Economics of Beneficial Management Practices Adoption by Beef Producers in Southern Alberta

by

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ABSTRACT

Beneficial Management Practices (BMPs) are a means by which the provision of ecosystem services and sustainability of agricultural production systems may be enhanced. However, achieving widespread adoption of BMPs may require policy intervention because studies have shown that the adoption and implementation of many BMPs are costly.

The research carried out in this project involves an analysis to assess the economics of adoption by southern Alberta cow-calf producers for a specified set of BMPs The BMPs examined in this study are intended to improve water quality, soil quality and other environmental attributes. The analysis is conducted for a representative mixed crop-beef farm assumed to be located in the Dark Brown soil zone of Alberta. Stochastic crop prices and yields as well as stochastic beef prices are incorporated in the analysis, along with participation in public business risk management programs (e.g., crop insurance). The study uses dynamic Monte Carlo Simulation and Net Present Value analysis methods to estimate farm-level costs and benefits of BMPs. The BMPs examined in the study include rotational grazing, crop residue management, enhancing tame pasture productivity through incorporation of legumes (alfalfa), manure management, and conservation of natural areas (i.e., retirement of native pasture area).

Results obtained from the analysis are mixed. Manure management results in a relatively small annual benefit per acre of land affected. The effects of rotational grazing and enhancing tame pasture productivity through incorporation of legumes depend on the degree to which tame pasture productivity is improved by the BMP. Conservation of natural areas and crop residue management BMPs result in a net cost per acre of land affected. Overall, economic incentives may be necessary to motivate producers to adopt BMPs that are costly. Conversely, information programs may be all the policy required in the cases of BMPs that are economically feasible on their own.

DEDICATION

To the memory of my late parents, Mr. Emmanuel Debrah Bruce and Madam Grace Kwadu-Amponsem.

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CHAPTER 1 : INTRODUCTION

1.1 Background

Society receives many benefits from ecosystem services for natural and managed ecosystems. Cook & Spray (2012), while quoting Milder et al (2010), defined ecosystem services as "the benefits people obtain from ecosystems. These benefits include provision services such as food and water; regulatory services such as regulation of floods, drought, land degradation and diseases; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nutritional benefits" (Cook and Spray, 2012, Pg. 94). Costanza et al (1997) also defined ecosystem services as direct or indirect benefits (e.g., food and waste assimilation) humans derive from ecosystem functions. These ecosystem functions represent the various habitat, biological or system properties or processes of ecosystems.

Agricultural practices have an impact on the environment by changing natural ecosystems and ecosystem processes (McRae et al., 2000). The ecosystem services affected by agricultural practices include water quality, pollination, nutrient recycling, soil retention, carbon sequestration and biodiversity conservation. Agricultural productivity, in turn, is affected by ecosystem services. The interconnected trends link with agricultural practices to affect ecosystems include water scarcity, nutrient overloading, biodiversity loss, ocean over exploitation, climate change and habitat change (Davari et al, 2010). The impact of agricultural activities is also related to choices made by producers with respect to land management, where a given change can have downstream consequences that are difficult to predict.

One of the agricultural sectors of interest in Canada is the beef sector. This represents an important part of the larger Canadian agricultural economy. In 2014, Canada exported 317.7 thousand metric tonnes of beef to countries such as USA, Hong Kong, Macau, Mexico, Japan, and China. The total amount of money accrued from the export of the beef was $ 1.936 billion. Canada was 5th among the world's beef and cattle exporters in 2014. Canada exported 750 thousand metric tonnes (carcass weight equivalent) (7% of world export) out of a total of 10,292 thousand metric tonnes supplied to the world market (Canfax, 2015).

[1]Beef production affects ecosystem services, and in some cases the impacts are negative. Cattle production contributes to the emission of three greenhouse gases (GHG); carbon dioxide, methane and nitrous oxide (BCRC, 2015). Carbon dioxide represents about 5% of total emissions from Canadian beef production. Much of this is due to the use of fossil fuel which is associated with crop production (fertilizer and fuel) and the transportation of feed, cattle and beef to markets (BCRC, 2015). Anaerobic conditions (without oxygen) promote the growth of methanogens which produce methane gas. Another 5% of total emissions from Canadian beef production are from methane gas (BCRC, 2015). Nitrous oxide emissions (e.g., from manure storage and treatment) account for approximately 25% of total GHG from Canadian beef production. This gas is known to have a much higher global warming potential than either methane or carbon dioxide (BCRC, 2015).

Intensive feedlot beef operations are known to have a negative impact on air quality through the release of dust and odours (BCRC, 2015). Towns or acreages that are located downwind of feedlots are often faced with these issues. Pen surfaces, alleys and roads can generate dust and the degree to which it affects humans is influenced by humidity, temperature and wind speed. Ammonia and odoriferous organic compounds such as amines, sulfides, phenols and volatile fatty acids emissions

[1] This section summarises the effects of beef production on ecosystem services using information from the BCRC website which provides a review of primary research results in this area.

may occur. They can be transported several kilometers from the feedlot depending on the compound.

Although the long-term health effects associated with the exposure to particulate matter from feedlots are largely not known, its impact on individuals suffering from chronic respiratory diseases can be severe. Ammonia, apart from contributing indirectly to nitrous oxide emissions, ammonia and organic compound deposition may adversely impact water quality. In areas where beef production is more intensive, long-term effects of applying cattle manure to cropland have become an important issue since this practice leads to increase rate of nutrient accumulation in soils (BCRC, 2015).

Protozoa (e.g. giardia, cryptosporidium) and bacteria such as *Escherichia coli,* campylobacter that cause disease in humans can be carried by beef cattle. Water can serve as a vector for these microbes because the risk of faecal matter from beef cattle coming in direct contact with surface water is high (BCRC, 2015).

As a result of these issues associated with beef production in Canada, both the federal and provincial governments have been working to develop policy in the areas that influence land use practices, especially for land that is traditionally used by cattle producers for grazing, hay and silage production. In Alberta, the Agricultural Operation Practices Act (AOPA) was passed and implemented to regulate intensive livestock operations. For example, on wintering sites (where livestock are fed and sheltered over the winter) and livestock corrals, producers must reduce runoff risks by locating wintering sites and corrals 30 metres or more from a common body of water (NRCB, 2007a). Regarding manure management regulations for cow-calf producers (manure storage and record keeping), AOPA stipulates that producers with short-term solid manure storage sites must locate manure at least: 150 metres from residences or occupied buildings that the producer does not own, 100 metres from a spring or water well, 1 metre above the water table and 1 metre above the 1-in-25-year maximum flood level. Producers are required to keep records on soil test results, amount of manure produced or handled, land location where manure is applied and application rate of manure and fertilizer (NRCB, 2007b). The body responsible for administering the regulations under AOPA is the Natural Resources Conservation Board (NRCB).

In Canada, the policy approach currently taken to influence the impact of beef production on ecosystem services also involves incentive schemes for implementation of beneficial management practices (BMPs) by farmers (Boxall et al, 2008). BMPs have been determined to be a potentially effective and practical means by which beef cattle producers and cattle producers in general can mitigate the impact of their activities on the environment (Shiefield, 2007). A BMP is defined as "an agricultural management practice which ensures the long-term health and sustainability of land-related resources used for agricultural production; positively impacts the long-term economic and environmental viability of the agricultural industry; and minimizes negative impacts and risk to the environment" (Boxall et al, pg. 17, 2008).

BMP programs such as Alberta Riparian Habitat Management have encouraged the adoption of agri-environmental BMPs by beef cattle producers through the use of incentives. However, in such programs, the incentives provided by these programs are not based on the implementation costs and benefits of the practices on the part of the producer (Amy et al, 2012).

Beef cattle production is classified into three operations. These operations include cow-calf, backgrounding and finishing. This study focused on cow-calf operations. In cow-calf production, pasture is a major production input. As a result, it has become imperative on the part of the producers to ensure the sustainability of pasture through the choice of BMPs that will ensure proper management of pasture. Pasture management is defined as a complex inter-relationship that exists among plant, temperature, light, soil, organisms, nutrients, water, and livestock that make the pasture a dynamic ecosystem (Murphy, 1995). Good pasture management is the foundation of sustainable livestock production.

1.2 Economic Problem

BMP adoption is important for ecosystem services provision and sustainability of agricultural production systems. Significant adoption of BMPs may require policy intervention because the limited evidence available suggests that adoption is costly. The choice of appropriate policy requires estimates of both public and private benefit (Pannell, 2008). For example, positive incentives for land-use change (e.g., subsidies) should not be used unless there are positive public net benefits associated with the change, whereas positive incentives should not be used if landholders would adopt land-use changes without the proposed incentives (i.e., there are positive private benefits) (Pannell, 2008).

Currently, there is limited or little information available concerning both private and public benefits associated with BMP adoption by beef producers. Most studies conducted so far on BMP adoption by cattle producers identify BMPs and the factors that influence the adoption of the BMPs related to cattle production. Examples of these studies include Kim et al (2004) who examined the effects of economic factors on decisions by North Dakota beef producers to adopt BMPs and Winkle (2011) who identified current management practices and factors that influence adoption rates of best management practices relating to surface water pollution by North Dakota beef cow producers.

Koeckhoven (2008) represents one of the few studies examining costs and benefits associated with BMP adoption by beef producers. Koeckhoven's (2008) study examines pasture management BMPs in the Lower Little Bow watershed in southern Alberta. A similar study was conducted by

Dollevoet (2010) for southern Saskatchewan. These two studies show that some pasture management BMPs come at a net cost to producers even though they are associated with positive effects in terms of ecosystem services production. Therefore, as a policy, from Pannell's framework perspective, producers may need to be provided with positive incentives in order to implement these management practices if the benefits exceed the negative private benefits. However, the scope of BMPs considered by Koeckhoven (2008) and Dollevoet (2010) was limited. The purpose of this study was to help fill the gap out among beef producers at the farm level in southern Alberta to inform policy development.

1.3 Research Problem and Objectives

The main objective of the study is to assess the economic performance of a representative southern Alberta mixed crop-beef farm, with and without the adoption of BMPs. The specific objective of the study is to estimate the private economic costs and benefits associated with the adoption of BMPs related to mixed crop-beef industries in southern Alberta. The results of the study provide producers with quantifiable estimates of the net cost or benefit associated with the adoption BMPs related to a mixed crop-beef farm. This will help them to make the right decisions in terms of the adoption of BMPs related to mixed crop-beef farm.

The estimation of the private economic costs and benefits associated with the adoption of BMPs related to mixed crop-beef farm in the study area is important for policy makers, researchers and organizations involved BMP adoption programs. This will enable them get information about the cost or benefit associated with the adoption of the selected BMPs in this study, which in turn would help them to identify suitable policy initiatives.

1.4 Organization of the Study

The study consists of seven chapters. Chapter 2 reviews relevant existing literature based on the objectives of this study. Chapter 3 describes the study area. Chapter 4 outlines the methodology which was used to accomplish the objectives of the study. Chapter 5 discusses the characteristics of the representative farm as well as the empirical simulation model of this study. The presentation of results and discussions are in Chapter 6. The final chapter contains summary, conclusions and recommendations of the study.

CHAPTER 2 : BACKGROUND AND LITERATURE REVIEW

This chapter provides background information and a review of relevant literature related to the research objectives of this study. The main purpose of this chapter is to give a picture of the beef industry in Canada and Alberta and the role the industry plays in environmental sustainability or ecosystem and ecosystem services. The chapter is organized into subtopics on ecosystem and ecosystem services, Canada and Alberta's beef industry, grazing management, beneficial management practices related to beef production, beneficial management practices of interest and studies on the economics of BMP adoption by beef producers.

2.1 Ecosystem and Ecosystem Services

2.1.1 Overview of Ecosystem and Ecosystem Services

The term ecosystem describes a specific area in which climate, landscape, plants and animals interact constantly. An ecosystem is made up of physical and chemical components which include soils, water and nutrients that support the organisms living within them. The organisms range from large animals and plants to microscopic bacteria. Ecosystems are further explained as the interactions among all organisms in a given habitat and the flow of energy from one component to another. Human beings are part of ecosystems and as a result, the health and wellbeing of humans depend on services provided by ecosystems and their components (Davari et al, 2010).

Ecosystem services as defined previously, are components of nature, directly enjoyed, consumed, or used to yield human well-being (Boyd and Banzhaf, 2007). When ecosystem services are being described as directly enjoyed or consumed or used, the impression one gets is that the final services are end-products of nature, suggesting that ecosystem services are final goods rather than being intermediate goods in terms of welfare accounting. However, many components and functions of an ecosystem are also intermediate products due to the fact that they are essential to the production of services but are not classified as services themselves.

Ecosystem processes and functions, on the other hand, are the biological, chemical and physical interactions between ecosystem components. Ecosystem components include, for example, resources such as surface water, oceans, vegetation types and species that are used to provide ecosystem services (Boyd and Banzhaf, 2007). Table 2.1 provides an inventory of ecosystem services associated with particular benefits (Boyd and Banzhaf, 2007).

Table 2.1: Inventory of ecosystem services associated with particular benefits

Illustrative benefits	Illustrative ecosystem services
Harvests:	
Managed commercial	Pollinator populations, soil quality, shade and shelter, water availability
Subsistence	Target fish, crop populations
Unmanaged marine	Target marine populations
Pharmaceutical	Biodiversity
Amenities and fulfillment:	
Aesthetic	Natural land cover in view sheds
Bequest	Wilderness, biodiversity, varied natural land cover
Spiritual	
Emotional	
Existence benefits	Relevant species populations
Damage avoidance:	
Health	Air quality, drinking water quality, land uses or predator populations hostile to disease transmission
Properties	Wetlands, forests, natural land cover
Waste assimilation:	
Avoided disposal cost	Surface and ground water, open land cost
Drinking water provision:	
Avoided treatment cost	Aquifer, surface water quality
Avoided pumping, transport cost	Aquifer availability
Recreation:	
Birding	Relevant species population
Hiking	Natural land cover, vistas, surface water
Angling	Surface water, target population, natural land cover
Swimming	Surface waters, beaches

Source: Boyd and Banzhaf (2007).

2.2 Canada and Alberta's Beef Industry

Beef production is an important part of Canadian agriculture. From the 2011 Census of Agriculture, there were 12,789,965 cattle and calves in Canada. The number of farms which reported cattle and calves were 85,890. Out of total cattle and calves, there were 4,811,094 (representing 37.62%) cows reported by 74,472 farms. Out of the total cows, 3,849,368 (representing 80.01%) were beef cows, reported by 61,425 beef farms (Statistics Canada, 2012). Again, of the total cattle and calves, there were 1,498,894 (representing 11.72%) steers (one year and over) reported by 27,979 farms and 602,701(representing 4.71%) heifers for beef herd replacement reported by 34,272 farms (Statistics Canada, 2012),

Alberta is the largest cattle producing province in Canada. From the 2011 Census of Agriculture, Alberta had a total number of 5,104,605 cattle and calves (representing 39.91% of Canada's total) on 21,888 reporting farms. Of this total, there were 1,611,085 cows reported by 19,168 farms of which 1,530,391 (representing 94.99%) were beef cows reported by 18,618 farms (Statistics Canada, 2012). There were also 819,409 steers (one year and over) reported by 7,387 farms and 264,372 heifers for beef herd replacement reported by 10,623 farms out of the total cattle and calves (Statistics Canada, 2012).

Of the $49.6 billion in 2011 total farm cash receipts in Canada, $20.3 billion were receipts from livestock with cattle contributing $ 5.5 billion. In 2011, total farm cash receipts of Alberta were $10.3 billion, representing 20.74% of Canada's total. Total provincial receipts from livestock and livestock products were $4.4 billion of which cattle contributed approximately $3 billion (Statistics Canada, 2016).

There are different types of commercial beef operations in Canada. The production of beef begins with cow-calf operations to produce weaning calves, backgrounding (stocker or holding) and the feedlot.

2.2.1 Cow-calf Operations

Cow-calf operations maintain cows and raise calves until they are weaned which generally occurs at six to eight months of age and 500-600 pounds of weight. At that point the calves are put on a forage-based diet. The entire cow-calf process takes place outside on open pastures where the cattle graze and calves nurse on most farms until they are weaned in the fall. In early summer, breeding takes place and peak calving takes place in the following spring (SSGA, 2010). Herd sizes range from a few cows on small mixed farms to several hundred cows in large range herds. The average beef-cow farm in Canada has 61 cows with 48% of these herds located on farms with more than 122 head (Stringham, 2015). Cow-calf can be purebred or commercial operations. A purebred operation is defined as typically raising one breed of cattle with all the cattle registered and sold through purebred sales while a commercial operation is defined as raising crossbred cattle or unregistered purebred cattle (Barkley, 2017). Commercial large operations account for 13% of all beef farms. These are primarily located in the four western provinces where over two-thirds of Canada's breeding herds are located. Cow-calf operations are usually based on a low-cost pasture resource which may be sparsely vegetated areas (12 ha required per cow) or very intensively cultivated and irrigated pastures (0.5 ha per cow). Some of the largest operations are found on predominantly natural pastures requiring 8 ha or more per cow (Stringham, 2015).

2.2.2 Backgrounding (stocker or holding) Operations

Backgrounding operations feed or pasture calves in order to add size and weight. Calves are over-wintered on hay-based diets until their weight increases to about 900 pounds (SSGA, 2010). The calves are fed on roughage and pasture with the aim of getting as much efficient weight as possible.

2.2.3 Feedlot Operations

These operations feed weaned and/or backgrounded calves to weights of 1000-1400 pounds, when they are ready for slaughter. The animals are fed high-energy feed such as barley, corn and to some extent, wheat and oats, along with bulky roughages such as corn silage, hay and straw. Some refuse or by-products such as brewer's grains, beet pulp, milling and canning crop residues may form the basis of less efficient but profitable feeds in local areas. In the first part of the finishing period, lower-quality feeds are usually used but as the animal increases in weight, higher-energy feed is required to produce economical gains (Stringham, 2015).

2.3 Grazing Management

Grazing management is described as the care and use of range and pasture to obtain the highest sustainable yield of animal products without causing harm to forage plants, soil, water resource and other essential land attributes (AARD, 2004). Grazing lands are considered to be the chief support of cow-calf operations. They are also essential to wildlife, biodiversity as well as water quality (AARD, 2004).

Producers have incentives to make productive use of pasture resources so that livestock production goals can be met while maintaining and improving pasture as well as the ecosystem. To be able to manage and sustain pasture lands, producer need to know and understand the operation's grazing resources.

Each pasture type has unique characteristics and limitations that require specific management practices aimed at maintaining and improving it while protecting the ecosystem. The most appropriate grazing method is dependent on the relative amount of native range area, tame pasture area, cultivable lands readily available for annual pastures, herd nutrient requirements, competing enterprises on the farm and the availability of other feeds (AARD, 2004). The pasture types used by beef producers include tame pastures, annual pastures, native range, forest pastures and riparian pastures.

2.3.1 Tame Pastures

Tame pastures are described as cultivated fields planted with introduced (non-native) grass and legume species or cultivars with the aim of providing livestock grazing forage. They are responsive to intensive management and, depending on the species seeded, are useful for year-round grazing when environmental conditions are favourable (AARD, 2004). As a management strategy and to ensure efficiency, tame pasture should be grazed early and use of native pasture (described below) should be delayed until later in the season so as to allow tame pasture some rest to regrow for late summer or fall grazing (AARD, 2004).

Tame pasture may include both grass and legume species. The grass varieties normally used include crested wheat grass, intermediate wheat grass, tall wheat grass, Russian wild rye, Altai wild rye, smooth brome, meadow brome, meadow foxtail, orchard grass, timothy grass, Kentucky blue grass, tall fescue and reed canary grass. The legumes include alfalfa, white clover, red clover, cicer milkvetch, sainfoin, sweet clover and birds' foot trefoil (Aasen and Bjorge, 2009).

The species to grow is determined by considering regional adaptation as well as site adaptation; that is, climate and soil conditions determine where forages can be established (Aasen and Bjorge, 2009). For example, in the Dark Brown soil climatic zone in Alberta (the area of interest for the current study), brome grass is commonly grown in the moister parts of the region. Crested wheatgrass and intermediate wheatgrass are also commonly established. Alfalfa is well adapted and Altai wild ryegrass and Russian wild ryegrass are commonly used in the drier areas of the region (Aasen and Bjorge, 2009).

2.3.2 Annual Pastures

Annual pasture is made up of cultivated areas that are seeded with annual crops for the purposes of grazing. Using annual pastures allows a fallow period for native and tame pastures thereby lengthening the grazing season. Some of the annual crops used include barley, annual rye grass, oats, forage kale, fall rye, spring-seeded winter wheat and winter triticale (AARD, 2004).

The use of crop aftermath after harvesting of annual crops has also gained recognition by many cattle producers across western Canada to reduce feeding costs in mixed farm operations (Hutton, 2008). Crop aftermath is made up of grain, husks, leaves, cobs and/or stalks that are left on the field after harvesting (Rasby et al, 2008).

2.3.3 Native Pastures

Native range grasses are the dominant plants in the vast range land plant communities and are important in the understory of many forested areas. Native rangelands are categorized into four landscape units in Alberta. These include Mixed Grass Prairie, Fescue Prairie, Aspen Parkland and Boreal Forest (AARD, 2004).

As a pasture management strategy, AARD (2004) stipulates principles that can be used to maintain and foster healthy, productive native range. Livestock demands must be balanced with the forage supply that is available and enough residue should be left to protect plants and soil. Producers should use tools such as fencing, salt placement, and water development in order to spread the grazing load over the landscape and also to promote even distribution of livestock. Grazing of rangeland during sensitive periods such as early spring should be avoided because this can stress rangeland and deplete the new growth energy reserves. Rest periods must be provided during the growing season to allow range plants to recover from the stress of grazing.

2.3.4 Forest Pastures

A variety of plant species, including shrubs, forbs, and grasses provide forage in a forest pasture. However, the grazing period for forest pastures is relatively short. Before the middle of May or early June, plants in forest pastures produce little forage and the nutritional value quickly drops as the plants mature. The palatability also drops as the summer progresses. They do not tolerate heavy grazing. As a result, the grazing schedule during summer affects the survivability of plants in a forest pasture (AARD, 2004). As a management strategy, timing is very important in the use of forest pasture. There is a reduction in shrub growth when forest pasture is grazed early in the summer but late grazing in the summer and into the fall permits the forest undergrowth to develop (AARD, 2004).

2.3.5 Riparian Pastures

Riparian areas can be described as lands adjacent to water bodies where the vegetation and soils are strongly influenced by the presence of water. Some of the most productive ecosystems on the Prairies are these riparian areas. Vegetation and soils of these areas are rich due to the fact that water is collected, filtered, slowed and released in these areas. Although riparian pastures only make up a small portion of the landscape, they are more important than indicated by their size. There is abundant growth of trees, shrubs and grass in these areas which provide food and habitat to animals, birds, amphibians and fish. As a management strategy, riparian pastures should be grazed when moisture is low and the sod is firm (typically late summer). There should also be adequate rest period to allow vegetative growth recovery (AARD, 2004).

2.4 Beneficial Management Practices (BMPs) Related to Beef Production

A number of BMPs have been identified as having potential to be effective and practical means by which cow-calf beef cattle producers can manage pasture. There are different types of BMPs, as some are designed to maintain or improve the sustainability of pasture, while others are intended to improve water quality or other environmental attributes. Table 2.2 provides brief definitions for some of the BMPs suggested here and also group the BMPs into whether they are related to sustainability of pasture, water quality, or other environmental attributes.

Hadrich (2012), while carrying out a survey of the awareness and use of BMPs on North Dakota beef operations, identified six BMPs to contribute to pasture management. These BMPs include filter strips, riparian buffers, stream ban fencing, stream bridges, rotational grazing, and nutrient management. Kim et al (2004) studied the effect of economic factors on the adoption of best management practices in beef cattle production and suggested the following BMPs: water facility, continuous prescribed grazing, rotational grazing, field borders and filter strips, heavy use area protection, livestock exclusion, regulating water, riparian forest buffer, stream bank and shoreline protection. Kutz et al (2014) measured the willingness to adopt best management practice bundles by beef cattle operations in an East Tennessee watershed and identified exclusionary fencing, pasture improvement, fertilization to improve cover growth, riparian buffers, alternative water sources and stream crossings as BMPs associated with beef cattle operations.

Table 2.2: Brief definitions of some BMPs and associated services

BENEFICIAL MANAGEMENT PRACTICE	DEFINITIONS	ECOSYSTEM SERVICE
Filter strips	Vegetative areas used to trap sediment, organic material, nutrients, and chemicals before reaching sensitive environmental areas through surface runoff and waste water.	Biodiversity
Riparian buffers	Vegetative areas adjacent to surface water to remove excess amounts of sediment, organic material, nutrients, chemicals, and other pollutants.	Water quality Biodiversity
Stream bank fencing	The practice of excluding livestock from surface water through the use of fencing.	Water quality
Stream bridges	Generally used in conjunction with stream bank fencing to allow livestock to move across the stream/river with minimal contact to the water.	Water quality
Rotational grazing	The practice of dividing pastures into sections. Each section is grazed for a short period of time and then rested from grazing until vegetation in that section has recovered.	Pasture sustainability
Nutrient management	The practice of using manure from agricultural/farm operations in an environmentally sound manner by following recommended application rates.	Water quality Soil quality
Cover and green manure	Crop of close-growing grasses, legumes or small grain grown for seasonal soil protection and improvement.	Soil quality Natural land cover
Critical area planting	Planting trees, shrubs, vines, grasses or legumes, on highly erodible or critically eroding areas.	Soil quality Biodiversity
Grassed water ways	Natural or constructed channels that are shaped or graded to required dimensions and planted in suitable vegetation to carry water runoff.	Soil quality
Heavy used area protection	Establishment of vegetative cover, installing suitable surface materials and constructing needed structures where animals congregate.	Natural land cover

Table 2.2 Continued

BENEFICIAL MANAGEMENT PRACTICE	DEFINITIONS	ECOSYSTEM SERVICE
Livestock exclusion	Excluding animals from an area to protect, maintain or improve the quantity and quality of the natural resources.	Biodiversity
Regulating water in drainage	Controlling the removal of surface runoff, primarily through the operation of water control structures.	Water quality Soil quality Water retention
Shoreline protection	Use of vegetation or structures to stabilize and protect banks of streams, lakes, estuaries or excavated channels against erosion.	Water quality
Water facility	Watering system installed to provide drinking water for livestock.	Pasture sustainability
Mortality management	Proper management of animal carcasses using cremation or deep burial to prevent, control and eradicate contagious or communicable diseases and viruses.	Disease prevention Environmental protection
Alternative watering systems	Livestock Watering BMP intended to address environmental risks associated with livestock drinking directly from surface water sources. These risks include contaminating water with urine and manure, spawning bed trampling, stream bank trampling and removal of riparian vegetation through trampling and grazing.	Water quality Pasture sustainability
Wild life damage prevention	Intended to reduce both the impacts that wildlife can have on farm operations and the impacts that farms can have on wildlife. The BMP provides cost-sharing for the installation of wildlife fencing to mitigate or eliminate agriculture-wildlife conflicts particularly involving stored feed, irrigation lines and crops.	Wildlife habitat
Holding ponds	Incorporates proper pen slopes to provide good drainage and pen drying.	Soil quality Water quality
Exclusionary fencing	Excluding livestock from surface water through the use of fencing.	Water quality

Source: Hadrich (2012) and Kim et al (2005)

2.5 Beneficial Management Practices of Interest

In this section, BMPs of interest chosen for the study area are examined. As mentioned earlier, there are a lot of practices that can be considered as BMPs for adoption in mixed crop-beef farm operations. However, BMPs are chosen based on the suitability to the area under consideration. BMPs considered for this study include crop residue management, manure management, enhancing tame pasture productivity through incorporation of legumes (alfalfa), rotational grazing and conservation of natural areas (retirement of native pasture area).

2.5.1 Crop Residue Management

Crop residues are the parts of the plants left over in the agricultural field after harvesting of crops. Examples include stalks, stubble, leaves and seed pods. Crop residues have been at times considered as waste materials that need to be disposed of but it has become increasingly realized that they are potentially useful natural resources rather than waste. There are several options that are available to farmers in the management of crop residues. These include burning, incorporation, leaving as surface residues, removal by baling, or use as feed or bedding material for livestock (Kumar and Goh, 2000).

When left in the field, crop residues play a number of essential functions such as maintenance of soil moisture, accommodation of beneficial microbes, recycling of plant nutrients and increasing soil organic matter (Oo and Lalonde, 2012). Due to the functions mentioned above, agricultural land requires a certain amount of crop residues to maintain the quality of the soil (Oo and Lalonde, 2012). Excessive residues, on the other hand, can lead to slower soil warming in the planting season, difficulties in operating planting machinery and increased emissions of greenhouse gases from the decomposition of residues (Oo and Lalonde, 2012). The removal of crop residues is very site-specific and depends on crop rotation and soil management practices of individual farmers (Oo and Lalonde, 2012).

An advantage of crop residue removal through burning or baling is that it is a quick method to clear the land of residues before the establishment of the next crop, especially in high-intensity cropping areas (Kumar and Goh, 2000). However, this exposes the land to both wind and water erosion which may have negative effect such as leaching of nutrients and may affect subsequent crop yield (Kumar and Goh, 2000).

According to Dormaar and Carefoot (1996), depending on methods of cultivation used, crop residues can be incorporated partially or completely into the soil. This can result in ground cover which has important implications for controlling water and wind erosion. However, as noted by Chaman and Cope (1994), the method of incorporation can affect yield and decomposition. Thus, deep incorporation has the potential to reduce possible yield depressions but slows down cultivation and requires more time, labor and energy costs (Chaman and Cope, 1994).

2.5.2 Manure Management

Under Alberta's Agricultural Operation Practices Act (AOPA), manure includes livestock excreta, straw, other bedding material, litter, soil, wash water and feed in the manure. Manure is considered to be both a natural by-product of livestock production and a source of plant nutrients for crop production (MAFRI, 2009). Manure is known to contain nitrogen (N), phosphorus (P), potassium (K) and micro-nutrients that are needed for crop production and therefore can be a replacement for synthetic fertilizers (MAFRI, 2009). In addition, unlike inorganic fertilizers, manure is known to increase soil organic matter when applied to land. This results in improvement in a number of soil quality properties such as soil tilth, structure and aggregate stability, water infiltration rates, soil biota diversity and activity, aeration, water-holding capacity and soil fertility as well as reducing spring runoff and soil erosion (Grande et al, 2005).

Compared to synthetic fertilizer, the nutrient concentration of manure is low. Therefore, high application rates would be required in order to apply equivalent amount of nutrients (SSCA, 2000). Getting the maximum value out of cattle manure requires applying the manure at proper rates and frequency because over application can lead to transport of nutrients into the groundwater through leaching or overland flow (SSCA, 2000). Over application can also lead to losses of ammonia and nitrous oxide into the atmosphere. Contamination of the soil can also occur as excessive loading of nutrients, sodium and other soluble salts has the potential to reduce soil quality and productivity (SSCA, 2000).

In order to minimize the negative effects of manure application in Alberta, manure application regulations have been established. Manure management is regulated by the AOPA. The Natural Resources Conservation Board (NRCB) is the regulatory agency of the Government of Alberta responsible for regulating Alberta's confined feeding operations (AAF, 2015a). AOPA requires that manure be incorporated within 48 hours of application except when manure is applied to forges, direct-seeded, frozen or snow covered land (AAF, 2015a). In addition, when manure is applied adjacent to common bodies of water, a setback distance of 10 metres is required if the manure is injected, or 30 metres if it is surface applied and incorporated within 48 hours (AAF, 2015a). There is also a restriction on manure application rates based on soil nitrate-nitrogen (NO_3-N) in the top 60 cm of soil. The maximum level allowed depends on soil texture, depth to water table and soil type. Table 2.3 shows soil nitrate-nitrogen limits for agricultural soils in Alberta.

Table 2.3: Soil Nitrate-N Limits for Agricultural Soils in Alberta

Soil	Soil Texture		
	Course Textured Soils (i.e. > 45% sand)		Medium and Fine Textured Soils
	Depth to Water Table < 4m	Depth to Water Table > 4m	
Brown	80 kg/ha	140 kg/ha	140 kg/ha
Dark Brown	110 kg/ha	140 kg/ha	170 kg/ha
Black	140 kg/ha	170 kg/ha	225 kg/ha
Grey	110 kg/ha	140 kg/ha	170 kg/ha
Wooded (Grey Luvisol)			
Irrigated	180 kg/ha	225 kg/ha	270 kg/ha

Source: AAF (2015a)

2.5.3 Enhancing Tame Pasture Productivity through Incorporation of Legumes (alfalfa)

Tame pasture is typically composed mainly of forage grass, but can also include legume species. Unlike forage grasses which have a fibrous root, most legumes are tap-rooted. The tap root of legumes not only absorbs water and nutrients from the soil but also has the ability to store carbohydrates and proteins needed during regrowth after defoliation as well as for winter survival (Jim and Jon, 2007). The root hairs of legumes are infected by symbiotic rhizobia bacteria and make nitrogen available to the plants through the fixation of nitrogen (Jim and Jon, 2007).

