University of Alberta

The Economics of Beneficial Management Practices Adoption on Representative Alberta Crop Farms

by

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Abstract

Monte Carlo simulation was used to examine the on-farm economics from adoption of Beneficial Management Practices (BMPs) on five representative Alberta cropping farms. Adoption of shelterbelts, buffer strips, residue management, and the addition of annual and perennial forages, field peas, and oats in crop rotations were included as BMPs that contribute positively to Ecological Goods and Service production from agriculture.

Results suggest positive on-farm benefits associated with perennial forage and field pea BMPs. Conversely, BMPs that reduce availability of land for cropping activities, such as shelterbelts and buffer strips, and BMPs that do not increase revenues, such as oats and annual forages in rotation, are costly to producers. The results of this thesis have important policy implications. Policy mechanisms that incorporate positive mechanisms may improve adoption of BMPs that are costly to producers, while extension mechanisms, such as information programs, may improve the adoption of economically feasible BMPs.

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List of Acronyms

AAFC – Agriculture and Agri-Food Canada

AARD – Alberta Agriculture and Rural Development

ADF – Augmented Dickey-Fuller

AEPB – Agri-Environmental Policy Bureau

AESB – Agri-Environment Services Branch

AFSC – Agricultural Financial Services Corporation

AIC – Akaike Information Criterion

ANPV – Annualized Net Present Value

ANS – Allowable Net Sales

AOPA – Agricultural Operations Practices Act

APF – Agricultural Policy Framework

ARR – Accounting Rate of Return

BMP – Beneficial Management Practices

BRM – Business Risk Management

CCPP – Cover Crop Protection Program

CLT – Central Limit Theorem

CML – Capital Market Line

CPI – Consumer Price Index

CSC – Crop Sequence Calculator

CWB – Canadian Wheat Board

DUC – Ducks Unlimited Canada

ECSWCC – Eastern Canada Soil and Water Conservation Center

EFP – Environmental Farm Plan

EG&S – Ecological Goods & Services

ELS – Entry Level Stewardship

EPEA – Environmental Protection and Enhancement Act

FCC – Farm Credit Canada

FEMS – Farm Environmental Management Survey

IRR – Internal Rate of Return

KPSS – Kwiatkowski-Phillips-Schmidt-Shin

MAFRI – Manitoba Agriculture, Food, and Rural Initiatives

MNCF – Modified Net Cash Flow

MSUE – Michigan State University Extension

NPKS – Nitrogen-Phosphorus-Potassium-Sulfer

NPV – Net Present Value

NRCBA – Natural Resources Conservation Board Act

OLS – Ordinary Least Squares

PFRA – Prairie Farm Rehabilitation Act

PM – Production Margin

PP – Payback Period

PSP – Prairie Shelterbelt Program

RM – Reference Margin

SAF – Saskatchewan Agriculture and Food

SAGES – Sustainable Agriculture Environment Systems

SC – Schwartz Criterion

SIP – Spring Insurance Price

SPE – Spring Price Endorsement

SUR – Seemingly Unrelated Regression

TSX – Toronto Stock Exchange

USDA – United States Department of Agriculture

VAR – Vector Autoregression

VPB – Variable Price Benefit

WAAF – Western Australia Agriculture and Food

WTA – Willingness to Accept

Chapter 1: Introduction

1.1 Background

Agricultural practices can have a variable impact on the surrounding environment and these impacts are often experienced at the societal level. Well managed agricultural lands provide more than food; they provide improved water quality, carbon sequestration, wildlife habitat, reduced soil erosion, and recreational opportunities (AAFC, 2001; DUC, 2006). As demand for land and water resources increases with population and economic growth it is essential that farmers and society use these resources with care (AARD, 2004-a). Efficient use of resources in agriculture protects and prevents degradation of natural resources while providing society with natural capital (DUC, 2006). Natural capital, the stock of natural ecosystems that yields ecological goods and services (EG&S) such as food production, materials for manufacturing and improved air and water quality, is essential to the economy (DUC, 2006). EG&S are the benefits humans derive from the services provided to ecosystems (Costanza et al., 1997).

Agricultural production can contribute to EG&S through the implementation of on-farm Beneficial Management Practices (BMPs). BMPs are practices that are beneficial to the environment and at the same time, practical for producers and meet or exceed legal requirements (AARD, 2004-a). Adoption of agricultural BMPs can result in increased environmental benefits and/or mitigate the negative environmental impacts from agricultural production (DUC, 2006). Agriculture and Agri-Food Canada (AAFC) recognize three general categories of agricultural BMPs: reducing inputs, controlling erosion and runoff, and barriers and buffers to intercept and contain contaminants (AAFC, 2000). Examples of agricultural BMPs include fertilizer/nutrient management, strip cropping, shelterbelts, buffer strips, cover crops, crop residue management, and conversion of cropland to permanent forage. These practices all contribute in some way to the supply of EG&S in ecosystems where agriculture plays a significant role.

Since healthy, diverse habitats provide economic and quality of life benefits for farmers and rural communities it is worthwhile to protect and preserve them (AARD, 2004-a). However, pressure to be competitive in the agricultural industry often results in extensive use of practices such as the cultivation of marginally productive lands and wetland drainage, and the higher use of agricultural chemicals, all of which contribute negatively to EG&S (DUC, 2006). When this happens, costs are incurred by society, such as increased water treatment costs, increased government payments, increased illness and healthcare costs due to decreased air and water quality, and increased costs for agricultural production (DUC, 2006). To correct for these externalities, governments may introduce policies to encourage the adoption of BMPs among producers or penalties for producers who are not meeting obligatory standards for management practices.

1.2 Economic Problem

For the purposes of this project it is assumed that producers are rational economic agents. While it is not always the case in reality that farmers minimize costs or maximize profits it is assumed that they act in an optimal way given labour, land, and financial constraints and unpredictable events. Therefore, producers provide an optimal level of EG&S, given their objectives. However, the optimal level of EG&S production from a producer perspective may be lower than what would be optimal from society's perspective. In this case, further adoption of BMPs to provide additional EG&S is not beneficial for producers and would likely result in net direct costs to producers. Previous research has shown that many BMPs come at a net cost to producers, such as lost agricultural land base and increased management costs (Cortus, 2005; Koeckhoven, 2008; Kort, 1988).

If BMP adoption is associated with a net cost for producers it is likely that policy intervention will be necessary for increased adoption to occur, with increased EG&S production as a consequence. The optimal type and degree of intervention should be based on relative costs and benefits associated with the resulting outcomes. Pannell (2008) divides the effects of land use change into “public” (i.e., societal) and “private” (i.e., producer) benefits. Pannell’s policy framework suggests that the appropriate policy instrument depends on the sign (i.e., positive versus negative) and relative magnitude of the public and private benefits. Policy mechanisms could include positive and negative incentives, such as subsidies and taxes when the public net benefit is greater than the private net cost or when the public net costs are greater than the private net benefits, respectively. Other policy mechanisms could include education programs where the BMP is beneficial to both society and producers but the practice is not yet known to producers.

Applying this framework to the economic problem in the current study, the public benefit is the potential value of increased EG&S production resulting from adoption of cropping BMPs. In identifying an appropriate policy response, this public benefit should be compared to the private benefit which is the direct financial impact of BMP adoption for crop producers. As suggested above, in many cases adoption may result in a net cost, which represents a negative private benefit. Quantitative estimates of these benefits, both public and private, are often lacking in many previous studies. This represents the economic problem addressed by the analysis in this thesis.

Literature on adopting BMPs in agricultural production to improve or create additional EG&S is relatively new and incomplete. In some cases, practices that have been used on farms for many years, such as shelterbelts, are now being recognized as potential BMPs. Other practices, such as zero-tillage seeding, have emerged (relatively) more recently due to technological innovation. Much of the current literature on this subject area describes the costs and benefits of BMP adoption in a qualitative manner. Other studies have quantified the costs and benefits using dynamic simulations, opportunity costs methods, and direct measurement of actual farming practices. This research proposes to quantify the benefits and costs of agricultural BMP adoption, accounting for stochastic events in agriculture and incorporating the assumption that producers will optimize production decisions based on current information.

1.3 Research Problem and Objectives

The purpose of this study is to quantify and evaluate the economic performance of representative Alberta crop farms with and without the adoption of BMPs. Specifically, the objective of the study is to evaluate the private economic costs and benefits associated with adoption of alternative BMPs for a set of representative Alberta farms. The motivation of the study includes determining quantifiable estimates of the net cost or benefit associated with BMP adoption for producers. The approximations from the study will be useful to both producers for making informed decisions and producer organizations in estimating sector impacts when consulting with government in policy development.

This study will also assess alternative BMPs in terms of the direct economic impact for producers. The results from this analysis are again useful to producers in providing estimates of the incentives required to make BMP adoption feasible. In addition to producers, policymakers will find this element of the analysis relevant in terms of identifying optimal policy instruments to ensure the appropriate mechanisms are used to encourage producers to adopt BMPs.

