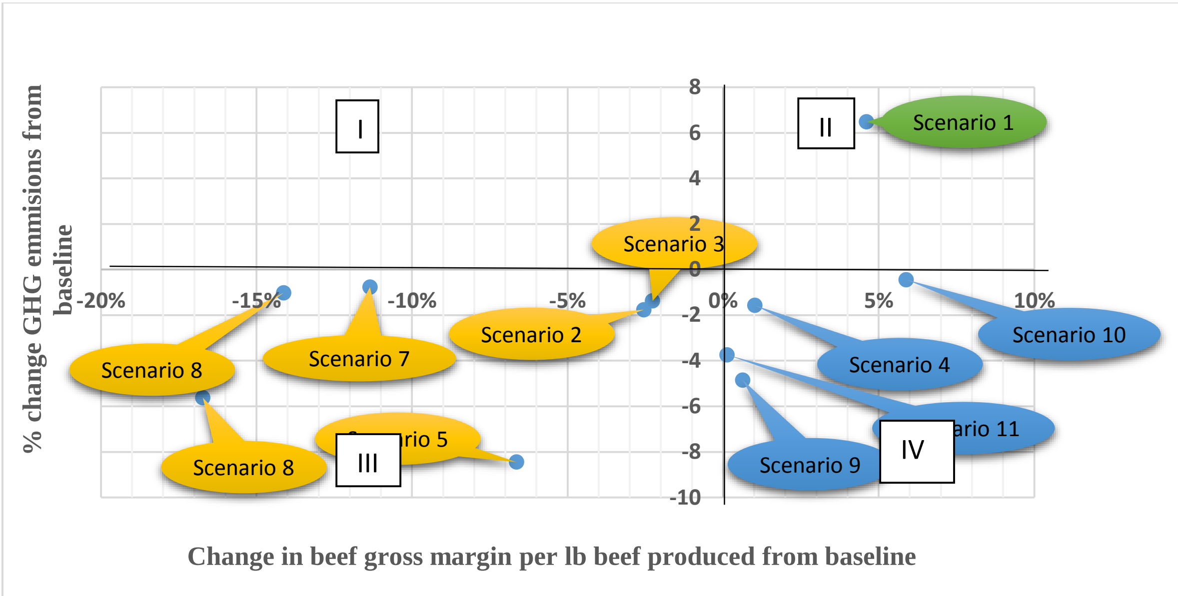


Figure 6.1 Beef Environmental-Economic Trade-off of adopting GHGMPs

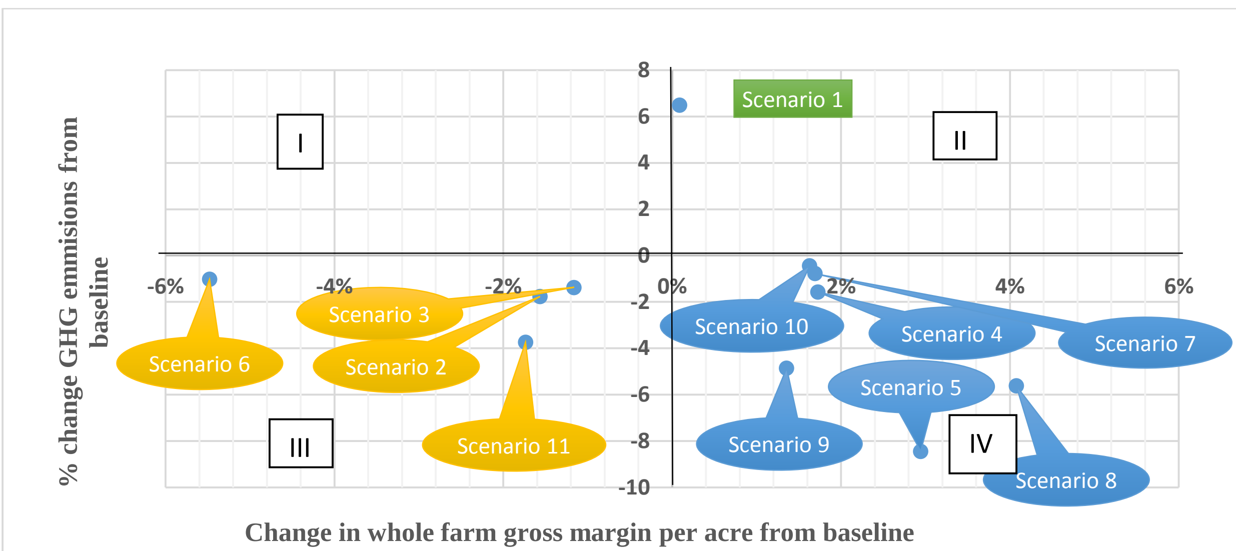


Figure 6.2 Whole Farm Environmental-Economic trade-off of adopting GHGMPs

6.5.1 Study Performance Ranking of GHGMPs

This section reports on the performance rankings of the GHGMPs according to the profits/costs per tonne of carbon dioxide equivalent of GHG emissions. The following equation was used to measure the profits/costs of implementing the GHGMP;

Profit/Cost per tonne GHG emissions = $\frac{\Delta WFGM_{ghgmp}}{\Delta WFGHG_{ghgmp}}$ (6.1)

Where: $\Delta WFGM_{ghgmp}$ and $\Delta WFGHG_{ghgmp}$ is the incremental change in gross margin and GHG emissions, respectively, relative to the baseline scenario. The results obtained from the evaluation of the scenarios are shown in Table 6.20 below.

Table 6.20 Ranking of GHGMP based on profits/costs per tonne GHG emissions

Win-Win Scenarios		**Discounted Gross Margin ($/tonne)**	**Rank**
7	CDDG in finishing	238.11	1
4	Canola seed in Finishing	115.30	2
8	CDDG in Breeding stock	78.66	3
10	Increase Weaning rates	47.25	4
5	Canola Seed in Breeding stock	37.25	5
9	Improved Hay for Breeding stock	30.31	6
Win-Loss Scenarios			
3	Canola Seed in backgrounding	(90.41)	7
2	Extended Grain finishing	(96.39)	8
11	Add 1 Prod cycle	(475.52)	9
6	CDDG in Backgrounding	(582.46)	10
Loss-Win Scenario			
1	Increased Forage for growing cattle	1.45	11

The ‘win-win’ scenarios are the profitable strategies of reducing GHG emissions. Six scenarios were placed in this category in Figure 6.2. The gross margin per tonne of GHG mitigation ranged from $238.11/tonne to $30.31/tonne. Of these scenarios, using CDDG in finishing rations ranked 1st with a discounted gross margin of $238 per tonne, and improved hay for the breeding stock came last in the category ranking 6th at $30.31 per tonne.