To enhance pasture productivity, most producers are encouraged to incorporate alfalfa which is a perennial legume. Alfalfa (*Medicago sativa)* is a deep tap-rooted perennial forb (Jim and Jon, 2007). Alfalfa is known to be very palatable and can have crude protein levels as high as 21% and digestible dry matter levels of about 71%, withstand grazing well and after defoliation, alfalfa starts to re-grow quickly (Jim and Jon; SFC, 2007). However, the build up of food is slow and frequent defoliations at short intervals deplete food reserves and reduce survival (Jim and Jon, 2007). It is therefore recommended that pastures with alfalfa should be rested five to six weeks after grazing, stubble height should be two inches, grazing should be terminated three to four weeks before the first killing frost to allow food reserve build up for winter survival. To reduce bloat, it is recommended that alfalfa should be mixed with 50% or more grass or grazing should be delayed until after bloom (Jim and Jon, 2007). Recommended stocking rates of alfalfa are 1.2 AUM/acre (3 AUM/ha) in the Brown soil zone, and 1.8 AUM/acre (4 AUM/ha) in the Dark Brown, Black and Grey soil zones (SFC, 2007).

2.5.4 Rotational Grazing

Rotational grazing is defined as a grazing management system strategy that is associated with moving livestock periodically to fresh paddocks to allow time for pasture regrowth before they are grazed again (Beetz and Rinehart, 2010). Rotational grazing is often characterized by the provision of additional water source and fencing.

Relative to continuous grazing[2], many producers utilizing rotational grazing systems have reported increased health and animal performance (Sayre, 2001). As long as adequate forage is available to maintain high growth rates, according to Beetz and Rinhart (2010), continuous grazing frequently results in higher per-animal gains than rotational grazing but rotational grazing increases pounds of animal production per acre. As noted by Kole (1992), it is often possible to double forage use by moving from continuous grazing to rotational grazing and as result, there is considerable profit potential for the farmer who is willing to commit to an initial capital investment and increased management time.

Smith et al (2011) suggest that rotational grazing has a number of potential advantages. These include reduced costs for machinery, fuel and facilities, reduced supplemental feeding and pasture waste, improved monthly pasture distribution and yield, and improved animal waste distribution

[2] "Continuous grazing is the use of one pasture for the entire grazing season" (Smith et al, 2011, Pg. 2).

and nutrient use. Changing to rotational grazing increases pasture yield, as it allows for quick defoliation of forage to a target residual height followed by a rest period to allow for forage regrowth (Smith et al, 2011). Most forages in continuous grazing are never consumed and eventually decay. According to Smith et al (2011), only 30 to 50% of the available forage may be used as the rest is either trampled, soiled, or of little value due to over maturity. However, with the appropriate stocking density in place, shortening the grazing period to three to seven days increases utilization 50-65%; to two days, 55-70%; and to one day, 60-75% (Smith et al, 2011).

2.5.5 Conservation and Sustainable Use of Natural Areas (retirement of native pasture)

A conserved area is defined by IUCN (1994, Pg. 75) as a "geographically defined area managed through legal or other effective means to protect and maintain biological diversity and natural and associated cultural resources". Excluding cattle from native pasture can be considered as conserving natural area and, as such, represents a BMP.

The main role of pasture is as a primary support system for livestock production but as noted by Al-Kaisi et al (2004), the management/utilization of pasture can affect soil carbon storage, soil quality, and water quality. Along with biodiversity, carbon sequestration has become an important issue in agriculture. Pasture (especially grasses) is a natural carbon storage facility. Carbon storage will be maximized if the pasture is left undisturbed (Al-Kaisi et al, 2004). According to Al-Kaisi et al (2004), limiting or preventing livestock access to some pasture areas will also prevent the hooves of the animals from exposing the soil, thus reducing soil compaction and/or erosion. The aggregation of soil and its associated structural units cannot withstand the pressure exerted by cattle for prolonged periods especially in wet areas or in areas where sandy soils are located (Al-Kaisi et al, 2004). As well, there is potential for significant sediment and nutrient (e.g., C, P, K, N) losses as well as loss of organic matter (Al-Kaisi et al, 2004). Heavy animal traffic and mismanaged grazing exerts constant pressure on soil properties such as soil structure, infiltration rate, organic matter and the soil environment thereby affecting soil quality (Al-Kaisi et al, 2004).

According to McNeely (n.d.), conserved areas can provide valuable services such as soil regeneration, nutrient cycling, pollination, recreation, provision of pure water, continued evolution of genetic resources and maintenance of the functioning ecosystem which yields harvestable resources. The productive capacity of the conserved area can be preserved through good soil protection by natural vegetation cover and litter (McNeely, n.d.). Conserved areas are also known to support agriculture especially through the protection of watersheds, protection against flood, erosion control and improvement of groundwater supplies (McNeely, n.d.).

2.6 Studies on the Economics of BMP Adoption by Beef Producers

Few studies have been carried out to look at the economics of BMP adoption by beef producers. Koeckhoven (2008) performed an economic cost/benefit analysis for implementation of BMPs by a large mixed farm in the Lower Little Bow River basin in southern Alberta. The aim of the study was to better understand the private benefits and/or costs to a producer who introduces riparian habitat and water preservation and conservation practices onto their operation. By modeling a farm representative of a large mixed crop and livestock operation in the Lower Little Bow Watershed in southern Alberta through the use of Monte Carlo simulation analysis, Koeckhoven (2008) concluded that BMP implementation comes at a net cost to beef producers and as such, incentive payments can be given to producers to encourage them to implement BMPs. The pasture management BMPs studied by Koeckhoven (2008) included off-stream watering, fencing riparian areas, and buffer strips.

Implementation of off-stream watering with temporary access fencing to protect riparian area during sensitive times of the year results in an annualized cost per acre. This cost varies between

$169.23 and $122.20, depending on the amount of riparian area being protected. If cattle are permanently excluded from the riparian area, using permanent fencing, Koeckhoeven (2008) determined that the annualized cost per acre varied between $206.03 and $158.92.

Koeckhoven (2008) also examined a BMP involving conversion of cropland (with aftermath grazing) to buffer strips in order to protect riparian area from both nutrient runoff and use by beef cattle for pasture. For this BMP, the annualized cost per acre varied from $179.89 to $174.10, with the cost depending on the proportion of riparian area being protected.

Another study was done by Dollevoet (2010), who examined private wealth implications of on-farm ecological goods and services practices that promote wildlife habitat for the Lower Souris River Watershed in South-Eastern Saskatchewan. Dollevoet (2008) also concluded that implementing an ecological goods and services policy or encouraging environmental stewardship practices comes with costs to farm wealth. On conversion of riparian habitat to tame pasture, draining wetland and seeding tame grass for pasture purposes resulted in an annual cost ranging from $ 46.62 to $ 46.70 per acre converted. Conversely, conversion of forested habitat to tame pasture resulted in increased wealth (as measured using net present value). However, the cost of maintaining forested habitat rather than converting to tame pasture ranged from $42.22 to $47.58 per converted acre (Dollevoet, 2010). Dollevoet (2010) also examined the economics of converting cropland to tame pasture. This resulted in an annualized cost of $49.42 per acre converted to tame pasture (Dollevoet, 2010).

Lastly, Dollevoet (2010) examined adoption of rotational grazing, varying the degree of improvement in pasture condition. For versions of this practice such that the utilization factor increase by more than 1.5% per year for four consecutive years, the cost of construction is recouped as total farm NPV is increased (Dollevoet, 2010).

Amy et al (2012) showed that environmental outcomes are positive but in some cases, depend on on-going maintenance and upkeep of certain BMPs. The largest barrier to adoption for BMPs appears to be cost. The majority of net present values calculated by Amy et al (2012) while studying socio-economic and environmental assessment of BMPs in British Columbia, Canada suggest that the benefits of BMPs to society outweigh the costs. However, BMPs may be costly to implement by producers. The study evaluated four BMPs; alternative watering systems to manage livestock, riparian buffer establishment, irrigation management and wildlife damage prevention. Amy et al (2012) identified environmental factors as the source of motivation for riparian BMPs adopters. On the other hand, the source of motivation for the adoption of irrigation management and wildlife damage prevention BMPs were identified as on-farm benefits offered by the BMPs (Amy et al, 2012). Factors such as costs associated with BMP adoption, lack of awareness of risks to the environment from farm practices, lack of understanding about how the BMP will benefit their operation, no succession plan for their farm, lack of support from public agencies, lack of industry pressure and logistic were identified as barriers to the livestock watering BMP (Amy et al, 2012).

2.7 Chapter Summary

The sustainability and maintenance of ecosystem and ecosystem services are becoming a global concern. An ecosystem is made up of physical and chemical components which include soils, water and nutrients that support the organisms living within them. Any activity embarked on by humans must take the effects on the ecosystem into consideration.

The importance of beef to Canadian agriculture is increasing steadily and Alberta is the largest cattle producing province in Canada. For that reason, it is important for cattle producers to make use of BMPs that are aimed at sustaining and protecting the environment. Several BMPs have been suggested to contribute to pasture management, water quality or other environmental attributes. The BMPs of interest chosen for this study are also primarily aimed at the same reasons.

Few studies have carried out to look at the economics of BMP adoption by beef producers. Those studies that examined this issue have found adoption of many BMPs to come at a net cost to producers. This study seeks to extend the literature in this area through the use of a representative farm approach. By using statistical data and expert opinion, this study models a representative mixed crop-beef farm using Monte Carlo simulation and NPV analysis method. This approach is used to determine the economics of BMP adoption.

CHAPTER 3 : THE STUDY AREA

This chapter presents a brief overview of southern Alberta in terms of its suitability for agriculture which includes crop and animal (livestock) production. Due to the intensity of agriculture and its reliance on the availability of pasture for beef production, southern Alberta provides the potential for beef pasture BMP implementation that will support a number of ecosystem services such as improved water quality and biodiversity.

A decision was made to locate the study in southern Alberta, and further to concentrate on the Dark Brown soil zone. This was done for purposes of undertaking an analysis representative of cow-calf beef production in the southern part of the province of Alberta. While the specific location of the farm being modeled is in Lethbridge County, in order to be sufficiently representative, municipalities or counties which share boundaries and have the same soil type as that of Lethbridge County were also taken into consideration. Therefore, Willow Creek Municipal District and Vulcan County are also considered as part of the study area because they share boundaries with Lethbridge County and are located in the Dark Brown soil zone.

Much of the data used for the study are available at county level and so much of the discussion in this chapter is presented at that level of disaggregation. The information provided here serves as the starting point to define the representative farm used for this study in the subsequent chapters. An overview of ecosystem service concerns as well as the systems that have been put in place by beef producers to curb these concerns support the need for the analysis presented in this study.

3.1 Agriculture in southern Alberta

The study defines southern Alberta as the area covered by the South Saskatchewan Land-use region[3]. There are sixteen municipal districts (MD) in this region. Based on 2011 Census of Agriculture data, there were 9,915 farms (representing approximately 22.93% of all farms which reported in Alberta) in southern Alberta. The farms are further classified based on size in Table 3.1 (AARD, 2014). As shown in Table 3.1, a similar proportion of all Alberta farms (46.2%) are between the acreages of 10 to 559 as in southern Alberta (46.6%). However, there is a slightly greater proportion of farms in Alberta (30.7%) falling in the range of 560 to 2,239, compared with southern Alberta (26.7%), while the proportion of larger farms (at least 2,240 acres) is greater in southern Alberta (17.4%) than in the province as a whole (12.6%). In addition, based on 2011 Census of Agriculture data, 26% of Alberta cattle (beef) farms are located in southern Alberta as well as 23% of provincial grains and oilseed farms and 17% of other crops farms (sugar beets, hay, hay and grass seeds, etc.).

Table 3.2 provides a breakdown of land use in Alberta in general and also for southern Alberta (out of the number of farms), based on 2011 Census of Agriculture data. As shown in Table 3.2, approximately 43% of total farm area in southern Alberta is in crop production as against 48% of total farm area in Alberta. A similar proportion of land in southern Alberta (3%) is in summer fallow compared to the province overall (2.5%). However, a smaller proportion of land in southern Alberta is in tame/seeded pasture (9%) compared to the whole province (12%), and there is a significantly greater proportion of native pasture (42%) in the southern region (31% for Alberta).

[3]The Government of Alberta created seven Land-Use regions, for the purposes of policy development associated with land use management. "The seven regions are based on the major watersheds, with boundaries aligned to best fit with existing municipal boundaries and the natural regions", and include Lower Peace, Lower Athabasca, Upper Athabasca, Upper Peace, North Saskatchewan, Red Deer and South Saskatchewan (AARD, 2014, Pg. iii).

Table 3.1: Number of farms by farm size (2011 Census of Agriculture)

	Alberta	Southern Alberta
Total number of farms	43,234	9,915
Under 10 acres	879	281
10 – 129 acres	6,668	2,020
130 – 239 acres	7,917	1,507
240 – 399 acres	5,395	1,090
400 – 559 acres	3,653	647
560 – 759 acres	3,258	611
760 – 1,119 acres	3,997	763
1,120 – 1,599 acres	3,335	657
1,600 – 2,239 acres	2,694	616
2,240 – 2,879 acres	1,575	402
2,880 – 3,519 acres	1,025	292
3,520 acres and over	2,838	1,029

Source: Statistics Canada, 2011 Census of Agriculture. Prepared by Alberta Agriculture and Rural Development, Economics and Competitiveness Division, Statistics and Data Development Branch (2014).

Table 3.2: Land Use by Southern Alberta, 2011

	Alberta	**Southern Alberta**
Total Area of Farms (acres)	50,498,834	16,148,248
Land in Crops (acres)	24,102,289	6,984,717
Summer Fallow (acres)	1,263,051	519,820
Tame/Seeded Pasture (acres)	5,920,507	1,385,030
Native Pasture (acres)	15,903,273	6,737,027
All Other Land (acres) [a]	3,309,714	521,654

Source: Statistics Canada, 2011 Census of Agriculture. Prepared by Alberta Agriculture and Rural Development, Economics and Competitiveness Division, Statistics and Data Development Branch (2014).

[a] The land on which farm buildings, barnyards, lanes, home gardens, greenhouses and mushroom houses are located; idle land as well as land that was reported as too wet to seed.

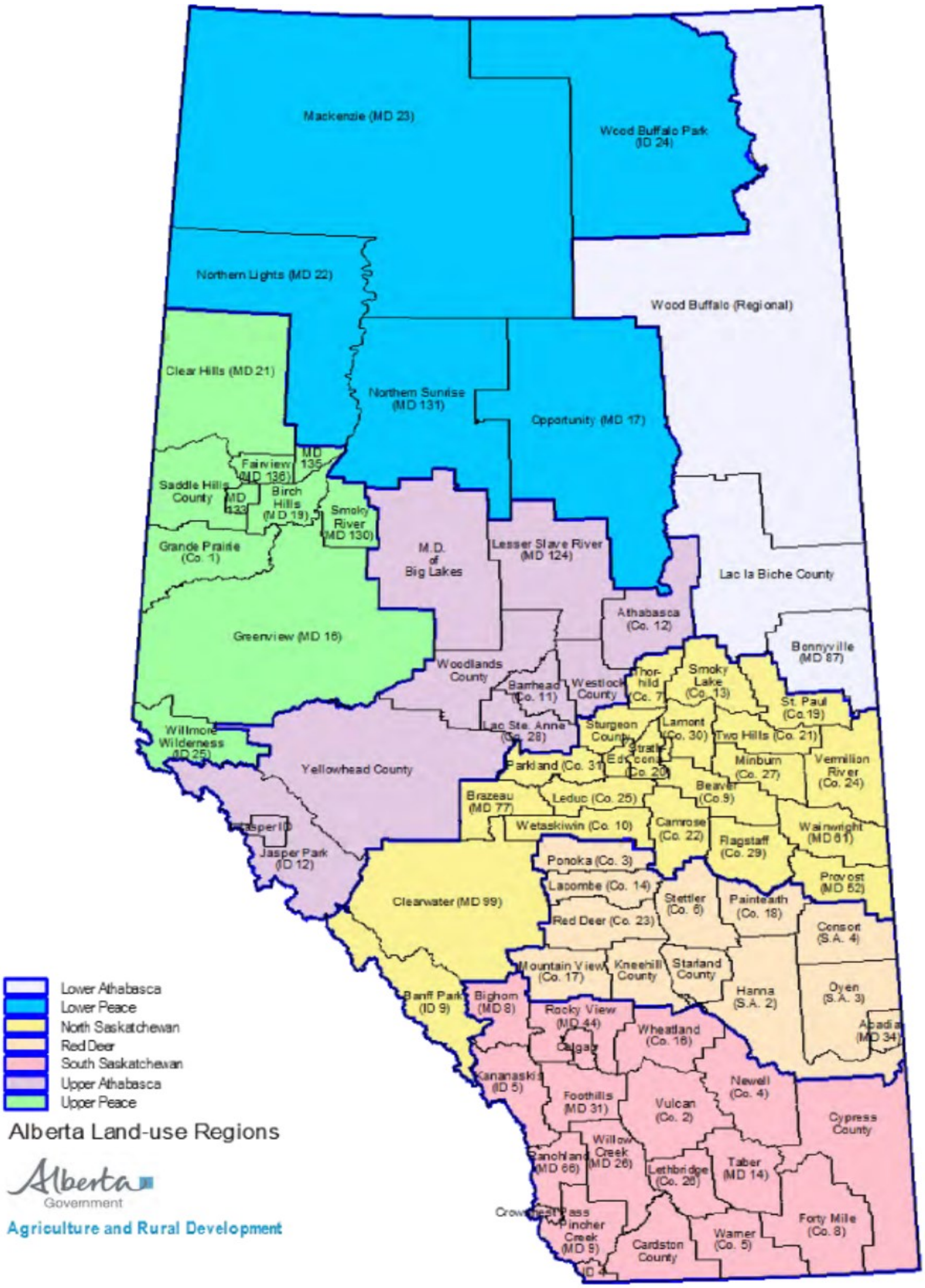


Figure 3.1: Alberta Land-Use Regions

Field crops grown in 2011 in southern Alberta included spring wheat, durum wheat, winter wheat, oats and barley. Based on the Census of Agriculture information as well as expert opinion concerning crop rotation practices common in the region, spring wheat, barley and canola are chosen for inclusion in the crop rotation for this study. Table 3.3 shows the acreages of these field crops (spring wheat, barley and canola) from the 2011 Census of Agriculture, for Alberta and southern Alberta. The acreage of spring wheat for southern Alberta represents 31% of Alberta's total in 2011.

Table 3.3: Some Field Crops Grown in Southern Alberta, 2011

	Spring Wheat	Barley	Canola
	Acres	Acres	Acres
Alberta	5,971,359	3,610,111	6,071,744
Southern Alberta	1,865,215	1,289,845[a]	1,350,094[b]

Source: Statistics Canada, 2011 Census of Agriculture. Prepared by Alberta Agriculture and Rural Development, Economics and Competitiveness Division, Statistics and Data Development Branch (2014).

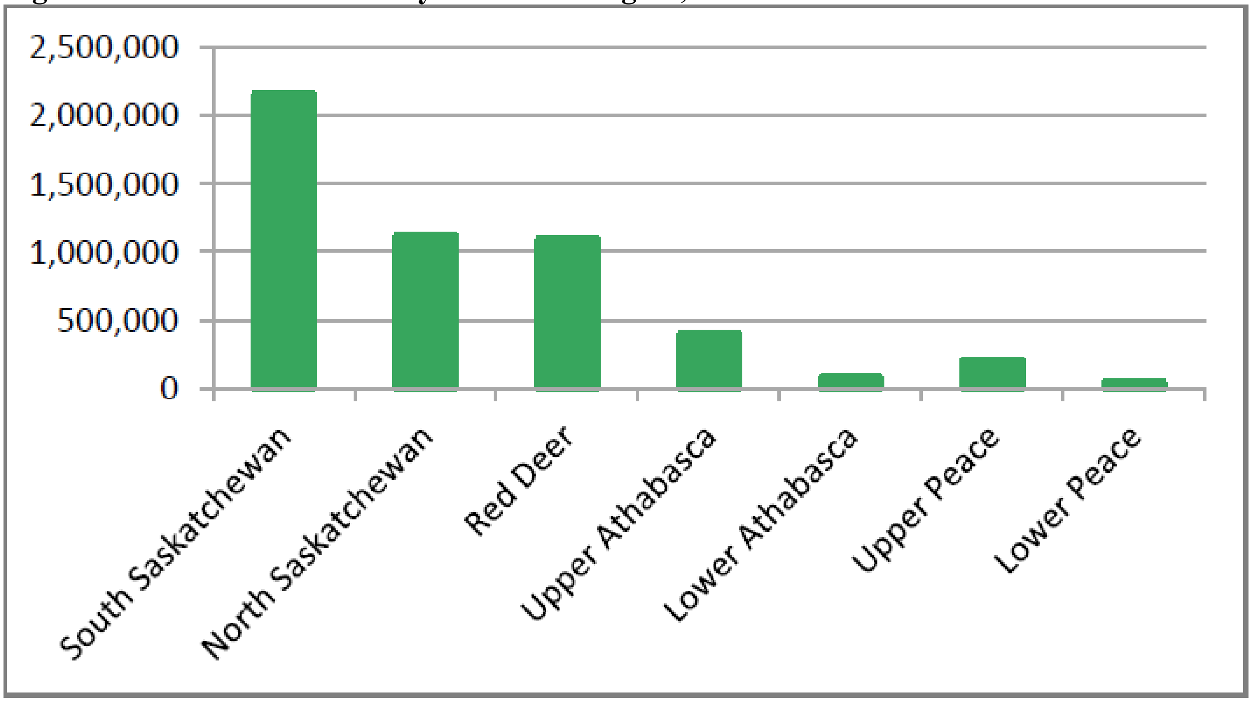
[a]Not all counties or municipalities have values reported because of low numbers and confidentiality. This value excludes Bighorn No. 8 and Ranchland No. 66.

[b]Not all counties or municipalities have values reported because of low numbers and confidentiality. This value excludes Bighorn No. 8 and Calgary.

The South Saskatchewan Region had more cattle in 2011 than any other region in Alberta. Out of the total of 5.1 million cattle and calves reported in 2011 in Alberta (from the 2011 Census of Agriculture), over 2.1 million of them were from South Saskatchewan Region, as shown by Figure 3.2.

From the 2011 Census of Agriculture, 21,888 farms reported having cattle and calves in Alberta. Table 3.4 presents numbers of cattle and calves in Alberta and southern Alberta for the 2011 census year. Beef cows in southern Alberta represented 29% of Alberta's total.

Figure 3.2 Cattle and Calves by Land-Use Region, 2011



Source: SSI (2014)

Table 3.4: Cattle and Calves in Southern Alberta, 2011

	Alberta (Head)	Southern Alberta (Head)
Total Cattle and Calves	5,104,605	2,149,785
Bulls	90,813	26,534
Total Cows	1,611,085	473,061
Dairy Cows	80,694	22,717
Beef Cows	1,530,391	450,344
Total Heifers (includes beef & dairy)	989,230	548,075
Beef Replacement Heifers	264,374	82,078[a]

Source: Statistics Canada, 2011 Census of Agriculture. Prepared by Alberta Agriculture and Rural Development, Economics and Competitiveness Division, Statistics and Data Development Branch (2014).

[a]Not all counties or municipalities have values reported because of low numbers and confidentiality. This value excludes Calgary.

3.2 Crop and Land Use Information for the Study Area (Lethbridge County, Vulcan County and Willow Creek)

The 2011 Census of Agriculture is used to determine the most common crops in Lethbridge County and their estimated acreage. The crops with more than 1000 acres are outlined in Table 3.5. From Table 3.5, the sum of the top three crops (spring wheat, barley, and canola) represent 66.9% of the total crop acreage.

Table 3.5: 2011 Census of Crops with more than 1000 acres in Lethbridge County

Crop	Farms	Acres
Spring wheat (excl durum)	284	123,197
Barley	361	115,228
Canola	240	101,032
Alfalfa and alfalfa mixtures	369	41,233
Durum wheat	73	24,539
All other fodder crops	174	20,731
Corn for silage	83	20,595
Dry field peas	44	16,045
Winter wheat	35	9,309
Sugar beats	37	6,079
Oats	37	6,027
Flax seed	27	5,472
Triticale	14	4,716
Forage seed for seed	14	4,373
Lentils	11	3,263
Other dry beans	13	2,159
Fall rye	12	1,830
Potatoes	7	1,366
Total	**1,835**	**507,194**

Source: Statistics Canada 2011 Census of Agriculture

As mentioned earlier, the study also considers Vulcan County and Willow Creek as part of the study area. The 2011 Census of Agriculture by Statistics Canada is used to determine the most common crops in Vulcan County and Willow Creek. The crops with more than 1,000 acres are listed in Table 3.6 and Table 3.7 for Vulcan County and Willow Creek respectively. From Table

3.6 and 3.7, the sum of the top three crop acreages represents 69.8% and 66.5% of the total crop acreage, respectively. Other than spring wheat, canola, and barley, the only other crop that is among the top three crops in any of the counties is alfalfa (and alfalfa mixtures), in Willow Creek.

Table 3.6: 2011 Census of Crops with more than 1000 acres in Vulcan County

Crop	Farms	Acres
Canola	315	217,742
Barley	274	166,838
Spring wheat (excl durum)	319	111,280
Dry field peas	132	66,161
Alfalfa and alfalfa mixtures	231	56,923
Durum wheat	92	45,519
All other fodder crops	82	20,045
Winter wheat	21	10,101
Mustard seed	15	4,580
Oats	38	4,363
Flax seed	10	2,201
Triticale	8	1,725
Corn for silage	7	1,565
Forage seed for seed	7	1,321
Total	**1,551**	**710,364**

Source: Statistics Canada 2011 Census of Agriculture

Table 3.7: 2011 Census of Crops with more than 1000 acres in Willow Creek

Crop	Farms	Acres
Barley	220	119,280
Spring wheat (excl durum)	131	85,737
Alfalfa and alfalfa mixtures	386	76,434
Canola	127	74,444
Dry field peas	36	19,358
All other fodder crops	118	19,161
Dry field peas	36	19,358
Oats	75	9,521
Total	**1,129**	**423,293**

Source: Statistics Canada 2011 Census of Agriculture

Table 3.8 provides the land area and usage for Lethbridge County, Vulcan County and Willow Creek in 2006 and 2011, according to Statistics Canada. From the table, it can be seen that as total number of farms and total area of farms are decreasing for Lethbridge County and Vulcan County. In Willow Creek, the number of farms also decreased in 2011 but the total area of farms increased slightly. Average farm size in all three counties increased from 2006 to 2011. Table 3.8 also shows that average farm size is larger in Vulcan and (particularly) Willow Creek, relative to Lethbridge County. The smaller farm size in Lethbridge County may be due to the presence of intensive livestock operations and/or the prevalence of extensive cow-calf production in the other two counties. Given that this study models activities and performance for mixed beef-cropping agricultural production, the average farm sizes in Vulcan and Willow Creek may be more relevant.

Table 3.8: Farm numbers and area for Lethbridge County, Vulcan County and Willow Creek in 2006 and 2011

Lethbridge County			
	2006	**2011**	**% change**
Total number of farms	1,058	933	-11.8
Total area of farms (acres)	725,426	701,095	-3.4
Average farm size (acres)	685.7	751.4	9.6
Vulcan County			
	2006	**2011**	**% change**
Total number of farms	653	603	-7.7
Total area of farms (acres)	1,403,176	1,354,405	-3.5
Average farm size (acres)	2,148.8	2,246.1	4.5
Willow Creek			
	2006	**2011**	**% change**
Total number of farms	808	772	-4.5
Total area of farms (acres)	1,120,663	1,126,368	0.5
Average farm size (acres)	1,387	1,459	5.2

Source: Statistics Canada 2006 Community Profile, Statistics Canada 2011 Census, Statistics Canada 2011 Census of Agriculture

Table 3.9 provides the area farm land by use of land for southern Alberta as well as the counties in the study area. As shown in the table, 73% of total farm area in Lethbridge County is in crop production as compared with 65% for Vulcan and 39% for Willow Creek. For southern Alberta, 43% of total farm area is in crop production. Conversely, 15% of Willow Creek farm area is in tame pasture, with lesser proportions in Lethbridge and Vulcan (9% and 7%, respectively). Willow Creek also has a larger percentage of farm area in native pasture (43%) relative to the other two counties in the study area; 20% for Vulcan County and 11% for Lethbridge County.

Table 3.9: Farm Land Area Classified by Use of Land by Lethbridge County, Vulcan County and Willow Creek, 2011

	Total Area of Farms	Land in Crops	Summer Fallow	Tame/Seeded Pasture	Native Pasture
	Acres	Acres	Acres	Acres	Acres
Southern Alberta	16,148,248	6,984,717	519,820	1,385,030	6,737,027
Lethbridge County	701,095	514,337	20,333	60,873	79,393
Vulcan County	1,354,405	885,191	69,337	92,015	276,110
Willow Creek	1,126,368	437,293	9,877	163,658	484,387

Source: Statistics Canada, 2011 Census of Agriculture. Prepared by Alberta Agriculture and Rural Development, Economics and Competitiveness Division, Statistics and Data Development Branch (2014).

3.3 Cattle Numbers in Lethbridge County, Vulcan County and Willow Creek

In 2011, the South Saskatchewan Region had more cattle than any other region in Alberta. Out of the total of 5.1 million cattle and calves reported in 2011 in Alberta (from the 2011 Census of Agriculture), over 2.1 million of them were from South Saskatchewan Region of which the largest proportion were in Lethbridge County (SSI, 2014). The county with the second highest number of cattle in the region had slightly more than half of the value for Lethbridge County. Figure 3.3 shows the top four areas in the region in 2011. In 2011, as shown by Figure 3.3, Vulcan County was among the top four counties or municipalities that for numbers of cattle and calves in southern Alberta. The higher number of cattle in Lethbridge is due in large part to the presence of intensive beef feedlot operations.

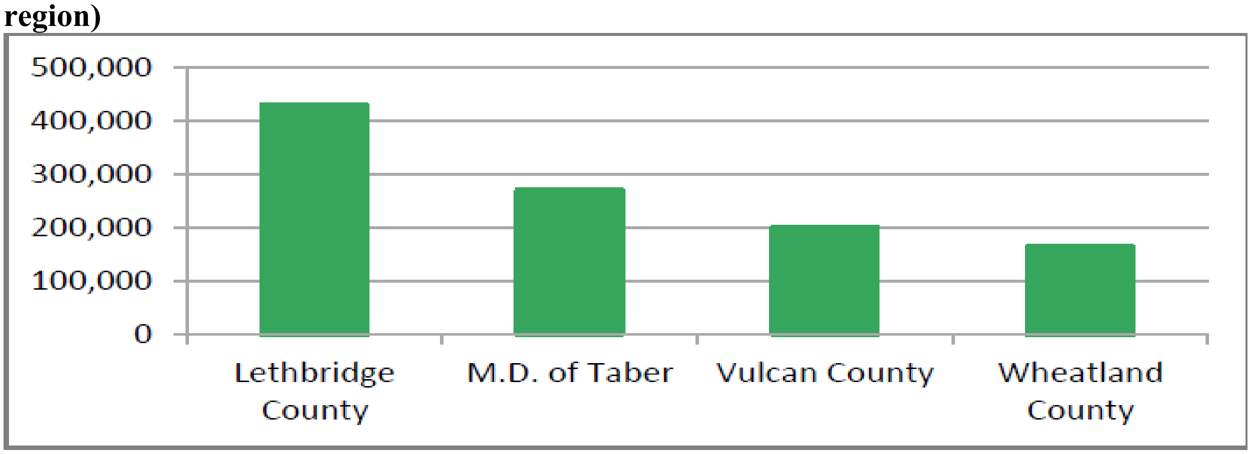
Table 3.10 presents the distribution of cattle and calves by type of animal in southern Alberta, Lethbridge County, Vulcan County and Willow Creek for the 2011 census year. All three counties in the study area have a significant number of beef cows, indicating the importance of cow-calf production. Of the three counties, Willow Creek had the greatest number of beef cows. This is consistent with the earlier information shown earlier concerning land use and the amount of tame and native pasture in that county.