1.4 Organization of the Thesis

In addition to this introductory chapter, there are six subsequent chapters in this thesis. Chapter 2 provides a detailed look at BMPs in agriculture. This chapter discusses the background information of the issues the research problem in this thesis will address. The difficulties in implementing BMPs on crop farms and the currently measured economic costs and benefits of adopting BMPs will be discussed. This chapter will also provide an overview of the BMPs of interest for this project and how BMPs contribute to the production of EG&S. This chapter will cover literature relevant to the research problem, including BMP projects in Alberta, Canada, and internationally, literature on BMP simulation analysis, studies on the costs and benefits of implementing agricultural BMPs, and examples of policy for BMP adoption in Alberta.

Chapter 3 will provide an overview of agriculture in the regions of the representative farms. Specifically current adoption of BMPs in Alberta will be presented. Chapter 3 will also present results from agricultural data at the provincial and county level. For instance, the average farm size, crops grown and farming practices used will be discussed. This chapter also begins the methodology as to how each representative area is chosen, based on statistical agricultural activity.

Chapter 4 will discuss the logistics of the modelling techniques used to address the research objectives. Capital budgeting techniques, Monte Carlo simulation, and optimization will be compared with other techniques that are used for similar analyses.

In Chapter 5 a detailed description of the representative farms and the simulation model is given. The characteristics of the representative farms are given here as well as the simulation model structure which includes stochastic crop yield and crop price models. Chapter 5 outlines the economic relationships to be included in the final models to determine the effect of BMP adoption. Scenarios are developed and sensitivity analyses are discussed in this chapter. The sixth chapter will present the results and provide discussion of the modelling introduced in Chapter 5.

The final chapter, Chapter 7 will draw conclusions from the results presented in Chapter 6. These conclusions will determine the potential net benefit or cost to producers and how this impact affects producers and policy decisions. This chapter will then conclude with model limitations and future research that could be extrapolated from this study.

Chapter 2: Beneficial Management Practices and Agriculture

This chapter provides an overview of the issues and existing literature related to Beneficial Management Practices (BMPs) and agriculture in Alberta. The objective of the chapter is to use past studies and literature to identify areas of concern in agricultural practices and determine suitable BMPs to address the concerns. From this, BMPs can be analyzed based on the need for further research as indicated from past studies. This chapter summarizes what BMPs are, how they are relevant for agricultural operations, explores relationships between BMPs and ecological goods and services (EG&S), and examines how BMPs are implemented. Following this, a discussion of findings from BMP related studies and simulation modelling studies is presented. This chapter discusses existing methodology used to implement BMP adoption, including incentive and deterrent methods, followed by a literature review of existing BMP projects. Within the literature review previous studies using simulation analysis and cost-benefit analysis are examined.

2.1 Beneficial Management Practices

This section describes what BMPs are and the importance of BMP implementation to provide EG&S. Studies have shown that the societal optimum of EG&S is often higher than the amount supplied through BMP adoption by producers (Ruhl, 2008; Swinton, 2008; Zhang et al., 2007). Policy targeted at improving adoption rates of BMPs has addressed this issue to an extent. However, there is little research that specifically examines the quantitative costs and benefits of BMP adoption. Accurate estimates of the economic feasibility of BMP adoption are necessary to determine appropriate policy instruments to encourage sufficient adoption of BMPs.

2.1.1 Agricultural Beneficial Management Practices

There are various definitions of what constitutes a BMP. Boxall et al. (2008) define an agricultural BMP as an agricultural management practice that “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” (p. 5). BMPs improve soil, water, air, and wildlife habitat, contributing to farm profitability and environmental quality (AARD, 2004-a). Benefits of on-farm BMPs also extend to societal benefits, such as improved water, air, and wildlife habitat quality in areas surrounding farming operations.

Agricultural BMPs have a cost, whether it is time or money or both (Brethour et al., 2007). For adoption to occur it is assumed that producers would perceive the benefits to outweigh the costs of adoption, whether it be occurring from the practice itself or through policy programs. Before further analysis on the adoption of BMPs it is necessary to determine what types of practices qualify as BMPs and how these practices can be adopted.

Agriculture and Agri-Food Canada (AAFC) recognize three general types of BMPs: reducing inputs, controlling erosion and runoff, and barriers and buffers (AAFC, 2000). Within these categories, there are over 30 specific BMPs that are recognized by the Canadian Federal-Provincial Farm Stewardship program (AAFC, 2006). BMPs of interest in this project include riparian area management (greencover), erosion control structures, land management for soils at risk, improved cropping systems, cover crops, shelterbelt establishment (greencover), and nutrient management planning. These BMPs are of interest as they represent a set of practices that potentially address environmental concerns associated with crop production in Alberta. More specifically, this project examines adoption of managed crop rotations, shelterbelt establishment, buffer strips around wetlands, and residue management. While there are many categories of BMPs, some provide the same benefits that may be achieved using multiple practices. For instance, improving cropping systems could incorporate a nutrient management plan, diverse crop rotations, and erosion control structures to improve soil quality, thus improving the cropping system. As such, overlap of the categories is apparent in this project, as discussed in the current and subsequent chapters.

2.1.2 Ecological Goods and Services (EG&S)

Ecological systems provide EG&S, which are the valued goods and services humans get from nature (Constanza et al., 1997; Daily, 1997). Agricultural practices affect surrounding ecological systems, which can then affect agricultural productivity and societal well-being through changes in the production of EG&S (Dale and Polasky, 2007). EG&S can be classified into four general categories: provisioning, regulating, cultural, and supporting services (Zhang et al., 2007). Provisioning includes providing food, fiber and fuel; provisioning services are often optimized at the expense of environmental conditions (Ruhl, 2008). Regulating services maintain the balance of systems at levels that allow human survival, and include climate, water quality, and disease regulation (Swinton, 2008). Cultural services include recreational and spiritual human activities. Supporting services allow the previous three services to be possible by enabling organic matter and nutrient cycling, soil formation, photosynthesis, and other services. It should be noted that some agricultural production practices result in "dis-services", or reduced levels of EG&S production. For example, some practices may reduce productivity (e.g., competition among species for water and nutrients) or increase production costs (e.g., increased use of fertilizers in marginally productive soils) (Zhang et al., 2007).

EG&S that contribute to the success of managed agricultural systems include soil structure and fertility, pollination, water provision, and genetic diversity. Soil fertility is essential for agricultural productivity. Soil structure and fertility can be maintained with soil organic matter, soil carbon, and nutrient cycling (Swinton et al., 2007; Zhang et al., 2007). Carbon provides energy for invertebrates and microbes that allow the release and fixation of nutrients (Swinton et al., 2007; Zhang et al., 2007). Non-crop plants, such as cover crops, contribute to soil fertility by reducing soil erosion (as compared to summerfallow) and replenishing nutrients (Sullivan, 2003; Zhang et al., 2007). Seeding riparian areas to greencover or buffer zones further reduces erosion and improves soil fertility and structure (Blanco and Lal, 2010).

Agriculture depends on EG&S such as soil formation, nutrient cycling, and pollination, but the benefits from many EG&S have no direct value to the private producer (Swinton et al., 2007). Provisioning services are valued through commodity markets and as such producers have incentives for efficient production of these services. Crop and livestock production are the best quantified services provided from agriculture, as production benefits are typically proportional to the amount of effort extended (Dale and Polasky, 2007). However, in considering EG&S that provide regulating, cultural, and supporting services, they are either not fully captured in the commercial market, or there is no explicit market for these services (Costanza et al., 1997; Tilman et al., 2002). As such there are no private incentives for these services to be produced (Ruhl, 2008; Zhang et al., 2007). Many EG&S that are considered regulating services are only currently measured qualitatively. Currently there are no market based methods for measuring the private or social benefit of non-provisioning services (Dale and Polasky, 2007; Rae, 2007). In addition, most EG&S are specific to locations, making it difficult to define a market for such services (Kroeger and Casey, 2007). As such, farms tend to produce more provisioning services than regulating services, even though they are capable of producing multiple services (Ruhl, 2008).

To an extent the private cost of land reflects the supply of EG&S in terms of soil fertility and depth, as this relates to higher yields and production value for producers (Swinton et al., 2007). However this value does not consider EG&S provided at a societal or global scale. Since these types of EG&S benefit many people there is a lower incentive to produce them privately (Swinton et al., 2007). This creates a common pool resource problem at higher scales (Zhang et al., 2007). Producers are faced with the problem of all "public goods" in that they are non-rival and non-exclusive (Kroeger and Casey, 2007; Ruhl, 2008) and neighbouring producers can benefit from the actions of another. While market mechanisms work well for guiding supply decisions for provisioning services, the benefits associated with many EG&S are public in nature (Farber et al., 2002), providing benefit to producers and society at different scales. Since many policies do not consider coordinated behaviour among crop producers (Swinton et al., 2007), this promotes the problem of under-supply of EG&S at larger scales. Also a single producer who reduces environmentally damaging actions, such as high levels of nitrogen fertilizer application, would improve surrounding environments, but this could occur at the cost of lower yields and profit; the benefit of improving the surrounding environment has no direct benefit to the farm (Tilman et al., 2002).