The ‘win-loss’ scenarios ranked from 7 to 10. This category is the scenarios that reduced GHGs but at a cost to the producer. The costs ranged from $92.06/tonne to a high of $582.46/tonne. The highest loss was from using CDDGs in backgrounding rations (scenario 6) and the lowest loss came from using canola seed in backgrounding rations (scenario 3) .

Finally, the only scenario that increased GHG emission intensity was the increased use of forage for growing cattle which ranked last. Despite being profitable, this scenario was ranked last because the objective of this study was to identify GHGMP which could profitably reduce emissions from beef operations.

6.6 Sensitivity Analysis

For modelling purposes, some of the variables used as representative of the study farm were assumed based on data which were available and from literature reviewed. Data from 2010 were used for the cost of feed and cattle sales; however, prices change almost continually in response to market pressures. It is therefore, necessary to evaluate the change in profitability of the farm and implementation of GHGMP subject to changes in these variables. The discount rate was also set at 5 percent but as already discussed in Chapter 4: (section 4.2.1), there is no single appropriate discount rate for mixed farms. This also necessitated sensitivity analysis.

6.6.1 Sensitivity Analysis with Respect to Discount Rate

A discount rate of 5 percent was used in this study despite the lack of certainty on the appropriate rate for a mixed farm. Koeckhoven (2008) found a value of 7.5 percent to be appropriate; however, other studies have used values as low as 1 percent (Conestoga-Rover and Associates 2011). In this study, sensitivity analysis was performed using 3 and 7 percent for the baseline scenario, and for GHGMP scenarios. For the purpose of analysis, baseline scenario, and Scenario 1(increased use of forage in growing cattle) sensitivity results are reported in Table 6.21. Discount rate sensitivity results of all other GHGMP are reported in Appendix section, Table A.1.