Table 3.10: Cattle and Calves in Sothern Alberta, 2011

	Southern Alberta (Head)	Lethbridge County (Head)	Vulcan County (Head)	Willow Creek (Head)
Total Cattle and Calves	2,149,785	427,602	197,851	176,664
Bulls	26,534	926	1,333	2,682
Total Cows	473,061	24,906	27,590	47,374
Dairy Cows	22,717	8,840	1,478	1,125
Beef Cows	450,344	16,066	26,112	46,249
Total Heifers	548,075	191,457	75,128	42,827
Beef Replacement Heifers	82,078[a]	8,487	2,638	8,765

Source: Statistics Canada, 2011 Census of Agriculture. Prepared by Alberta Agriculture and Rural Development, Economics and Competitiveness Division, Statistics and Data Development Branch (2014).
[a] Not all counties or municipalities have values reported because of low numbers and confidentiality. This value excludes Calgary.

Figure 3.3: Cattle and Calves in South Saskatchewan Region, 2011 (top 4 areas in the region)



Source: SSI (2014).

3.4 BMPs Adopted in the Study Areas

This section provides a summary of BMPs adopted in the study area in cases where producers received support (i.e., incentives) from the Growing Forward On-Farm Stewardship program in Alberta. The goal of this program is to support the implementation of BMPs which reduce the risk of contaminants from agriculture entering water or soil resources (GoA, 2013, 2015). The On-Farm Stewardship program provides financial support for the implementation of approved projects that reduce agriculture's impact on water quality and enhance sustainable management of inorganic agricultural wastes (GoA, 2013, 2015).

Under the Growing Forward 1 Stewardship program (2009-2013), grazing and winter feeding management BMPs received maximum funding of $15,000, with the grant funding 50% of eligible expenses to complete the BMP from the government. The remaining 50% was to be provided by the adopting producer (GoA, 2013). Examples of eligible BMPs include alternative watering systems, year-round watering, fencing to protect sensitive areas, fencing to enhance grazing management, riparian area management etc. For integrated crop management BMPs the maximum funding was $20,000, with the cost sharing provision (GoA, 2013). Examples of eligible BMPs included shelterbelts, riparian area management, native upland range establishment or restoration, wetland restoration, etc.

For the Growing Forward 2 On-Farm Stewardship program (2013-2018), the grant funding cost share is between 50%-70% of eligible expenses to complete the BMP and with maximum funding of $50,000 over the program term (GoA, 2015). BMPs eligible for support under the Growing Forward 2 program were similar to those for the previous version.

Table 3.11 and Table 3.12 present examples of BMPs implemented in the study area under the Growing Forward 1 and 2 programs, and the payments (i.e., government contributions). The

BMPs listed in the two tables were selected based on meeting at least one of the following criteria:

- Associated with beef production;
- BMPs that, based on the description, appeared to be related to beef production; or
- BMPs that, based on the description, appeared to be similar to the BMPs of interest for the current study.

From Tables 3.11 and 3.12, it can be seen that producers have taken advantage of the cost-sharing program to implement BMPs related to manure management and cattle watering. Fencing projects have also had some uptake by producers.

Table 3.11: Select BMPs implemented through Growing Forward 1 in the study area

Project description	Municipality /County of project	Total payments ($)	Year
Solid liquid separation	Lethbridge	50,000.00	2010-2011
Solid liquid separation for cattle liner truck wash	Lethbridge	50,000.00	2010-2011
Vertical beater spreader	Vulcan	8,500.00	2010-2011
Watering systems and pasture pipeline	Willow Creek	15,000.00	2010-2011
Fencing to enhance grazing	Willow Creek	5,422.00	2010-2011
Year round watering system	Willow Creek	9,578.00	2010-2011
Alternative watering system	Vulcan	4,281.00	2010-2011
Fencing to enhance grazing	Vulcan	2,421.00	2010-2011
Alternative watering system	Vulcan	421.45	2012-2013
Portable watering system	Lethbridge	225.00	2012-2013
Fencing sensitive areas	Willow Creek	6,163.75	2012-2013
Portable watering system	Willow Creek	2,672.50	2012-2013
Pasture pipeline	Willow Creek	15,000.00	2012-2013
Alternative watering system	Willow Creek	1,731.50	2012-2013
Fencing to protect sensitive areas	Willow Creek	2,438.55	2012-2013
Alternative watering system	Willow Creek	4,400.52	2012-2013
Relocate feedlot; decommission old site and landscape for seasonal calving site	Willow Creek	50,000	2012-2013
Solid liquid separator system	Lethbridge	50,000	2012-2013

Source: GoA (2013)

Table 3.12: Select BMPs implemented BMPs through Growing Forward 2 in the study area

Project description	Municipality /County of project	Total payments ($)	Year
Riparian fencing	Lethbridge	4,494.85	2013-2014
Winter water	Lethbridge	5,247.45	2013-2014
Winter water/shelter/fencing	Lethbridge	9,572.00	2013-2014
Riparian Fencing	Lethbridge	1,028.55	2014-2015
Year-round water system	Lethbridge	9,100.00	2014-2015
Construction of a manure storage/compost pad (beef)	Lethbridge	5,695.00	2016-2017
Re-slope pens and enlarge a catch basin as part of surface water management (beef)	Willow Creek	26,457.83	2016-2017

Source: GoA (2015)

3.5 Chapter Summary

The main objective of this study is to assess the economics of adoption of BMPs that are intended to improve water quality, for a representative mixed crop-beef farm. Looking at the aforementioned water quality issues associated with agriculture (crop and livestock production), southern Alberta and for that matter, Lethbridge County provides the potential for beef pasture beneficial management practices (BMPs) implementation that will support quite a number of ecosystem services such as improved water quality and biodiversity.

CHAPTER 4 : METHOD OF ANALYSIS

The implementation of a BMP on a farm by beef producers is important for ecosystem services provision and sustainability of agricultural production systems. However, an appropriate tool is needed to evaluate the on-farm cost and benefit of producers adopting and implementing a particular BMP. One of the most common methods used to evaluate economic phenomena for projects being considered by decision makers is the Net Present Value (NPV). The use of NPV to evaluate BMP adoption is consistent with an assumption of wealth maximization by producers. This chapter discusses the NPV technique, which is used to evaluate BMP adoption in this study. The model structure for the representative farm used for this study is also discussed.

4.1 Net Present Value (NPV) Analysis

An assumption is often made that producers maximize profit (in the short run) or wealth (in the long run). Thus an economic analysis of BMP adoption decisions by agricultural producers should use a performance measure that is consistent with this assumption. Also, beef production is dynamic and the adoption of a BMP by a producer may have both economic and environmental impacts over an extended period of time and the impacts may vary over time. For example, a producer practising rotational grazing (i.e., the use of several pastures with one being grazed for a short period of time and then rested) may be able to reduce supplemental feeding and pasture waste as a result of adopting this practice. However, the producer has to take into consideration the expenses of rotational grazing in terms of increased fencing costs, increased labour requirements and a likely investment in a watering system. Given the time frame over which these effects occur, it makes sense that the impact on wealth should be assessed rather than just the change in annual profit. As a result of the aforementioned impacts, a method used to assess them must allow for the changes of wealth and must also take the time into account. Net Present Value analysis takes both into consideration.

An NPV for a project is defined as the present value of the difference between the project's value and its associated cost (Brealey et al., 2001). NPV analysis consists of choosing of a discount rate that represents time value of money and applying this discount rate to future cash flows to compute their present values (McSweeney, 2006). A present value represents what the future value is worth today (i.e., in the present) to the decision maker. By converting all future values to their equivalent present values, cash flows received/paid in different time periods may be directly compared.

The NPV calculation can be expressed as:

$$NPV = \sum_{t=1}^{N} \frac{(CF_t)}{(1+r)^t} - I_0 \quad (4.1)$$

where CF_t is the net cash flow in time t, r is the discount rate, and I_0 is the initial cash outlay. N is the duration of the project, in years. If the discount rate at time t (r) is considered as an interest rate, then a dollar invested for t years will grow to be $(1+r)^t$. As a result, the amount of money that can be deposited today so that it would grow to be one-dollar t years in the future is given by $(1+r)^{-t}$. This is termed the discounted value or present value of a dollar available t years in the future. The net benefit of the projects is estimated as the sum of the present value of the benefits less the present value of the costs (Watkins, 2015).

4.1.1 Net Present Value (NPV) as a Measure of Producer Wealth

As noted above, ideally a measure should be used to evaluate BMP adoption that is consistent with wealth maximization. According to Trigeorgis (1996), where managerial flexibility is absent, NPV is the only available current valuation measure consistent with a firm's objective of maximizing its shareholder's wealth. Trigeorgis (1996) also writes that NPV is generally regarded to be superior to other methods of valuation such as the payback period, accounting rate of return and internal rate of return.

According to Baker and Powell (2005) and Copeland and Weston (1988), the use of NPV provides certain conceptual and computational advantages, including being a metric consistent with the goal of maximizing producer's wealth. Agricultural producers, with the assumption of wealth maximization, are required to make a number of long-term decisions about their farming enterprises. Among these decisions include whether or not to adopt a BMP associated with their operations. Depending on the nature of the BMP, it may be considered as a long-term investment decision. Assuming that the decisions to adopt or not to adopt BMPs go in hand with wealth maximization, the producer can make use of NPV in deciding whether the investment is potentially beneficial; that is, whether it contributes positively to wealth. If the NPV for a particular investment (e.g., adoption of a BMP) is positive, then the investment earns at least the required rate of return (as represented by the opportunity cost, or discount rate) from the capital invested, and the value of the NPV represents the amount added to wealth. Conversely, if the NPV is negative, the investment does not add positively to wealth and thus should not be implemented given the assumption of wealth maximization.

Alternatively, in a broader sense, the producer may weigh the utility derived from adopting a BMP rather than just wealth maximization. Producer utility can be defined in terms of the usefulness of something or the flow of satisfaction derived from something. As suggested by Rode et al (2015), the adoption of a certain practice by a producer may be due to intrinsic motivation; that is, the immanent satisfaction the practice come along with such as the fun, challenges involved and the personal conviction of the producer. This satisfaction goes beyond wealth maximization. For example, a beef producer may be willing to reduce the herd size in order to adopt practices that are aimed at conserving natural areas due to the personal utility derived from it.

4.1.2 Selecting Appropriate Discount Rate for NPV Analysis

The discount rate, also known as the required rate of return, is used in a discounted cash flow analysis to determine the present value of future cash flows. Discounting provides a way to compare the dollar value of costs and benefits received in different time periods to present values, and thus the choice of discount rate is important. According to Watkins (2015), choosing an appropriate discount rate is essential because different rates can yield very different cost-benefit results and therefore may affect policy recommendations. Selecting a high discount rate has the tendency to reduce sizable future benefits and costs to very small present values and a lower discount rate reduces future values less, making the value of future benefits and costs closer to current dollar values (Watkins, 2015). An individual investor determines an appropriate discount rate by normally considering his or her opportunity cost of capital.

At an intuitive level, the discount rate used should be consistent with both the riskiness and type of cash flow being discounted if the project is uncertain (Damodaran, 2000). This suggests that discounts rate differ among investments depending on the riskiness of the project.

Following the discussion above, it can be concluded that the key things that a discount rate should reflect are the opportunity cost of capital and the riskiness of the project. One of the methods that can be used to determine a discount rate is the Capital Market Line (CML) where the unique risk associated with an investment can be measured and taken into consideration. In CML, the required rate of return (discount rate) for an investment depends on risk-free rate of return, the standard deviation of market portfolio, expected market return as well as the standard deviation of returns or cash flows for the investment (Sharpe et al., 2000).

In terms of previous similar studies (i.e., farm-level studies examining adoption of BMPs or other environmental stewardship practices), Cortus (2005) used the CML approach to calculate an initial discount rate while studying the economics of wetland drainage in Canada's Prairie Pothole Region. Although Cortus (2005) calculated a discount rate of 13.91% as the maximum based on similar projects, he settled on a rate 10% for the analysis. Koeckhoven (2008), while studying the economics of agricultural BMPs for a mixed cow-calf and cropping operation in the Lower Little Bow Watershed in southern Alberta, also used 10% discount rate, at least in part because of Cortus' work. Trautman (2012) also studied the economics of BMP adoption on representative Alberta crop farms and made use of the same 10% discount rate.

4.2 Modeling Agricultural Systems

The NPV approach which makes use of discounted cash flows to generate the changes of producer's wealth over an extended period of time by adopting BMPs is used in this study. In order to generate the cash flows representative enough for the production system considered in this study, an appropriate modeling technique is required. Agricultural production (crop and livestock) processes are neither static nor deterministic (Chavas et al, 1985). They take place in a dynamic setting where deciding on stochastic parameters, in this case yields and prices, can impact heavily on response efficiency (Chavas et al, 1985). In order to build a model that is sufficiently representative to mimic the actual farming system, general approaches such as mathematical programming or simulation analysis have been used extensively in literature.

4.2.1 Mathematical Programming

Mathematical programming deals with the optimum allocation of limited resources among competing activities under a set of constraints imposed by the nature of the problem being studied. These various constraints could reflect technological, organizational, financial, marketing considerations. In a broader perspective, mathematical programming is defined as a mathematical representation with the objective of programming or planning the best possible allocation of scarce resources. In a situation when the mathematical representation exclusively uses linear functions, a linear programming model is established. When one or more of the model relationships are non-linear, a non-linear model is established.

Mathematical programming has been used in previous agri-environmental studies. For example, Withey and van Kooten (2011) applied positive mathematical programming to examine the impact of climate change on land use in the Prairie Pothole Region of Western Canada, with particular emphasis on how climate change will impact wetlands. The positive mathematical programming was used to calibrate land use in the area to observed acreage in 2006 and with policy simulations for both climate effects as well as the effects of biofuels policies, how climate change will affect land use and wetlands were determined.

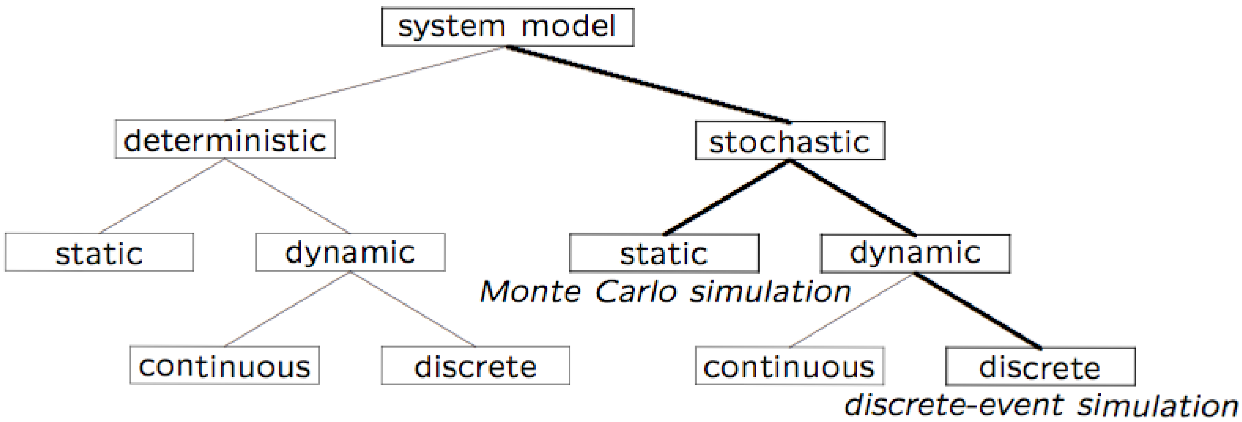
In a situation when mathematical programming is applied in agriculture, it can be used to maximize the profit of a farming system or can be used to minimize the cost to a set of target outcomes. However, mathematical programming models have a specific structure (i.e., objective function and constraints). When it comes to the incorporation of complex relationships and objectives, it is often difficult to fit the relationships within the required structure. The farm-level analysis undertaken in the current study is complex in that there are stochastic parameters (e.g., crop yields) to be modeled, linkages between cropping and livestock activities, contingent outcomes from risk management programs, etc. This makes the use of mathematical programming problematic. Therefore, this methodological approach is not used in this study.

4.2.2 Simulation Analysis

As defined by Olenev (2004, Pg. 5), simulation is “the technique of imitating the behaviour of some system or situation by means of an analogous model, situation, or apparatus, either to gain information more conveniently or to train personnel”. Simulation can be used to model discrete or continuous events. Discrete event simulation deals with the modeling of a system as it occurs over time by representing the changes that occur as separate events (Olenev, 2004). In continuous simulation, the system evolves as a continuous function (Olenev, 2004). The simulation approach provides more flexibility and convenience in that there is no predetermined structure that needs to be satisfied. Banks et al (2010) state that a simulation model can be deterministic or stochastic. Simulation models can also be static or, if time is a significant consideration, dynamic in nature (Banks et al, 2010). Banks et al (2010) presented Figure 4.1 as a simulation model taxonomy.

Bechini and Stockle (2007) stated that simulation models are extensively used in presenting agricultural systems and in the evaluation of alternative farm planning scenarios. In the context of agriculture, a simulation model can be used when forecasting outcomes of farm economic performance that are based on a combination of decision variables such as the use of manure, management practices and random variables such as beef prices, crop yields and crop prices.

Figure 4.1: Simulation Model Taxonomy



Source: Banks et al (2010)

A common form of simulation is the Monte Carlo simulation or Probability simulation. Monte Carlo simulation is a technique that is used to understand the impact of risk and uncertainty in financial, project management, cost, and other forecasting models (RiskAmp, 2016). Typically, Monte Carlo simulation is defined as a computerized mathematical technique that allows analysts to account for risk in quantitative analysis and decision making (Palisade Corporation, 2016). Based on the range of estimates, in Monte Carlo simulation, a random value is selected for each of the understudy tasks and the model is calculated based on the random value. The generated result is recorded and the process is repeated hundreds or thousands of times, each time using different randomly-selected values (RiskAMP, 2016). The results generated by Monte Carlo simulation are used to describe the likelihood or probability of reaching various results in the model. As such, the simulation only represents probabilities and not certainty (RiskAMP, 2016). Monte Carlo simulation is a valuable tool when forecasting a future that is unknown (RiskAMP, 2016).

Previous studies such as Koeckhoven (2008), Trautman (2012) and Xie (2014), have used Monte Carlo simulation to examine the economics of BMP adoption. Similar to the previous studies, this study uses dynamic Monte Carlo cash flow simulation to assess the economics of adoption of BMPs that are intended to improve water quality, for a representative mixed crop-beef farm in southern Alberta. Economic returns are assessed using a farm budgeting technique with modified cash flows built and analyzed using NPV method.

4.3 Model Structure for the Representative Farm

Monte Carlo simulation is chosen to model the agricultural system in this study. Monte Carlo simulation gives more flexibility and convenience when incorporating stochastic elements such as crop yields, crop prices and beef prices in modeling the representative farm as well as the adoption and implementation of the selected BMPs of interest. The study uses a Microsoft Excel add-in program, @Risk by Palisade Corporation (Palisade corporation, 2010). Probability distributions such as normal, lognormal, triangular and weibull associated with Monte Carlo simulation in @Risk are a much more realistic way of describing uncertainty in variables of a risk analysis where stochastic elements like crop prices, crop yields and beef prices are involved. The expected change in NPVs before and after the adoption of a BMP is calculated as a distribution of performance that includes a mean and standard deviation.

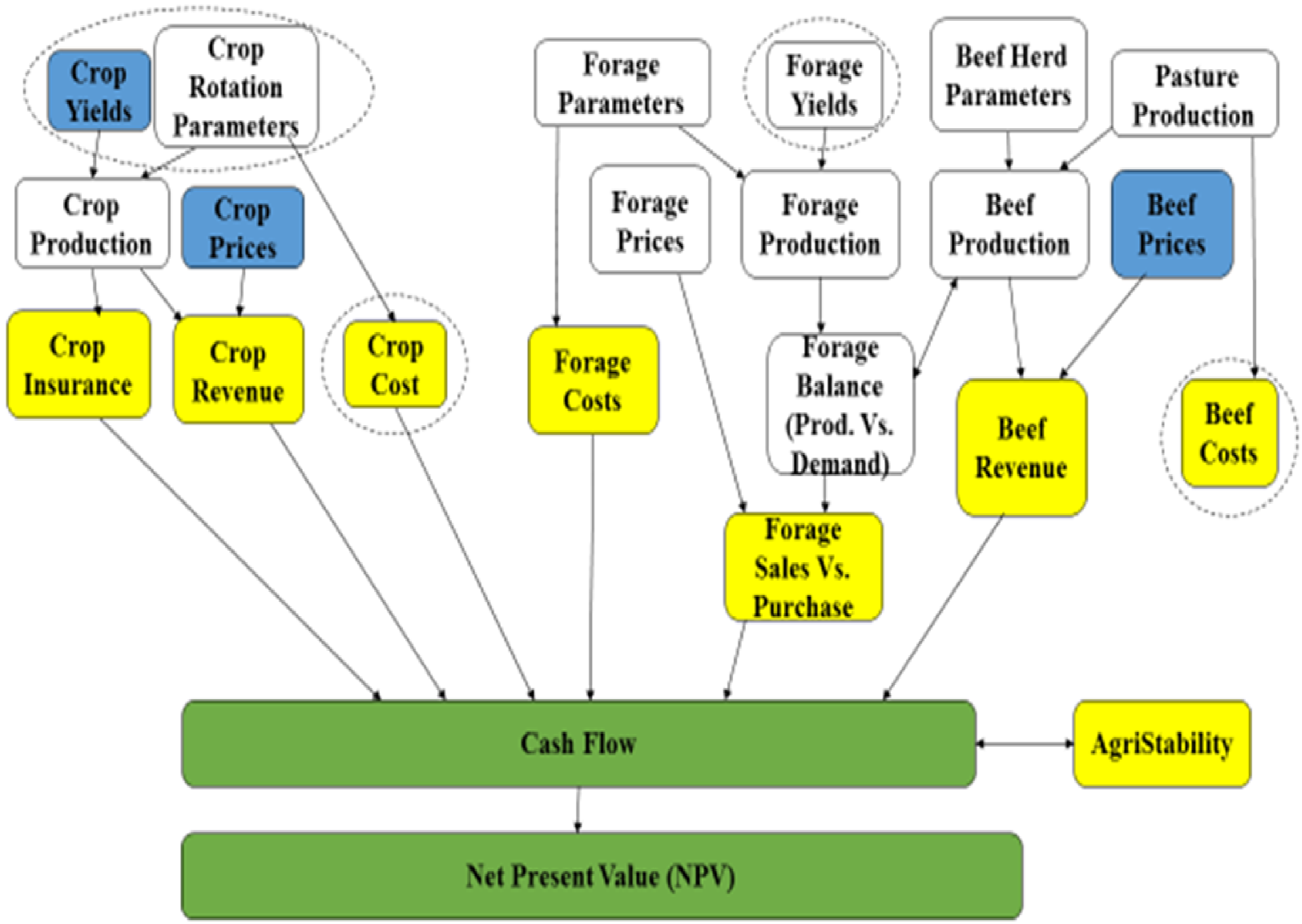
In order to understand the economic feasibility of a farmer adopting a BMP in a mixed farm with crops, forage and livestock production together with all the relationships or links among them in the study area, it is necessary to build a working simulation model. To begin with, all the characteristics such as the farm size, location, crop and forage choices, rotation, beef enterprise size and parameters of the representative farm are identified and incorporated into the model. Inputs costs such as fertilizer, seeds, chemical, veterinary and medicine, labour cost etc. associated with the representative mixed farm are also incorporated. All of the various risky parameters such crop prices, crop yields or beef prices are modeled stochastically and incorporated into the model. The NPV analysis captures the time value of money in the form of the discount rate. The costs associated with BMP adoption and implementation are incorporated into the baseline model to calculate the change in NPVs in the cash flow.

The representative farm consists of various components that are interlinked. Figure 4.2 shows the complete simulation structure including the relationships among them. Objects shaded in blue such as crop yields, crop prices and beef prices are parameters that are modeled stochastically. Subsequent crop yields from BMP adoption are also modeled stochastically. Business Risk Management (BRM) programs incorporated into the model include AgriStability as well as crop and hay insurance. Objects circled with dash lines are variables that are directly affected by BMP adoption and they include crop acreage, crop yields, crop costs, forage yield and beef costs. All objects shaded in yellow in Figure 4.2 such as crop costs, crop revenue, beef revenue, forage costs, forage sales make up the basics of the cash flow relationships that are used directly in the calculation of outputs in the form of net cash flow and NPV which are shaded in green.

4.4 Chapter Summary

The chapter discusses the various different techniques that are used in the study of economic feasibility of beef BMP adoption by a producer. NPV analysis is selected as the appropriate method to determine whether it makes economic sense for a famer to adopt and implement beef associated BMP. The NPVs are generated by using Monte Carlo simulation which is built in Microsoft Excel using @RISK software by Palisade Corporation.

Figure 4.2: The Simulation Structure of the Representative Farm



Blue – Stochastic Parameters	Yellow – Cash Flow Relationship
Green – Model Outputs	Dash Circled – Directly affected by BMP

CHAPTER 5 : REPRESENTATIVE FARM AND EMPIRICAL SIMULATION MODEL

This chapter discusses the specifics of the representative farm and the stochastic simulation model used to analyze the economic costs/benefits of best management practice implementation. All aspects of the representative farm were incorporated into the @Risk program for Monte Carlo simulation analysis, including the size of the land base for annual crops, hay production, pasture, prices, yields, etc. The chapter also outlines the procedures for evaluating farm revenue, production costs, and agricultural insurance through the use of estimated crop price, beef price and yield models. The effects of BMPs on the representative farm are evaluated and NPV analysis is performed over a 20-year time period calculating an annual net cash flow for the farm operation.

5.1 Representative Farm Characteristics

This section provides an explanation of how the characteristics of the representative commercial farm used for the study were derived and calculated. Specifically, the location of the farm, size of the farm, crop-forage production and rotation, cow-calf enterprise, winter feeding and feed inventory and machinery complement are discussed.

5.1.1 Location

The farm represents a typical mixed cow-calf cropping farm in southern Alberta. As mentioned in Chapter 3, the study area considered in this thesis is the Dark Brown soil zone in southern Alberta, with the counties of Lethbridge, Vulcan and Willow Creek used to represent this area. A decision was necessary regarding a specific location for the farm and so it was decided to locate the farm in Lethbridge County. This was at least in part due to the completeness of data availability for Lethbridge County (e.g., crop yield data).

5.1.2 Farm Size

The development of the representative farm started with identifying typical herd size in the region by using farm-level cow-calf data obtained from Alberta Agriculture and Food (AAF). The size of the representative farm is dependent on the size of the beef enterprise, because of the relationship between the number of beef cows and the required areas for cultivated forage (i.e., hay) and pasture (both tame and native). The herd size was estimated making use of the average herd size of the last five years (2011-2015) from the Alberta Cow-calf dataset. Based on this, it was decided to model a farm with a 160 cow herd.

The proportions and resulting areas of tame and native pasture required to support this herd size were developed based on a project (Nutrient Beneficial Management Practices Evaluation project) carried out by AAF in the region in 2012. Based on the advice of an expert who expressed a concern that the herd size would not result in the cow-calf enterprise being financially viable (Raven, 2016), a decision was made to also include commercially viable cropping enterprises. As a result, 2000 acres of annual crops and forages were included as part of the overall farm operation. The choice of 2,000 acres was based on work by Trautman (2012) for the study area. Trautman (2012), while studying the economics of BMP adoption by Alberta crop producers, used a farm size of 3,200 acres of annual crops as being representative commercial cropping operation in the study area. However, Trautman's (2012) work only considered cropping operations; that is, farms that were only into the production of annual crops, without raising of livestock. The farm modeled in this study is a representative mixed cow-calf cropping farm and therefore a smaller area of annual crops and forages was included as part of the overall farm operation relative to what was used by Trautman (2012) in her work.

The total area of the representative farm is 4,786 acres. Of this area, 1,830 acres (38.2%) are allocated to the production of annual crops and 170 acres (3.6%) are allocated to forage production; that is, production of tame hay used to feed the beef cattle herd in winter. The remaining 2,786 acres (58.2%) are allocated as pasture for the beef cattle. The size of the representative farm is such that it would be considered a larger than average farm for the study region. Specifically, relative to information from the 2011 Census of Agriculture, the representative farm is among the top ten percent of the distribution of farm sizes in southern Alberta, top three percent in Lethbridge County, top 18 percent in Vulcan County and top 11 percent in Willow Creek.

Table 5.1 shows the breakdown of the total acreage by crop, forage and pasture type for the representative farm. The annual crops covered represent the major crops cultivated in the county (Table 3.4). Discussion of how the specific areas for each crop and type of pasture are determined is provided in the following sections.

Table 5.1: Breakdown of Representative Farm (Summary of farm acreage)

Crop	Area (acres)	Forage	Area (acres)	Pasture	Area (acres) and AUM[a]
Spring Wheat	610	Alfalfa Grass Mix	170	Native Pasture	2,130 (0.6 AUM)
Barley	610			Tame Pasture	656 (1.54AUM)
Canola	610			Aftermath G.	1,830 (0.15AUM)
Total	**1,830**		**170**		**4,616**
Farm Total	**4,786**				

a AUM represents Animal Unit Months. AUM is defined as the average amount of forage needed by an animal unit (AU) grazing for a month.

5.1.3 Crop-Forage Production and Rotation

A crop rotation is the method of sequentially growing different types of crops on the same piece of land (Christensen, 2012). The representative farm is assumed to follow a representative crop rotation although for the purposes of simulation the rotation is not specified exactly in the model in terms of which annual crops follow each other over time. Instead, the model simply assigns the acreages shown in Table 5.1 to each crop. Based on expert opinion (Raven, 2016) and prevalence of these crops in the region, it is assumed implicitly that a crop rotation in the study area is implemented using spring wheat, barley and canola. The overall area devoted to annual crops is thus divided into three equal parts to determine the area for each crop in each year of the simulation.

In the simulation model of the representative farm, there is forage production for the purpose of using it as a feed for the beef cattle. Alfalfa-grass hay is the forage included in the model.

5.1.4 Cow-Calf Enterprise

A summary of cow-calf herd parameters used for this study is presented in this section. A variety of parameters related to the representative farm's beef enterprise are estimated and used in the simulation analysis. These include herd parameters such as conception, calving, death and culling rates, stocking rates for pasture, winter feed requirements, etc. The following subsections provide explanation and justification for the calculation of various parameters.

5.1.4.1 Herd Parameters

As noted earlier, the beef enterprise for the representative farm was assumed to consist of a 160 cow herd. Given this assumption, the size of the entire enterprise during any given year of the analysis was set at 198 animals. This number is made up of 160 cows, 30 replacement heifers and eight bulls. Replacement heifers represent animals that are yet to have calves and are retained by the producer to replace cows that are culled from the herd. The procedure for determining the number of replacement heifers is discussed in section 5.1.4.2 and the procedure for the estimation of the number of bulls is discussed in section 5.1.4.3.

Cow-calf herd parameters such as conception rate, calving rate, weaning rate, cow death loss and daily weight gain were included in the model. All of these parameters were estimated from the average of the last five years (2011-2015) using farm-level cow-calf data obtained from AAF. Conception rate is the percentage of cows or heifers that are able to conceive after breeding. The conception rate used for this study was 89.12%. Calving rate is the percentage of cows or heifers that, after being confirmed as pregnant, are able to give birth to calves when the gestation period is over. The calving rate used for the study was 98.14%. The calving rate takes into account miscarriages and calving difficulties leading to the death of calves. Besides calf deaths occurring at the time of birth there may be later calf deaths due to nutritional deficiency, health problems, or being preyed upon during the grazing season. The likelihood or probability of a calf surviving the grazing season is referred to as the weaning rate. The weaning rate used in the study was 97.24%. A cow death loss of 2.72% was also factored in the study, where these deaths are assumed to occur for similar reasons as in the case of calves.

A daily weight gain, calculated as the difference between desired minimum selling weight and birth weight divided by the number of grazing season days was incorporated into the model. The desired minimum selling weight and the birth weight were assumed to be 550 pounds and 80 pounds, respectively. These weights were established based on expert opinion (Linquist, 2016). The grazing season was assumed to be nine months, which was confirmed by Raven (2016), an expert in the study area. Each month was assumed to be 30.5 days in length, for ease of modeling. Therefore, a daily weight gain of approximately 1.71 pounds was estimated and used in the model. The daily weight gain of 1.71 pounds is used to achieve the desired minimum weaning weight of 550 pounds. The daily weight gain parameter is important for some of the BMP scenarios (e.g., conservation of natural area), where adoption of the BMP results in a change to the number of grazing days available to the beef herd.