Appropriate policies are needed to balance the trade-offs between private financial gains and social losses from alternative management choices (Zhang et al., 2007). Public policies should optimize these trade-offs to maximize socially desirable outcomes. To implement policy effectively it may be necessary to examine multiple EG&S in the same system (Zhang et al., 2007).

Related to the study of agriculture's role in the provision of EG&S is the issue of how the impact can be measured. One way in which agricultural practices may be linked to their impact on EG&S production is through the use of ecological indicators. Ecological indicators are measures used to assess the condition of the environment and monitor trends over time to provide warning of environmental changes (Dale and Polasky, 2007). Use of ecological indicators relates to managing farming practices as they can be used to predict how effective farm practices are in providing EG&S and evaluate farming conditions and events in how they provide EG&S (Dale and Polasky, 2007). Examples of ecological indicators include water quality and quantity, soil quality, and air quality. More specifically, water quality can be measured as the amount of phosphorus and nitrogen, soil quality can be measured as the degree of soil organic matter and soil aggregates present, and air quality can be measured as the amount of dust particles present.

Ecological indicators are useful to assist in revealing the value of EG&S from agriculture under various management scenarios as they provide a measure to quantify the impact of BMPs, which can then be used for valuation purposes. For example, buffers around riparian areas may provide additional EG&S, as compared to the scenario without buffer strips, by reducing erosion, improving water quality, increasing biodiversity, and expanding wildlife habitats (Dale and Polasky, 2007). A more specific example might be if water quality is improved from reduced chemical (i.e., phosphorus and nitrogen) runoff to a point where reduced treatment is needed for human consumption of the water, then buffer strips are at least worth the savings of reduced water treatment. This use of ecological indicators to predict the ability of systems to produce EG&S can also determine the best way to implement BMPs and estimate the effect of adoption of specific BMPs. However, the problem of scale persists as indicators may span large areas and benefits from providing EG&S may be non-exclusive, making it difficult to determine the appropriate measures and effects for single producers.

2.2 Beneficial Management Practices of Interest

This section discusses BMPs of interest for the regions in Alberta being examined. As noted earlier, there are many practices that could be considered as BMPs for adoption in cropping operations. Just as some EG&S are specific to spatial areas, BMPs are chosen based on the suitability to the regions and vary slightly between regions.[1] BMPs considered include variation of the crop rotations to include forages, field peas, cover crops, and oats, as appropriate by region. Non-rotational BMPs considered include shelterbelts, buffer strips, and residue management, which are considered at varying degrees again, as appropriate by region. Further information on the study areas is provided in Chapter 3. Information on how the BMPs are incorporated into the cash flow models for analysis is discussed in Chapter 5.

2.2.1 Crop Rotation Beneficial Management Practices

Effective crop rotations reduce diseases, insect pests, and weeds (AARD, 2008-b; Johnston et al., 2005). Crop rotation systems can reduce dependence on external inputs through internal nutrient cycling, maintenance of the long-term productivity of the land, and breaking weed and disease cycles (Gebremedhin and Schwab, 1998). Criteria taken in choosing crop rotations include the impact of specific crops on soil fertility, environmental quality, and farm profitability (Gebremedhin and Schwab, 1998). Crops of interest that are considered BMPs for this project include alfalfa, field peas, legume green manures, and oats. It is assumed that farms have base rotations and the BMP crops are added to these rotations. Rotating cereals with broadleaf crops, such as oilseeds or pulses, improves weed control without increasing the risk of herbicide resistance and can break most disease cycles (AARD, 2004-a). Further information on the base and BMP crop rotations is provided in Chapter 5.

2.2.1.1 Alfalfa in Crop Rotations

Alfalfa is a member of the flowering legume or pulse (*Fabaceae*) taxonomic family, and is a commonly grown forage crop. Alfalfa hay is used as feed for animals kept for recreation or other agricultural purposes, such as dairy or beef cattle, and has one of the highest feeding values of all common hay crops (Kansas Rural Center, 1998).

Alfalfa is also important as a crop that can help to achieve broader social goals (Putnam et al., 2001). Putnam et al. (2001) outline several benefits of growing alfalfa. Introducing alfalfa hay to crop rotations has the potential to protect soil from erosion due to the perennial nature of the crop. Protection from erosion leads to reductions in sediment loss into waterways, and improves water quality. The ability of alfalfa to fix atmospheric nitrogen leads to a reduction in the need for added fertilizers. By reducing the fertilization of crops there are energy savings through reduction in inputs and energy required to run machinery used for applying fertilizer. Reducing chemical inputs also improves the soil structure and reduces the amount of chemical that is leached into

[1] BMPs for each region (i.e., each representative farm) are chosen based on the relevance of the BMPs in addressing an environmental concern in the area of interest, and the feasibility of the BMPs themselves.

groundwater and the amount that enters surface water through runoff. Many mammal and fowl species, including endangered species, make their homes in alfalfa fields. Alfalfa fields are a source of insect diversity, which includes beneficial insects that control other pest insects found in crops. Seeding land to a perennial crop such as alfalfa also provides aesthetic value and open spaces, which are valued for both their use and non-use (or passive use) values by humans.

Hoyt and others (e.g., Hoyt, 1990; Hoyt and Hennig, 1971; Hoyt and Leitch, 1983) have conducted experiments to examine crop yields with and without the presence of perennial forage crops. Hoyt and Hennig (1971) conducted experiments in northern Alberta where wheat was grown continuously after forage crops, including alfalfa, bromegrass and red fescue, or a fallow year. Yields of wheat crops were 71, 82, 75, and 68% greater in the first, second, fourth and fifth year following alfalfa, respectively, as compared to the wheat crops following summerfallow with no additional fertilizers applied.[2] For wheat crops following bromegrass or red fescue forages the yields were comparable to yields following fallow practices. Hoyt and Hennig (1971) found an average yield benefit of 93% for wheat crops following alfalfa, as compared to wheat crops following other grasses, and conclude that legume crops benefit succeeding crops more than do grasses.

Hoyt and Leitch (1983) examined the effect of forages, including alfalfa, birdsfoot trefoil, alsike clover, red clover, and sweet clover, on subsequent barley yields in multiple regions in Alberta, as compared to yields following fallow practices. In three of the five regions studied barley yields were higher following the legumes when no additional fertilizer is applied, as compared to barley yields following fallow. In the remaining two locations there was no significant difference between barley yields following legumes or fallow. The authors also found moisture levels to be approximately the same in subsequent barley crops following both legumes and fallow. Due to significant yield increases in three of the five locations the authors concluded that including legumes that are used as hay crops (i.e., only the top layer is removed, retaining the roots) in rotation should generally be beneficial to grain crops, particularly in the Peace River region of Alberta.

A similar study by Hoyt (1990) found that the yield benefits to wheat crops following alfalfa extended up to thirteen years after the alfalfa stand is broken up, as compared to wheat following summerfallow. For the first eight crops of wheat following alfalfa, yields ranged from 66 to 114% greater than yields for eight years of continuous wheat following a year of fallow. This study also tested the effect of bromegrass and alfalfa mixtures and bromegrass alone on subsequent wheat yields. A bromegrass and alfalfa mixture had similar wheat yield results as alfalfa alone, while bromegrass alone resulted in significantly lower subsequent wheat yields than for the treatments that included alfalfa.

In other studies done in the United States, alfalfa is attributed to higher wheat yields for as long as fourteen years after alfalfa was in the rotation (Kansas Rural Center, 1998). Australian studies on alfalfa show similar yield impacts for subsequent crops. Holford (1980) found beneficial effects, including grain yield, nitrogen uptake and grain protein, on wheat crops following alfalfa, with the greatest effect reached in the second year, as compared to wheat grown after fallow practices. Many studies have reported the nitrogen benefit to crops following alfalfa stands to last up to seven years (Entz et al., 1995).

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[2] There is no recorded yield in the third year for Hoyt and Hennig's (1971) study due to loss from frost.

Holford (1980) also studied the effect of alfalfa stand length on subsequent crop benefits in Australia and found beneficial effects strongest when there are two or more years of alfalfa, with the optimal length being three years for improved wheat yields. Drawing from previous studies Entz et al. (1995) find that the minimum alfalfa stand duration for optimum nitrogen accumulation and weed suppression is two to three years, while the economically optimal alfalfa stand duration is four to five years. A three or four year stand of alfalfa provides the same nitrogen and weed suppression benefits as a six year stand, but according to Entz et al. (1995), Canadian prairie producers are less likely to break a stand of alfalfa after only two or three years due to difficultly in establishing alfalfa stands. Recommended lengths of alfalfa stands are four years in some areas of the United States, with the recommended subsequent crops in rotation being corn and small grains (Kansas Rural Center, 1998). Environmental benefits from including alfalfa in crop rotations can be improved by increasing the frequency with which this crop occurs in rotation and decreasing the length of the stand (Entz et al., 1995). The economics of reducing alfalfa stand length can be addressed with proper management of previous and subsequent crops. For example, in managing alfalfa in rotations it is best to follow alfalfa stands with a drought resistant crop (Kansas Rural Center, 1998). In preparing for seeding alfalfa a crop of wheat or oats in the same year helps establish young alfalfa plants (Kansas Rural Center, 1998).