For the baseline, at the 3 percent discount rate beef gross margin increased by $58,381 (25%) and whole farm gross margin increased by 88,333 (14%) compared to the 5 percent discount rate. As expected, opposite results were found when using the 7 percent discount rate. Beef gross margin decreased by $48,521 (21%) and whole farm gross margin decreased by $74,650 (13%). Results of scenario one shows the same trend in responsiveness of gross margin values to the discount rate used. Using a discount rate 3 percent increased Scenario 1 beef gross margin by $60,825 (24%) and whole farm gross margin by $88,736 (15%).

Table 6.21 Comparisons of the study farm gross margin values using 3% and 7% in comparison with the baseline discount of 5%, and implementation of Scenario 1

	Baseline@3%	Baseline@5%	Baseline@7	Scenario 1@3%	Scenario 1@5%	Scenario 1@7%
Beef Gross Margin	$294,154.27	$235,772.48	$187,251.10	$313,984.21	$253,159.21	$202,555.42
Gross Margin($)/lb marketed beef	$0.32	$0.26	$0.20	$0.33	$0.27	$0.22
Whole Farm Gross Margin	$678,976.78	$590,642.98	$515,992.53	$679,919.52	$591,156.13	$516,168.51
Whole Farm Gross Margin/acre	$13.09	$11.38	$9.95	$13.10	$11.39	$9.95

Increasing the discount rate to 7 percent reduced Scenario 1 beef gross margin by $50,603) and whole farm gross margin $74,987.

This changes in gross margin values shows that the implementation of a GHGMP scenario can be affected by the discount rate used. A high discount rate can make a GHGMP scenario unattractive whereas a low discount rate can make a GHGMP more attractive.

Sensitivity analysis was also performed for all the GHGMP at 3 percent and 7 percent to determine if ranking of the scenarios will change in response to different discount rates. Table 6.22 shows the ranking of the scenarios under different discount rates.

Table 6.22 Ranking of GHGMP in response to 3, 5, and 7 percent discount rates

Rank	@3%	@5%	@7%
1	7	7	7
2	4	4	4
3	8	8	8
4	10	10	10
5	5	5	5
6	9	9	9
7	3	3	3
8	2	2	2
9	11	11	6
10	6	6	11
11	1	1	1

The results of Table 6.22 shows that the use of different discounts rates did not affect the rankings of GHGMPs, except for scenario 11 and scenario 6, which exchanged rank 9 and 10 at the 7 percent discount rate compared to rankings at 3 percent and 5 percent. Scenario 11 was the one that kept the breeding stock one additional year to produce 8 calf crops compared to the 7 calf crops of the baseline scenario. Going back to the concept of time value of money, it is evident that profitability of the additional year will be low in present value terms if a high discount rate is used. This is the reason why scenario 11 falls into rank 10 at the 7 percent discount rate. Scenario 6 jumps to rank 9 at the 7 percent discount rate not because it improved profitability of the farm at the 7 percent discount rate, but because scenario 7 performed poorly.

6.6.2 Sensitivity Analysis with Respect to Feed and Cattle Prices

Feed and cattle prices change over time subject to market pressures and natural events such as droughts and flooding. The baseline scenario of this study used 2010 data for feed costs and cattle prices, and also treated that data as constant throughout the beef production cycle. However, data from 2000 to 2011 obtained from AARD (2011b) shows that there is variation in cattle prices over time. The annual percentage deviation of steer prices in that period was 10.5 percent. In the same period, heifer prices had a 12 percent deviation from the mean price. Monthly price deviation from the mean price for 2010 was 7 and 8 percent for steers and heifers, respectively. Based on these figures a 10 percent increase and decrease in prices was analyzed to determine the impacts of variation in cattle prices on the implementation of GHGMPs.

Data on feed costs and prices (i.e. hay and silages) is very limited in western Canada, mainly because a big portion of cattle feed is produced on farm or some producers may buy from their neighbors to supplement any shortages. These makes it almost impossible to know the market price of feeds. However, feed barley prices are closely related to feeder cattle prices. Feed costs were also assumed to have a 10 percent deviation from the baseline scenario prices for the purpose of sensitivity analysis.

Sensitivity analysis was done for four combinations of feed to cattle prices; high-high, high-low, low-high, and low-low. The baseline scenario and scenario 1 were used to evaluate the impacts of this different combinations of feed and cattle prices on the profitability of the beef enterprise and the whole farm. Table 6.23 shows the sensitivity results for the baseline and Table 6.24 shows sensitivity results of scenario 1. Sensitivity results of the other GHGMPs are shown in the Appendix section, Table A2 –A5.