The average cow weight is assumed to be 1,400 pounds, based on expert opinion (Linquist, 2016). The average cow weight is important as it is used as the basis for determining daily winter feed requirements for cows, and replacement heifers (discussed later in this chapter). Table 5.3 gives a complete summary of the cow-calf herd statistics used for the study.

Table 5.2: Cow-calf herd model parameters

Cows	160
Replacement Heifers	30
Bulls	8
Mean Cow Weight (pounds)	1,400
Conception Rate (%)	89.12
Calving Rate (%)	98.14
Weaning Rate (%)	97.24
Cow death Loss (%)	2.72
Calf Daily Weight Gain (pounds)	1.71
Desired Selling Weight (pounds)	550

5.1.4.2 Cull and Replacement Heifer Management

Once calves are weaned, the producer sells the steers and most of the heifers to either backgrounding or feedlot operations. Within the beef cow herd, old cows that become susceptible to reproductive problems or have other health problems are sold as cull cows. In order to maintain a consistent cow herd size, the cow-calf producer needs to retain and raise some of the heifers for future breeding and calving purposes.

Cows that do not become pregnant at breeding or have calves at the end of the grazing season are culled. The number of cows that are culled in each season is a function of the herd statistics from breeding to weaning. The culling percentage used for this study was 17.26% (approximately 30 cows and/or heifers) per year. Thus, 17.26% of the herd which is made up of cows and/or heifers are culled each year. Culled animals in each year are replaced with heifers retained after weaning. The replacement heifers are brought in at the beginning of breeding in the following year.

5.1.4.3 Bulls

In order to produce a calf annually, the cow must be bred within 80 days after calving. As a result, the cow-calf operator is assumed to have bulls with the cow herd for breeding purposes. To achieve high conception rates in a restricted breeding season, the bulls must not be overworked (Hamilton, 2009). Table 5.4 shows the number of cows that can be serviced by a bull of average fertility in a 60-day breeding season on pasture. The number of cows per bull may be increased by about 30% if cattle are confined in an area or are presented to the bull only when in heat (Hamilton, 2009).

Table 5.3: Maximum Number of Cows Per Bull for Pasture Mating

Bull Age	Number of Cows
Yearling	15-20
2 Years Old	20-30
3+ Years	30-40

Source: Hamilton (2009)

Based on expert opinion (Raven, 2016) from the study area, the bull to cow ratio for this study was 1:25; that is, 1 bull for every 25 cows and/or heifers. Therefore, a total of 8 bulls were used in this study since the sum of the cows and replacement heifers was 190 (Table 5.3).

5.1.4.4 Pasture and Grazing

For any cow-calf operation, well-managed pasture plays a key role in providing sufficient levels of nutrition (Lunn, 2003). Annual forage yields of 3,000 pounds of dry matter per acre can be realized on pasture and well-managed pastures can produce 500-600 pounds of gain per acre in growing cattle (Lunn, 2003). Managing stocking density and grazing management are important decisions for cow-calf producers because they can lead to improved forage inventory and production per acre and as such, will maximize profitability (Lunn, 2003).

Pasture is managed through decisions regarding stocking rates (or stocking density). Stocking rate is defined as the number of animals per unit area of a pasture. Stocking rate decisions should consider how well pasture can recover from grazing during the pasture season, future production of pasture, forage availability quality, and animal performance (Lunn, 2003).

Stocking rates are also influenced by pasture requirements for the animals, usually expressed in Animal Unit Months (AUM) (Lunn, 2003). An AUM is the average amount of forage needed by an animal unit (AU) grazing for a month (Lunn, 2003). One AU is defined as one mature cow (weighing 1,000 pounds) with or without its suckling calf. On a dry matter basis, one AU requires about 1,000 pounds of forage over a month. However, the number of animal units per actual animal depends on body size. Animals with large body sizes have higher AU values. The body size of an animal also determines its forage requirement. A large framed mature cow weighing 1,400 pounds has an AU of 1.4 and also means that the forage required by this animal is 1.4 times that of a 1,000 pound cow. Table 5.2 shows typical AUs based on cattle type and animal size.

Table 5.4: Animal Unit based on the type of cattle and Animal Size

Cattle Class	**Animal Unit (AU)**	**Animal Size (pounds)**
Mature Cow (With or Without calf)	1.0	1,000
Mature Bull	1.5	1,500
Yearling Steer or Heifer	0.8	800
Weaned Calf	0.6	600

Source: Lunn (2003)

Pasture productivity is defined in terms of the number of AUMs provided per unit of area. This, in turn, determines the sustainable stocking rate for the pasture. For example, pasture that provides 1.5 AUM per acre is able to support 1.5 AUs for one month on each acre. If there are 1,000 acres of this pasture available, the maximum stocking rate would be 1.5 AUs per acre (1,500 AUs in total) for one month. If the grazing season length is six months, the maximum stocking rate is 0.25 AUs per acre over the entire grazing season; the 1.5 AUM per acre is equivalent to 0.25 available per month (1.5 divided by six). The 1,000 acres could therefore be stocked with 250 AUs for the six months period. This process can be "turned around" to determine the amount of pasture (with a given productivity) required to support a certain number of animals (or AUs) over a specified length of grazing season. For example, suppose a producer has 250 cows (each representing one AU) that are to be placed on pasture for an eight month grazing season. The producer requires 2,000 AUMs in total forage (250 multiplied by 8). If the available pasture provides 1.5 AUM per acre, the producer requires 1,333.33 acres of pasture.

The pasture productivities for the tame and native pastures of the representative farm on per acre basis are set at 1.54 and 0.6 AUMs, respectively (Table 5.1). The 1.54 AUM for tame pasture was adopted from Koeckhoven (2008) who used this value for tame pasture in his Lower Little Bow Watershed study, based on AAFC expert opinion at the time. The 0.6 AUM per acre for the native pasture is based on expert opinion (Raven, 2016) from the study area.

These pasture productivities were used to determine how much land in pasture is assumed to be controlled by the representative farm. The proportions of each type of pasture (tame versus native pasture) were decided based on study site proportions from a project carried out by AAF in the region in 2012. According to the project carried out by AAF in the region in 2012, 29.7% of the land in the study area is in pasture; 22.7% in native pasture and 7% in tame pasture. Based on these percentages, the proportions of native versus tame pasture were calculated to 0.8 (22.7/29.7) and 0.2 (7/29.7) respectively (rounded to one decimal point). Based on the proportions of each type of pasture, the weighted average pasture productivity (AUM/acre of pasture) for the farm was calculated. A value of 0.788 AUM/acre of pasture was obtained; (1.54 AUM/acre*0.2) + (0.6 AUM/acre*0.8).

The AUMs required by the herd size of this study were calculated using the length of grazing season, herd size statistics and AUM/month required by both cows and bulls. The length of grazing season in this study is assumed to be nine months, based on expert opinion (Raven, 2016). The total number of AUs on pasture for the representative farm is 277.2, based on 198 animals (190 cows and heifers, and 8 bulls) with an assumed average cow and bull weight of 1,400 pounds. Total AUMs required by the herd size in this study were calculated to be 2,494.8; 277.2 AUs multiplied by nine months.

Total AUMs required by the herd was used to calculate acres of pasture required. The required area of pasture using this method is calculated to be 3,165.99 acres (2494.8 AUMs divided by 0.788 AUM/acre). However, this does not take into account crop aftermath productivity. The representative farm has 2,000 acres used for crop production and it is assumed that the beef herd is allowed to graze that area after crops have been harvested (i.e., aftermath grazing, as discussed in Chapter 2). Based on Koeckhoven's (2008) study, the productivity used for aftermath grazing is 0.15 per acre[4].

Using the 0.15 AUM value for aftermath grazing, AUMs of forage available from crop aftermath are calculated. This value is 300 AUMs (0.15 AUM/acre * 2,000 acres of crop). The aftermath grazing AUM value (300 AUMs) is subtracted from the initial total AUM requirement for the herd to get the net forage requirement from tame and native pasture; 2,494.8 AUMs total requirement minus 300 AUMs from aftermath grazing, leaving 2,194.8 AUMs to be provided by tame and

[4] Koeckhoven (2008) determined this value based on AAFC expert opinion at the time of his study.

native pasture. This is used to determine the area of pasture required by the producer to support the beef herd, which is 2,785.3 acres (2,194.8 AUMs divided by 0.788 AUM per acre of pasture). Using the earlier assumed proportions of tame and native pasture, the resulting areas of pasture are 656 acres of tame pasture and 2130 acres of native pasture. These are the areas provided in Table 5.1. The acres of native versus tame pasture used in this study (Table 5.1) were calculated from the revised acres of pasture by using the proportions obtained from the project carried out by AAF in the region in 2012 as mentioned earlier.

5.1.5 Winter Feeding and Feed Inventory

The crop enterprise is linked to the cow-calf enterprise through the production of crops for winter feeding. Hay and part of the barley grain produced during the growing season are stored and fed to the cows, heifers and bulls during the winter season. The length of winter feeding used for the base model of this study is three months (with 30.5 days in a month).[5]

The demand for winter feed is based on the number of animals that are being winter fed and the required diet needed by those animals. Table 5.5 shows the winter diet requirements for different types of cattle in southern Alberta. These daily feed requirements for cows, bulls, and replacement heifers were obtained from AAF (Linquist, 2016).

Table 5.5: Cattle Winter Feed Requirement (pounds of dry matter/animal/day)

Feed Type	Cows	Bulls	Replacement Heifer
Hay	22	27.53	26
Barley Grain	4	1.01	4
Minerals	0.1	0.14	0.1

Source: Linquist (2016)

[5] The number of grazing season days may change following the implementation of a BMP. In a situation where the implementation of a BMP reduces the grazing season days, the winter feeding days are increased.

The daily feed requirements of hay for cows, bulls, and replacement heifers were used to calculate acres of hay required by the producer. The herd size of the study is made up of 160 cows, 30 replacement heifers and eight bulls. Total daily herd hay requirement (pounds) was calculated to be 4,520.24 pounds; (22 pounds of dry matter hay per day * 160 cows) + (27.53 pounds of dry matter hay per day * 8 bulls) + (26 pounds of dry matter hay per day * 30 replacement heifers). The 4,520.24 pounds is equivalent to 2.05 tonnes. As mentioned earlier, the length of winter feeding used for the base model of this study is three months (with 30.5 days in a month). Therefore, the total winter hay required by the herd size was calculated to be 187.6 tonnes (2.05 tonnes * 91.5 days).

The total winter hay requirement is expressed on a 100% dry matter basis. Converting to an "as fed" basis requires taking into account moisture levels in hay. While this may vary, a 15% moisture level is assumed, based on Koeckhoven's (2008) work. The "as fed" requirement of hay was calculated to be 220.7 tonnes (187.6 tonnes/0.85). Given an assumption of 1.3 tonnes of yield per acre for hay on an "as fed" basis, 170 acres (220.7 tonnes/1.3 tonnes per acre) are included in the crop rotation. This is provided in Table 5.1. The 1.3 tonne yield per acre was adopted from Koeckhoven (2008).

Research has indicated that wasted feed has a potentially significant effect on feed inventory requirements and the associated costs when feeding cows over the winter (AAF, 2007). Cattle are known to waste feed when feeding. Some of the feed gets trampled or "spilled" outside of where it cannot be reached. AAF (2007) suggests that cattle can waste between 12 to 15 percent of feed when a ring feeder is used. The study assumed 10% wastage of hay by cattle when feeding and this was factored into the simulation analysis.

Based on the hay yields that are obtained and the length of the grazing season, the quantity of hay produced may not be enough to meet the requirements of the animals. In such situations, additional hay is purchased by the producer at market value. There is also the tendency to maintain extra stocks of hay as a cushion in the event of a poor year with respect to yields. As described by Koeckhoven (2008), there is a market to sell excess feed in southern Alberta due to the presence of intensive feedlot operations. Based on this, in this study, it was decided to implement a producer decision rule regarding stores of hay. Specifically, the farm would store up to a year's worth of hay feed inventory (based on expected winter feeding requirements). Any excess beyond that level is sold at market value, adding to farm revenue.

5.1.6 Machinery Complement

The representative farm is assumed to have a machinery complement sufficient to accomplish all activities for both crop and cow-calf beef production. Machinery plays an important role in the activities of the farm and as such, has an effect on the farm cash flow. The use of machinery results in variable costs that are associated with repairs and maintenance as well as fuel use. Aside from repairs, maintenance and fuel use, there is a need to replace machinery at some point in time due to effects of use (i.e., wearing out). However, the timing of these replacement decisions are producer-specific and are therefore not easy to determine for modeling purposes. However, the cash flow implications of machinery replacement do need to be reflected in model calculations and resulting NPV values.

Koeckhoven (2008), Trautman (2012), and Xie (2014) developed explicit machinery complements for their representative farms. In these studies, an initial machinery value was first determined, based on the types and sizes of machinery required and assumptions about average machinery age. Annual depreciation was then calculated for the complement. This depreciation value was used as the annual cash expenditure (i.e., cash outflow) required to maintain the initial value of the complement; that is, it represents a proxy for expenditures associated with machinery replacement. The current study uses a similar approach for machinery replacement expenditure. However, rather than developing an explicit machinery complement for the representative farm, the earlier work by Koeckhoven (2008) and Trautman (2012) are adapted for use.

In Koeckhoven's (2008) study, for the case of the cow-calf enterprise, an annual machinery replacement expenditure of $15.69 per acre was estimated and incorporated into the model. In the case of Trautman (2012), only cropping operations were modeled (i.e., no livestock enterprises). The representative farm modeled by Trautman in the Dark Brown soil zone was of a similar size and crop mix (larger area of crops but same crop rotation). Trautman (2012) estimated the annual per acre expenditure for machinery replacement to be $17.95.

This study uses the $17.95 annual machinery replacement expenditure estimated by Trautman (2012). Although Trautman's (2012) representative farm did not include livestock, her approach to designing machinery complement was consistent with what was used by Koeckhoven (2008) whose representative farm was made up of crops and livestock. Since the size of the crop farm modeled by Trautman (2012) in the same study region is similar to the size modeled in this study, it was decided that $ 17.95 should be the machinery replacement cost in this study.

5.2 Stochastic Simulation Model Parameters

This section discusses the methods that were used to establish the stochastic model parameters of this study. The stochastic models include crop yields, crop prices and beef prices and the parameters were modeled based on historical data. The estimated stochastic models are set in Dynamic Monte Carlo simulation using Excel add-in @Risk.

5.2.1 Crop and Forage Yield Models

5.2.1.1 Crop Yield Model

In this study, crop yields are modeled as being stochastic due to fact that yields typically show substantial variation, mostly as a result of varying environmental factors (e.g., weather) and improvements in technology. In some previous BMP studies (e.g. Cortus, 2005; Koeckhoven, 2008), the approach used for crop yield modeling is to estimate a function associating crop yield with temperature and precipitation. The reason for associating crop yield with temperature and precipitation in these studies is that crop yields are directly affected by these elements of the weather providing much of the resulting variability. The stochastic crop yield models in those studies are based on draws from weather variable distributions. This method was tried for the current study, using different precipitation data from the study area, but it was shown to be problematic. Specifically, when modeling the impact of heat (i.e., Growing Degree Days) and growing season precipitation on yields using weather variables from nearby weather stations, the estimates suggested that yields increase at an increasing rate with greater values of a precipitation-to-heat ratio. These results are contrary to what would be expected, and so this approach was not pursued further.

An alternative, used by Trautman (2012) and Xie (2014), is to directly identify the distributions of historical crop yields; that is, in the simulation, each stochastic crop yield is a draw from the estimated crop yield distribution. That approach is applied in this study. County-level dryland crop yield data for the period 1978 to 2013 were provided by the Agriculture Financial Services Corporation (AFSC) and used in this study. Table 5.6 shows a summary of the historical crop yield data from Lethbridge County.

Table 5.6: A summary of historical crop yield data from 1978 to 2013 (kg/acre) from Lethbridge County

Crop	Mean	St. Dev.	Minimum	Maximum
Spring Wheat	835	301	264	1,422
Barley	1,030	390	245	1,791
Canola	546	218	113	965

5.2.1.1.1 De-trending Crop Yield Data

Crop yields typically show substantial variation, mostly as a result of varying weather events and improvements in technology. However, for the purposes of the current analysis, only the year to year variability in yields resulting from weather variability is relevant. Thus, the volatility associated with changes in technology is isolated and removed from the crop yield data. This is accomplished by "de-trending" the historical crop yield data prior to empirical analysis.

The ability to determine the "right" trend is important for further analysis (Conradt et al., 2012). When trend is estimated inaccurately, it may lead to incorrect determination of higher moments of the distribution thereby leading to non-stationary crop yield distributions; that is, the inability to account for the whole effects associated with changes in technology resulting in overestimation of the risk faced by a producer (Just and Weninger, 1999). Overestimation of a trend parameter may have implications for risk identification and may lead to an underestimation of the underlying risk (Mara and Schurle, 1994).

Trends in crop yield may be linear or non-linear; that is, trends may be described with second or third order degree polynomial, for example (Conradt et al., 2012). There is a linear trend if there is a constant rate of change in crop yield from year to year and non-linear if the trend has a variable slope. Previous studies have shown that crop yields often exhibit a linear time trend (Hafner, 2003; Tannura et al., 2008), at least in developed countries. An Ordinary Least Squares (OLS) approach remains a popular method for de-trending crop yield series and OLS was employed in this study. De-trending is generally carried out with the OLS approach by regressing crop yields on time. The coefficient on the time trend is then tested for significance (Haan, 2002). The study uses the most recent year (2013) of available data as the base year. The historical county-level crop yields are regressed on year and crop yield series that showed significant time trends are de-trended by using Equation 5.1 as used by Zindi (2006):

$$Y_t^* = \hat{Y}_{2013} * \frac{Y_t}{\hat{Y}_t} \qquad (5.1)$$

where Y_t^* represents the de-trended yield for year t, $\hat{Y}_{2013}$ is the predicted yield for the base year, Y_t is the actual yield for year t and $\hat{Y}_t$ is the predicted yield for year t. Table 5.7 provides summary statistics and test statistics for historical crop yields before de-trending. The null hypothesis of the test is that the coefficient on time equals zero.

Table 5.7: Summary Statistics and Test Statistics for the time trend, crop yields before De-trending (kg/acre)

Crop	Mean	Standard Deviation	Intercept Coefficient	Time Trend Coefficient	t-Statistics	p-Value
Spring Wheat	835	301	-34714.25	17.81	4.65	0.000
Barley	1,030	390	-38920.38	20.02	3.75	0.001
Canola	546	218	-19608.90	10.10	3.27	0.002

The test statistics as shown by Table 5.7 indicate that we reject the null hypothesis that there is no trend in the crop yield. All of the time trend coefficients are significant at a 1% significant level. Table 5.8 provides summary statistics of the historical crop yield after de-trending.

Table 5.8: Summary statistics for Crop yields after De-trending (kg/acre)

Crop	Mean	St. Dev.	Minimum	Maximum
Spring Wheat	1,154	378	440	2,043
Barley	1,390	514	413	2,613
Canola	727	273	136	1,292

5.2.1.1.2 Distribution Fitting

In order to select the best fitting distribution for the de-trended crop yield series, the "Fit Distribution" option in @Risk is used. Each de-trended crop yield series (i.e., spring wheat, barley and canola) is fitted to the best distribution for further analysis. The @Risk "Fit Distribution" option fits the historical de-trended crop yield data to different distributions by estimating the parameters, and also displays which distributions best describe or replicate the data set. Beta, Gamma, Exponential, Triangular, Weibull, Uniform, and Lognormal distributions were the types of distribution tested to be used for this analysis, because they can all be truncated at zero thereby excluding the possibility of negative yields. These distributions also, with the exception of the uniform distribution, allow crop yield distributions to be skewed. This is important because of a desire for flexibility, along with empirical evidence that yields are not distributed symmetrically around a mean value (Upadhyay and Smith, 2005).

Based on the results from fitting alternative distributions, the Weibull distribution is used to represent all three crops. This decision was made based on the use of three test statistics in @Risk. The test statistics, which test goodness of fit of historical input data for a specified distribution, are Chi-Squared, Anderson-Darling and Kolmogorov-Smirnov (K-S) statistics. In choosing the best fit, a smaller fit statistic is preferred because that shows a better fit between the distribution and the data.

There was no single distribution that was "best" for all combinations of crops and test statistics. For spring wheat, Weibull was the best fitting distribution under Chi-Squared and Anderson-Darling tests. However, using the Kolmogorov-Smirnov (K-S) test statistic, LogLogistic was the best fitting distribution for spring wheat. For barley, Weibull was the best fitting distribution for all the three test statistics. For canola, Weibull was the best fitting distribution under Chi-Squared while the Triangular distribution was the best fitting distribution under Anderson-Darling and Kolmogorov-Smirnov (K-S) statistics.

Considering the nine possible combinations of three crops and three test statistics, Weibull was ranked among the top three choices in all nine cases, while the Triangular distribution (the next "best" choice) was in the top three six times. As well, Weibull was ranked as the best choice six times as against two times for the Triangular distribution. The test statistics and the ranking of the test statistics to choose the best distribution for this study are provided in Appendix A.

The Weibull distribution is characterised by the following probability density function:

$$f(x) = \frac{\alpha x^{\alpha-1}}{\beta^{\alpha}} e^{-(x/\beta)^{\alpha}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5.2)$$

where f(x) is the probability density function, α is the continuous shape parameter with $\alpha > 0$ and β is the continuous scale parameter with $\beta > 0$ (Palisade Corporation, 2010). From the density function, the distribution mean is given by $\beta\Gamma\left(1 + \frac{1}{\alpha}\right)$, and the variance is given by $\beta^2 \left[\Gamma\left(1 + \frac{2}{\alpha}\right) - \Gamma^2\left(1 + \frac{1}{\alpha}\right) \right]$, where Γ is the Gamma function (Palisade Corporation, 2010). The estimated distribution parameters for each de-trended historical yield series are shown in Table 5.9.

Table 5.9: Estimated Weibull distribution parameters for each de-trended historical crop yield series

Crop	Mean (kg/acre)	St. Dev.	α	β
Spring Wheat	1,153	376	3.3839	1,283.3
Barley	1,388	508	2.9729	1,554.4
Canola	726	264	2.9944	812.77

5.2.1.1.3 Correlation of Crop Yields

Correlations among crop yields are important in modeling stochastic crop yields. Crops growing in the same area are affected in similar ways by climatic or environmental conditions such as temperature, pressure, wind, humidity and precipitation. As a result, it is likely that crop yields in the same area are positively correlated.

This study takes into account crop yield correlations. Field-level correlation matrix coefficients were provided by AAF, based on 2004-2006 field level data on dryland farms in Risk Area 2 in Alberta. Risk Area 2 is located in southern Alberta and includes the counties in the study area. Table 5.10 provides the resulting crop yield correlations used in the simulation model.

Table 5.10: Correlation coefficients of crop yields on dryland farms for Risk Area 2 in Alberta

Crop	Spring Wheat	Barley	Canola
Spring Wheat	1		
Barley	0.472	1	
Canola	0.600	0.547	1

5.2.1.1.4 Validation and Adjustment (Marra-Schurle (M-S) Adjustment)

This study uses historical county-level yield data to represent farm-level yields. However, as noted by Finger (2012), the use of county-level yield data for this purpose is associated with aggregation bias. Variability in yield at the farm-level, in particular, is significantly higher than for more aggregated levels of yields (e.g., county). This has implications for the conclusiveness of the results on farm level risk estimates. Marra and Schurle (1994), while studying Kansas wheat yield risk measures and aggregation, also attested to the fact that the variability of farm-level yields is greater than for more aggregated levels. Further, they estimated that county level yield variability needs to be adjusted upwards by approximately 0.1% for each 1% difference between county acreage and average farm acreage within the county. This approach has been used by Koeckhoven (2008), Trautman (2012) and Xie (2014) to adjust county level yield variability to approximate farm level variability.

Based on the approach, the standard deviations of each de-trended crop yield series are adjusted in the current study. County acreage and total farm acreage for each crop are used to represent the total county farm acreage and total farm acreage, respectively, in the adjustment procedure proposed by Marra and Schurle (1994). Table 5.11 provides calculation results to illustrate this procedure. Using spring wheat as an example, the percentage difference between farm and county acreage is obtained by subtracting the farm acreage from the county acreage and dividing by the farm acreage. The value obtained is multiplied by 100 to convert it to percentage; that is, ((123,197 – 610)/610) *100 = 20,096.23%. The percentage standard deviation change is obtained by multiplying the percentage difference between the farm and county acreage by the M-S adjustment coefficient and dividing by one hundred; that is, (20,096.23*0.1)/100 = 20.10%. The increase in standard deviation is calculated by multiplying the percentage standard deviation change by the county-level standard deviation and dividing by one hundred; that is, (20.10*377.67)/100 = 75.90. The revised standard deviation is obtained by adding the increase in standard deviation to the county-level standard deviation; that is, 75.90 + 377.67 = 453.57. Similar calculations are provided for barley and canola in Table 5.11.

Table 5.11: Marra-Schurle adjustment of standard deviation of crop yields (after de-trended)

	Spring Wheat	Barley	Canola
Farm Acreage	610	610	610
County Acreage (2011 Census of Agriculture)	123,197	115,228	101,032
% Difference between farm and county acreage	20,096.23	18,789.84	16,462.62
M-S adjustment coefficient (%)	0.1	0.1	0.1
% Standard Deviation Change	20.10	18.79	16.46
Increase in Standard Deviation	75.90	96.59	44.92
County-level Standard Deviation	377.67	514.05	272.85
Revised Standard Deviation	453.57	610.63	317.77

After revising the standard deviations of the crops, the estimated Weibull yield distribution parameters are adjusted accordingly. The approach used is to change the continuous shape parameter (α) and the continuous scale parameter (β) to match the revised standard deviation, without altering the mean. The revised α and β are re-estimated by solving equations for the mean and variance of the Weibull distribution probability density function (provided in Appendix B). Table 5.12 shows the estimates of the crop yield parameters after the M-S standard deviation adjustment.

Table 5.12: Estimates of the Weibull distribution crop yield parameters after M-S Standard Deviation Adjustment

Crop	Mean (kg/acre)	St. Dev.	α	β
Spring Wheat	1,153	453.57	54.14	1,148.68
Barley	1,388	610.63	21.71	1,554.4
Canola	726	317.76	17.97	769.61

Validation of the yield models was conducted to ascertain if the simulated yields match the historical yield data in terms of means and correlations[6]. This was done by testing the estimated crop yield distributions and correlations by using @Risk. In order to test if the estimated crop yield variables accurately estimate the historical yield correlations, a simulation was run for the

[6] Given that the variability is adjusted upward to reflect farm-level risk, the variances would not be expected to match the values from historical county-level data.

representative farm using @Risk. The base model was run for 10,000 iterations and the resulting sample correlations calculated from the simulation results were tested for equivalence with the correlation coefficients obtained from AAF. While the calculated correlation coefficients were slightly different from the historical values, there was no statistically significant difference (at 5% level of significance) between the simulated means of the yield data and the historical yields, for all the crops under consideration. For all crops, the p-value for the t-test assuming unequal variances between de-trended historical yields and simulated yields was greater than 0.46.

5.2.1.2 Forage Yield Model Estimation & Incorporation

One of the crops included in the representative farm model is tame hay, consisting of alfalfa-grass mix. However, there were not enough yield data available for a reasonable or continuous period of time for tame hay from the study area. As a result, stochastic tame hay yields are modeled using the correlation between the yield of tame hay and a reference crop. In previous studies conducted by Koeckhoven (2008) and Trautman (2012), barley has been shown as the appropriate reference. Therefore, this study uses barley as the reference crop. The yield of tame hay in any period is based on the average yield, the change in barley yield from the previous to the current year and the yield correlation from AAF. The relationship is shown by equation 5.3, where $Y_{hay,t}$ represents the calculated yield (kg/acre) of tame hay in year t, E[Y_{hay}] is the estimated yield of tame hay, ΔY_{barley} is the change in barley yield from the previous year to the current year, and $\rho_{barley,hay}$ is the AAF correlation coefficient between barley and hay. In year one, the average yield of tame hay obtained from the study area was used as the starting value. The AAF correlation coefficient used in this analysis is 0.3.

$$Y_{hay,t} = E\left[Y_{hay}\right] * \left[1 + (\Delta Y_{barley} * \rho_{barley,hay})\right] \quad (5.3)$$

5.2.2 Crop and Forage Price Models

The study models the crop and forage prices as stochastic parameters, with the assumption that producers face price risk; that is, the actual price received for sale of commodities is unknown at the time that production decisions are made. Annual price data for barley, canola and tame hay were obtained from AAF. The price data for Canadian hard spring wheat were obtained from the Canadian Wheat Board (CWB) and wheat was assumed to be of No. 1 grade with 13.5% protein. Historical annual crop prices from 1963 to 2014 were used in the estimation of crop prices models. Prior to carrying out the statistical analysis, the price data were adjusted for inflation by using the Consumer Price Index for all items from Statistics Canada and 2014 as the base year. Table 5.13 shows the summary price statistics after inflation adjustment.

Table 5.13: Summary Statistics of CPI-Adjusted Crop Prices ($/kg) (2014 Base Year)

	Mean	St. Dev.	Minimum	Maximum
Spring wheat	0.3081	0.1217	0.1576	0.7040
Barley	0.2301	0.1045	0.1122	0.6092
Canola	0.6174	0.2557	0.3065	1.4875
Tame hay	0.1372	0.0413	0.0705	0.2319

5.2.2.1 Test for Stationarity (Crop Prices)

The price series are tested for stationarity prior to the estimation of the price model. A stationary time series is defined as one whose statistical properties such as the mean, variance and autocorrelation structure are time invariant or remain constant over time (Mahadeva and Robinson, 2004). Unlike yield, in order to accurately model prices using time series model where current price is a function of previous prices, the price series should be stationary. In a situation where the price series is not stationary, a random walk process needs to be applied to model prices. Two of the most widely used tools for testing for stationarity are the Augmented Dickey-Fuller (ADF), and Kwiatkowski-Philips-Schmidt-Shin (KPSS) tests. If the results from the two tests are consistent, there is greater confidence in proceeding under the resulting assumption.

5.2.2.1.1 Augmented Dickey-Fuller (ADF) Test

The ADF test is conducted with a null hypothesis that the time series has a unit root; that is, the time series exhibit non-stationarity. Three versions of the ADF test for cross validation were conducted: one assuming a time trend, one assuming no time trend (baseline) and one assuming a drift (Ryan and Giles, 1998). A drift implies that there is an added upward or downward trend in the process. The results of the ADF test are shown by Table 5.14. Price data for spring wheat are stationary for the baseline, trend and drift tests at 10%, 5% and 1% levels of significance, respectively. Price data for barley are stationary for the baseline, trend and drift tests at 5%, 5% and 1% levels of significance, respectively. Canola and tame hay prices are stationary when a drift is assumed at 1% and 5% level of significance, respectively.

Table 5.14: Augmented Dickey-Fuller (ADF) Test Results of Crop Prices

		Test Statistics		
	Lag	Baseline	Trend	Drift
Spring Wheat	1	-2.751*	-3.679**	-2.751***
Barley	1	-2.950**	-3.595**	-2.950***
Canola	1	-2.451	-3.174	-2.451***
Tame Hay	1	-2.191	-3.148	-2.191**
1% Critical Value		-3.580	-4.150	-2.408
5% Critical Value		-2.930	-3.500	-1.678
10% Critical Value		-2.600	-3.180	-1.300

***, **, and * indicates significance at 1%, 5%, and 10% level, respectively.

5.2.2.1.2 Kwiatkowski-Philips-Schmidt-Shin (KPSS) Test

Unlike the ADF test, the null hypothesis of the KPSS test is that the time series are stationary; that is, there is no unit root. The KPSS test was conducted for each crop price series in STATA using automatic lag length selection and the Quadratic Spectral kernel (meaning that the autocovariance function should be weighted by the quadratic spectral kernel). Quadratic Spectral kernel yields more accurate results than other kernels (Andrews, 1991 and Newey and West, 1994). As shown by Table 5.15, the KPSS test statistics are insignificant even at a 10% level of significance, and so the null hypothesis of stationary price series cannot be rejected for any of the crops.