One of the greatest benefits of growing alfalfa is the nitrogen fixing ability of *Rhizobium* bacteria in the roots of this crop (Hoyt and Hennig, 1971). However, considering that yield benefits are consistently seen five years following alfalfa it is likely that other benefits occur, such as increased permeability of soils due to the root systems in alfalfa (Hoyt and Hennig, 1971). Alfalfa stands contribute to grain yield increases from nitrogen contribution in the topsoil and subsoil, as well as rotational benefits from weed suppression (Entz et al., 1995; Holford, 1980; Hoyt, 1990; Hoyt and Leitch, 1983). While there are other non-nitrogen benefits of including alfalfa hay in rotation, including reduction of crop disease and soil structure improvements, this study considers yield changes following an alfalfa hay crop and potential fertilizer reduction from residual soil nitrogen following alfalfa as the beneficial effects of including leguminous forages in rotation.

2.2.1.2 Field Peas in Crop Rotations

The benefits of including pulse crops in crop rotations are well documented (Adderley et al., 2006; Lafond et al., 2007; Soon et al., 2004; Stevenson and van Kessel 1996). Field peas, as a member of the legume family are able to convert nitrogen gas into a form useable by plants. However, even with rotational benefits there must be market demand for producers to include this crop in rotations. Field peas are rich in protein, lysine, and starch, and are able to provide essential nutrients and energy to animals, making this crop a good source of animal feed (Lafond et al., 2007). Peas are generally less competitive with weeds and suffer greater yield losses in high risk years, as compared to barley or canola (Soon et al., 2004). However, studies have found that including pulse crops in rotation with cereal grains and oilseeds contributes to a higher and more stable net farm income, despite increased expenditures for inputs (Zentner et al., 2002).

Yields following field peas are often higher, as compared to cereal crop yields following cereal crops, due to improved nitrogen stores in the soil. Field peas have similar abilities as alfalfa, as both are leguminous crops, to fix atmospheric nitrogen. Some of the other, non-nitrogen benefits of alfalfa hay also transfer to field peas, including diversification of crops reducing weed species and crop diseases (AARD, 2008-

e). There are direct and indirect benefits of including a pulse crop in rotation with cereal and other broadleaf crops. Direct benefits refer to the nitrogen dynamics in the soil as a result of pulse crops, while the indirect benefits refer to the positive effect of pulses for reducing root and leaf diseases in subsequent crops (Lafond et al., 2007).

Lafond et al. (2007) conducted a study comparing continuous cropping of field peas with a rotation involving field peas and wheat. They found that continuous field peas resulted in yield reductions, as compared to rotations that had at least one year of wheat in between pea crops. While yields were unaffected by only having one or two years between pea crops, root rot and seedling diseases did become a factor if peas were grown too frequently. However, the disease issue was eliminated when there was a four year break between field pea crops. Hamel et al. (2007) also conducted a study in 2004 and 2005, comparing durum wheat yields following chickpeas, peas, lentils, and durum wheat. Durum wheat yields were highest following peas, as compared to any of the other crops tested, with yields being the lowest in a monoculture durum wheat rotation (Hamel et al., 2007).

Several studies have looked at the effect of field peas on subsequent cereal crops. Johnston et al. (2005) found that wheat is the best crop choice for pea stubble under drought conditions. Including field peas in annual crop rotations increased the yield and nitrogen uptake for subsequent wheat crops (Entz et al. 1995). A study in Saskatchewan found barley, canola and wheat yields to be 140, 126, and 147%, respectively, of yields for those crops when following peas (Saskatchewan Pulse Growers, 2000). In another Saskatchewan study Stevenson and van Kessel (1996) found wheat yields from six sites to be 43% higher following field peas in rotation, as compared to following wheat in rotation. From the Stevenson and van Kessel (1996) study it was further determined that approximately 8% of the yield increase is attributed to additional soil nitrogen from pea residue, while the remaining 92% is due to non-nitrogen rotation benefits, including reduction of wheat root diseases. Also in Saskatchewan, Adderley et al. (2006) compared spring wheat yields following field peas and lentils. Spring wheat yield and soil nitrogen levels were higher following field peas under conditions of low soil fertility. When soil nitrogen was already high, wheat yields were similar regardless of whether wheat was following field peas or lentil crops (Adderley et al., 2006). Soon et al. (2004) studied the effect of field peas on subsequent barley crops and found higher barley yields following field peas as compared to barley following barley or canola. In contrast to the study by Adderley et al. (2006), Soon et al. (2004) determined that the nitrogen benefit from field peas contributes more to barley yield increases than the rotational effect.

Johnston et al. (2005), looking at crop sequence in rotation, found that diverse cropping sequences, where cereal and broadleaf crops are not seeded on their own stubbles, are the least risky in terms of risk of yield and quality loss. Wheat seeded on pea stubble resulted in the highest grain protein while wheat seeded on wheat stubble resulted in the lowest grain protein, and represented the highest risk rotation (Johnston et al., 2005). Wheat or barley grown after peas or canola usually performs better (i.e., 10% to 20% higher yields) than a cereal grown after a similar cereal crop (AARD, 2004-a). Average yield increase in cereals following pulse crops compared with cereals following cereals is approximately 54%. However, yield increases from 0 to 100% have been reported (Evans et al., 1989).

2.2.1.3 Legume Green Manures in Crop Rotations

The practice of summerfallow in agriculture has historically been used in semi-arid regions of the Canadian prairies to retain soil moisture (AARD, 2008-b; Zentner et al., 2004). However, long term use of this practice, particularly when combined with conventional tillage has been linked with declines in soil quality due to declines in soil organic matter, increased soil salinization, increased wind and water erosion, and depleted soil nitrogen reserves (AARD, 2008-b; Zentner et al., 2004). Replacing or partially replacing summerfallow with an annual legume green manure crop has been suggested as these crops have potential to protect soil against erosion and increase nitrogen fertility of the soil (Zentner et al., 2004). Previous studies have hypothesized that including legume green manure crops as a partial or complete replacement of summerfallow may be costly in terms of additional seed and annual care costs, but these costs may be offset by long term benefits such as enhanced grain yields and reduced fertilizer costs (Zentner et al., 2004).

Green manuring involves incorporating a forage crop into the soil after flowering occurs (Sullivan, 2003) to maximize nitrogen fixation (Zentner et al., 2004). Summer green manure crops occupy the land for a portion of the growing season and are used to improve soil conditions (Sullivan, 2003). Legumes are frequently used as green manures for their ability to add nitrogen and organic matter to soils (AARD, 2004-a). Nitrogen accumulations from legume crops range from approximately 40 to 220 kilograms of nitrogen per hectare (Sullivan, 2003). Tilling the crop mid-season returns residues to the soil, but it is good practice to leave some of the residue above the soil surface to reduce the risk of erosion (AARD, 2004-a). The addition of organic matter to soil improves soil aggregation, which further benefits soil quality as aggregates reduce risk of soil erosion.

Zentner et al. (2004) tested the impact of replacing fallow with a legume green manure in a three year rotation in the Brown soil zone of Saskatchewan where two years of spring wheat had followed fallow. The authors noted that previous studies had found that cereal crops were generally disadvantaged when following legume green manures in rotation, as compared to following summerfallow, due to depleted soil moisture. However, many of these studies had examined the impact of legume green manure on subsequent crops over a period of six years or less. Zentner et al. (2004) were of the opinion that benefits from including legume green manures as a complete or partial replacement for summerfallow would only be evident after a longer period of time, and that benefits are dependent on optimal management of the crop. Specifically, legume green manures should be seeded early in the season and be terminated before the middle of July to improve soil moisture conditions, even though this may be before the flowering of the legume crop.

Zentner et al. (2004) undertook a twelve year study in which wheat yields following summerfallow were compared to yields when wheat followed a legume green manure crop. In the study, when legume crops were not terminated before mid-July, soil moisture was affected and lower subsequent wheat yields were observed. However when the legume crop was terminated on time wheat yield following legume green manures was not significantly different from wheat yield following summerfallow. Also, gradual nitrogen fertilizer savings were observed as well as savings from reduced use of tillage and herbicides, as compared to summerfallow practices. It was further determined that these benefits offset the additional seed and management costs associated with legume green manure crops.

Ross et al. (2009) conducted a study in central Alberta where multiple varieties of annual and perennial clovers and non-leguminous crops were ploughed down and followed by barley crops. Two soil types were tested, one with high fertility and the other with low fertility. At the high fertility site the legume green manures had only minor effects on subsequent barley yield or soil nitrate. At the low fertility site almost all clover green manures improved barley yields, with the yield being greater following perennial clovers as compared to annual clovers.

In the Ross et al. (2009) study, annual clovers provided additional forage biomass and soil nitrogen in situations with adequate rainfall. While their study provides information on the benefits of clover legumes it should be noted that for the current project legume green manures are only considered in the Brown and Dark Brown soil zone as a complete or partial replacement for summerfallow. Conversely, the Ross et al. (2009) study was conducted in the Black soil zone, which has different soil and climate qualities, and is generally considered more fertile than Brown soils. As such, their results for legume green manures must be considered with care.