Table 6.23 Sensitivity analysis of feed and cattle prices on profitability of the baseline scenario

	Baseline Scenario (2010 data)	Baseline Scenario (high-high)*	Baseline Scenario (high-low)*	Baseline Scenario (low-high)*	Baseline Scenario (low-low)*
Beef Gross Margin	$235,772.48	$291,499.33	$135,029.61	$336,515.35	$180,045.64
Gross Margin($)/lb marketed beef	$0.26	$0.32	$0.15	$0.37	$0.20
Whole Farm Gross Margin	$590,642.98	$643,562.46	$487,092.75	$694,193.21	$537,723.50
Whole Farm Gross Margin/acre	$11.38	$12.40	$9.39	$13.38	$10.36
Percentage Change in Whole farm gross margin per acre	0.00%	8.96%	-17.53%	17.53%	-8.96%

*high-high: high feed + high cattle price, *high-low: high feed + low cattle price,*low-high: low feed + high cattle prices, *low-low: low feed + low cattle price.

Sensitivity results of the baseline scenario showed that prices of feed and cattle have a big impact on profitability of the farm. The discounted whole farm gross margin per acre shows different values under different feed and cattle price combinations. As expected, a combination of low feed and high cattle prices produced the highest profit for the farm, increasing discounted whole farm gross margin per acre by 17.53 percent compared to using 2010 prices. Conversely, having high feed cost and low cattle prices led to the lowest profit of the farm, decreasing whole farm gross margin by 17.53 percent.

Table 6.24 Sensitivity analysis of feed and cattle prices on Profitability of the farm under Scenario 1 (Increased use of forage in growing cattle)

	Scenario 1 (2010 data)	Scenario 1 (High-high)	Scenario 1 (high-low)	Scenario 1 (low-high)	Scenario 1 (low-low)
Beef Gross Margin	$253,159.21	$311,199.37	$151,232.09	$355,086.34	$195,119.06
Gross Margin($)/lb marketed beef	$0.27	$0.33	$0.16	$0.38	$0.21
Whole Farm Gross Margin	$591,156.13	$647,631.13	$487,663.85	$694,648.41	$534,681.12
Whole Farm Gross Margin/acre	$11.39	$12.48	$9.40	$13.39	$10.31
%change in Whole farm gross margin per acre	0.0%	9.6%	-17.5%	17.5%	-9.6%

*high-high: high feed + high cattle price, *high-low: high feed + low cattle price,*low-high: low feed + high cattle prices, *low-low: low feed + low cattle price.

Similar to the baseline scenario, sensitivity results of scenario one showed that profitability of GHGMP is very responsive to changes in feed and cattle prices, which could affect attractiveness of GHGMP implementation. The low feed and high cattle price combination produced the highest profit, with an increase of 17.5 percent in discounted whole farm gross margin per acre compared to 2010 prices. The lowest profit was observed under the high feed and low cattle price combination, decreasing whole farm gross margin per acre by 17.5 percent compared to 2010 prices.

Sensitivity analysis with respect to changes in feed and cattle prices was done for all GHGMPs to check if performance ranking of scenarios was affected by the price changes (Table 6.25).

Table 6.25 Ranking of GHGMPs in response to feed and cattle price changes

rank	2010 Prices	*high-high	*high-low	*low-high	*low-low
1	7	7	7	7	7
2	4	4	4	4	4
3	8	8	8	8	8
4	10	10	5	10	10
5	5	5	10	5	5
6	9	9	9	9	9
7	3	3	2	3	2
8	2	2	3	2	3
9	11	11	11	11	11
10	6	6	6	6	6
11	1	1	1	1	1

*high-high: high feed + high cattle price, *high-low: high feed + low cattle price,
*low-high: low feed + high cattle prices, *low-low: low feed + low cattle price.

Results in Table 6.25 suggests that there are some changes in rankings of GHGMPs in response to changes in feed and cattle prices. However, the top three and bottom three stayed in the same rank. Scenario 10 (increased number of calves weaned) is placed in rank 4 in all but the high feed and low cattle price combination. If feed costs are high and cattle prices are low, profitability of the farm is low. Scenario 10 drops from rank 4 to 5, indicating that profitability of the farm is worse off in this situation if producers increased weaning rates, as animals will consume more expensive feed but generate little revenues.