Table 5.15: KPSS test results for stationarity of crop price series data

Crop	Test Statistics
Spring Wheat	0.0900
Barley	0.0997
Canola	0.0828
Tame Hay	0.0842
1% Critical Value	0.216
5% Critical Value	0.146
10% Critical Value	0.119

5.2.2.2 Estimation of Crop Price Model

5.2.2.2.1 Length of Lag in Crop Price Model

Given that it is concluded that crop prices are stationary, an assumption is made that the current crop prices are functions of own lagged prices. Price equations are estimated using seemingly unrelated regression (SUR) to account for possible correlation between historical prices. Two tests, the Akaike Information Criterion (AIC) and Schwartz Bayesian Information Criterion (SBIC), are used to determine the number of lags appropriate for each crop price equation. OLS regression estimates with prices lagged from one to five years were tested. Table 5.16 shows the results for AIC and SBIC test. The smallest AIC and/or SBIC value determines the optimal lag length for each crop price model. As shown by Table 5.16, the most appropriate lag length for all crops was one.

Table 5.16: Akaike information criterion (AIC) and Schwarz Bayesian Information Criterion (SBIC) results

	Lags	1	2	3	4	5
Spring Wheat	AIC	-114.906*	-85.17259	-78.0816	-76.4150	-77.9525
	SBIC	-111.0423*	-81.34854	-74.2980	-72.6726	-74.2522
Barley	AIC	-134.3107*	-98.9010	-87.6925	-83.5910	-81.6590
	SBIC	-130.4470*	-95.0770	-83.9088	-79.8486	-77.9587
Canola	AIC	-55.8425*	-20.4277	-11.5463	-6.4353	0.7251
	SBIC	-51.9789*	-16.6037	-7.7627	-2.6929	4.4253
Tame Hay	AIC	-243.2977*	-203.6202	-190.3889	-183.7319	-178.0276
	SBIC	-239.4340*	-199.7961	-186.6052	-179.9895	-174.3273

The minimum values of AIC and SBIC are marked *

The price equations resulting from SUR analysis are presented below.

$$P_t^s = \alpha_0^s + \beta_1^s P_{t-1}^s + \varepsilon_t^s \quad (5.4)$$

$$P_t^b = \alpha_0^b + \beta_1^b P_{t-1}^b + \varepsilon_t^b \quad (5.5)$$

$$P_t^c = \alpha_0^c + \beta_1^c P_{t-1}^c + \varepsilon_t^c \quad (5.6)$$

$$P_t^h = \alpha_0^h + \beta_1^h P_{t-1}^h + \varepsilon_t^h \quad (5.7)$$

where P^s, P^b, P^c, and P^h, are prices for spring wheat, barley, canola and tame hay respectively. P_{t-n}^i is the price of the ith crop in period t-n. ε_t^i is the error term for crop i in time t. β_1^i are the coefficients on the lagged price variables to be estimated.

5.2.2.2.2 Crop Price Model Results and Incorporation

As mentioned earlier, the price model of this study is estimated using SUR in STATA. SUR estimators are more efficient than OLS estimator on an equation by equation basis when the error terms are correlated. Assuming that prices of the crops modeled in the current study can be affected by similar exogenous variables, it was appropriate to apply SUR. Table 5.17 shows the results of the SUR estimation. The chi-square value for the Breusch-Pagan test of independence obtained was 163.228. A p-value of 0.0000 (significant at 1% level of confidence) was also obtained. These two test statistics indicate that modeling prices taking into account the correlations are appropriate; that is, it is appropriate to use SUR estimator instead of estimating equation by equation using OLS.

Table 5.17: Seemingly Unrelated Regression (SUR) Model Results of Crop Prices

	Estimated Coefficients			
Variable	Spring Wheat	Barley	Canola	Tame Hay
Lag 1	0.7032***	0.5877***	0.6729***	0.8225***
	(0.0650)[a]	(0.0685)	(0.0650)	(0.0674)
Constant	0.0885***	0.0924***	0.1944***	0.0240***
	(0.0227)	(0.0181)	(0.0446)	(0.0098)
Standard Error (RMSE)	0.0759	0.0659	0.1415	0.0215
R^2	0.6024	0.5945	0.6881	0.7290

*** indicates significance at a 1% level.

[a] Numbers in the parentheses are standard errors for parameters

The study uses stochastic annual crop and forage prices in the simulation that are calculated using the estimated price equations from the SUR. The stochastic elements in the stimulation are introduced through the error term in each price equation. Standard normal draws are generated by @Risk. As noted by Hull (2003), the individual price equations are correlated. As a result, the correlations of the error terms in the equations need to be adjusted and scaled using the standard deviation. The correlations in the error term are calculated with the given formulae below (Hull, 2003)

$$\varepsilon_m = \sum_{k=1}^{k=m} \alpha_{mk}\, x_k \; subject\ to:$$

$$\sum_k \alpha_{mk}^2 = 1$$

$$\sum_k \alpha_{mk}\alpha_{jk} = \rho_{m,j} \tag{5.8}$$

where ε_m represents the correlated error term for the price of crop m, x_k is the error term draw scaled to the standard deviation of the corresponding crop price, $\rho_{m,j}$ is the correlation between the errors for crop prices m and j, and α_{mk} are the terms estimated from the constraints.

By solving the α_{mk} terms, the equations for the corrected error terms are presented below. Subscripts 1,2,3 and 4 correspond to spring wheat, barley, canola and tame hay, respectively.

$$\varepsilon_1 = x_1 \tag{5.9}$$

$$\varepsilon_2 = \rho_{2,1}x_1 + \left(\sqrt{1-\rho_{2,1}^2}\right)x_2 \tag{5.10}$$

$$\varepsilon_3 = \rho_{3,1}x_1 + \left(\frac{\rho_{3,2}-\rho_{2,1}\rho_{3,1}}{\sqrt{1-\rho_{2,1}^2}}\right) x_2 + \left[\sqrt{1-\rho_{3,1}{}^2-\left(\frac{\rho_{3,2}-\rho_{2,1}\rho_{3,1}}{\sqrt{1-\rho_{2,1}^2}}\right)^2}\,\right]x_3 \tag{5.11}$$

$$\varepsilon_4 = \rho_{4,1}x_1 + \left(\frac{\rho_{4,2}-\rho_{4,1}\rho_{2,1}}{\sqrt{1-\rho_{2,1}^2}}\right)x_2 + \frac{\rho_{4,3}-\rho_{4,1}\rho_{3,1}\left(\frac{\rho_{3,2}-\rho_{2,1}\rho_{3,1}}{\sqrt{1-\rho_{2,1}^2}}\right)\left(\frac{\rho_{4,2}-\rho_{4,1}\rho_{2,1}}{\sqrt{1-\rho_{2,1}^2}}\right)}{\sqrt{1-\rho_{3,1}{}^2-\left(\frac{\rho_{3,2}-\rho_{2,1}\rho_{3,1}}{\sqrt{1-\rho_{2,1}^2}}\right)^2}}\, x_3 x_4$$

$$+$$

$$\left[\sqrt{1-\rho_{4,1}{}^{2}-\left(\frac{\rho_{4,2}-\rho_{2,1}\rho_{4,1}}{\sqrt{1-\rho_{2,1}^{2}}}\right)^{2}-\left[\frac{\rho_{4,3}-\rho_{4,1}\rho_{3,1}\left(\frac{\rho_{3,2}-\rho_{2,1}\rho_{3,1}}{\sqrt{1-\rho_{2,1}^{2}}}\right)\left(\frac{\rho_{4,2}-\rho_{4,1}\rho_{2,1}}{\sqrt{1-\rho_{2,1}^{2}}}\right)}{\sqrt{1-\rho_{3,1}{}^{2}-\left(\frac{\rho_{3,2}-\rho_{2,1}\rho_{3,1}}{\sqrt{1-\rho_{2,1}^{2}}}\right)^{2}}}\right]^{2}}\right] \quad \ldots\ldots\ldots\ldots(5.12)$$

The SUR-estimated error correlations used are shown in Table 5.18.

Table 5.18: SUR-estimated error correlations for price equations

	Spring Wheat	Barley	Canola	Tame Hay
Spring Wheat	1			
Barley	0.149	1		
Canola	0.270	0.593	1	
Tame Hay	0.371	0.238	0.175	1

5.2.2.2.3 Validation and Adjustment of Crop Price Model

To determine whether the simulated prices are consistent with historical price patterns (i.e., whether the crop price model is valid), the historical inflation adjusted means of the crop prices are compared with the means of the simulated results in Year 20. A t-test was conducted to compare the means using a two-sample assuming unequal variances at 5% level of significance. The null hypothesis of the test is that the two means are equal. Based on the t-test statistics, the outcome is failure to reject the null hypothesis that the historical means are equal to the simulated means in all the prices series. Table 5.19 shows the results of the t-test as well as the historical and simulated means.

Table 5.19: Means of historical price data, simulated prices in Year 20 and t-test statistics

Crop	Historical Mean ($/kg)	Simulated Mean ($/kg)	Calculated Values	p-value
Spring Wheat	0.3081	0.2981	0.1085	0.46
Barley	0.2222	0.2241	-0.0313	0.49
Canola	0.6174	0.5943	0.2506	0.41
Tame Hay	0.1372	0.1350	0.044	0.48

5.2.3 Beef Price Model

The calculation of stochastic beef prices in this study are done using the same process and techniques as for crop prices. Similar to crop prices, a system of time series equations is estimated for beef prices used in the simulation analysis and correlations between beef price errors are used to calculate the simulated prices. Prices for feeder steers (500-600 pounds), feeder heifers (500-600 pounds) and cull cows for southern Alberta were obtained from AAF (Komirenko, 2015), for the period 1976 to 2014. The 500-600 pound weight class was used because the desired minimum weaning weight (550 pounds) of the animals in this study falls in this weight range.

The historical prices series were adjusted for inflation using the Consumer Price Index for all items from Statistics Canada. The base year used for the adjustment was 2014. The price data available were monthly prices but following a similar study by Koeckhoven (2008), a decision was made that prices would be drawn twice a year in the simulation. An assumption is made that cull cows and market calves would be sold potentially in May and November of each year. As a result, May and November prices from 1976 to 2014 are used for this study. Table 5.20 shows summary statistics of the data.

Table 5.20: Summary Statistics of CPI-Adjusted Beef Prices with 2014 as the base year ($/cwt)[a]

	Mean	Standard Deviation	Minimum	Maximum
Feeder heifer (5-6cwt)	158.34	38.91	99.35	300.06
Feeder steer (5-6cwt)	176.82	44.38	111.15	352.75
Cull cow	80.29	30.53	25.14	174.05

[a] The prices are per hundredweight (cwt) or per 100 pounds.

5.2.3.1 Stationarity Tests for the Beef Prices

Similar to crop prices, stationarity tests for the beef prices were performed using Augmented Dickey-Fuller and KPSS tests. Table 5.21 and Table 5.22 show the test statistics for the Augmented Dickey-Fuller and KPSS tests respectively. The null hypothesis for the Augmented Dickey-Fuller is that the price series has a unit root and the null for the KPSS test is that the price series is stationary.

Table 5.21: Augmented Dickey-Fuller (ADF) Test Results of Beef Prices

		Test Statistics		
	Lag	Baseline	Trend	Drift
Feeder heifer	2	-3.471**	-4.264**	-3.471***
Feeder steer	2	-3.127**	-3.793**	-3.127***
Cull cows	1	-2.370	-2.922	-2.370**
1% Crit. Value		-3.668	-4.270	-2.441
5% Crit. Value		-2.966	-3.552	-1.691
10% Crit. Value		-2.616	-3.211	-1.307

***, **, and * indicates significance at 1%, 5%, and 10% level, respectively.

Table 5.22: KPSS test results for stationarity of crop price series data

Crop	**Test Statistics**
Feeder Heifer	0.173
Feeder Steer	0.166
Cull cows	0.136
1% Critical Value	0.216
5% Critical Value	0.146
10% Critical Value	0.119

From Table 5.21, price data for feeder heifer and feeder steers are stationary for all three tests under the assumptions of no trend (baseline), trend, and drift. Cull cows prices are stationary only when a drift is assumed.

The results of the KPSS, as shown by Table 5.22, suggest that the null hypothesis of stationary feeder heifer and feeder steers are rejected at 10% and 5% level of confidence and cull cow prices are rejected at only 10% level of confidence. However, the results of both the ADF and KPSS tests show that the prices series are stationary in most of the cases and it is appropriate to model current price as being a function of previous prices.

5.2.3.2 Estimation of Beef Price Model

5.2.3.2.1 Length of Lag in Crop Price Model

Prior to the estimation of prices, the lag length of the models was determined using AIC and SBIC as shown by Table 5.23. As before, the minimum value of these statistics provides the appropriate lag length. However, beef prices exhibited decreasing test statistic values even at lag length ten, for all the three price series. However, after a lag length of two periods for feeder steers and feeder heifers and a lag length one period for cull cows, the p-values obtained were greater than 0.10 or 10% (i.e., not significant at a 10% level). Therefore, the lag length for both feeder heifers and feeder steers price series was set at two years and that of cull cow was set at one year. Equations 5.13, 5.14 and 5.15 show the price equations for feeder heifers, feeder steers and cull cows, respectively, where P^{fh}, P^{fs}, and P^{cc}, are prices for feeder heifers, feeder steers, and cull cows respectively. P^{i}_{t-n} is the price of the ith beef in period t-n. ε^{i}_{t} is the error term for beef i in time t. β^{i}_{0} to β^{i}_{n} are the coefficients on the lagged price variables to be estimated.

Table 5.23: Akaike information criterion (AIC) and Schwarz Bayesian Information Criterion (SBIC) results of Beef Prices

	Lags	1	2	3	4	5
Feeder heifer	AIC	359.843	344.211	321.765	313.172	304.090
	SBIC	363.065	347.378	324.876	316.225	307.083
Feeder steer	AIC	368.757	350.589	324.269	315.157	306.098
	SBIC	371.979	353.757	327.379	318.210	309.091
Cull cows	AIC	309.680	289.521	273.057	265.916	257.807
	BIC	312.902	292.688	276.168	268.968	260.800

$$P_t^{fh} = \alpha_0^{fh} + \beta_1^{fh} P_{t-1}^{fh} + \beta_2^{fh} P_{t-2}^{fh} + \varepsilon_t^{fh} \quad (5.12)$$

$$P_t^{fs} = \alpha_0^{fs} + \beta_1^{fs} P_{t-1}^{fs} + \beta_2^{fs} P_{t-2}^{fs} + \varepsilon_t^{fs} \quad (5.13)$$

$$P_t^{cc} = \alpha_0^{cc} + \beta_1^{cc} P_{t-1}^{cc} + \varepsilon_t^{cc} \quad (5.14)$$

The beef price model is estimated using SUR in STATA. Table 5.24 shows the results of the SUR estimation. The chi-square value for the Breusch-Pagan test of independence obtained was 83.806 A p-value of 0.0000 for the SUR was also obtained. As a result, it is appropriate to use SUR estimator instead of estimating equation by equation using OLS. Table 5.25 shows the error correlations between the price equations from Table 5.24.

Table 5.24: Seemingly unrelated regression (SUR) model results of Beef Prices

Variable	Estimated Coefficients		
	Feeder heifer	Feeder steer	Cull cows
Lag 1	0.6638*** (0.1067)[a]	0.6470*** (0.1025)	0.7589*** (0.0698)
Lag 2	-0.0551 (0.0915)	-0.0429 (0.0872)	
Constant	64.1626*** (15.6812)	71.7318*** (17.2395)	19.8430*** (6.1693)
Stand. Error (RMSE)	30.4088	34.3555	16.8600
R^2	0.3888	0.4146	0.7024

*** indicates significance at a 1% level.
[a] Numbers in the parentheses are standard errors for parameters

Table 5.25: SUR-estimated error correlations for price equations

	Feeder heifer	Feeder steers	Cull cows
Feeder heifer	1		
Feeder steer	0.980	1	
Cull cows	0.794	0.822	1

5.2.3.2.2 Validation and Adjustment of Beef Price Model

To determine whether the simulated prices are consistent with the underlying historical real prices, the means for historically inflation adjusted beef prices are compared with the means of the simulated results in Year 20. A t-test was conducted to compare the means using a two-sample assuming unequal variances at 5% level of significance. The null hypothesis of the test is that the two means are equal. From the t-test statistics, we fail to reject the null hypothesis that the historical means are equal to the simulated means in all the prices series and as such, there was no need to adjust the simulated prices in this study. Table 5.26 shows the results of the t-test as well as the historical and simulated means.

Table 5.26: Means of historical price data, simulated prices in Year 20 and t-test statistics

			t-Test Statistics		
Crop	Historical Mean ($/cwt)[a]	Simulated Mean ($/cwt)	Critical Values	Calculated Values	p-value
Feeder heifers	158.3382	158.0457	1.8595	-0.0585	0.48
Feeder steers	176.82	180.7671	1.8595	0.7894	0.23
Cull cows	80.2912	77.9921	1.9432	0.6498	0.21

[a] The prices are per hundredweight (cwt) or per 100 pounds.

5.3 Economic Relationships

This section discusses how the stochastic prices of crops and beef and yield variables are used to determine farm revenues and expenses, as well as cash flows associated with business risk management programs (i.e., AgriInsurance and AgriStability). These are all required for the purposes of calculating farm cash flow.

5.3.1 Revenues

The main revenues of the representative farm come from the sale of crops, calves, and cull cows. Other revenue sources include proceeds from the sale of hay in years where the inventory levels are exceeded, payments from the sale of crop residues (i.e., straw), and payments from crop insurance and AgriStability program participation. These latter two sources are discussed in detail later in this section.

The crop revenues in each year were calculated by multiplying the simulated crop prices by the simulated crop yield and their corresponding acreage. Revenues from the cow-calf enterprise are comprised of the value received from the sale of market heifers, market steers and cull cows. The revenues here are calculated by multiplying the relevant simulated beef price by the corresponding animal market weight and numbers sold, summed across cattle types.

5.3.2 Input Costs

Input costs consist of the costs of any inputs used directly on the representative farm. These include seed, fertilizer, chemicals, trucking and marketing, fuel, oil and lube, machinery repairs, building repairs, and utilities and miscellaneous costs. The costs used are obtained directly from 2014 Production Costs and Returns ($/acre) – AgriProfit$ Cropping Alternatives for Dark Brown soils, (AARD, 2014).

The input costs associated with the cow-calf enterprise were obtained from the Alberta cow-calf data set. The costs used were averages calculated over the five years period 2011-2015. Feed costs are not included here because they are addressed explicitly through production and use of crops. The non-feed beef costs used in this study include trucking and marketing, fuel, oil and lube, machinery repairs, corral and building repairs, utilities and miscellaneous, custom work, paid labour, veterinary and medicine and cattle purchases (i.e., purchased replacement bulls). Table 5.27 and 5.28 show the input costs associated with the crop enterprise and the cow-calf enterprise, respectively.

Table 5.27: Crops input costs for the representative farm ($/acre)

	Spring Wheat	Barley	Canola	Alfalfa-grass mix
Seed	7.44	5.67	13.02	1.31
Fertilizer (NPKS)	22.86	25.70	31.57	5.87
Chemical	14.69	5.42	12.89	0.56
Trucking & Marketing	9.91	12.33	5.51	8.48
Fuel, Oil and Lube	5.63	5.59	6.88	3.93
Machinery Repairs	5.22	5.12	6.39	4.05
Building Repairs	0.42	0.84	0.63	1.05
Utilities & Miscellaneous	2.43	2.83	3.24	4.05

Source: AARD (2014)

Table 5.28: Input costs associated with the cow-calf enterprise

Input	Cost ($/cow)
Trucking & Marketing	25.43
Fuel, Oil & Lube	20.08
Machinery Repairs	19.16
Coral & Building Repairs	15.04
Utilities & Miscellaneous	28.46
Custom Work	7.83
Paid Labour	13.76
Veterinary & Medicine	25.25
Cattle Purchases	284.13

5.3.3 Business Risk Management Programs

A number of public Business Risk Management (BRM) programs are offered in Alberta from the federal-provincial-territorial Growing Forward 2 Agreement. The main BRM programs include AgriInsurance, AgriStability, and AgriInvest. The body responsible for administering the BRM programs in Alberta is the Agricultural Finance and Services Corporation (AFSC), which is a Provincial Crown corporation (AFSC, 2017).

The study makes an assumption that the representative farm participates in the AgriInsurance and AgriStability programs and as such, these two programs are factored into the simulation analysis[7]. This study models these two programs based on the structure of AgriInsurance and AgriStability programs as implemented by AFSC.

[7] Both AgriStability and AgriInvest are public business risk management programs that are available to agricultural producers in Canada. While AgriStability provides protection from larger declines in income, AgriInvest is intended to address smaller fluctuations in income. Similar to AgriStability, participation in AgriInvest is voluntary. However, AgriIInvest is managed by the individual producers; producers can set up and manage their accounts at any Canadian bank.

5.3.3.1 Crop AgriInsurance Model

AgriInsurance program is a federal-provincial-producer cost-shared program that provides insurance coverage for annual crops to offset the economic effects of production losses caused by natural hazards. Coverage levels[8] of 50%, 60%, 70% or 80% can be selected for insurable crops by producers. The insurance policy provides a guarantee for yield and also guarantees a price for yield losses.

In a situation when there is a yield shortfall, an insurance payment is provided to the producer through AFSC. The payout level is determined through the use of spring insurance price (SIP), fall market price, risk area average yield, coverage rate, and actual yield (AFSC, 2017). There is a shortfall if the actual yield is less than the insured yield, where insured yield is the risk area average yield multiplied by the coverage level. With an assumption of a shortfall triggering a payout, the payout for crop insurance is given by the equation below.

Payout per acre

$$= (\text{Risk Area Average Yield} * \text{Coverage Level} - \text{Actual Yield}) * \text{SIP} \ldots\ldots\ldots \quad (5.15)$$

where the calculation in parentheses represent the loss in yield.

SIP is a predicted fall market crop price in spring that is based on analysis of historical and current prices as well as information or expectations regarding future price trends. In this study, SIP is calculated as the deterministic portion of the stochastic price equation; that is, the price calculated from the time series price equation without the stochastic error term. In other words, the price

[8] Coverage levels are defined as the percentage of the expected "normal" crop yield that are covered by insurance. The normal yield for a crop is based on the average of the yield records AFSC has gathered in their system through sources such as from harvested production reports, random audits conducted by AFSC adjusters to confirm how accurate harvested production reports are and yield information gathered by AFSC adjusters (AFSC, 2017).

based on the expected historical price relationships is used as the SIP. The fall market price is defined as the actual price of the insured crop after harvesting. The study uses the stochastic price generated from the estimated price model as the fall market price.

The actual crop yield is the yield drawn from the distribution in the model. The risk area average yield represents the "expected" yield for the producer. In the first year of the simulation this is equal to the historical average yield (i.e. the average yield of the de-trended yield). In the second year, the risk area average yield is calculated as the average between the first year risk area average yield and the yield drawn from the distribution in the second year (simulated yield for year 2). In the third year, risk area average yield is calculated as the average between the risk area average yield of year two and the yield drawn from the in the third year. In subsequent years risk area average yield follows the same calculations.

Variable Price Benefit (VPB) forms part of the AgriInsurance program. VPB insures crop yield against situations in which the SIP is significantly lower than the actual fall price. There is a payout of VPB for an insured crop when there is a yield shortfall and the fall market price of insured crop is at least 10% greater than the SIP. The VPB payout is equal to the yield shortfall multiplied by the difference between the fall market price and the SIP. This difference is capped at 150% of the SIP. The equation for the payout for the VPB is given below.

VPB per acre

$$= (\text{Risk Area Average Yield} * \text{Coverage Level} - \text{Actual Yield} \\ * (\text{Fall Market Price} - 1.5\text{SIP}) \tag{5.16}$$

where the calculations in parentheses represent the loss in yield.

Additional protection can also be purchased against price declines where the fall market price is at least 10% below the SIP. This is referred to as the Spring Price Endorsement (SPE). SPE payouts are limited to a maximum decline of 50% of SIP. With an assumption that the actual fall market price is not less than (0.5*SIP) and not greater than (0.9*SIP), the payout equation for the SPE is given below.

SPE per acre

$$= \text{Min (Actual Yield, Insured Yield Coverage)} * (\text{SIP} - \text{Fall Market Price}) \qquad (5.17)$$

As mentioned earlier, AgriInsurance program is a federal-provincial-producer cost-shared program and crop insurance premiums are jointly paid by the three parties involved in a ratio of 24:36:40 (AFSC, 2017). Due to this, the study assumes that 40% of insurance premium is paid by the producer. The producer's premium is calculated as the product of the dollar coverage and the producer's share of the premium rate. The premium also takes any applicable premium adjustments into account. This study assumes the producer chooses the 80% coverage level for all crops. The choice of the 80% coverage level is based on what is being practised in crop risk area 2 (as study area falls within this risk area). Table 5.29 shows the producer premium per acre for each crop in this study.

Table 5.29: Producer premium per acre of each crop ($/acre)

Crop	Premium
Spring Wheat	10.82
Barley	10.76
Canola	13.95

5.3.3.2 Hay Insurance Model

To qualify for insurance coverage, hay must be grown to be harvested mechanically for use as livestock feed. It is assumed that the hay produced by the representative farm is eligible for insurance coverage. The hay insurance is based on a production guarantee. When hay production is less than the guaranteed production and the loss is associated with an insured peril the shortfall is "covered" at the selected price option (AFSC, 2017). Insured perils include drought, excessive moisture, fire by lightning (in field only), flood, frost, hail, insect infestations, plant diseases, Richardson ground squirrel, snow, waterfowl and wildlife, wind, and winterkill.

New clients to the insurance policy start with the Risk Area average yield; that is, AFSC uses four years of risk area yields as the actual yield history of the new client. However, as the new client's annual yields become available, they replace the Risk Area average yields and every client develops his or her coverage adjustment to ensure stability (AFSC, 2017).

The annual yield of a farm is adjusted when an extremely high or low crop yield occur. Annual insurable yield is capped at (1.8 * the risk area average * adjustment coverage in previous year). In addition, when the actual yield is less than (70% * risk average yield for the same year * adjustment coverage in previous year), there is cushioning of the yield using a progressive formula (AFSC, 2017). In this study, the insurable yield "floor" is set at (70% * risk average yield * adjustment coverage in previous year) in order to simplify the process.

Similar to annual crops, clients can insure dryland hay at 50, 60, 70, or 80% coverage levels. The study sets the coverage level at 80%, which is the same as the crop insurance. There is a risk area "normal" yield calculated to reflect the hay yield clients are expected to achieve in a normal year (AFSC, 2017). The risk area "normal" yield used in this study follows the approach used by Trautman (2012). The risk area "normal" yield was determined as a simple average of yields from historic data (Trautman, 2012). The risk area "normal" yield estimated for this study is 3,434 kg per acre.

Hay insurance payouts are calculated in a manner similar to insurance for annual crops, including a VPB. VPB is also an option in AFSC hay insurance. The producer also pays 40% of the insurance premium. The producer premium per acre in this study is $ 2.27.

5.3.3.3 AgriStability

The AgriStability program provides protection against large margin declines for producers in their farm operation (AFSC, 2013). AgriStability provide payments equal to 70% of the decline in margin below a "trigger point" which is equal to 70% of a historical average margin (AFSC, 2013). AgriStability payments are calculated based on a production margin (PM), which is Allowable Income (AI) minus Allowable Expenses (AE) (AFSC, 2013). The revenue from the sale of crops, excess hay from inventory, sale of beef and residues is assumed to be the AI in this study. The AE is assumed to be the total input costs, with the exception of machinery replacement cost, for the crop production.

If a producer's PM in a particular year is less than 70% of the reference margin (RM), a payment is triggered. The RM is calculated as the Olympic Average[9] of the previous five years PM (AFSC, 2013). When initiating participation, if the producers has been farming for at least three years, the RM is calculated based on the previous three production margins. Conversely, if the producer has been farming for less than three years, industry average margins (per unit) are used to construct up to three production margins for the operation. The RM is then the average of these three production margins (AFSC, 2013).

[9] The Olympic Average is calculated by omitting the highest and lowest margins of the five years' production margins prior to the program year and averaging the remaining three (AFSC, 2013).

The AgriStability payout version modeled in this study is calculated as follows:

$$\text{AgriStability payment} = \begin{cases} 0, & \text{if PM} \geq 70\% \text{ of RM} \\ 70\% * (70\% \text{ of RM} - \text{PM}), & \text{if PM} < 70\% \text{ of RM} \end{cases} \tag{5.18}$$

In order to be considered as an eligible participant, producers are expected to pay a fee prior to the deadline. The participation fee is $4.50 for every $1,000 ($0.0045 per $1) of contribution RM, multiplied by 70% (AFSC, 2013). The minimum fee is $45 and an annual Administrative Cost Share (ACS) fee of $55 is also charged (AFSC, 2013).

5.4 Beneficial Management Practices (BMPs)

The main of objective of this study is to assess the economics of adopting select BMPs for a representative mixed crop-beef farm in southern Alberta. The BMPs under consideration are chosen based on discussion with AAF; that is, BMPs of interest to the provincial government for agricultural production in the study area. This section discusses the scenarios for each BMP and how each BMP is modeled on the representative farm.

5.4.1 Crop Residue Management

As defined earlier, crop residues are described as parts of the plants left over in agricultural field after harvesting of crops. Crop residues play a number of essential functions as discussed in section 2.5.1 of this study. The crop residue management BMP modeled in this study follows a similar approach to that used by Trautman (2012).

The baseline scenario in this study assumes that residue[10] (straw) from spring wheat and barley is baled every year and either sold or (as needed) kept for bedding. Residue from canola is left in the field. Crop residue "yield" is modeled as a proportion of the stochastic crop grain yield, based on information adapted from AARD (2008). The crop residue proportion of crop yield for spring wheat is 1.42, barley is 0.83 and canola is 1.30, where these values represent the yield of straw relative to the grain yield. For example, the amount of straw generated per acre for wheat is obtained by multiplying the stochastic wheat yield by 1.42.

As is the normal practice in the study area, a portion of baled barley straw is set aside to be used by the animals as bedding material. According to Raven (2016), on a daily basis, 100 animals (cattle) require 900 pounds of bedding material. Based on this, the required amount of barley straw is stored each year. Any straw over and above the amount required for bedding is sold. A price of $25 per 544 kg bale is assumed (AAF, 2016). Costs for baling and removing straw are charged at custom rates of $11.30 and $7.89 per 544 kg straw bale respectively (SAF, 2008).

The stochastic yield for each crop is assumed to be affected by the residue management strategy implemented by the producer. Specifically, the yield will potentially be affected by a combination of whether or not residue was retained on the field in the previous year and moisture conditions in the current year. The yield effect may be positive or negative, depending on the combination of residue/moisture conditions. Based on Lafond et al. (1992; 2009), crop yield will potentially be increased (decreased) in a dry year if crop residue was retained (removed) on the field in the previous year. In a wet year, crop yield will potentially be reduced if crop residue was retained in

[10] Here, the terms residue and straw are used interchangeably.

the previous year. The assumption is made that there is no yield effect in wet years if crop residue was removed in the previous year.

The yield effects from crop residue management are assumed to be stochastic. In the simulations they are modeled using draws from uniform distributions. Minimum and maximum values for the yield effects are determined based on studies by Lafond et al. (1992; 2009). These values were also used by Trautman (2012). Table 5.30 provides the minimum and maximum values of residue effects on crop yield.

Table 5.30: Minimum and maximum effects on crop yield (as % change from normal) from crop residue removal

Moisture Conditions	Residue Removal?	Minimum	Maximum
Dry	No	0%	3%
Dry	Yes	-3%	0%
Wet	No	-12%	0%
Wet	Yes	0%	0%

Source: Lafond et al. (1992; 2009)

As noted earlier in the discussion of crop yield modeling, weather conditions (e.g., growing season precipitation) are not explicitly modeled in this study. As a result, for the purposes of modeling the effects of crop residue management, a wet year is defined as one where the crop residue (in kg/acre) is greater than the average production level plus one standard deviation. A dry year is considered as the year where the crop residue is less than the average production level minus one standard deviation. Years for which yields are no greater (lower) than the average plus (minus) one standard deviation are considered to be "normal" and there are no yield effects from crop residue decisions.

The crop residue management BMP involves removing spring wheat and barley residue once every four years in any given field, as opposed to every year. Canola residue continues to be retained on the field every year. When left in the field, crop residues play a number of essential functions such as maintenance of soil moisture, accommodation of beneficial microbes, recycling of plant nutrients and increasing soil organic matter (Oo and Lalonde, 2012). However, there are potential trade-offs depending on moisture conditions, along with loss of revenue from sale of straw; and these are considered in modeling the economics of adoption.

5.4.2 Manure Management

The application of manure is considered as a BMP because the use of manure generated from wintering site can reduce cost of inorganic fertilizer and increase soil organic matter. This section discusses the method and benefit of applying manure.