Hilliard et al. (2002) recommend caution with respect to the use of green manure crops, as depletion of soil water by the cover crop or an inter-crop may increase yield risk, particularly in the Brown soil zone. The authors note that it has been observed by previous studies that summer green manure crops in a year with greater than average precipitation may still lower the yield of the next crop. As mentioned previously, the timing to ensure beneficial green manure crops is critical. Hilliard et al. (2002) note that in trials in the Brown soil zone, planting of legume green manures must be early and the crop should be terminated in July to conserve moisture.

Legumes can be beneficial to subsequent crops, but this effect is marginal in some cases. For example, Hoyt and Hennig (1970) found that yields for wheat crops grown after sweet clover only increased by an average of 20 kilograms per hectare as compared to wheat crops following fallow practices. When moisture limits production, legumes provide less yield benefit, and may even reduce yield (Saskatchewan Pulse Growers, 2000). However, from the research on the relationship of legume green manures with subsequent crops it is evident that careful management of the crop affects the potential benefit of including this crop in rotation. While the benefits of including legume green manures on subsequent crop yields is still debatable, and any yield benefits relative to summerfallow or crop residues may be regional, standing green biomass is considered approximately 2.5 times more effective at reducing the risk of soil erosion (McMaster and Wilhelm, 1997).

2.2.1.4 Oats in Crop Rotations

Oats are primarily grown as livestock feed, and to a lesser extent for human consumption and seed production. Benefits of growing oats include frost tolerance and high production potential (WAAF, 2007). Oat crops are also more successful on marginal lands (Wilde, 2011), such as lands with high moisture content and acidic soils, as compared to other cereal crops (ECSWCC, 2004). Properties of the crop may improve soil organic matter as there are higher residue amounts from oats, both on the surface and sub-surface root system (ECSWCC, 2004).

While including oats in crop rotations would not be considered by many crop producers as a BMP it is considered as such for this project. Oat crops require only about two thirds of the amount of inputs as other cereal grains (Wilde, 2011). Specifically, oat crops do not have wild oat herbicide, which implies that oats should only be grown on lands with low occurrences of wild oat. Fewer inputs suggest fewer chemicals to leach into groundwater or enter waterways in runoff. Fewer inputs also imply lower costs for producers. Also, the ability of oats to generate higher quantities of residue than some other cereal crops may be beneficial to producers as either revenue if it is removed or as a soil erosion management tool if it is retained.

2.2.2 Non-Rotational Beneficial Management Practices

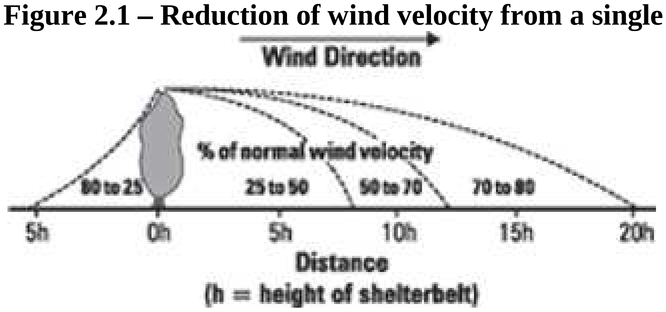
The non-rotational BMPs considered in this study have the potential to improve crop yields by reducing risk of erosion by wind or water. This directly improves soil condition and quality and may lead to improved yields. BMPs discussed in this section include shelterbelts, buffer strips around wetlands, and crop residue management techniques. In addition to these, other non-rotational BMPs that are not discussed in detail, may also have implications for reduced nutrient runoff and improve quality of surrounding water sources as well as soil quality.

2.2.2.1 Shelterbelts

A shelterbelt is a barrier of trees or shrubs (AARD, 2007-a) that is typically established to reduce soil erosion by wind. While modern agricultural practices, such as zero tillage, have reduced the risk of wind erosion there continues to be significant risk of soil loss due to wind erosion as a result of agricultural practices. This is particularly true for regions of southern Alberta in the Brown and Dark Brown soil zones (i.e., see Figure 3.3 in Chapter 3).

The primary benefit of shelterbelts is wind reduction. Figure 2.1 shows how wind velocity is changed as a result of a single row shelterbelt. Wind velocity can be reduced over a distance equal to twenty times the height of the trees (AAFC, 2007-b; AARD, 2007-a). Reducing wind velocity by directing wind up off the land with shelterbelts reduces the risk of soil erosion and soil moisture evaporation (Kock, 1990). Field shelterbelts may also increase yield productivity through increased snow retention and by providing protection for crops from damaging weather (i.e., wind and rain) (AAFC, 2007-b). Shelterbelts provide diversification opportunities, habitat for wildlife, reduce greenhouse gas emissions by storing carbon dioxide and beautify the landscape (AAFC, 2007-b; AARD, 2007-a). However, with the benefits of shelterbelts there are also associated costs which are discussed in this section. This section also discusses the importance of properly designed shelterbelts.

Figure 2.1 – Reduction of wind velocity from a single row shelterbelt



Source: *Adapted from* AARD (2007-a) *with permission from Alberta Agriculture and Rural Development*

Properly designed shelterbelts prevent or greatly reduce the risk of wind erosion (AARD, 2007-a). Dense thick walled shelterbelts do not reduce wind speed, but rather deflect wind upward temporarily (Kock, 1990). A single row of trees is a more effective shelterbelt as more wind will pass through the trees with resistance, thereby reducing wind speed (Kock, 1990). To provide protection to highly erodible prairie soils up to five to eight single rows of trees per quarter section planted at right angles to the prevailing winds is recommended (AAFC, 2007-b; AARD, 2007-a). However, while several rows per quarter section are recommended, any shelterbelt in the field is beneficial (AAFC, 2007-b).

Since field shelterbelts should be tall and long-lived, approximately 50% to 60% should be foliage from species such as scotch and white pine or spruce (AAFC, 2007-b; Kock, 1990). Taller trees, such as those previously mentioned, are also preferred since the area that can be protected is directly related to the height of the shelterbelt (AAFC, 2007-b). Shelterbelts are planted as young trees that will eventually mature and reach heights up to 15 metres and widths up to 10 metres (AAFC, 2007-b). Therefore, in planning field shelterbelts it is important to account for sufficient space between shelterbelt rows to permit the passage of maintenance equipment in the years immediately after establishment (AAFC, 2007-b). Spacing between trees also allows adequate light, moisture and nutrients for proper growth and establishment of the shelterbelt (AAFC, 2007-b). The cumulative effect of using more appropriate shelterbelt design, and not relying only on dense trees, will produce an agricultural system that is socially and environmentally beneficial (Kock, 1990).

Crop yield increases are possible from shelterbelts that are established using proper design and management. For example, a study in Ontario found soybean yields increased almost 30% with the use of shelterbelts (Kock, 1990), with the yield increases more than making up for the land that is taken out of cultivation. The increased yields are typically a result of some combination of prevention of wind erosion and damage, improved snow distribution, and microclimate modification (Kort, 1988). Lower wind velocity from shelterbelts reduces the risk of wind removing crop seeds before they root, decreases crop damage from blown soil particles, and decreases the risk of lodging[3] (Kort, 1988). Wind reduction also improves long term soil retention. In northern regions where soil moisture is relatively low, improved snow distribution may provide additional spring moisture, leading to improved crop yields (Kort, 1988). Shelterbelts may also change microclimate characteristics. This may improve crop yields through improved soil moisture, temperature, humidity, and evaporation conditions (Kort, 1988). Improving microclimate conditions has also been shown to increase crop quality and speed up maturity; increases in gluten up to 33% in wheat and canola harvest two weeks earlier have been observed (Kort, 1988).

Some studies have found that crop yield response from shelterbelts differs among crops. In a study by Kort (1988) comparing yield responses from the literature, it was found that of crops tested, winter wheat, barley, rye, millet, alfalfa and hay (mixed grasses and legumes) were highly responsive to protection, while spring wheat, oats and corn responded at a lesser degree. The effect of shelterbelts on crop yields is highly influenced by proper management. As previously mentioned, shelterbelt height and longevity, field width and shelterbelt orientation are important considerations in determining the effect of shelterbelts on crop yields (Kort, 1988). Baldwin (1988) also conducted a study comparing previous results from the literature on the effect of shelterbelts on yields of specialty crops.[4] Since prices for specialty crops are more dependent on quality than is the case for animal feed crops the author found that extensive wind protection is beneficial for these crops as quality improved in most crops examined and crop yields improved by 5 to 50% (Baldwin, 1988).