6.7 Summary

Simulation results of the baseline scenario for the full beef production cycle estimated a discounted beef gross margin value of $0.26/ lb marketed beef, and a discounted whole farm gross margin of $11.38 per acre. Performance of GHGMPs were measured on the incremental value they had to the baseline profit. Of the 11 GHGMPs evaluated, simulation results showed that 7 GHGMPs increased profitability of the farm, while the other 4 GHGMPs led to a loss. Economic-environmental trade-off analysis found 6 of the profitable GHGMPs resulting in a 'win-win' situation. The list below shows the 'win-win' scenarios in order of their performance in terms of profit per tonne of GHG reduction:

1. Scenario 7: CDDG in finishing ration
2. Scenario 4: Canola seed in Finishing
3. Scenario 8: CDDG in Breeding stock
4. Scenario 10: Increase Weaning rates
5. Scenario 5: Canola Seed in Breeding stock
6. Scenario 9: Improved Hay for Breeding stock

Sensitivity results of the discount rate showed that the level of discount rate used affected profitability of GHGMPs; however, it did not affect performance ranking of the 'win-win' scenarios. Similarly, feed and cattle price sensitivity analysis showed that profitability of GHGMPs is responsive to feed and cattle price changes; however, there was little impact on the performance ranking of scenarios.

Chapter 7

CONCLUSIONS

7.1 Introduction

Beef production is a major economic activity in western Canada, but also poses a threat to the environment through its GHG emissions which causes global warming. Canadian emissions of methane (a major beef GHG) have continued to rise over the years with an increase of 26 percent between 1990 and 2011 (Environment Canada 2013). In order to curb increase of beef production emissions, it is necessary to identify sustainable management strategies that reduces emissions without compromising profitability of beef production. Beauchemin et al (2011) found several GHGMP that can be used in western Canadian beef operations to reduce GHG emissions; however, the impact of those GHGMP on profitability of beef farms has not been evaluated.

The objective of this research was to measure the profitability of GHGMPs in western beef operations and to identify ones that can be sustainably adopted by beef producers to curb the high emission of GHGs from beef production. In order for producers to adopt such practices, they must produce a positive result on their profits. A simulation model was developed for a mixed farm in Vulcan County, southern Alberta. A farm representative of the study area (termed study farm) was constructed based on industry data and expert consultations. The farm was assumed to have 120 cows, 4 bulls and their progeny. Feed requirements of the herd were produced on 5765 acres of farmland, of which 724 acres was annual cropland and 5041 acres was native pasture. The farm was evaluated over a period of 9 years, in that period the breeding stock produced 7 calf crops[26]. Discounted gross margin (calculated by subtracting discounted variable costs from discounted revenues) was used as a profitability measure, and whole farm profitability was measured on a per acre basis to standardize the results.

A total of 11 GHG mitigation scenarios were evaluated. These mitigation scenarios were adopted from Beauchemin et al (2011), who measured their impact on GHG emission levels from a mixed farm in a similar regional setting. The mitigation strategies could be grouped under two categories: change in feed rations (i.e. including canola seed and corn distiller grains in diets; use

[26] Except one scenario that added one production year to the farm, making it 8 calf crops

of good quality feed) and change in animal husbandry practices (i.e. increasing weaning rates; keeping the breeding stock longer). Beauchemin et al (2011) found that substantial amount of emissions can be reduced with these strategies, with the highest reductions occurring in the cow-calf phase at 8 percent and up to 17 percent total reduction possible by combining different scenarios.

The tradeoff between environmental and economic impacts of GHGMPs was analyzed and scenarios were categorized according to their win or loss combinations. The tradeoff analysis allowed for identification of sustainable strategies. The profits and costs per tonne of GHG emission/mitigation were also estimated and the scenarios were ranked.

The main purpose of this chapter is to summarize the major conclusions of the study. Section 7.2 and 7.3 will summarize the major conclusions and implications of the study, respectively. Finally, section 7.4 will discuss the limitations of the study and suggestions for future research.

7.2 Conclusions

The major conclusion of the study is that there are GHGMPs that can be adopted to western Canadian beef operations to reduce GHG emissions without sacrificing profitability of beef farms, and also without any major changes to the structure of beef operations.