According to SSCA (2008), the proper application of manure requires knowledge of nutrient content of the manure, determination of nutrients available in the soil, and the ability to match crop nutrient demand to total nutrients applied and strategy for application. In Alberta, manure can be applied based on soil nitrogen limits, the nitrogen requirements of intended crops, or the phosphorus requirements in one or more years of crop production (AAF, 2015a).

Manure application for both the baseline and BMP scenarios depends on the quantity of manure generated by the beef enterprise. It is assumed that manure produced during the winter period (i.e., when cattle are not on pasture) is applied to fields used for annual crop production. According to Statistics Canada (2006), daily production of manure varies by type of beef animal; bulls produce 42 kg/day, beef cows produce 37 kg/day and heifers produce 24 kg/day. In this study, the representative farm is made up of 160 beef cows, 30 replacement heifers and 8 bulls.

Manure produced per day based on number of animals for representative farm is calculated as follows:

(37 kg/cow * 160 cows) + (30 kg/heifer * 24 heifers) + (42 kg/bull * 8 bulls) = 6,976 kg/day

Assuming a three month wintering period, and 30.5 days per month, total manure produced by the animals in a year is calculated as follows:

(6,976 kg/day * 30.5 days/month * 3 months) = 638,304 kg or 638.304 tonnes

Nutrient content of manure is often expressed on a dry matter equivalent basis. As noted by AAF (2015a), manure contains approximately 50% moisture. As a result, total dry matter of manure produced by the beef herd during the winter period is 50% of 638,304 kg (638.304 tonnes), or 319,152 kg (319.152 tonnes). Table 5.31 provides representative nutrient content for beef manure, based on information from AAF (2015a). Using these values, the manure produced by the representative farm's beef enterprise contains 2,904.28 kg of total N (of which 734.05 kg is NH_4-N), 1595.76 kg of P, and 2,329.81 kg of K.

Table 5.31: Nutrient content of manure

Total N	NH_4-N	P	K	S	Moisture	Loss of NH_4-N in 48 hours
		kg/tonne				
9.1	2.3	5	7.3	0	50%	15%

Source: AAF (2015a)

Availability of nutrients from manure depends on the mineralization rate. Mineralization is defined as the process where microbes convert the organic portion of manure into inorganic materials. These inorganic materials are essential plant nutrients such as nitrogen, phosphorus and potassium. Table 5.32 provides representative mineralization rates for manure nutrients by year following application. For example, 25% of total organic N in the manure is mineralized in the first year following application.

Table 5.32: Mineralization rate of organic nutrients

	N	P	K	S
1st year	25%	70%	90%	0%
2nd year	12%	20%	0%	0%
3rd year	6%	6%	0%	0%
Total	43%	96%	90%	0%

Source: AARD (2008)

For the purposes of the baseline and BMP scenarios in this study, the key nutrient is nitrogen. Total organic N in the 319.152 tonnes of manure generated by the beef enterprise is calculated as the difference between total N and ammonia N (NH_4):

$$(2,904.28-734.05) = 2,170.23 \text{ kg}$$

Mineralized N from total organic N in the first year following application is:

(0.25 * 2,170.23) = 542.56 kg

Available N from NH_4-N from the 319.152 tonnes of manure produced by animals in a year is

(734.05 * (1-0.15)) = 623.94 kg

where the (1-0.15) adjustment is to reflect the 48 hours loss in N after application (i.e., as per the information in Table 5.32).

Total available N in the first year of application is thus (623.94 + 542.56) = 1,166.50 kg.

In the baseline model scenario, manure is applied using the maximum allowed application rate. This is based on the soil nitrate nitrogen limit for Dark Brown Medium and Fine Textured Soils which is 170 kg/ha (68.80 kg/acre), as discussed in Chapter 2 (Table 2.3). Based on this application rate, the available N from total manure production (1,166.50 kg) is applied on approximately 17 acres (i.e. 1166.5 kg divided by 68.80 kg/acre) of land.

For the manure management BMP, the strategy is to apply manure based on one-year N requirement of crops. This approach was also used by Xie (2014) in modeling a manure management BMP for irrigated crop production in southern Alberta. In the current study, it is assumed that the manure is applied on spring wheat, based on the one-year N requirement for spring wheat.

The nutrient requirement per acre for each crop in this study is assumed to be constant in each year and is based on the fertilizer rates provided by the 2014 AgriProfit$ Cropping Alternatives (AARD, 2014), shown by Table 5.33.

Table 5.33: Annual nutrient requirements for dryland crops in Southern Alberta (kg/acre)

Crop	N	P_2O_5	K_2O	S
Spring wheat	27.2	11.3	2.3	0
Barley	31.8	11.3	2.3	0
Canola	34	13.6	4.5	6.8

Source: AARD (2014)

Given the N requirement of 27.2 kg per acre for spring wheat, there is sufficient available N from total manure production to apply manure on 42.89 acres of wheat; that is, 1,166.5 kg available N divided by 27.2 kg N per acre.

There is evidence that manure application provides a yield boost for grain crops (Lupewayi et al., 2005). Based on this literature and prior work by Xie (2014), the gains in crop yields from this source are assumed to within the range of 1% to 5%. Therefore, an average gain in crop yield of 3% on land applied with manure is factored into both the base model scenario and the BMP scenario.

5.4.3 Rotational Grazing

Rotational grazing is considered as a BMP because of the potential benefits for soil quality. By allowing pasture time to regrow before being grazed again, soil productivity is enhanced. The importance of practising rotational grazing is discussed in detail in section 2.5.4. This section discusses how rotational grazing BMP is implemented on the representative farm.

In the baseline scenario, it is assumed that grazing occurs on both the native pasture and the tame pasture without rotational grazing. In other words, the entire pasture area is available to the beef herd throughout the grazing season.

In the BMP scenario, the tame pasture land (656 acres) is split into two “partitions” for rotational grazing purposes. In this study, it assumed that native pasture is leased rather than owned (possibly Crown land) and is not considered for rotational grazing. It is also assumed that there is already one off-stream watering site present in one of the tame pasture partitions. As a result, when adopting this BMP it is necessary to construct an additional off-stream site in the other partition to ensure that cattle have consistent access to water. The investment cost per cow for constructing the off-stream watering site is \$39.25 per cow (Dollevoet, 2010). The total cost for constructing the off-stream watering site is \$7,771. The breakdown and source of this investment and maintenance cost is provided in Appendix C.

The tame pasture is partitioned by the use of temporary fencing. The length of the temporary fence constructed is 5,345.59 ft[11]. The fence is constructed at the cost of \$0.206 per foot with an annual maintenance fee of 10% of the total investment. The breakdown and source of this investment and maintenance cost is provided in Appendix C.

The impact of rotational grazing is to increase the ability to more fully utilize available forage provided by pasture; that is, increase the AUMs per unit of area for pasture. However, this impact

[11] The tame pasture area to be fenced is 656 acres. These acres are converted into square feet (28,575,360 ft^2). The entire area is assumed to be a square with sides of 5,345.59 feet. It is assumed that there is an already existing fence around the tame pasture and so a fence of 5,345.59 feet in length is constructed to partition the pasture.

is unknown; that is, no information was found in the literature to justify a particular degree of improvement. Therefore, the study models alternative degrees of increased utilization that result in different levels of increase in AUMs. In the base case scenario of this study, the animals are assumed to utilize half of the available forage produced from the pasture effectively. The use of rotational grazing leads to improvement in pasture productivity, thereby resulting in increasing forage availability and increase in AUMs. As available forage increases, animals are expected to utilize more forage relative to the base case scenario in this study. The annual increase in pasture forage utilization (measured in AUMs) is increased from the base case scenario by 0.2%, 0.25%, 0.5%, 1% and 1.5%.

As well, there is no definitive information available about the length of time over which productivity increases as a result of the BMP; that is, whether it increases for one year, two years, etc. The "base" value used for the BMP, and the one used for the alternative levels of increase from the previous paragraph, is four years; that is, pasture productivity increases by a given percentage annually for the first four years following adoption and then remains constant. To test the sensitivity of the results to changes in duration, the annual increase in pasture forage utilization is held constant at 1% with the number of years of improvement being alternatively set at three, four, five, and six years.

With the adoption of this BMP, the productivity of the tame pasture is increased. This results in a change in total days of grazing available to the herd and therefore both the length of the grazing season and the length of the winter feeding period. Adjustments are made in winter feeding costs accordingly.

5.4.4 Enhancing Tame Pasture Productivity through Incorporation of Legumes

Enhancing tame pasture productivity through incorporation of legumes is considered as a BMP because the use of a leguminous plant such as alfalfa improves pasture productivity thereby increasing grazing season days and reducing the cost associated with winter feeding. Incorporation of alfalfa leads to much improved forage quality and hence feeding value (Raven, 2016). This section discusses how the incorporation of alfalfa into tame pasture is modeled in this study.

In the base case scenario, the study assumes that tame pasture is not reseeded by producers. Based on expert opinion, for the BMP scenario a portion of tame pasture is removed from use each year and reseeded. Two alternative BMP scenarios are modeled that differ in terms of the length of time between reseeding; specifically, reseeding is done either every five years or every seven years. The study models this by dividing the tame pasture land into five or seven "partitions"[12] and reseeding a portion every year with alfalfa.

The introduction of alfalfa increases pasture productivity. Available information suggests that productivity of alfalfa as pasture is 1.8 AUM/acre in the Dark Brown soil zone (SFC, 2007). However, deriving an appropriate productivity for the tame pasture after reseeding with alfalfa proved to be challenging. Given that the alfalfa is seeded into what is initially grass pasture, the study uses an average of the initial productivity for tame pasture from baseline scenario (1.54 AUMs) and the 1.8 AUM suggested by SFC (2007) as the initial AUM value for the BMP. Thus, the initial productivity of the tame pasture after reseeding with alfalfa is 1.67AUM/acre. Since there is uncertainty surrounding these figures, sensitivity analysis is undertaken by increasing the productivity over and above this value by 10%, 25%, 50%, and 70%.

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[12] These are not true partitions in the sense of dividing the tame pasture into five or seven paddocks. Instead, it is assumed that either $1/5^{th}$ or $1/7^{th}$ of the tame pasture area is removed each year and reseeded.

The seeding cost per acre for alfalfa is $1.31. This value is obtained from the 2014 AgriProfit$ Cropping Alternatives (AARD, 2014). The tame pasture areas reseeded annually when the tame pasture land is divided into five and seven partitions are 131.2 acres and 93.71 acres, respectively. Therefore, the total seeding costs per year when the tame pasture land is divided into five and seven partitions are $172.03 and $122.88, respectively. The total cost for breaking and preparing the soil for seeding each year in the case of dividing the tame pasture land into five is $5,490.64 and that of dividing the tame pasture land into seven is $3,921.89. These costs are adapted from costs used for similar analysis by Dollevoet (2010). There is also a cost associated with constructing a temporary fence around the seeded portion to prevent access by the cattle. The length of the fence is 10,691.18 feet[13], which is constructed at a cost of $2,202.38 ($0.206 per foot). The breakdown and source of this investment cost information is provided in Appendix D.

With the adoption of this BMP, total area of tame pasture is reduced each year, by the area removed to be reseeded. At the same time, the productivity of the remaining tame pasture is increased. The net result is a change in total days of grazing available to the herd, thus affecting the length of the grazing season and the length of the winter feeding period. Adjustments are made in winter feeding costs accordingly.

5.4.5 Conservation of Natural Areas (retirement of native pasture area)

Conservation of natural areas is regarded as a BMP because it is done to protect and maintain biological diversity and natural and associated cultural resources. Conserved areas can provide valuable services such as soil regeneration, nutrient cycling, pollination, recreation, provision of

[13] The tame pasture area to be fenced is 656 acres. These acres are converted into square feet (28,575,360 ft^2). The entire area is assumed to be a square with sides of 5,345.59 feet. It is assumed that there is an already existing fence around the tame pasture and so a fence of 10,691.18 feet in length is constructed to partition the pasture.

pure water, continued evolution of genetic resources and maintenance of the functioning ecosystem which yields harvestable resources. A version of this type of BMP is assumed to be adopted by the representative farm, in the form of retirement of a portion of native pasture.

The base case scenario assumes that the animals are allowed access to every part of the pasture without any restriction. In the BMP scenario, a section (i.e., 640 acres) of the native pasture is set aside and "retired" from use. A permanent fence is constructed around the section of conserved land to prevent cattle from accessing the area. As a result of the section of native pasture land set aside, the grazing season length is reduced and results in increased days of winter feeding. This in turn affects winter feeding costs, as additional hay is assumed to be purchased to supplement winter feeding.

The length of the permanent fence is 9,631.48 feet[14], which is constructed at a cost of $7,691.08 ($0.7985 per foot). The annual maintenance cost of the fence is 10% of the total investment cost. The breakdown and source of the investment and maintenance cost information is provided in Appendix E.

5.5 Simulation and Cash Flows for Beneficial Management Practices Analysis

The study uses cash flow simulation to assess the economics of adoption of BMPs, described in the previous sections, for a mixed crop-beef farm. The study uses annual cash flow to determine the yearly performance of the representative farm. The series of net cash flows for each scenario are converted into Net Present Values (NPV). The analysis of the farm models is done using Monte Carlo simulation. The study compares the simulated NPV results of the representative farm

[14] The native pasture area to be fenced is 2130 acres. These acres are converted into square feet (92,765,376 ft^2). The entire area is assumed to be a square with sides of 9,631.48 feet. It is assumed that there is an already existing fence around the tame pasture and so a fence of 9,631.48 feet in length is constructed.

without and with the BMPs. The differences generated are regarded as the economic impacts of the BMPs on the representative farm.

5.5.1 Number of Iterations in Simulation Analysis

The study conducts dynamic Monte Carlo cash flow simulation using the Excel add-in @Risk (Palisade Corporation, 2010). For each iteration, @Risk draws a new set of random numbers from the pre-modeled probability distributions and recalculates all Excel worksheets using the new selected values. The generation of the distribution results from repeating this for a number of iterations. The Excel add-in @Risk (version 5.7) has different numbers of iterations (e.g., 100, 500, 1,000, 5,000 and 10,000) that can be chosen.

Although the number of iterations one can select for an analysis depends on the nature of the analysis, Barreto and Howland (2006) suggest that Monte Carlo simulation is always an approximation to the exact truth because the exact truth, in a context of sampling, is based on an infinite number of iterations. In many cases 1,000 iterations will usually generate a fairly good approximation, but 10,000 would even be closer to the truth (Barreto and Howland, 2006). Again, according to Barreto and Howland (2006), Monte Carlo simulation cannot be used to generate the exact right answer, but an increasingly good approximation can be generated as the number of iterations is increased. However, there is a trade off between the number of iterations and the amount of time required for the simulation to be completed

Both a t-test and Kolmogorov-Smirnov (K-S) test were performed to compare model results using 10,000 iterations with model results using 15,000 iterations, and model results using 10,000 iterations with model results using 25,000 iterations. The paired t-test and the K-S test were conducted based on the null hypotheses that means from models using 10,000 iterations and 15,000 iterations, and means from models using 10,000 iterations and 25,000 iterations are equal. None of the null hypotheses was rejected. However, it took a longer time to produce results for 15,000 and 25,000 iterations, compared with the 10,000 iterations. The tests statistics are reported in Appendix F. The study uses 10,000 iterations (which is the highest default value for the number of iterations in @Risk version 5.7) in order to achieve a balance between accuracy and time.

5.5.2 Time Horizon for the Simulation

A dynamic simulation analysis (i.e., over multiple years) is used in this study. This is done at least in part because of the dynamic nature of the crop rotation used by the producer (i.e., spring wheat, barley, canola and perennial forage), as well as the dynamic aspects of the business risk management programs (e.g., historical margins used to determine coverage for AgriStability).

A choice of time horizon is required for the simulation analysis The time horizon used for the analysis is 20 years. A 20-year simulation model is chosen due to the long-term nature of some of the BMPs. For example, the pasture reseeding BMP takes five or seven years to fully implement in this study. As well, the impact of BMPs such as manure management and rotational grazing in terms of soil quality may take several years. It was felt that 20 years was sufficient to allow for full implementation and effects for the various BMPs.

5.5.3 NPV Calculation and Use

As mentioned earlier, the time horizon used for the simulation in this study is 20 years. The 20 years of cash flows are used to calculate an NPV for each scenario (i.e., baseline and alternative BMPs). However, ending the analysis at 20 years ignores the impact of any changes to the farm in terms of subsequent cash flows beyond the 20 year time horizon. Given that NPV is used as a proxy for wealth in this study, it is appropriate to consider cash flows into perpetuity. Since an infinite time horizon for the simulation model is impractical, an alternative approach is used. The NPV is calculated in perpetuity; that is, the stream of cash flows from the representative farm is assumed to continue indefinitely into the future. The approach of calculating the NPV in perpetuity is given by Equation 5.20.

$$NPV_{perpetuity} = \sum_{t=1}^{20} \frac{(C_t)}{(1+r)^t} + \frac{C_{20}}{r} \frac{1}{(1+r)^{20}} \quad (5.20)$$

where C_t is the cash flow at time t (t = 1 to 20), and r is the interest rate. In other words, the net cash flow in the final year of the simulation (year 20) is assumed to continue in perpetuity. That cash flow (C_{20}) is treated as an infinite annuity and converted to a year 20 present value through dividing by the discount rate (r), and is then discounted to a year 0 present value.

The NPVs obtained from the baseline and BMP simulation analyses are used for the purposes of calculating the net benefit or cost associated with BMP adoption. The difference between the NPVs (in perpetuity) for the BMP scenario and the baseline scenario is calculated and interpreted as the impact of BMP adoption on wealth. Positive differences represent net "benefits" while negative differences represent net "costs". Depending on the specific BMP being examined, this difference in wealth is converted to an annualized value per acre for the purposes of comparing annual net benefits or costs per acre for the various BMP scenarios. The annualized NPV difference equation is shown as Equation 5.21

$$A = \Delta NPV * r \quad (5.21)$$

where A is annualized NPV difference, ΔNPV is the difference between BMP and baseline NPVs, and r is the discount rate. The annualized difference (A) is then converted to a per acre value. In each case, the area used to convert to a per acre value is the area affected by the BMP. For example, in the case of the natural area conservation BMP, the area used to convert the difference is 640 acres (i.e., the area retired from use).

5.5.4 Chapter Summary

The chapter uses statistical data and expert opinion to build a representative mixed crop-beef farm in southern Alberta. The land base for crop, forage and pasture production as well as the dynamics of cow-calf herd are identified.

Based on the historical data, stochastic crop price, crop yield and beef price models are estimated. These stochastic parameters are used to generate production revenue and production costs. Agricultural insurance programs are modeled by incorporating the built stochastic parameters. Net Cash Flows are converted into net present values.

The model is able to analyse the five BMPs that are considered for implementation on the representative farm. The adoption of each BMP will lead to changes in aspects of the representative farm such as forage acreage, crop yields, production costs and revenue. The changes in net present values with and without the adoption of BMP are considered as the on-farm benefits or costs of BMP adoption.

CHAPTER 6 : RESULTS AND DISCUSSION

This chapter presents and discusses the results of the study. This includes results and discussion for the baseline scenario, the BMP scenarios as well as BMP sensitivity analyses. The discussion compares both the BMP scenarios and sensitivity analyses with the baseline scenario to assess the economic impacts of producers adopting BMPs on the representative farm.

6.1 Baseline Scenario Results

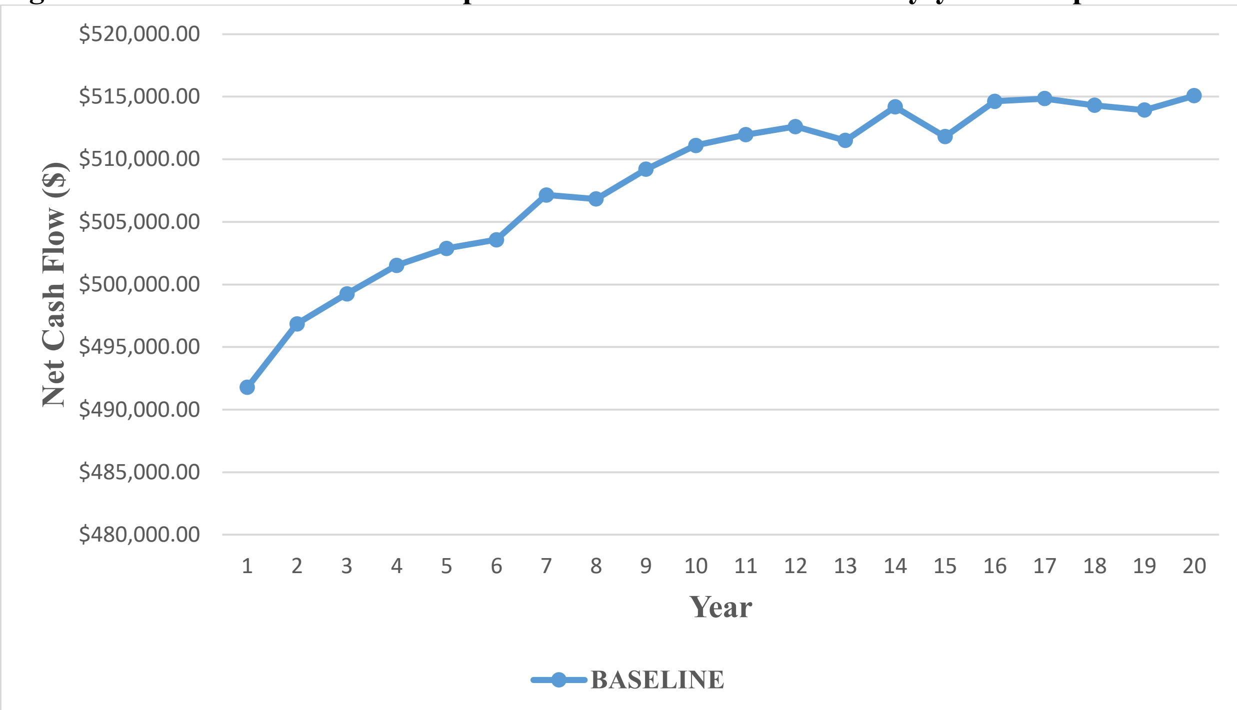
In the baseline scenario, it is assumed that none of the BMPs are adopted by the producer. The results of the baseline scenario for the representative farm are used as the basis for comparing the changes arising from the adoption of the BMP and the sensitivity analysis. All the relationships modeled and described in Chapter 5 are simulated to provide the baseline output for all aspects of the representative farm. Table 6.1 gives summary statistics of the baseline scenario for the representative farm that will be used to compare each BMP scenario and sensitivity analysis.

Table 6.1: Baseline results of the representative farm

Mean Farm NPV	$4,309,286.49
Standard deviation	$743,658.53

Figure 6.1 shows the annual mean cash flow of the representative farm over the twenty-year time period. The cash flow increases from year one to year twelve and after, fluctuates around $515,000.

Figure 6.1: Net cash flow of the representative farm over the twenty-year time period



6.1.1 Validation of the Representative Farm Model

Validation is the process of examining the degree to which a model accurately represents the real world from the perspective of the objectives of the model (Sargent, 2011). According to Sargent (2011), model validation is concerned with building confidence among potential users about the use of the model and in the information obtained from that model.

In previous farm-level BMP studies (Koeckhoven, 2008; Trautman, 2012; Xie, 2014), validation has been done by comparing the results from the baseline scenario (i.e. NPV values) to land values. The justification for this approach is that the NPV (in perpetuity) can be interpreted as a wealth measure. As such, in principle it should be related to the value of land, which makes up the biggest part of the asset base for the business. In theory, value of land is determined by agricultural productive capabilities, which are reflected in the NPV measure.

Historical average land values are available, by county, from AAF. Averages are provided for different "classes" of land as rated by the Canada Land Inventory (CLI) rating system. CLI classification is based on agricultural capability of land, taking into account any limitations associated with soils, climate, topography, etc. CLI ratings go from class 1 to class 7 with higher numbers representing greater limitations associated with agricultural use.

The study uses 2011-2015 average land values (based on agricultural real estate transfers) for the study area (i.e., Lethbridge, Willow Creek and Vulcan counties) to compare with baseline simulation results. Tables 6.2 and 6.3 show the NPVs with perpetuity per acre for the representative farm and the agricultural real estate values ($ per acre for the different classes) from AAF respectively. The agricultural real estate values used are averages from year 2011 to 2015. The NPVs are converted to per acre values to be comparable with the reported land values.

Table 6.2: NPVs in perpetuity per acre for the representative farm

	Acreage	NPV in perpetuity per acre ($/acre)
Crop and Tame pasture combined	2,656	$1,622.47
Crop only	2,000	$2,154.64

Table 6.3: Average (2011-2015) Agricultural Real Estate Land Values ($ per acre)

Area	CLI1	CLI2	CLI3	CLI4	CLI5	CLI6
Lethbridge	$4,224.44	$4,818.53	$3,792.32	$2,120.42	$627.02	$3,266.48
Willow Creek	-	$2,555.39	$3,542.22	$2,932.97	$2,900.19	$5,753.72
Vulcan	$3,289.59	$1,979.28	$2,961.96	$2,778.31	$1,898.67	$1,223.19

Source: AAF, (2015b).

In this study, it assumed that native pasture is leased rather than owned (possibly Crown land) and so it is excluded from consideration here. The result is a mean NPV of $1,622.47 per acre. However, this is calculated over both cropped land and tame pasture. The two types of land may well be very different in terms of land quality (i.e., lower quality for pasture area), but the wealth cannot be divided between the two areas. Assuming that pasture has significantly lower value, the wealth per acre for cropped area could be calculated as $2,154.64. In this study, the wealth per acre for cropped area ($2,154.64) is considered as the upper limit of potential land value (based on productivity) for the representative farm.

As shown by Table 6.3, there is significant variability across CLI classes and between counties, and that pattern is not consistent. The variability across CLI classes and between counties as well as the inconsistent pattern can be possibly due to a) small numbers of land transactions, b) factors other than CLI class impacting on value (e.g. proximity to urban areas, improvements present on parcels, size of parcels). This limits the ability to do a rigorous validation exercise.

The study considers the representative farm to consist of land in Classes 2 and/or 3, as they represent productive land if managed properly and there is limited amount of Class 1 land in the study region. The land value implied from the simulation results (for both full area and cropped area only, as shown by Table 6.2) is lower than averages for these two land classes. The closest are Class 2 land in Willow Creek and Vulcan County.

The differences may be attributed to non-agricultural factors such as oil/gas and proximity to urban areas affecting price of land in real estate transactions. Again, irrigation may also play an important role in terms of the differences. Ability to irrigate land increases effective productivity of land (i.e. reduces or removes limitations associated with moisture), allowing for higher crop values to be produced, with resulting upward impact on the value of land. Irrigation is used throughout the study region (including the three counties used for comparison here), and is particularly prevalent in Lethbridge County. Table 6.4 shows the use of irrigation in agriculture for the selected areas for comparison for the year 2011 (i.e., most recent Census of Agriculture data available at the time of the analysis). From Table 6.4, prevalence and effect of irrigated production likely explains differences between land values for Lethbridge County versus Willow Creek and Vulcan County, for Classes 1, 2, and 3.

Table 6.4: Use of Irrigation: Lethbridge County, Willow Creek and Vulcan County – 2011

	Lethbridge County	Willow Creek	Vulcan County
Total number of farms	933	772	603
Total area of farms - Acres	514,337	437,293	885,191
Number of farms reporting use of irrigation	558	98	118
Irrigated acres	215,201	37,330	80,721
% irrigated acres out of total farm area	41.84	8.54	9.12

Source: 2011 Census of Agriculture, Statistics Canada.

Given the magnitude of the implied land value from the simulation model relative to market land values in the study area, and the non-agricultural factors that could affect those market values, it is concluded that the model is valid for use in this study. Therefore, this model is used in predicting the costs and benefits of adopting a BMP in the study area.

6.2 Results of BMP Scenarios

6.2.1 Beneficial Management Assessment

As discussed in Chapter 5, the NPV results for the various model scenarios are used to assess the financial impact of BMP adoption on the representative farm. In the case of each BMP, the NPV for BMP adoption and NPV from the baseline scenario are annualized. The difference between the annualized NPV for the baseline scenario and the annualized NPV for a BMP scenario determines the annual net cost or benefit associated with the adoption of that particular BMP. The annualized

NPV is obtained on per acre basis by dividing the difference by the farm acreage affected by the particular BMP to obtain the net benefit or cost per acre.

6.2.2 Crop Residue Management

As discussed in the previous chapter, the baseline scenario in this study assumes that crop residue of spring wheat and barley straw is baled every year and either sold or (as needed) kept for bedding. In the BMP scenario, the study assumes that residues of spring wheat and barley are removed once every four years from any given field, other than the amount needed for winter bedding. Residue from canola is left in the field.

The assessment of the effect of crop residue management BMP on farm performance is carried out by comparing the results of the BMP scenario with the results of a revised baseline scenario; that is, the baseline scenario for the representative farm (with no BMP adoption) is re-simulated, taken into account that residues from spring wheat and barley are removed and either sold or (as needed) use for bedding. The revised baseline simulation was required in order to account for yield effects associated with both the baseline scenario and the BMP scenario.

The average annual net return per acre from sale of crop residue for the baseline scenario is $30.65. This value is reduced by 75% ($7.66) following the implementation of the BMP. The average annual net return per acre was calculated by finding the average of the yearly net return from sale of crop residue on per acre basis. The yearly net return from sale of crop residue values were obtained by dividing net return from sale of crop residue in each year (calculated as revenue from the sale of straw bales minus custom rate of baling and bale removal cost) by the acreage of crop under consideration.

Table 6.5 shows the results for the baseline and BMP scenarios. The mean NPV decreases by approximately 2.8% when crop residue management BMP is adopted by the producer. The annualized NPV difference per acre, calculated as the difference between the baseline scenario amount (given as the product of the present value and the discount rate) and the BMP scenario amount divided by acreage of farm under consideration, is -$6.03. Since this BMP is related to the crop production part of the representative farm, the amount obtained by subtracting the baseline scenario amount ($430,928.649) from the BMP scenario amount ($418,869.459), is divided by 2,000 acres (total crop acreage of the representative farm).

Table 6.5: Simulation Results for the crop residue management BMP

	Baseline scenario	**BMP scenario**
Mean NPV	$4,309,286.49	$4,188,694.59
Standard Deviation	$743,658.53	$741,747.03
Annualized NPV[a]	$430,928.649	$418,869.459
Annualized Difference/Acre[b]		-$6.03*

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference per acre is calculated by taking the difference between the annualized BMP scenario NPV and the baseline scenario BMP and dividing by the area affected by the BMP; in this case the 2,000 acres of annual cropland.
*Indicates significance at the 5% level.

The results from Table 6.5 indicate that there is no improvement in expected NPV with adoption of the BMP; that is, there is a net cost associated with the BMP. If expressed on an annual benefit per acre, it is equal to -$6.03, which represents a relatively small negative impact on the farm. It can also be noticed from Table 6.5 that there is a small decrease in variability, as indicated by the standard deviation. The adoption of this BMP results in loss of returns from retaining the crop residue; that is, foregone opportunity for sale of crop residue. The results of the BMP therefore suggest that the cost of the forgone opportunity to remove and sell crop residue together with the potential for reduced yield in some years (pertaining to retaining crop residue in wet years) is not offset by the benefit associated with yield increases when crop residue is retained in dry years.