A shelterbelt study was conducted by AARD (2004-b) from 1990 to 1995 in Brown, Dark Brown, Black, and Dark Grey soil zones in Alberta. Crops examined included wheat, oats, barley, peas, canola, and hay. The study also looked at various types

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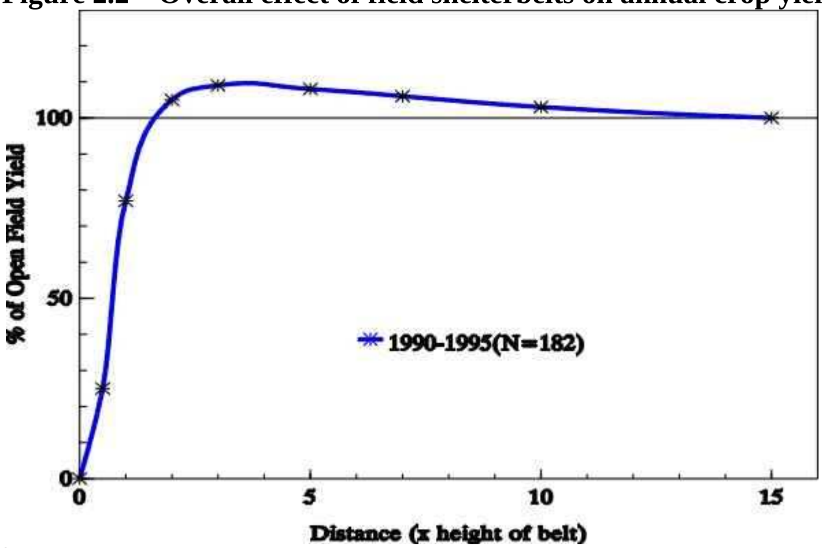
[3] Lodging occurs when the stem or root of the plant is bent or broken. This can result from structural conditions of the plant or environmental conditions. When lodging occurs over large areas, flattened crops can reduce crop quality and/or yield due to reduced photosynthesis potential and harvestability (Kort, 1988).

[4] The definition of specialty crops differs from study to study. For example, Baldwin (1988) defined specialty crops to include beans, sugar beets, tomatoes, potatoes, melons, tobacco, strawberries, and raspberries. AARD (2009) considers all field crops, excluding the six major crops (i.e., wheat, barley, oats, rye, canola, and flaxseed) along with vegetables and tame hay, to be specialty crops.

of tree species within the shelterbelt, including caragana, poplar, spruce, green ash, willow, and mixed shelterbelts. Overall, the study found a crop yield reduction, as a percentage of the open field yield (i.e., unaffected by the shelterbelt), in the areas directly adjacent to the shelterbelts. In the area outside of this there was an observed yield increase (Figure 2.2). It was determined that yield increases were observed in areas farther from the shelterbelt since the crops were not competing with the trees for moisture and nutrients. Further, the study cautioned that above normal precipitation occurred in the years from 1993 to 1995, when most of the data were collected. Considering the crop yield effect due to shelterbelt establishment would likely be greater in dry years, the results obtained may be conservative. Further results from this study are discussed in Chapter 5 in the context of the assumptions made in modelling shelterbelt adoption for the current study.

Figure 2.2 – Overall effect of field shelterbelts on annual crop yields[a]



[a] N is the number of sites in the study. For the horizontal axis, “Distance” refers to the distance from the shelterbelt measured in terms of the height of the trees.

Source: *Adapted from* AARD (2004-b) *with permission from Alberta Agriculture and Rural Development*

When determining the net effect of shelterbelt establishment the area required for the shelterbelts should be considered, as the amount of land available for cropping activities is reduced (Hilliard et al., 2002). Also, as shelterbelts are living barriers that require nutrients and water, crop yields directly adjacent to the trees may decrease due to competition for these resources (Kort, 1988). While increased snow in areas adjacent to shelterbelts may improve soil moisture conditions, it may cause increased nitrogen leaching, which could also lead to decreased yields in these areas. This could be mitigated, however, by increasing nitrogen fertilization in these areas (Kort, 1988). Hilliard et al. (2002) also point out that while shelterbelts provide habitat for species, including at risk and beneficial insects, they may also harbour nuisance species, which could result in crop losses.

While it has been known for nearly a century that field shelterbelts benefit crops by providing shelter, the overall net benefit from shelterbelts is difficult to quantify (Kort, 1988). Therefore, the results of previous studies should be considered with caution. Many studies only consider crop yields near shelterbelts in a limited perspective, making it difficult to determine actual overall benefit. Often factors that are not considered include land lost from production for field shelterbelts, the tree species that make up the shelterbelts, soil texture, climate, number of years in the study, yield sampling techniques, the spacing of the shelterbelts, and the number of shelterbelts per field (Kort, 1988). The degree of crop yield decreases due to competition with shelterbelt trees is dependent on the tree species, crop species, and geographical location (Kort, 1988). Previous studies have shown that Siberian elm is more competitive for resources with crops than are green ash trees (Kort, 1988). Corn yields have also been shown to be less affected by adjacent shelterbelts than other annual crops (Kort, 1988). Many of these factors are not considered in examining literature on crop yields adjacent to shelterbelts, and as such it is difficult to accurately determine the true yield effects from shelterbelts.

Shelterbelts also have a lifespan, and if the benefits are to continue, the shelterbelt will eventually need to be replaced (Hilliard et al., 2002). Many studies also do not consider the social benefits of shelterbelts, which include, but are not limited to, air quality benefits, reduced greenhouse gas emissions, water quality benefits, enhanced biodiversity, consumptive wildlife use, non-consumptive wildlife habitat, odour reduction, aesthetic value, and reduction in pesticide drift (Kulshreshtha and Kort, 2009).

2.2.2.2 Buffer Strips

Buffer strips are corridors of vegetation established around waterways to filter sediment, reduce water runoff, and remove nutrients leaving upland ecosystems (Blanco and Lal, 2008; Crop Nutrients Council, 2004; Hilliard et al., 2002). Sediments are mineral or plant materials that are suspended in water and wind (AAFC, 2000). Sediments can fill in waterways, ruin fish habitat, contribute to the transport of plant nutrients, and increase the costs of water treatment (AAFC, 2000). Nutrients are minerals required for plant growth that are present in chemical fertilizers, manure and other organic fertilizers, such as plant residues (AAFC, 2000). Nutrients can be transported from agricultural lands to surface and ground water and can produce unwanted growth of algae and aquatic plants (AAFC, 2000). Buffers can trap over 70% of sediments, over 50% of phosphorus and over 80% of nitrate runoff (AARD, 2004-a; Blanco and Lal, 2008). Buffers can also stabilize eroding banks and soil, bind soil aggregates and increase soil organic matter content (Vanderwel and Jedrych, 1997; Blanco and Lal; 2008). Finally, buffers are potentially important for wildlife habitat and protection of biodiversity (Vanderwel and Jedrych, 1997; Blanco and Lal, 2008).

Buffer strips can be as simple as grassed areas bordering waterways or as complex as an entire riparian zone (Crop Nutrients Council, 2004). For the purposes of this project buffer strips will refer to grassed filter strips around wetlands. Based on the placement of buffer strips they are an interface between terrestrial and aquatic ecosystems (e.g., see Figure 2.3), making the functionality of the buffers dependent on both terrestrial and aquatic environments (Blanco and Lal, 2008).

Figure 2.3 – Buffer strip between a waterway and cropland

Source: Cows and Fish (Alberta Riparian Habitat Management Society)© (2003) *with permission from Cows and Fish*

The use of buffer strips has been gaining in popularity (Crops Nutrients Council, 2004), and buffer strips are considered a BMP for water quality management (Blanco and Lal, 2008). However, the adoption of buffer strips is still limited in Canada and the United States due to management and economic constraints (Blanco and Lal, 2008; Toma and Bouma Management Consultants, 2007). A study exploring the net changes in expected farm revenues found that losses occur in all areas considered when buffers are adopted, with the greatest net decrease observed in the Black soil zone in Alberta (Toma and Bouma Management Consultants, 2007).

Hilliard et al. (2002) reviewed previous studies on the sediment trapping ability of vegetated buffer strips. The authors found that early research reported high trapping efficiencies by vegetation, but as flow rates increased effectiveness decreased to a point where it was ineffective in removing sediment. Different buffer widths were required to effectively remove different sized particles. Hilliard et al. (2002) indicated that larger particles, such as sand, were effectively removed with a three metre wide buffer, but silt and clay were only effectively removed with 15 and 122 metre buffer strips, respectively.

While buffer strip width is an important consideration in the design of successful buffer strips, Hilliard et al. (2002) also determined that the height of the buffer strip vegetation may be more important than the strip width. In particular, greater vegetation height resulted in more effective filtering. Simulated erosion models indicated that approximately five and nine metre vegetated buffer strips could remove 63% and 78% of sediment from cropland runoff. Effectiveness of buffer strips varies due to incoming sediment load, flow rate per unit length, vegetation height and density, and filter slope and width (Hilliard et al., 2002).

A study using simulated models of a 60 hectare watershed in central Alberta by Vanderwel and Jedrych (1997) examined the effect of buffer strips on sediment retention. It was assumed in this study that the slope of the watershed ranges from 4% to 7% in upland areas and 16% to 100% in riparian areas. A 20 metre wide buffer strip reduced the sediment leaving the watershed by 11%, while a buffer strip 90 metres wide reduced the sediment leaving the watershed by 38%.