Six of the eleven analyzed scenarios had a 'win-win' outcome, meaning that they reduced GHG emissions and also improved profitability of the farm. The highest profitable scenario was the 'use of CDDG in finishing rations', making a whole farm gross margin discounted value of $238.11 per tonne of GHG reduced. Beauchemin et al (2011) identified the breeding stock as the major source of beef herd emissions. Four of the 'win-win' outcome scenarios were directly applied to the breeding stock. They included: one, the use of canola seed; two, CDDG in breeding stock rations; three, feeding improved hay to the breeding stock; and four, increased number of calves weaned. Profitability of these scenarios were $78.66, $37.81, $30.31, and 47.25 per tonne of GHG reduced, respectively.

The other two 'win-win' outcome scenarios came from change in feedlot rations: one, including CDDG, and two, canola seed in finishing rations. These two were the most profitable scenarios; however, feedlot scenarios led to very small reductions in GHG emissions from the beef operation (Beauchemin et al 2011).

The 'win-loss' scenarios had costs ranging from $92.06 to $582.46 per tonne GHG reduced. These scenarios will be adopted only if policy measures are introduced to compensate producers.

One of the major conclusions was that profitability of feed rations is different in different stages of beef production. Using canola seed and CDDG were found to be sustainable in finishing rations of the feedlot but not in backgrounding rations. Profitability of feed related management practices depends on the substitution effect of feeds in cattle rations which is dependent on the energy level of the feed and the costs of producing feeds. Substituting low quality feed for high quality feed means a longer time for animals to gain desirable weights, which might lead to lower feed costs on one side, but higher variable costs on the other side. Land availability is also vital in selecting a GHGMPs. In this study land was assumed to be owned; however, if land is not owned, acquiring land for scenarios that require land expansion can be daunting to the profitability of beef operations as land is very expensive to buy/lease.

7.3. Implications of Study

As discussed in Chapter 2, beef production contributes a big portion to farm cash receipts for western Canadian farmers, and also plays a vital role in the economy of the region and for Canada as a whole. Economically and environmental sustainability of beef production systems at the farm level is vital for continuity and growth of the beef industry. Scenarios identified as having the 'win-win' outcome provide beef farmers with a choice of sustainable GHGMPs that can be adopted to beef operations. Implementation of these strategies will help reduce the increasing levels of GHG emissions in western Canada and also increase profitability of beef operations.

To facilitate the adoption of sustainable GHGMPs it is important to familiarize farmers with how they work, and their benefits to their operations. This can be done through the use of electronic or print mediums or any other form of communication to farmers including workshops and conferences.

7.4 Limitations of Study and Further Research

The cost and price data used in the study was assumed to be constant through the 9 years of the beef production cycle. This was due to lack of complete data on cost of beef production for the study area. As seen in sensitivity analysis, feed and cattle prices determines the attractiveness of GHG mitigation scenarios. Having realistic data would also make these results more appealing to beef producers. In the future, if such data can be made available it will be a major step to have a model that is dynamic capturing the real changes in prices and costs of the industry with time.

Another limitation of this study is that it was limited to Vulcan County. As already discussed, beef producers are faced with different challenges, i.e. feed and resource availability, uncertainty, among others. This makes profitability of beef operations different across western Canada, leading to some producers specializing in cow-calf or feedlot operations. It would be interesting to see how these GHGMPs affect profitability of different farms across western Canada in order to make a recommendation for the whole region.

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Appendix A : SENSITIVITY ANALYSIS RESULTS

Table A.1 Discounted gross margin values using 3 percent and 7 percent discount rate