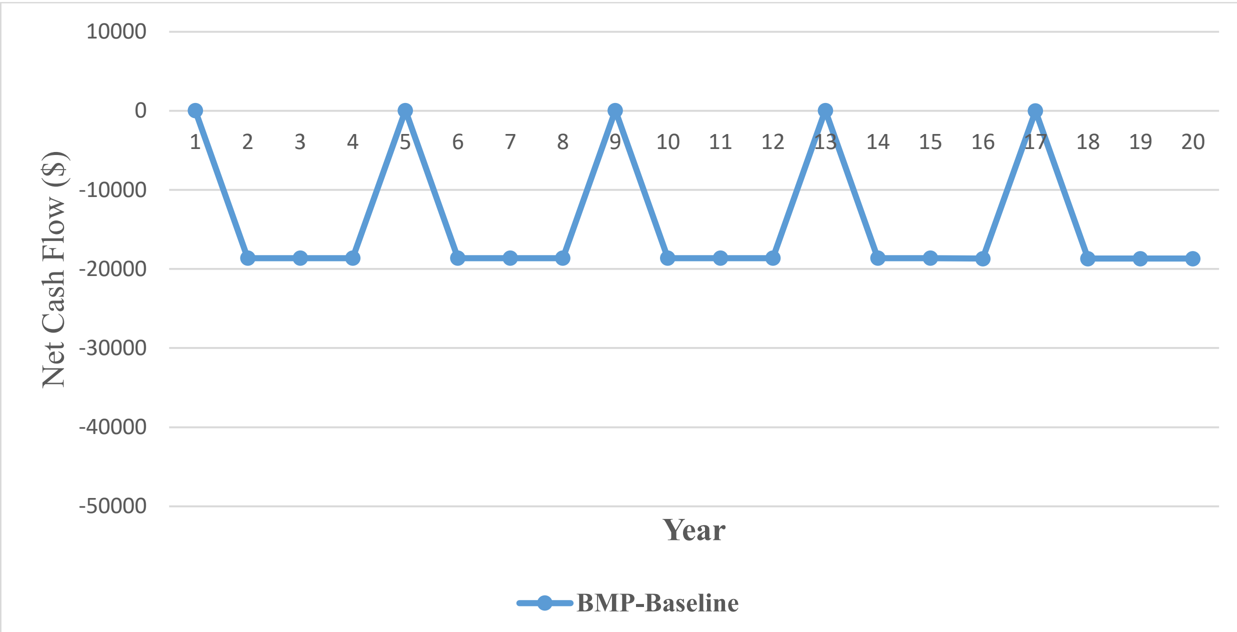
The t-test conducted to compare the baseline scenario and the BMP scenario mean NPVs showed that there is significant difference between the two means. However, from an economic point of view, the annualized NPV per acre obtained from the results is relatively small and as such, may be insignificant to the producer; that is, there may be no economically significant impact associated with adoption.

Figure 6.2 compares the annual net cash flows of the baseline scenario with the BMP scenario over the twenty-year period. The differences in mean annual net cash flows between the BMP and baseline scenario are graphed in Figure 6.2. As mentioned earlier, in the baseline scenario, it is assumed that crop residue of spring wheat and barley is baled every year and either sold or (as needed) kept for bedding. In the BMP scenario, crop residue is removed from spring wheat and barley fields in the same year[15], once every four years as shown by Figure 6.2. This results in the pattern obtained in Figure 6.2. As the pattern shows in Figure 6.2, for the years where crop residue is removed in the BMP scenario, there are little or no differences between the mean net cash flows for the baseline scenario and the BMP scenario. The little mean net cash flow differences obtained between the baseline scenario and the BMP scenario in the years where crop residue is removed in the BMP scenario are obtained due to the fact that crop residue is modeled stochastically. As the pattern in Figure 6.2 also shows, for the years where crop residue is retained on the field, there are foregone opportunities for sale of crop residue and these forgone opportunities to remove and sell crop residue together with the potential for reduced yield in some years (pertaining to retaining

[15] Alternative patterns could have been modeled (e.g. where crop residue is removed from spring wheat and barley in different years, once every four years) but the impact on the mean results is minor.

crop residue in wet years) are not offset by the benefit associated with yield increases when crop residue is retained in dry years.

Figure 6.2: Mean difference in net cash flow for the crop residue management BMP and baseline scenario



6.2.3 Manure Management

As stated in the previous chapter, the application of manure is considered as a BMP because the use of manure generated from wintering site can reduce cost of inorganic fertilizer and increase soil organic matter. The manure BMP, in this study, is defined as applying manure based on one-year N requirement of crops.

In the base model scenario, all the manure is applied using the maximum allowed application rate based on Soil Nitrate Nitrogen Limits in 0-60cm for Dark Brown Medium and Fine Textured Soils which is 170 kg/ha (68.80 kg/acre), as presented in Table 2.3. Based on this application rate, the manure (1,166.50 kg) obtained in the calculation in the previous chapter is applied on approximately 17 acres (i.e. 1166.5 kg / 68.80 kg/acre) of land. In the BMP scenario, the manure is applied on 42.89 acres of land.

The gains in crop yields due to the application of manure are assumed to be within a range of 1% to 5%. Therefore, an average gain in crop yield of 3% on land applied with manure is factored into both the base model scenario and the BMP scenario.

Table 6.6 shows the results for the baseline and the BMP scenarios. The mean NPV increases by approximately 0.44% when the manure management BMP is adopted by the producer. The annualized NPV per acre net benefit is $0.94.

Table 6.6: Simulation Results for the manure management BMP

	Baseline scenario	**BMP scenario**
Mean NPV	$4,309,286.49	$4,328,155.97
Standard Deviation	$743,658.53	$7423,658.53
Annualized NPV[a]	$430,928.649	$432,815.597
Annualized Difference/Acre[b]		$0.94*

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference per acre is calculated by taking the difference between the annualized BMP scenario NPV and the baseline scenario BMP and dividing by the area affected by the BMP; in this case the 2,000 acres of annual cropland.
* Indicates significance at the 5% level.

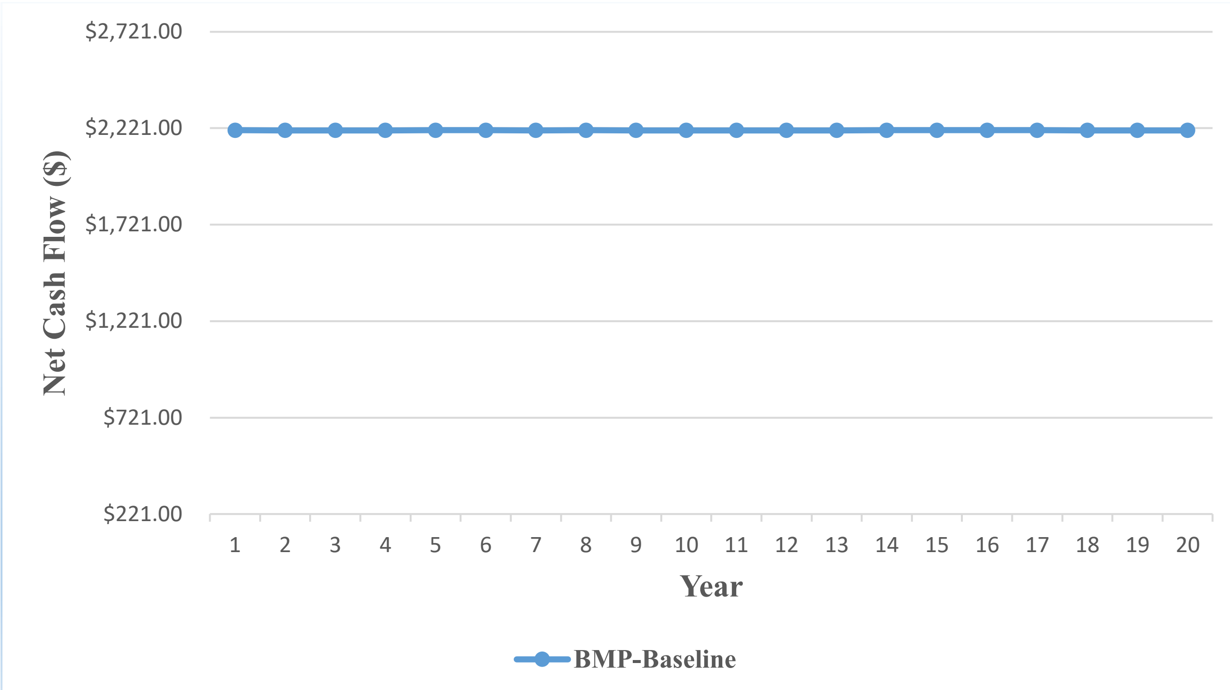
Table 6.6 shows that there is an improvement in expected NPV following the implementation of the manure management BMP. Thus the BMP provides a net benefit to the producer although the magnitude of the benefit is relatively small. This is likely due at least in part to the fact that the animals spend much of the year grazing on pasture, compared to the length of time they spend at wintering site (three months). As a result of this pattern, there is a limited amount of manure available to be spread on cropped fields. Thus the area on which manure can be used is relatively small and so the overall impact of manure application on financial performance will also be small.

With the adoption of the manure management BMP, the manure application rate is tailored to the nitrogen requirements for the crop in question, which results in the impact being a net benefit. Xie (2014) examines a similarly defined manure management BMP for an irrigated cropping operation in southern Alberta and obtained results that implied a larger net benefit. However, in Xie (2014) case, it was assumed that enough manure could be obtained from livestock operations to apply to the complete farm; that is, Xie (2014) representative farm had a greater supply of manure available for use.

Similar to the crop residue management, the t-test conducted to compare the baseline scenario and the BMP scenario mean NPVs shows that there is a statistically significant effect attributable to the manure management BMP. However, the annualized NPV difference per acre obtained from the results is relatively small and as such, likely does not represent an economically significant impact for the producer who adopts this BMP.

Figure 6.3 compares the annual net cash flows of the baseline scenario with the BMP scenario over the twenty-year period. The differences in mean annual net cash flows between the BMP and baseline scenario are graphed in Figure 6.3. The annual net cash flow of the BMP is slightly higher than the baseline scenario. This is because, following the use of manure, the annual cost associated with the use of inorganic fertilizer is reduced.

Figure 6.3: Mean difference in net cash flow for the manure management BMP and baseline scenario



6.2.4 Rotational Grazing

The baseline scenario assumes that grazing occurs on both the native pasture and the tame pasture without rotational grazing and as such, the pastures are not allowed a rest period to regrow or improve. In the BMP scenario, the tame pasture land (656 acres) is split into two "partitions" for rotational grazing purposes. In this study, it assumed that native pasture is leased rather than owned (possibly Crown land) and so it is not considered for rotational grazing.

The impact of rotational grazing is to increase the ability to more fully utilize available forage provided by pasture; that is, increase the AUMs per unit of area for pasture. However, the magnitude of this impact is unknown. Therefore, the study defines and models alternative increases in utilization that result in different increases in AUMs. In order to account for the degree to which forage availability increases and the duration over which it occurs, the annual increase in the utilization of forage measured in AUMs is increased from the baseline scenario alternatively by 0.2%, 0.25%, 0.5%, 1% and 1.5%, while holding the number of years over which the AUM increases constant at four years. A revised set of BMP scenarios is then modeled in which the annual increase in the utilization of forage is held constant at 1% with the number of years over which pasture productivity improves being varied; three, four, five, and six years.

Tables 6.7 and 6.8 present the simulation results for the different versions of this BMP. The NPV results as shown by Table 6.7 suggest that the cost involved in implementing the rotational grazing BMP is recouped after the AUM increases by at least 0.25%. Below this percentage (i.e., 0.20% and lower), the impact of the BMP on the total farm NPV is negative. At 0.20%, the total farm annualized NPV decreases by $748.86 which corresponds to an annualized NPV per acre loss of -$0.11. If the annual increase is 0.25%, however, the annualized net benefit per acre is slightly positive ($0.42 per acre). The magnitude of the net benefit increases with higher annual increases in AUMs.

As shown in Table 6.7, all of the mean differences in NPVs between the BMP and baseline are statistically significant. However, from an economic point of view, it is debatable whether any of these impacts are significant until pasture productivity increases by 1.50% (with annualized NPV of $13.84). The rest of the annualized NPV differences per acre are relatively small to impact the wealth of the producer.

Table 6.7: Rotational grazing simulation results, varying the annual increase in AUMs

	Mean NPV	Std. Deviation	Annualized NPV[a]	Annualized Difference/Acre[b]
Base (AUM of 1.54)	$4,309,286.49	$743,658.53	$430,928.649	
Increase in AUM per unit area of pasture				
0.20%	$4,308,537.63	$743,658.51	$430,853.763	-$0.11*
0.25%	$4,312,058.28	$743,658.50	$431,205.828	$0.42*
0.50%	$4,329,662.14	$743,658.47	$432,966.214	$3.11*
1.00%	$4,364,869.88	$743,658.40	$436,486.988	$8.47*
1.50%	$4,400,077.47	$743,658.33	$440,007.747	$13.84*

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference per acre is calculated by taking the difference between the annualized BMP scenario NPV and the baseline scenario BMP and dividing by the area affected by the BMP; in this case the 656 acres of tame pasture land.
* Indicates significance at the 5% level.

The study also examines the impact of rotational grazing on the total farm NPV in terms of number of years over which productivity is increased. In this case, the annual increase in AUMs per acre is held constant at 1% with the number of years of improved pasture productivity being alternatively set at three, four, five, and six years. As shown by Table 6.8, the NPV results show that the cost associated with rotational grazing is recouped even when the number of years the pasture improves is three. The annualized NPV increases by $3,921.7 from the baseline scenario when the number of years pasture improves is three and has a net benefit per acre of $5.97. Not surprisingly, as the number of years over which productivity improves is increased, so does the net benefit.

T-tests (Table 6.7) confirm that the change in mean NPVs associated with these BMP scenarios are statistically significant. However, from an economic point of view, it is likely that there needs to be at least five years of improved pasture productivity before the impact of the BMP is significant.

Table 6.8: Rotational grazing simulation results, varying the number of years of improvement in tame pasture productivity

	Mean NPV	Std. Deviation	Annualized NPV[a]	Annualized Difference/Acre[b]
Base (AUM of 1.54)	$4,309,286.49	$743,658.53	$430,928.649	
Number of years the pasture improves				
3	$4,348,604.97	$743,658.42	$434,860.497	$5.99*
4	$4,364,869.88	$743,658.40	$436,486.988	$8.47*
5	$4,379,300.56	$743,658.39	$437,930.056	$10.67*
6	$4,392,065.46	$743,658.50	$439,206.546	$12.61*

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference per acre is calculated by taking the difference between the annualized BMP scenario NPV and the baseline scenario BMP and dividing by the area affected by the BMP; in this case the 656 acres of tame pasture land.
* Indicates significance at the 5% level.

This BMP has an initial implementation cost associated with it; installation of fence and a watering system. However, given the time frame over which the BMP is being evaluated, this initial investment is overshadowed by the benefits associated with improved pasture productivity, even for relatively low levels of improvement (i.e., as small as 0.25%). As discussed earlier, there is a lack of information available regarding both the degree of increase and duration of increase in pasture productivity resulting from implementation of rotational grazing. However, the results here suggest that the BMP is likely to provide at least small net benefits per acre, with those benefits potentially becoming more significant (numerically) as the duration of improvement increases.

Figures 6.4 and 6.5 compare the annual net cash flows of the baseline scenario with the BMP scenario over the twenty-year period. The differences in mean annual net cash flows between the BMP and baseline scenarios are graphed in Figures 6.4 and 6.5 for the scenarios involving varying annual increases in AUM and varying the number of years over which pasture productivity improves, respectively. The negative impact on cash flow in year one is due to implementation costs associated with the BMP. This pattern of results occurs because, apart from the increased in productivity due to increase in AUMs, there is a cumulative benefit in the years where the AUMs are increased. This results in an increased cash flow in those years, but the benefit eventually stabilizes at the higher level. It can also be seen that there are differences in the degree of increase between the different BMP sub-scenarios as shown by Figures 6.4 and 6.5. The differences are as a result of the annual increase in the utilization of forage measured in AUMs.

Figure 6.4: Mean difference in net cash flow for the increase in AUM per acre of pasture and baseline scenario

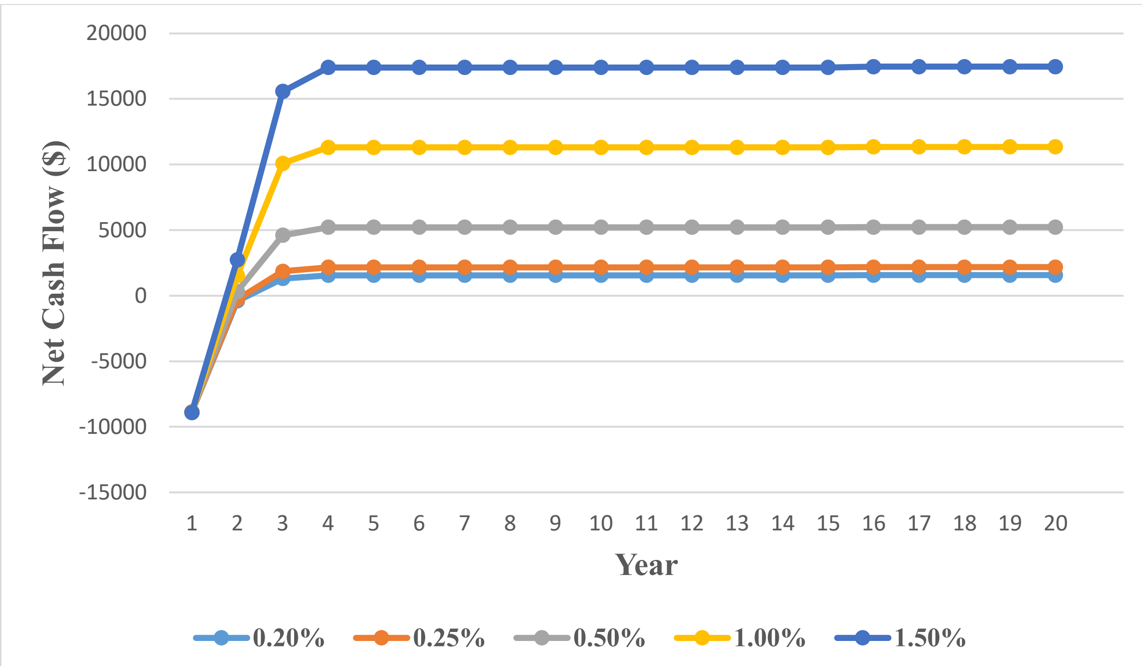
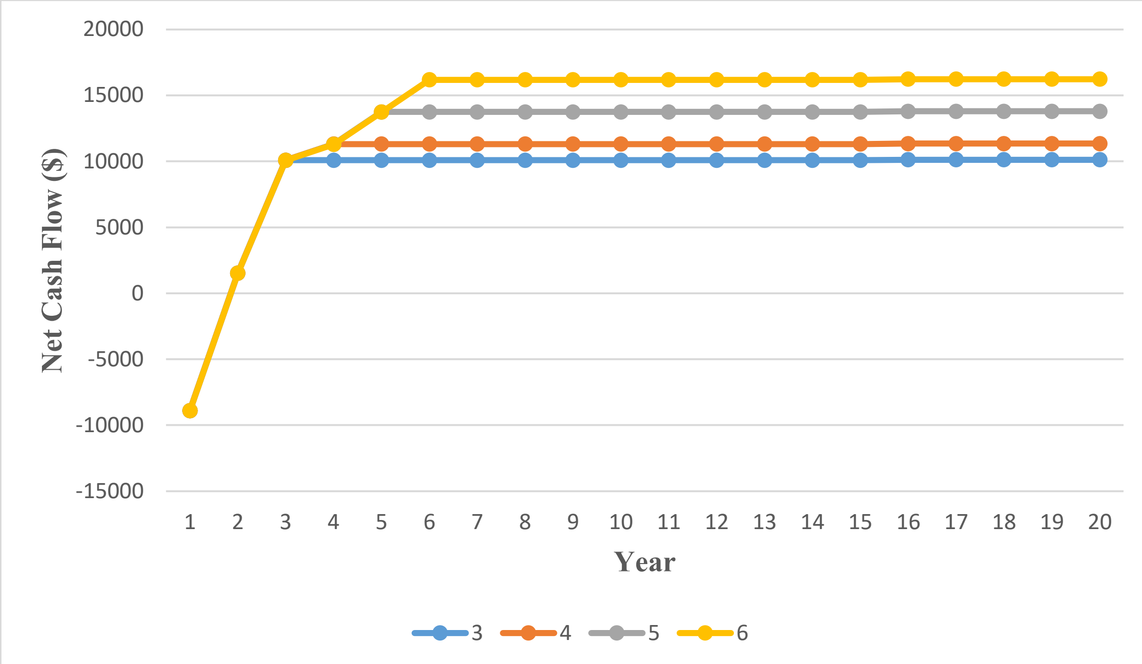


Figure 6.5: Mean difference in net cash flow for the number of years tame pasture improves and baseline scenario



6.2.5 Enhancing Tame Pasture Productivity through Incorporation of Legumes

As discussed in Chapter 5, this BMP involves removing a portion of tame pasture each year and reseeding it with a mixture of grass and alfalfa. The purpose of the BMP is to increase the productivity of the tame pasture through the addition of the legume (alfalfa). Two alternative BMP scenarios are modeled that differ in terms of the length of time between reseeding; specifically, reseeding is done either every five years or every seven years. The study models this by dividing the tame pasture land into five or seven parcels and reseeding one of these parcels every year with alfalfa.

As discussed in Chapter 5, there is uncertainty about the level of pasture productivity resulting from the BMP (i.e., AUMs per acre). The initial assumption made is that the reseeded pasture provides 1.67 AUM/acre, which is an average of the assumed productivity for alfalfa (1.8 AUM/acre), suggested by SFC (2007), and the initial productivity for tame pasture from the baseline scenario (1.54 AUM/acre). However, sensitivity analysis is conducted by increasing the productivity over and above the initial 1.67 value, by 10%, 25%, 50%, and 70%.

Table 6.9 presents the BMP scenario results when the tame pasture is reseeded every five years; that is, pasture divided into five parcels, reseeding a portion every year with alfalfa. As shown by Table 6.9, the cost involved in implementing the BMP can be recouped only when the initial pasture productivity (1.67AUM) increases by at least 70%. All other scenarios for this version of the BMP result in net costs associated with adoption; -\$48.74 to -\$6.57 per acre annually depending on the degree of increase in productivity. Even increasing the AUMs by 70% (to 2.92 per acre) results in a small net benefit per acre (\$0.79).

This pattern of results occurs because of the nature of the trade-offs associated with the BMP. While pasture productivity is increased by adding a perennial legume to tame pasture, there are implementation costs as well. A temporary fence is required to exclude cattle from the area being reseeded each year. More significantly, the area of tame pasture available to cattle each year is reduced by the area being reseeded. For those scenarios resulting in a net annual cost, the improved pasture productivity is not able to offset the effect of reduced pasture area; that is, a shorter grazing season and increased winter feed costs.

T-tests conducted to compare the statistical significance of the baseline scenario mean NPV to the mean NPVs of the BMP scenarios indicate that all mean differences in NPVs between the BMP and baseline are statistically significant. However, from the annualized NPV differences per acre (Table 6.9), the economic significance of the results varies, with the impact of the 50% and 70% increase scenarios likely not being significant.

Table 6.9: NPV results of seeded pasture (5 years)

AUM/Acre	Mean NPV	Std. Deviation	Annualized NPV[a]	Annualized Difference/Acre[b]
Base (AUM of 1.54)	$4,309,286.49	$743,658.53	$430,928.649	
1.67 (Starting AUM)	$3,989,537.09	$742,376.46	$398,953.709	-$48.74*
1.84 (1.67 up by 10%)	$4,009,564.83	$742,966.09	$400,956.483	-$45.69*
2.09 (1.67 up by 25%)	$4,039,016.95	$743,838.44	$403,901.695	-$41.20*
2.51 (1.67 up by 50%)	$4,266,176.92	$745,714.42	$426,617.692	-$6.57*
2.92 (1.67 up by 70%)	$4,314,478.55	$747,175.45	$431,447.855	$0.79*

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference per acre is calculated by taking the difference between the annualized BMP scenario NPV and the baseline scenario BMP and dividing by the area affected by the BMP; in this case the 656 acres of tame pasture land.
* Indicates significance at the 5% level.

Table 6.10 presents the results when the tame pasture is reseeded every seven years; that is, tame pasture divided into seven parcels with a portion reseeded every year with alfalfa. As shown in Table 6.10, this version of the BMP generates net benefits when the initial pasture productivity increases by at least 50% over and above the original assumed increased BMP of 1.67 AUM/acre. The pattern in this case is similar to what was obtained when one-fifth of tame pasture was reseeded each year; the BMP is costly unless there is a significant increase in productivity. The difference in this case is that since only one-seventh of the pasture is removed each year for reseeding, the degree of increased productivity required to generate positive net benefits is lower (i.e., 50% instead of 70%).[16]

T-tests conducted to compare the statistical significance of the baseline scenario mean NPV to the mean NPVs of the BMP scenarios indicated that the mean differences in NPVs between BMP and

[16] It should be noted that both versions of this BMP assume that the reseeded pasture maintains a consistent level of productivity throughout the years between reseeding (i.e., five years or seven years). It may be the case that productivity declines due to reduced levels of alfalfa within the pasture over time (i.e., if it is outcompeted by grasses).

basline are all statistically significant. However, the economic significance of the results does vary, with only the negative outcomes (i.e., for the scenarios from the initial 1.67 AUM/acre up to a 25% increase over that value) representing significant impacts on performance.

Table 6.10: NPV results of seeded pasture (7 years)

AUM/acre	Mean NPV	Std. Deviation	Annualized NPV[a]	Annualized Difference/Acre[b]
Base (AUM of 1.54)	$4,309,286.49	$743,658.53	$430,928.649	
1.67 (Starting AUM)	$4,039,040.94	$7412,789.89	$403,904.094	-$41.20*
1.84 (1.67 up by 10%)	$4,060,499.00	$743,423.92	$406,049.900	-$37.92*
2.09 (1.67 up by 25%)	$4,092,055.13	$744,362.31	$409,205.513	-$33.11*
2.51 (1.67 up by 50%)	$4,322,749.06	$746,351.26	$432,274.906	$2.05*

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference per acre is calculated by taking the difference between the annualized BMP scenario NPV and the baseline scenario BMP and dividing by the area affected by the BMP; in this case the 656 acres of tame pasture land.
* Indicates significance at the 5% level.

Figures 6.6 and 6.7 show the yearly net cash flows when the tame pasture is reseeded every five or seven years respectively. The differences in mean annual net cash flows between the BMP and baseline scenarios are graphed in Figures 6.6 and 6.7 for reseeding tame pasture every five or seven years, respectively. There are differences in the degree of increase between the different sub-scenarios of the BMP as shown by Figures 6.6 and 6.7. This is due to the length of time between reseeding of the tame pasture. In Figure 6.6, tame pasture is divided into five parcels and a portion is reseeded every year with alfalfa. In Figure 6.7, tame pasture is divided into seven parcels and a portion is reseeded every year with alfalfa. As shown by Figures 6.6 and 6.7, there is stable change in mean net cash due to the fact that each BMP sub-scenario is associated with relatively constant cost of implementation annually; that is, each BMP is associated with the same costs such as fencing cost and reseeding cost on annual basis. Again, the degree of pasture improvement is also relatively constant yearly.

Figure 6.6: Mean difference in net cash flow of seeded pasture (5 years) over the twenty-year period of time and baseline scenario

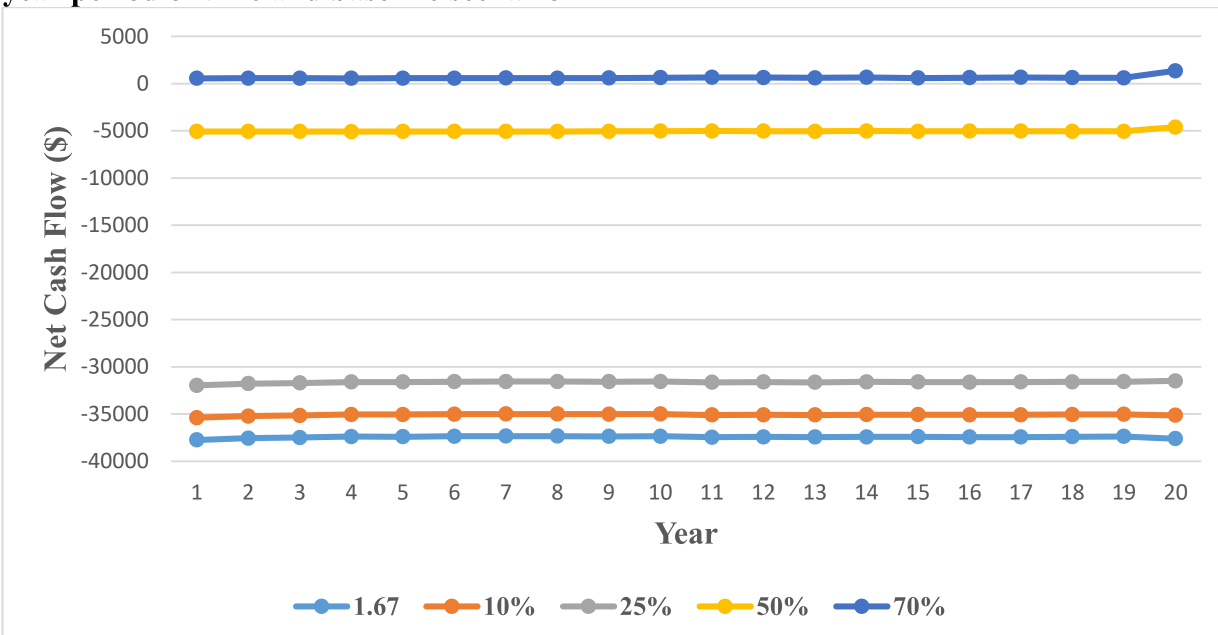
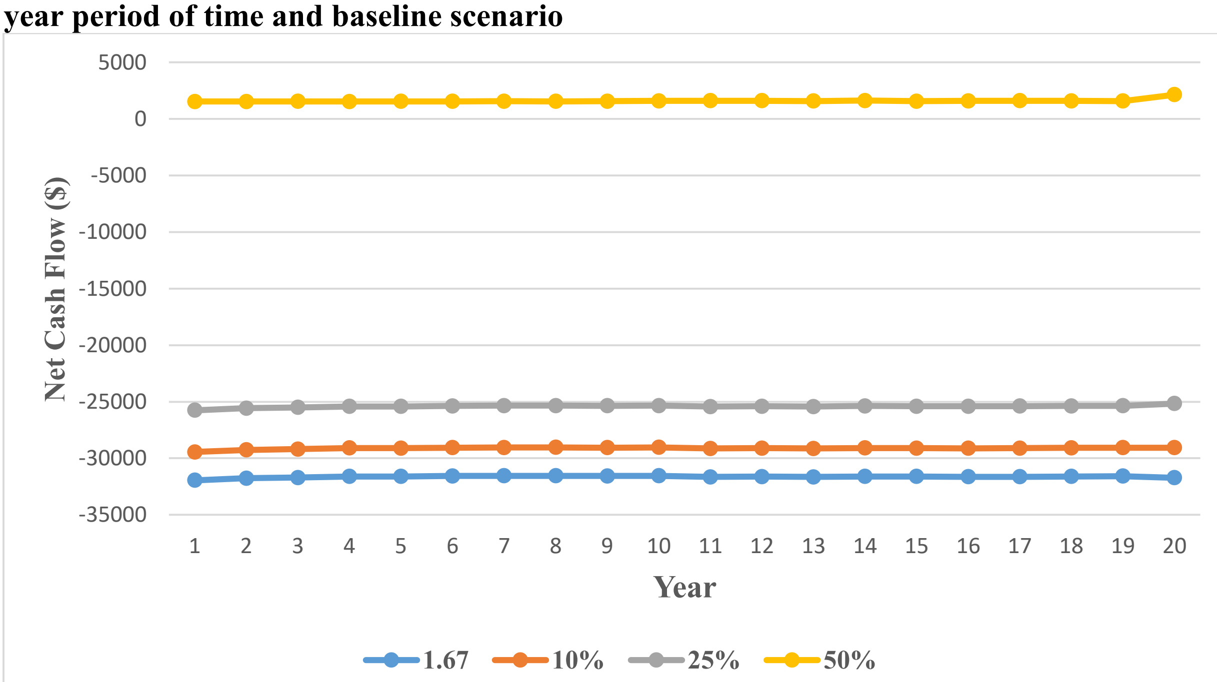


Figure 6.7: Mean difference in net cash flow of seeded pasture (7 years) over the twenty-year period of time and baseline scenario



6.2.6 Conservation of Natural Areas (Retirement of Native Pasture Area)

In adopting this BMP, the producer sets aside or "retires' a section of the native pasture (i.e., 640 acres) so that cattle are excluded from accessing that area. A permanent fence is constructed around the section of conserved land. As a result of the section of native pasture land set aside, the grazing season length is reduced and results in increased days of winter feeding. This in turn affects winter feeding costs, as additional hay is assumed to be purchased to supplement winter feeding.

Table 6.11 presents the results of the baseline scenario and the BMP scenario. As shown by Table 6.11, the implementation of the BMP has negative impact on the total farm NPV. The baseline scenario annualized NPV is reduced by 9.28% following the implementation of the BMP. The annualized cost of adoption for this BMP is -$60.93 per conserved acre. The explanation of this result is relatively straightforward. As noted above, the beef cattle have access to less pasture, which reduces the length of the grazing season and increases the requirements for winter feed. As a result, there is a significant annual cost (per acre) associated with this BMP.

The t-test conducted to compare the statistical significance of the baseline scenario mean NPV to the mean NPV of the BMP scenario indicates that the change in mean NPV is statistically significant. The annualized change in NPV per acre (-62.31) is also numerically significant, suggesting that there would be a significant economic impact on farm performance.