Rao et al. (2009) conducted a study on the minimization of non-point source pollution in agricultural watersheds in New York and found that the introduction of buffer strips did not change stream discharge or the baseflow phosphorus concentration.

Also, the introduction of buffer strips on 3.2% of the land required other land uses to be adjusted by reducing the amount of land available for production. However, the authors noted that the fact there was no impact from BMP adoption may be attributable to a lag effect; that is, a lag between adoption and when the effects of adoption become measurable.

In a study on the economic impact of buffer strip adoption, Sparling and Brethour (2007) concluded that buffer strips reduce expected net revenue on model farms in various regions of Canada. Loss of revenues was attributed to high costs of buffer strip establishment and lost crop production in the area of the buffer. However, their study did not consider the environmental benefits that could be captured from buffer strips, such as reduced erosion, and as a result the benefit of buffer strips may be underestimated.

In a study using Finnish data for nutrient and sediment runoff it was discovered that, based on the private benefits of grassed buffer strips, adoption would not occur unless either producers were paid to establish buffer strips or the BMP was made mandatory; that is, regulated (Lankoski et al., 2006). The Finnish study also examined tillage technology with different crops and found that optimal buffer strip payments depend on the cropping and tillage technologies used by producers (Lankoski et al., 2006).

As is the case for shelterbelt adoption, when designing a buffer zone it is important to identify and account for any issues or problems in order to provide the most benefit (Vanderwel and Jedrych, 1997). This may require determining the appropriate buffer zone width, vegetation types (trees, shrubs, grass) and (if relevant) grazing strategies (Vanderwel and Jedrych, 1997). While the benefits of buffer strips around wetlands, such as top soil retention which improves crop production, aesthetic appearance, and harvest of trees or grass crops are important they are often difficult to quantify in terms of value (Boxall et al., 2008).

2.2.2.3 Residue Management

Crop residues are the materials left over after grain harvest (e.g., straw from cereal crops). Residues can be retained or removed by baling, burning or tillage operations. Retaining crop residues on the field potentially offers many benefits, including increased snow catch and water infiltration, reduced moisture evaporation, increased soil organic matter, improved soil structure and plant nutrient cycling, reduced chance of wind and water erosion, and reduction of some weed species (AARD, 1999-b). Retention of crop residues on the soil surface has a significant effect on soil quality by increasing soil organic carbon, improving soil physical properties, and enhancing microbial activity and biomass (Krupinsky et al., 2007). Removal, incorporation or burning of residues may predispose the soil to erosion (AARD, 2000). Maintaining crop residues is particularly beneficial when combined with direct seeding technology. Standing crop residues have been shown to provide erosion control, soil and water conservation, and lead to higher grain yields (Lafond et al., 2009).

Higher levels of soil organic matter in the top layer of soils improve soil aggregation. Soils with greater aggregation have a lower risk of erosion. Aggregation is important for good soil structure, aeration, water infiltration, and resistance to erosion (AARD, 2000). Soil organic matter improves the aggregation ability of the top layer of soil, and raw plant residues on soil surfaces contribute up to 10% of soil organic matter (AARD, 2000). In Alberta the Brown soil zones have the least amount of organic matter due to lower inputs of plant residues when the soils were developing (AARD, 2000). Therefore, retaining crop residues may be more beneficial in the Brown soil zone. The Black soil zone developed under cooler and wetter conditions, which allowed for more growth and residue to accumulate, leading to higher organic matter levels (AARD, 2000). Excessive cultivation of soils leads to soil organic matter loss. This is a concern as lower levels of organic matter result in declines in crop productivity (AARD, 2000). Reducing summerfallow, incorporating forages into crop rotations, reducing tillage frequency, and returning crop residues to the soil improve the ability to maintain soil organic matter for profitable crop production (AARD, 2000).

Malhi et al. (2006) conducted a four year field study near Star City, Saskatchewan to determine the effect of tillage type and crop residue management on crop yields, nitrogen uptake, carbon removal by cropping, soil organic carbon, and soil aggregation. The study considered scenarios that included conventional and no tillage technologies and the removal versus retention of crop residues. In the study the rotation used consisted of barley, peas, wheat, and canola. There was no seed or straw yield effect from no-till or residue retention for the first three crops. However, in the fourth year, when canola is grown on wheat residue, residue retention increased seed and straw yields of canola by 33 and 19%, respectively. No-till also increased seed and straw yields by 55 and 32% in the fourth year of the study. Total soil organic carbon after four years was greater in the soils for which residue had been retained. Erodible aggregates were lower in plots with no-till and residue retention and large aggregates were more common under this treatment, indicating less potential for soil erosion when tillage practices are removed and residues are retained.

Singh and Malhi (2006) conducted a six year study on Black and Grey soils in Alberta to determine the effect of tillage type and residue management on soil aggregation and infiltration rate. As in the study conducted by Malhi et al. (2006) tillage treatments included conventional and no-till and residue management treatments included straw removal and retention. In the Black soil zone large dry aggregates were higher under no-till with straw retention, and lowest under conventional tillage with straw removal. However, it was concluded that soil aggregation benefited more from no-till practices than from residue retention. Residue retention did improve infiltration rates under both types of tillage in the Black soil zone. In the Grey soil zone tillage types and residue management had no effect on infiltration rate. Conclusions from this study included recommendations for residue management and no-till practices in western Canada in order to improve aggregation of soil particles and reduce the risk of soil erosion.

Krupinsky et al. (2007) conducted a study examining the influence of crop and crop sequencing on crop residue coverage of soils. Crops considered in the study included buckwheat, canola, chickpea, corn, dry peas, grain sorghum, lentils, sunflowers, proso millet, and hard red spring wheat. Of the crop sequences considered in the study, sequences containing wheat, millet and sorghum crops resulted in the greatest amount (i.e., by weight) of crop residues. Their study considered the effect of residue cover after two years, concluding that a first year crop of one of the three previously mentioned crops with higher residue amounts could provide sufficient residue even when the second crop had low or less durable residues (e.g., dry peas or sunflowers). Producers operating on more erodible or marginal soils were advised to grow crops with higher residues in the year before crops with lower residue amounts.

As soil organic matter differs between soil zones, so does optimal management of crop residues. In the Brown and Dark Brown soil zones of Alberta residual stubble is often left to control wind erosion and trap snow (AARD, 1999-b). In the Black and Grey soil zones larger amounts of residue may require more frequent removal to ensure that soils drain and warm in the spring (AARD, 1999-b). Crop residues must be spread evenly and removed or partially removed in some cases to avoid machinery complications, poor seed germination, disease, weed and insect infestations, and cold soils (AARD, 1999-b).

Sidhu and Beri (1988) conducted an experiment examining the effect of chopped and unchopped wheat residues on subsequent grain yields and soil properties. After four years of the study, results showed that wheat residue incorporation into the soil improved soil properties and increased grain and stover yields of subsequent corn crops significantly. However, wheat yields following the incorporation of wheat residues were depressed. This outcome is likely partially due to rotational benefits of including more diversity in crop rotations.

A study of corn and soybean residues in the Midwestern United States found that crop residues can reduce stress on crops, as compared to crops where surface residues are removed (Power et al., 1986). The authors found that increasing amounts of crop residue resulted in reduced maximum soil temperatures during the hot growing season, increased soil water storage, and improved nitrogen uptake ability of crops (Power et al., 1986). This study is specific to a geographical region where the growing season is frequently hot and dry. Therefore retained crop residues improve the growth of the crops by providing more optimal conditions for microbial activity, namely more favourable temperature and moisture conditions.

In general, changes in surface soil condition from crop residue management improve the functioning of cropping systems through increased water storage, reduced soil erosion, and improved nutrient conservation (Krupinsky et al., 2007). Improvements in soil condition through the retention of crop residues increase the resilience of cropping systems to droughts, wet periods, intense precipitation events, and extreme temperatures, all of which are common in the prairie regions of Canada (Krupinsky et al., 2007). However, when high amounts of crop residues are present with high moisture conditions, germination of crops may be delayed or reduced due to lower soil temperatures and excessive moisture.

The amount and distribution of crop residues on and near the soil surface can influence solar energy at the soil surface, the extent of protection against raindrop impact and strong winds, as well as soil biological activity (Singh et al., 1994).Therefore, active crop residue management, where producers determine whether to retain or remove crop residues based on soil conditions, is necessary for economic success of this BMP. The management of crop residue is important because of its implications on soil moisture conservation in the short term, and on soil organic matter content over the longer term (Korol, 2004). With crop residue management, well designed crop rotations are also essential as they determine the type and amount of crop residues present and the rate of residue decomposition (Lafond et al., 2009).

2.3 Evidence of Beneficial Management Practices Awareness and Adoption by Producers

The objective of this study is to determine if selected BMPs are economically feasible for adoption on Alberta crop operations. However, it is also useful to examine producer awareness of BMPs as evidence of adoption rates for BMPs. This information provides support for the current research in two ways. First, if producers do not appear to be aware of the role of certain production practices as BMPs, more information concerning the impact of those practices may be valuable to both producer organizations and policymakers. Secondly, for those practices with which producers are familiar and for which there has been significant adoption, it may not be necessary to do any further analysis. Determining where gaps exist and examining patterns in BMP adoption and policy helps focus research efforts in this study. In the following section, literature concerning awareness and adoption of BMPs by Canadian agricultural producers, with emphasis on cropping operations, is reviewed.