	Beef Gross Margin	***Beef Gross Margin($)/lb Marketed Beef***	***%Change Beef Gross Margin($)/lb Marketed Beef***	***Whole Farm Gross Margin***	***Whole Farm Gross Margin/acre***	***%Change Whole Farm Gross Margin/acre***
@3% Discount Rate						
Baseline Scenario	$294,154.27	$0.32	0.00%	$678,976.78	$13.09	0.00%
Scenario 1	$313,984.21	$0.33	3.99%	$679,919.52	$13.10	0.14%
Scenario 2	$282,927.53	$0.31	-2.20%	$668,401.85	$12.88	-1.56%
Scenario 3	$288,169.69	$0.32	-2.03%	$671,291.87	$12.94	-1.13%
Scenario 4	$296,829.11	$0.32	0.91%	$690,385.84	$13.31	1.68%
Scenario 5	$276,947.58	$0.30	-5.85%	$698,045.83	$13.45	2.81%
Scenario 6	$256,883.21	$0.28	-12.67%	$642,774.93	$12.39	-5.33%
Scenario 7	$264,203.95	$0.29	-10.18%	$690,132.91	$13.30	1.64%
Scenario 8	$250,849.17	$0.27	-14.72%	$705,392.11	$13.60	3.89%
Scenario 9	$295,786.31	$0.32	0.55%	$687,764.03	$13.26	1.29%
Scenario 10	$327,469.78	$0.34	5.14%	$691,343.68	$13.32	1.82%
Scenario 11	$339,550.52	$0.32	1.00%	$749,410.84	$13.00	-0.66%
@7 % Discount						
Baseline Scenario	$187,251.10	$0.20	0.00%	$515,992.53	$9.95	0.00%
Scenario 1	$202,555.42	$0.22	5.38%	$516,168.51	$9.95	0.03%
Scenario 2	$178,626.52	$0.20	-3.00%	$507,890.14	$9.79	-1.57%
Scenario 3	$182,454.15	$0.20	-2.56%	$509,831.94	$9.83	-1.19%
Scenario 4	$189,395.12	$0.21	1.14%	$525,143.60	$10.12	1.77%
Scenario 5	$172,934.54	$0.19	-7.65%	$531,875.20	$10.25	3.08%
Scenario 6	$157,376.48	$0.17	-15.95%	$486,975.56	$9.39	-5.62%
Scenario 7	$163,244.42	$0.18	-12.82%	$524,959.88	$10.12	1.74%
Scenario 8	$151,219.75	$0.17	-19.24%	$538,002.94	$10.37	4.27%
Scenario 9	$188,609.01	$0.21	0.73%	$523,307.11	$10.09	1.42%
Scenario 10	$211,788.32	$0.22	6.82%	$523,363.58	$10.09	1.43%
Scenario 11	$212,273.35	$0.20	-0.81%	$557,388.88	$9.67	-2.78%

Table A.2 Discounted gross margin values using high feed and high cattle prices

	Beef Gross Margin	*Beef Gross Margin($)/lb Marketed Beef*	*%Change Beef Gross Margin($)/lb Marketed Beef*	*Whole Farm Gross Margin*	*Whole Farm Gross Margin/acre*	*%Change Whole Farm Gross Margin/acre*
Baseline Scenario	$291,499.33	$0.32	0.00%	$643,562.46	$12.40	0.00%
Scenario 1	$311,199.37	$0.33	4.01%	$647,631.13	$12.48	0.63%
Scenario 2	$280,329.33	$0.31	-2.21%	$632,974.85	$12.20	-1.65%
Scenario 3	$285,616.03	$0.31	-2.02%	$636,159.15	$12.26	-1.15%
Scenario 4	$294,128.90	$0.32	0.90%	$654,001.32	$12.60	1.62%
Scenario 5	$274,262.03	$0.30	-5.91%	$659,371.37	$12.71	2.46%
Scenario 6	$258,275.14	$0.28	-11.40%	$611,294.19	$11.78	-5.01%
Scenario 7	$268,664.53	$0.29	-7.83%	$657,478.89	$12.67	2.16%
Scenario 8	$253,509.28	$0.28	-13.03%	$669,085.88	$12.90	3.97%
Scenario 9	$293,134.27	$0.32	0.56%	$651,715.62	$12.56	1.27%
Scenario 10	$320,767.87	$0.33	3.93%	$653,899.96	$12.60	1.61%
Scenario 11	$331,375.75	$0.32	-0.53%	$703,477.23	$12.20	-1.62%