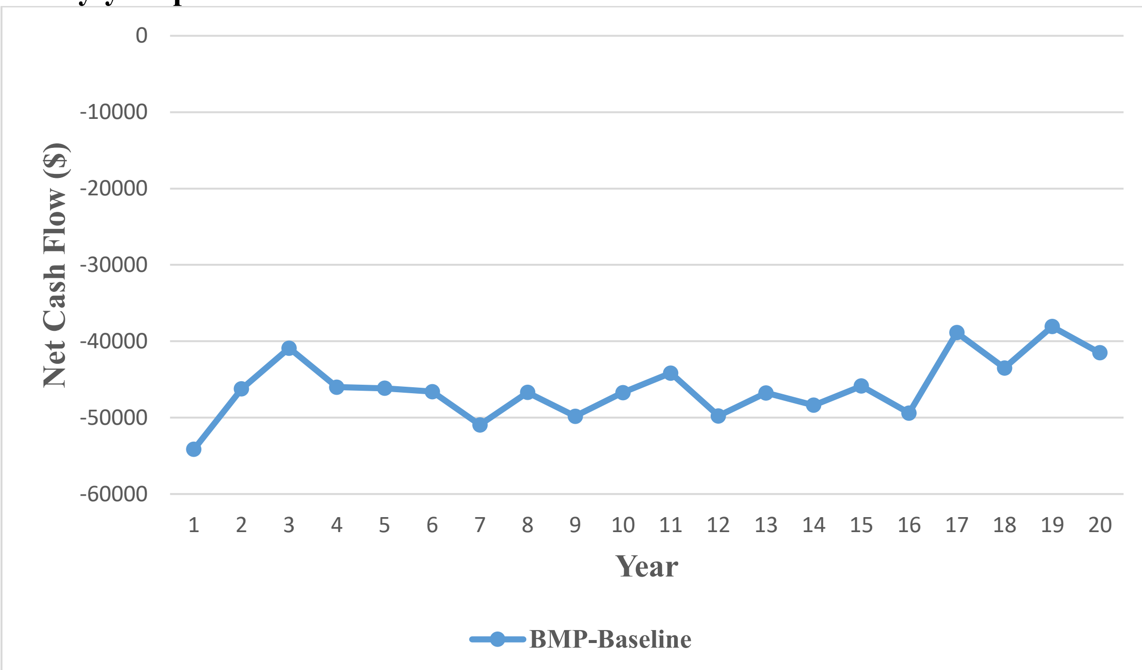
Table 6.11: Simulation Results of conservation of natural areas

	Mean NPV	Std. Deviation	Annualized NPV[a]	Annualized Difference/Acre[b]
Base	$4,309,286.49	$743,658.53	$430,928.649	
BMP Implemented	$3,909,567.27	$725,102.76	$390,956.727	-$60.93*

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference per acre is calculated by taking the difference between the annualized BMP scenario NPV and the baseline scenario BMP and dividing by the area affected by the BMP; in this case the 640 acres of native pasture land.
* Indicates significance at the 5% level.

Figure 6.8 shows the yearly net cash flow of the baseline scenario and the BMP scenario over the twenty-year time period. The implementation of the BMP decreases the yearly net cash flow over the twenty-year time period. The differences in mean annual net cash flows between the BMP and baseline scenarios are graphed in Figures 6.8. As shown by Figure 6.8, there are differences in the impact on net cash flow in each year. The negative impact on cash flow in year one is due the implementation cost (cost of a permanent fence) associated with the BMP. As also shown by Figure 6.8, there are differences in mean net cash flow from year to year. This may be attributed to the cost of winter feeding and the annual maintenance cost associated with the permanent fence in each year in the simulation. Although, following the implement of the BMP, the same quantity of winter feed may be required each year, prices of tame hay are modeled stochastically in the simulation. The stochastic tame hay prices result in changes in mean net cash flows as shown by Figure 6.8.

Figure 6.8: Mean difference in net cash flow of conservation of natural areas BMP over the twenty-year period of time and baseline scenario



6.3 Chapter Summary

The chapter presents the results of the baseline and BMP scenarios. In this study, five BMPs were analysed. The BMPs include crop residue management, manure management, rotational grazing, enhancing tame pasture productivity through incorporation of legumes (alfalfa) and conservation of natural areas (retirement of native pasture area). The simulation results, as measured by NPV, suggest that crop residue management is not economically feasible for the representative farm. Manure management is economically feasible for the producer to implement, although the benefit obtained annually is relatively small. In the case of rotational grazing, the results demonstrate increase in pasture utilization, which is a measure of pasture improvement condition, plays an essential role in determining the economic feasibility for adoption by the producer. Relative improvement in the utilization by 0.25% or more, as suggested by the simulation results, will make this BMP economically feasible for the producer to implement. The results obtained show that the economic feasibility for the producer to enhance tame pasture productivity through incorporation of legumes depends on the productivity of the pasture.

Similar to crop residue management BMP, the simulation results obtained for conservation of natural areas suggest that it is not economically feasible for the producer to implement this BMP. The implementation of this BMP leads to reduction in grazing season days thereby increasing the winter days. As winter days increase, the producer is required to buy additional feed to supplement winter feeding.

CHAPTER 7 : SUMMARY AND CONCLUSIONS

Adoption of BMPs by agricultural producers is important for provision of ecosystem services and sustainability of agricultural production systems. However, there has been limited analysis done regarding the economics associated with relevant agricultural BMPs, either in terms of farm-level impacts or the value to society. The limited evidence available from Western Canadian studies suggests that significant adoption of BMPs by agricultural producers may require policy intervention because adoption of many BMPs results in a net cost to producers. The appropriate type of intervention requires estimates of public and private benefits or costs (Pannell, 2008).

The study conducted an economic cost-benefit analysis for the implementation of BMPs by a representative mixed crop-beef farm in southern Alberta. The main objective of the study was to assess the economics of adoption of BMPs that are intended to improve water quality, soil quality, pasture management and other environmental attributes. In particular, the study was examined private costs and benefits to a representative producer who implements rotational grazing, crop residue management, manure management, enhancing tame pasture productivity through incorporation of legumes (alfalfa) or conservation of natural area (retirement of native pasture area). The study uses Lethbridge County, Vulcan County and Willow Creek in southern Alberta, all of which are in the Dark Brown soil zone, as the representative study area. This area is chosen due to suitability for agriculture which includes crop and livestock production and also due to the intensity of agriculture and its reliance on the availability of pasture for beef production thereby providing the potential for beef pasture BMP implementation.

Historical crop yield, crop price, beef price and cost data were collected. These were combined with expert opinion from individuals knowledgeable about agriculture in the study region to develop a Monte Carlo simulation model. Crop and beef production activities for the representative farm were simulated over a twenty-year period, and net present values (NPVs) in perpetuity were calculated to measure the financial performance. This was done initially for a baseline scenario (assuming no BMP adoption) and then for a series of BMP scenarios. In order to integrate risk into the simulation, crop yield, crop prices and beef prices were modeled as stochastic parameters. The representative farm producer was assumed to participate in public business risk management programs; specifically, AgriInsurance and AgriStability. The study compares the financial performance (using NPV analysis) of the representative farm with and without the implementation of the BMPs under consideration.

This chapter provides a summary of the empirical results for the study, along with a discussion of implications for agri-environmental policy. Limitations of the work undertaken in this study are identified, and suggestions for further research are presented.

7.1 Economic Feasibility of Implementing the BMPs

The on-farm costs and benefits for adopting each BMP under consideration are quantified in this study to determine the economic feasibility to implement each BMP on the representative farm. Crop residue management is considered as BMP because when left in the field, crop residues serve to provide a number of functions, as discussed in section 2.5.1 of this study. However, the removal and sale of crop residue serves as additional source of revenue to the producer. The BMP modeled in this study involves crop residue being removed once every four years, depending on the moisture conditions. Crop residue management results in a mean net cost of -$6.03/acre.

The use of manure is considered as a BMP because manure application on cropped fields can reduce the cost of inorganic fertilizer and increase soil organic matter. The manure management BMP modeled in this study involves changing manure application rates from the maximum allowed under provincial regulations to application based on the one-year requirement of nitrogen for spring wheat. Taking into account the ability to apply manure over a larger cropped area with corresponding reduction in inorganic fertilizer needs and enhanced yields, the manure management BMP results in an annual net benefit of $0.94/acre.

Rotational grazing is considered as a BMP because of the role that this practice has in maintaining vegetation and soil quality. The importance of practising rotational grazing is discussed in Chapter 2 (section 2.5.4). In this study, the area of tame pasture on the representative farm (656 acres) is split into two partitions for rotational grazing purposes. The use of rotational grazing leads to pasture improvement, thereby resulting in increasing forage availability. However, the degree to which forage availability increases and the duration over which the improvement occurs are not certain. As a result, this study models alternative BMP scenarios by varying the degree of increased pasture productivity and the number of years over which pasture improves, to account for the uncertainties. In particular, the annual growth in pasture utilization (measured in terms of AUMs/acre) is increased from the base case scenario by 0.2%, 0.25%, 0.5%, 1% and 1.5% while holding the number of years over which the utilization increases constant at four years. In the alternative case, the growth in pasture utilization is held constant at 1% with the number of years pasture improves varying from three to six years. Results suggest that while adoption of the BMP does not provide positive net benefits for all sub-scenarios, the cost involved in the rotational grazing BMP is recouped as long as the increase in pasture productivity is at least 0.25% annually, assuming that the increase occurs over a four year period. Similarly, if pasture productivity increases by 1% annually, the increase would need to occur for at least three years in order for the BMP to provide positive net benefits. Overall, it cannot be said with certainty that rotational grazing provides positive net benefits for adopting producers but positive net benefits do occur for most of the sub-scenarios examined in this study.

Enhancing tame pasture productivity through incorporation of legumes is considered as BMP because the use of a leguminous plant such as alfalfa improves pasture productivity thereby increasing grazing season days and reducing the cost associated with winter feeding. The introduction of alfalfa into the pasture results in increased productivity (i.e., AUMs/acre) and thus extends the grazing season (Raven, 2016). The BMP is modeled by removing a portion of the tame pasture area from use each year for the purposes of reseeding it. Two versions are modeled; reseeding one-fifth of the pasture each year, or reseeding one-seventh of the pasture each year. As with rotational grazing, the impact of incorporating alfalfa into the tame pasture on pasture productivity is unknown. As a result, for both versions of the BMP alternative sub-scenarios are modeled. The results for this BMP suggest that in many cases, the costs of adoption (i.e., reseeding costs, temporary fencing, reduced area of pasture available each year) outweigh the benefits from increased AUMs/acre. If one-fifth of the pasture is reseeded each year, there are positive net benefits only if pasture productivity is at least 70% higher than the initial assumed BMP value of 1.67 AUM/acre. In the case of one-seventh being re-seeded each year, productivity must be at least 50% higher than the 1.67 AUM/acre value initially used for the BMP. Thus, it appears likely that re-seeding tame pasture with perennial legumes is not economically viable for the representative farm in terms of providing positive net benefits.

The last BMP considered in the study is conservation of natural areas. In the case of the representative farm, this is defined as retiring one section (640 acres) of native pasture from use. This can be considered as a BMP because of the potential benefits for biodiversity and natural and associated cultural resources. The 640 acres of the native pasture is set aside by constructing a permanent fence to exclude the beef cattle from accessing it. The effects on the representative farm are all "costs". As a result of the section of native pasture land being set aside, the grazing season length is reduced from 275 days to 236 days, thereby increasing the length of the winter feeding period. Therefore, there is a net cost associated with adoption of the BMP, equal to $60.93 per acre on an annual basis.

7.2 Conclusions and Implications for Policymaking

The research carried out in this project was intended to increase the understanding of private benefits and costs of adoption for BMPs intended to improve water quality, soil quality, pasture management and other environmental attributes by southern Alberta cow-calf producers. The results obtained from the analysis are mixed. Manure management results in relatively small annual benefit per acre of land affected. The results for pasture based BMPs (rotational grazing and enhancing tame pasture productivity through incorporation of legumes) depend on the degree to which tame pasture productivity is improved by the BMP. The conservation of natural areas (retirement of native pasture) and crop residue management BMPs result in cost to the producer. Given an assumption of profit or wealth maximization for producers, it is likely that they would consider adopting BMPs that provide direct net benefits. On the other hand, it is unlikely that producers will voluntarily implement "costly" BMPs that are associated with negative net benefits.

From Pannell's (2008) framework perspective, what constitutes appropriate policy instruments to encourage adoption of given production practices is dependent on the relative signs and magnitudes of private and public net benefits. The study takes as given that there are positive public net benefits associated with adoption of the BMPs examined for the representative farm, although the magnitude of these net benefits is not known.

The study shows that there is negative private net benefit associated with the crop residue BMP. The annualized cost of adoption for this BMP is -$6.03 per acre of land affected. Pannell's (2008) framework would suggest that if public net benefits from the ecosystem services provided by the adoption of this BMP are greater than -$6.03 on per acre basis, then positive incentives (e.g., subsidies) should be used for producers to adopt and implement this BMP. However, if the public net benefits are less than -$6.03 on per acre basis, then no action should be taken; that is, it is not worthwhile trying to encourage the adoption of this BMP by producers. It should be noted that given the small magnitude of this expected cost, it is likely that any public benefits likely outweigh the cost to producers.

The study shows that manure management BMP adoption has a relatively small private net benefit associated with it. If expressed on an annual benefit per acre, it is equal to $0.94, which represents a relatively small impact on the farm. From Pannell's (2008) framework, if public net benefits from the ecosystem services provided by the adoption of this BMP are greater than $0.94 on per acre basis, positive incentives should not be used because producers will adopt this BMP without the proposed incentives. Information programs may be all the policy required for producers to adopt this BMP.

The study shows that there is a significant negative private net benefit associated with conservation of natural areas BMP. The annualized cost of adoption for this BMP is -$60.93 per conserved acre. Pannell's (2008) framework would suggest that if public net benefits from the ecosystem services provided by the adoption of this BMP are greater than -$60.93 on per acre basis, then positive incentives (e.g., subsidies) should be used for producers to adopt and implement this BMP. However, if the public net benefits are less than -$60.93 on per acre basis, then no action should be taken; that is, it is not worthwhile trying to encourage the adoption of this BMP by producers.

In the case of the pasture related BMPs (rotational grazing and enhancing tame pasture productivity through incorporation of legumes), the outcome is uncertain and depends on resulting changes in pasture productivity. In this situation, positive incentives should not be used unless there are positive public net benefits from the ecosystem services provided by these BMPs. Positive incentives should also not be used if producers would adopt these BMPs without the proposed incentives; that is, if there are positive private benefits associated with the adoption of these BMPs.

There are a number of agri-environmental policies currently existing within the Growing Forward 2 policy framework which are appropriate given the findings of this study. These programs include confined feeding operation stewardship, on-farm stewardship and the livestock production program.

Confined feeding operation stewardship program aims at helping Alberta livestock producers and commercial manure applicators to assess their potential risk to water quality and make the necessary steps to minimize that risk, benefitting their business and the environment. This goes in hand with manure management BMP of this study.

On-farm stewardship program provides funds to project that help livestock and crop producers to implement on-farm management practices in five areas which have positive impact on water quality and encourage sustainable management of inorganic agricultural wastes. The program has multiple categories. Program Category A is grazing management. Grazing management includes riparian area fencing and management, summer and year round watering systems, and wetland restoration. These activities are linked with the pasture related BMPs of this study that also aim at grazing or pasture management. Category B is manure and livestock facilities management. Manure and livestock facilities management includes improvements to manure storage facilities, livestock facilities, runoff control and livestock facilities and relocation. The livestock production embraces programs such as confined feeding operation stewardship and on-farm stewardship programs discussed already.

The results of the study in terms of the costs associated with the pasture related BMPs (rotational grazing and conservation of natural areas) were used to compare the Growing Forward cost share environmental ecosystem services and that involve fencing programs. The results of this study are based on a 20 year time horizon. However, the Growing Forward cost share payment by the government is one-time payment; that is, not an annual payment.

The Growing Forward Fencing to Protect Sensitive Areas project, was purposed to construct a fence to help manage livestock access to environmentally sensitive areas on the farm property, thereby leading to the protection of aquatic life, riparian vegetation, wildlife habitat and water quality. The ineligible costs items included perimeter fencing and repair and maintenance of existing fence. This program is relevant for the BMP in which 640 acres of native pasture is retired from use by the beef herd.

In this study, the total cost involved in constructing a permanent fence (4 standard barbed, 2-2strand wire fence) of length 9,631.48ft to retire a section (640 acres) of native pasture is $7,691.08. This cost does not include perimeter fencing as it is assumed that there is an already existing perimeter fence. However, the fence is associated with annual maintenance cost of 10% of total cost. The representative farm in this study would have received a payment of $3,845.54 (i.e., 0.5*$7,691.08) from the government following the cost share of 50% of eligible expenses to complete the fence.

From the simulation results, the annual cost (calculated as the difference between the annualized NPVs of the BMP scenario and the baseline scenario) associated with the adoption of retirement of a section of native pasture BMP is $39,971.922. This implies that the single payment received from the Growing Forward program regarding fencing sensitive areas represents only 9.62% of the total annual cost associated with the adoption of retiring a section of native pasture BMP. Thus the incentives provided by this program do not come close to reflecting the total costs on the part of the producer.

The adoption of rotational grazing BMP requires fencing and the construction of off-stream watering system. In this study, the cost involved in partitioning 656 acres of tame hay into two in terms of fencing (5,345.59 feet) for rotational grazing purposes is $1,101.01. The construction of one small off-stream watering system comes at a cost of $7,771. The Growing Forward cost share programs include support for alternative watering systems, year-round watering systems, fencing to enhance grazing management. These projects had a grant funding cost share of 50% of eligible expenses to complete the project; that is, the costs involved were supposed to be shared between the government and the producer at 50% each (GoA, 2013).

In the Growing Forward Alternative Watering Systems project, the purpose was to construct watering systems to enhance grazing management, to reduce the effect of animals on water sources and to actively encourage the distribution of manure across the landscape (GoA, 2013). The ineligible costs items included dugout aeration systems, deeply buried pipelines (below the frost level) and water sources such as new wells or dugouts (GoA, 2013).

The total cost involved in constructing an off-stream watering system in this study for 198 herd size is $7,771.00. This total cost is made up of wet well intake cost of $7,064.55 and miscellaneous cost of $706.45. There is also 10% of total cost as annual maintenance cost. The Growing Forward

Alternative Watering System project does not make reference to miscellaneous cost and annual maintenance cost. Therefore, the representative farm in this study would have received a one-time payment of $3,532.28 (i.e., 0.5*$7,064.55) from the government following the cost share of 50% of eligible expenses to complete the project.

The Growing Forward Fencing to Enhance Grazing Management project, was purposed to construct a fence to enhance the use of the land base, to increase distribution of manure and to release grazing pressure pastures and riparian areas by allowing the implementation of rotational, seasonal, rest, swath or extended grazing systems (GoA, 2013). The ineligible costs included perimeter fencing and repair and maintenance of existing fence.

In this study, the total cost involved in constructing a temporary fence of length 5,345.59ft to divide 656 acres of tame pasture is $1,101.19. The representative farm in this study would have received a payment of $550.60 (i.e., 0.5*$1,101.19) from the government following the cost share of 50% of eligible expenses to complete the fence.

Tables 7.1 and 7.2 provide the simulation results for the alternative scenarios modeled for the rotational grazing BMP. These are the same simulation results presented and discussed in Chapter 6, with the annual net cost or benefit being expressed at the farm level (as opposed to the per acre values reported in Chapter 6). As shown in Tables 7.1 and 7.2, for most of the rotational grazing BMP scenarios, the producer receives a net benefit from adoption. Thus, no incentives should be required for adoption to occur. Thus, there should be no need for Growing Forward

Table 7.1: Rotational grazing simulation results, varying the annual increase in AUMs

	Mean NPV	Std. Deviation	Annualized NPV[a]	Annualized Cost or Benefit[b]
Base (AUM of 1.54)	$4,309,286.49	$743,658.53	$430,928.649	
Increase in AUM per unit area of pasture				
0.20%	$4,308,537.63	$743,658.51	$430,853.763	-$74.89
0.25%	$4,312,058.28	$743,658.50	$431,205.828	$277.18
0.50%	$4,329,662.14	$743,658.47	$432,966.214	$2,037.57
1.00%	$4,364,869.88	$743,658.40	$436,486.988	$5,558.34
1.50%	$4,400,077.47	$743,658.33	$440,007.747	$9,079.10

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference between the annualized NPV of the BMP scenario and the baseline scenario.

Table 7.2: Rotational grazing simulation results, varying the number of years of productivity improvement

	Mean NPV	Std. Deviation	Annualized NPV[a]	Annualized Benefit[b]
Base (AUM of 1.54)	$4,309,286.49	$743,658.53	$430,928.649	
Number of years the pasture improves				
3	$4,348,604.97	$743,658.42	$434,860.497	$3,931.85
4	$4,364,869.88	$743,658.40	$436,486.988	$5,558.34
5	$4,379,300.56	$743,658.39	$437,930.056	$7,001.41
6	$4,392,065.46	$743,658.50	$439,206.546	$8,277.90

[a] The NPV is annualized (i.e., converted to an annual value) by calculating the equivalent perpetual annuity.
[b] The difference between the annualized NPV of the BMP scenario and the baseline scenario.

Just like the Growing Forward Alternative Watering System, as a policy (from Pannell, 2008

program payments and again there is no connection between the level of (or need for) incentives and the on-farm impacts of adoption.

As shown by Table 7.2, the producer should not have received the payment of $3,532.28 from government because the producer would adopt this BMP without the proposed incentive.

7.3 Limitations and Assumptions of the Model

It should be noted that the results of this study are dependent on the specific characteristics of the representative farm. Although the representative farm used in the study is modeled in such a way to be consistent with commercial agricultural production in the study area, it is not devoid of assumptions due to modeling technique restrictions or inadequate information. As well, the representative farm is just one farm. There will be significant heterogeneity in the nature of farms that actually exist in that region and this limits the ability to generalize the results to the wider population. The results might be different if multiple farms had been simulated, perhaps varying factors such as the size of the farm, which enterprises were present (e.g. different crop rotation), production practices (e.g. use of summer fallow) and ownership (e.g. ownership of native pasture versus assumption of leasing Crown land).

Another limitation associated with this study is associated with availability of data. In particular, there are cases where complete and accurate information or data on which to estimate model or BMP parameters is lacking. For example, one limitation associated with rotational grazing BMP is the degree of improvement in forage availability. Although existing literature suggests that pasture will improve when rotational grazing is implemented as against continuous grazing, it is not clear as to how much pasture would improve. The study models this by altering the baseline pasture utilization and the number of years pasture improves. However, given the limitation, the results obtained for these sub-scenarios should be carefully considered with respect to the private net benefits or costs realized by producers. A similar comment can be made concerning the effect of introducing alfalfa into tame pasture.

Lastly, all the cow-calf parameters used were estimated from the average of the last five years (2011-2015) Alberta Cow-calf dataset. The dataset provided a good source for these parameters. However, the number of farms captured by the dataset was small.

7.4 Future Research

The analysis in this study was basically conducted with a single representative farm in mind. Farm sizes in the study area vary significantly and some may be larger or smaller than the representative farm. Future studies can be carried out by considering different sizes of farm in the study area if possible.

Furthermore, the study assessed only the private costs and benefits associated with a producer adopting a set of BMPs. However, as stated by Pannell (2008), an appropriate policy decision should take into consideration both private and public net benefits of these BMPs. The study considers preservation of soil and water quality as public net benefits. Future research would require estimates of public benefits.

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APPENDIX A: DISTRIBUTION FITTING FOR THE ANNUAL CROPS

Table A1: Test statistics for distribution fitting for the annual crops

Crop	Chi-squared	Anderson-Darling	Kolmogorov-Smirnov
Spring Wheat	Weibull (13.7778)	Weibull (1.2995)	LogLogistic (0.1557)
	Triangle (13.7778)	BetaGeneral (1.4375)	BetaGeneral (0.1579)
	BetaGeneral (16.8889)	Triangle (1.5996)	Weibull (0.1613)
Barley	Weibull (5.6111)	Weibull (1.0043)	Weibull (0.1328)
	BetaGeneral (6.0000)	Triangle (1.1163)	BetaGeneral (0.1424)
	LogLogistic (6.7778)	BetaGeneral (1.1283)	LogLogistic (0.1459)
Canola	Weibull (2.1111)	Triangle (0.4386)	Triangle (0.1055)
	Triangle (3.6667)	BetaGeneral (0.5940)	BetaGeneral (0.1275)
	BetaGeneral (4.4444)	Weibull (0.6220)	Weibull (0.1432)

Table A2: Yield distribution fitting rankings

Distribution	Rankings	No. of times ranked	No. of times ranked first	Sum of the two highest ranked
Weibull	1,1,1,1,1,1,3,3,3	9	6	15
Triangle	1,1,2,2,2,3	6	2	
BetaGeneral	2,2,2,2,2,2,3,3,3	9	0	21
LogLogistic	1,3,3	3	1	

APPENDIX B: AD-HOC ADJUSTMENT OF ALPHA AND BETA (YIELD ADJUSTMENT)

The distribution mean is given by $\beta\Gamma\ (1 + \frac{1}{\alpha})$, and the variance is given by

$\beta^2 \left[\Gamma\ (1 + \frac{2}{\alpha}) - \Gamma^2\ (1 + \frac{1}{\alpha}) \right]$, where Γ is the Gamma function.

Barley					
Factor	Alpha	Factor	Beta	Distribution	Std. Dev.
6.3013	21.70603	0	1554.4	1516.1965	610.6346
Spring Wheat					
Factor	Alpha	Factor	Beta	Distribution	Std. Dev.
15	54.1424	-0.1049	1148.682	1136.8168	453.5737
Canola					
Factor	Alpha	Factor	Beta	Distribution	Std. Dev.
5	17.9664	-0.0531	769.6119	747.1308	317.7584

APPENDIX C: OFF-STREAM WATERING AND FENCING COSTS

Table C1: Off-stream watering site construction costs

Construction costs for small off-stream watering site	
	Total Cost ($)
Wet Well Intake	$ 7,064.55
Miscellaneous (10%)	$ 706.45
Total	**$ 7,771.00**
$/cow (198 herd size)	**$ 39.25**

Source: Dollevoet (2010) (Adjusted for inflation)

Table C2: Fencing construction costs

Cost to erect 4 standard barbed, 2-strand wire fence	
Length of fence to be constructed	5,345.59ft
Cost per foot	$ 0.206
Total cost	**$ 1101.19**

Source: Koeckhoven (2008) (Adjusted for inflation)

APPENDIX D: COSTS ASSOCIATED WITH RESEEDING TAME PASTURE

Table D1: Costs associated with reseeding tame pasture (5 years)

Tame pasture acreage to be seeded	131.2 acres
Cost associated with two passes of a heavy tandem (assuring rental equipment) per acre	$ 22.51
Rental rate for one cultivator operation per acre	$ 7.44
Cost of glyphosate application rate	$ 11.90
Total cost per acre	$ 41.85 (22.51+7.44+11.90)
Total cost of breaking up the soil per year	**$ 5,490.72 (41.85*131.2)**

Source: Dollevoet (2010) (Adjusted for inflation)

Table D2: Fencing construction costs

Cost to erect 4 standard barbed, 2-strand wire fence	
Length of fence to be constructed	10,691.18ft
Cost per foot	$ 0.206
Total cost	**$ 2,202.03**

Source: Koeckhoven (2008) (Adjusted for inflation)

Table D3: Costs associated with reseeding tame pasture (7 years)

Tame pasture acreage to be seeded	93.713acres
Cost associated with two passes of a heavy tandem (assuring rental equipment) per acre	$ 22.51
Rental rate for one cultivator operation per acre	$ 7.44
Cost of glyphosate application rate	$ 11.90
Total cost per acre	$ 41.85 (22.51+7.44+11.90)
Total cost of breaking up the soil per year	**$ 3,921.89 (41.85*93.713)**

Source: Dollevoet (2010) (Adjusted for inflation)

APPENDIX E: COSTS ASSOCIATED WITH RETIREMENT OF NATIVE PASTURE AREA

Table E: Permanent fencing construction costs

Cost to erect 4 standard barbed, 2-strand wire fence	
Length of fence to be constructed	9,631.48
Cost per foot	$ 0.7985
Total cost	**$ 7,691.08**

Source: Koeckhoven (2008) (Adjusted for inflation)

APPENDIX F: THE T-TEST AND K-S TEST STATISTICS FOR COMPARING NUMBER OF ITERATIONS (A = 5%)

Mean NPV (10,000 iterations): $ 4,309,286.49

Mean NPV (15,000 iterations): $ 4,306,068.72

Mean NPV (25,000 iterations): $ 4,309,808.78

Table F1: K-S test statistics for 10,000 and 15,000 iterations

Hypothesized Mean Difference	0
t Stat	3.82294E-07
t Crit	2.98639E-04

Table F2: K-S test statistics for 10,000 and 25,000 iterations

Hypothesized Mean Difference	0
t Stat	5.44305E-08
t Crit	2.98639E-04

Table F3: t-test statistics for 10,000 and 15,000 iterations

Hypothesized Mean Difference	0
df	8
t Stat	0.657032
P (T<=t) one-tail	0.264802285
t Critical one-tail	1.859548038
P (T<=t) two-tail	0.52960457
t Critical two-tail	2.306004135

Table F4: t-test statistics for 10,000 and 25,000 iterations

Hypothesized Mean Difference	0
df	8
t Stat	-0.09363
P (T<=t) one-tail	0.463852
t Critical one-tail	1.859548
P (T<=t) two-tail	0.927704
t Critical two-tail	2.306004

APPENDIX G: NET CASH FLOW OF THE REPRESENTATIVE FARM OVER THE TWENTY-YEAR TIME PERIOD

Year	Mean	Std. Deviation	Minimum	Maximum
1	$ 491,870.19	$ 151,271.66	-$ 55,486.16	$ 1, 085,385.41
2	$ 496,941.06	$ 151,806.28	-$ 40,734.97	$ 1,070,621.89
3	$ 499,348.43	$ 152,564.61	-$ 23,238.64	$ 1,116,102.43
4	$ 501,620.90	$ 151,702.50	-$ 19,426.89	$ 1,039,315.67
5	$ 502,972.83	$ 151,176.21	-$ 30,848.65	$ 1,095,766.53
6	$ 503,615.49	$ 152,275.01	-$ 73,260.51	$ 1,122,472.38
7	$ 507,185.17	$ 152,662.53	-$ 106,047.28	$ 1,059,399.29
8	$ 506,868.54	$ 153,841.40	-$ 37,733.48	$ 1,125,826.31
9	$ 509,243.45	$ 153,026.15	-$ 63,660.92	$ 1,073,684.51
10	$ 511,156.67	$ 151,083.27	$11,664.89	$ 1,104,494.90
11	$ 512,012.32	$ 15,975.02	-$ 44,964.27	$ 1,137,784.06
12	$ 512,661.70	$ 152,534.99	-$ 40,066.32	$ 1,185,209.74
13	$ 511,550.83	$ 153,734.21	-$ 46,794.72	$ 1,046,673.46
14	$ 514,228.92	$ 153,204.29	-$ 1,689.72	$ 1,080,404.79
15	$ 511,852.28	$ 153,722.41	-$ 61,171.94	$ 1,143,993.21
16	$ 514,674.64	$ 152,849.02	$16,281.48	$ 1,218,870.03
17	$ 514,885.16	$ 152,997.65	-$ 100,254.40	$ 1,071,938.46
18	$ 514,352.38	$ 152,973.24	-$ 32,557.87	$ 1,139,971.22
19	$ 513,964.92	$ 153,864.67	-$ 25,512.14	$ 1,133,817.65
20	$ 515,114.67	$ 152,485.62	-$ 31,753.18	$ 1,118,155.57

APPENDIX H: SUMMARY STATISTICS FOR FARM NPV

Summary Statistics for NPV with Perpetuity	
Minimum	$ 1,458,917.86
Maximum	$ 7,115,762.65
Mean	$ 4,309,286.49
Std. Dev.	$ 743,658.53
Variance	5.53028E+11
Skewness	0.015276083
Kurtosis	3.031503076
Median	$ 4,305,254.08
Mode	$ 4,276,438.34
Left X	$ 3,092,012.39
Left P	5%
Right X	$ 5,538,831.99
Right P	95%
Diff X	$ 2,446,819.60
Diff P	90%
#Errors	0
Filter Min	Off
Filter Max	Off
#Filtered	0