Table A.3 Discounted gross margin values using high feed and low cattle prices

	Beef Gross Margin	*Beef Gross Margin($)/lb Marketed Beef*	*%Change Beef Gross Margin($)/lb Marketed Beef*	*Whole Farm Gross Margin*	*Whole Farm Gross Margin/acre*	*%Change Whole Farm Gross Margin/acre*
Baseline Scenario	$135,029.61	$0.15	0.00%	$487,092.75	$9.39	0.00%
Scenario 1	$151,232.09	$0.16	9.11%	$487,663.85	$9.40	0.12%
Scenario 2	$126,049.32	$0.14	-5.08%	$478,694.83	$9.23	-1.72%
Scenario 3	$129,146.31	$0.14	-4.36%	$479,689.44	$9.25	-1.52%
Scenario 4	$137,659.19	$0.15	1.95%	$497,531.60	$9.59	2.14%
Scenario 5	$117,792.32	$0.13	-12.77%	$502,901.65	$9.69	3.25%
Scenario 6	$101,805.42	$0.11	-24.61%	$454,824.48	$8.77	-6.62%
Scenario 7	$112,194.82	$0.12	-16.91%	$501,009.18	$9.66	2.86%
Scenario 8	$97,039.57	$0.11	-28.13%	$512,616.17	$9.88	5.24%
Scenario 9	$136,664.56	$0.15	1.21%	$495,245.91	$9.55	1.67%
Scenario 10	$160,714.77	$0.17	12.41%	$493,846.86	$9.52	1.39%
Scenario 11	$158,262.41	$0.15	2.55%	$530,363.89	$9.20	-2.00%

Table A.4 Discounted gross margin values using low feed and high cattle prices

	Beef Gross Margin	*Beef Gross Margin($)/lb Marketed Beef*	*%Change Beef Gross Margin($)/lb Marketed Beef*	*Whole Farm Gross Margin*	*Whole Farm Gross Margin/acre*	*%Change Whole Farm Gross Margin/acre*
Baseline Scenario	$336,515.35	$0.37	0.00%	$694,193.21	$13.38	0.00%
Scenario 1	$355,086.34	$0.38	2.80%	$694,648.41	$13.39	0.07%
Scenario 2	$325,854.03	$0.36	-1.54%	$684,114.27	$13.19	-1.45%
Scenario 3	$331,701.74	$0.36	-1.43%	$687,859.59	$13.26	-0.91%
Scenario 4	$338,666.82	$0.37	0.64%	$704,153.96	$13.57	1.43%
Scenario 5	$322,412.11	$0.35	-4.19%	$713,136.17	$13.74	2.73%
Scenario 6	$303,120.83	$0.33	-9.92%	$661,754.60	$12.75	-4.67%
Scenario 7	$305,816.60	$0.33	-9.12%	$700,245.68	$13.50	0.87%
Scenario 8	$295,628.78	$0.32	-12.15%	$716,820.10	$13.82	3.26%
Scenario 9	$337,853.03	$0.37	0.40%	$702,049.10	$13.53	1.13%
Scenario 10	$367,937.77	$0.38	3.26%	$706,684.58	$13.62	1.80%
Scenario 11	$ 381,318.26	$0.36	-0.85%	$759,387.97	$13.17	-1.55%

Table A.5 Discounted gross margin values using low feed and low cattle prices

	Beef Gross Margin	*Beef Gross Margin($)/lb Marketed Beef*	*%Change Beef Gross Margin($)/lb Marketed Beef*	*Whole Farm Gross Margin*	*Whole Farm Gross Margin/acre*	*%Change Whole Farm Gross Margin/acre*
Baseline Scenario	$180,045.64	$0.20	0.00%	$537,723.50	$10.36	0.00%
Scenario 1	$195,119.06	$0.21	5.58%	$534,681.12	$10.31	-0.57%
Scenario 2	$171,574.01	$0.19	-3.10%	$529,834.25	$10.21	-1.47%
Scenario 3	$175,232.03	$0.19	-2.67%	$531,389.87	$10.24	-1.18%
Scenario 4	$182,197.11	$0.20	1.19%	$547,684.24	$10.56	1.85%
Scenario 5	$165,942.40	$0.18	-7.83%	$556,666.45	$10.73	3.52%
Scenario 6	$146,651.11	$0.16	-18.55%	$505,284.89	$9.74	-6.03%
Scenario 7	$149,346.89	$0.16	-17.05%	$543,775.97	$10.48	1.13%
Scenario 8	$139,159.07	$0.15	-22.71%	$560,350.39	$10.80	4.21%
Scenario 9	$181,383.32	$0.20	0.74%	$545,579.39	$10.52	1.46%
Scenario 10	$207,884.67	$0.21	9.05%	$546,631.48	$10.54	1.66%
Scenario 11	$208,204.91	$0.20	1.19%	$586,274.63	$10.17	-1.87%