Producer surveys provide insight of the current on-farm activities and how these activities relate to the environment. The Farm Environmental Management Survey (FEMS) is a national program that surveys Canadian crop and livestock producers, on a voluntary basis (AAFC, 2007-a), as to types of practices in use that are linked to the environment. To date there have been two sets of FEMS, one in 2001 and the other in 2006. The surveys are used to establish baselines in management activities and develop agri-environmental indicators (AAFC, 2007-a). Soil, water, and air quality are used as indicators to provide insight and management for environmental risks from agriculture (Eilers et al., 2010; Lefebvre et al., 2005). These indicators determine the current status of environmental management on farms across Canada and identify areas in which assistance may be required in order for sufficient adoption levels of appropriate practices to occur (AAFC, 2007-a). The FEMS investigates several indicators involving land and water management and whole farm management. From this information policy can be designed to encourage further adoption of BMPs through education, regulations, or incentives. Census of Agriculture surveys also provide baseline information of on-farm activities and contribute to policy decisions.

A topic addressed in the FEMS is the frequency with which Environmental Farm Plans (EFP) are used by producers. The EFP program is a voluntary self-assessment designed to help producers reduce risk through education concerning agricultural impacts on the environment, namely on soil, water, air, and habitat quality (Alberta EFP, 2011). Producer participation in EFP increases the likelihood of producers decreasing farm inputs such as fertilizers and chemicals, with resulting improvement in the health and safety of agricultural operations (Alberta EFP, 2011). Respondents to the 2006 FEMS indicated that 28% of farms in Canada had formal, written EFP and 10% had plans under development (Eilers, 2010).[5] In Alberta approximately 24% of respondents indicated that EFPs were in use in 2006, with this estimate increasing to 40% of respondents with an EFP in 2010 (AARD, 2011-a).

From 1981 to 2006, agricultural land use, specifically with crop land area, increased in intensity across Canada. The proportion of cropland to total farm land increased, and the area under summerfallow decreased (Eilers et al., 2010). Over this same period cropping diversity also increased in response to market opportunities for oilseeds, pulses, and forages (Eilers et al., 2010). Increased agricultural intensity increases the potential for environmental risks due to changes in soil, water and air quality. Agriculture uses many inputs to improve yields and profitability, including chemical and manure fertilizers and pesticides.

Manure management is an environmental challenge as improper storage and application techniques can increase environmental risks (Eiler et al., 2010). While storage is primarily a problem for livestock producers, application of manure provides nutrients for crops, and therefore is an important consideration for cropping operations as well. The rate, method, and timing of manure application and incorporation can influence the total nutrients lost in runoff (Eiler et al., 2010). Manure BMPs (e.g., incorporation of manure into the soil, improved manure storage through composting) on farms in Canada are designed to prevent runoff, protect groundwater and surface water, minimize odour and air pollution, provide sufficient manure storage until applied to the land, and minimize nutrient losses during storage (Beaulieu, 2004; Bourque and Koroluk, 2003).

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[5] The number of farms per province with EFP or EFP under development was not available in the publication by Eilers (2010).

According to the 2001 FEMS, 32.6% of manure produced was on farms that had fully implemented manure management BMPs, while 15.9% of manure produced was on farms having partially implemented manure management BMPs (Beaulieu, 2004). Conversely, farm respondents reporting that they were unfamiliar with BMPs for manure in their region were responsible for 41.7% of manure produced (Beaulieu 2004). Almost one quarter of farms with livestock did not have any type of manure storage in 2001 (Bourque and Koroluk, 2003). According to the 2006 FEMS farms with an EFP were more likely to have runoff containment when storing manure, as compared to farms without an EFP (Eilers et al., 2010).

Nitrogen and phosphorus are plant nutrients added to agricultural crops in the form of fertilizers and manure in order to increase yields (Eilers et al., 2010). However, there is potential for these nutrients to leach into the broader environment, particularly into groundwater sources, thereby affecting water quality in environments surrounding agricultural lands (Eilers et al., 2010). While essential to plant growth, excessive amounts of nitrogen and phosphorus can cause eutrophication of water bodies and excess manure can harbour disease causing organisms. Both of these situations are potentially damaging to human, livestock, and wildlife well-being. According to the 2001 FEMS approximately 75% of Canadian farmers who grow crops use fertilizers, with approximately 90% of the fertilizer being applied in the spring (Korol, 2004). Approximately half of responding Canadian farmers use soil test results to determine the amount of fertilizer required, but less than 20% do this annually (Korol, 2004). Of survey participants that grew nitrogen fixing crops (i.e., leguminous crops such as alfalfa, field peas, red clover), 69% adjusted fertilizer applications the following year to account for nutrients left in the soil (Brethour et al., 2007).

Pesticides are used to prevent losses in crop yield. As is the case for nutrients, pesticides also have the ability to leach through soils and travel to water bodies via runoff. Almost 75% of Canadian farmers who grow crops and/or have pasture apply pesticides. Proper application of herbicides allows for reduction in summerfallow tillage, which reduces soil erosion (Koroluk et al., 1998). Findings from the 1995 Farm Inputs Management Survey in Canada indicate that use of crop rotations is the most common non-chemical pest control method (Koroluk et al., 1998).

Prevention of erosion is essential for maintaining clean water and minimizing the loss of productive soils (Eilers, 2010). Without soil cover land is more susceptible to erosion by wind and water. This can lead to increased potential for ground and surface water contamination by solids, nutrients, and chemicals (Eilers et al., 2010). Residue or crops covering agricultural lands improve soil organic matter levels and fertility in the long term and has implications for soil moisture conservation in the short term (Korol, 2004). The amount of residue remaining after a crop harvest is dependent on the type of crop grown and the yields of that crop in the given year. Forage crops provide cover year round, while annual crops may leave some soil exposed after harvest (Eilers et al., 2010). According to the 2001 FEMS 42% of producers used the “chop and spread” technique to distribute crop residues, while approximately 40% removed crop residues by baling (Korol, 2004). According to the 2006 FEMS 34% of producers reported planting permanent forages on erodible land (Eilers et al., 2010). In addition to this, 23% seeded green manures after harvest, and 11% planted winter cover crops (Eilers et al., 2010). The 2006 survey also reported 31% and 20% of producers having farmstead and field shelterbelts, respectively. Erosion risk is also reduced using conservation tillage, which has become increasingly applied to agricultural lands due to proven improvements in soil moisture and erosion (Lefebvre et al., 2005).

Most farms in Canada have permanent or seasonal surface water in various forms, including wetlands, streams, dugouts or ponds (Eilers, 2010). As mentioned previously, runoff containing soil particles or chemicals can degrade water quality. Approximately 75% of respondents to the 2001 FEMS indicated that at least a portion of areas surrounding surface water was vegetated, usually with permanent vegetation (Grimard, 2007). Of producers that had land adjacent to natural sources of water 44%, 6%, and 1% respondents used permanent vegetation, annual vegetation, and winter cover crops, respectively, to reduce runoff into the water bodies (Brethour et al., 2007). However, only half of respondents to the 2006 survey indicated that a riparian buffer and setback was maintained on all seasonal and permanent wetlands (Eilers, 2010). Producers are less likely to maintain buffers for seasonal surface waters as these areas may be partially utilized for agricultural production (Eilers, 2010). Farms with an EFP are more likely than farms without an EFP to provide limited or no access to grazing livestock near surface waters, and maintain riparian buffer areas around seasonal or permanent wetlands (Eilers, 2010).

The FEMS also examined producer awareness of BMPs. Awareness varied between provinces, with increased awareness appearing to lead to higher adoption rates (Brethour et al., 2007). As a general trend from the 2001 FEMS, awareness of BMPs seemed to be the lowest in Nova Scotia, Saskatchewan, and Alberta, with the highest awareness among producers in Quebec, British Columbia, and Prince Edward Island. For example, in Quebec 6% of respondents indicated they were unfamiliar with fertilizer and water management BMPs in their region and 66, 65, and 58% of producers had fully or partially implemented fertilizer, manure, and water management BMPs, respectively (Brethour, 2007). Conversely, approximately two-thirds of producers in Nova Scotia indicated they were unaware of potential BMPs for their region, and 20% or less indicated partial or full implementation of manure, fertilizer, and water BMPs (Brethour et al., 2007). The rate of adoption for EFP was also related to producer awareness of BMPs, with low adoption rate of EFP among producers who are unaware of BMPs in their region (Brethour et al., 2007). According to Eilers et al. (2010), producers with EFP are more likely than farms without an EFP to:

- have runoff containment and impermeable pads to store solid manure;
- use soil testing, manure testing and crop nutrient requirements as factors to determine application rates of manure;
- incorporate solid manure after application;
- use soil testing, nutrient requirements of crops, or nutrient carry-over to determine fertilization rates;
- use BMPs that reduce pesticide drift, such as spraying when wind speed is below recommended thresholds;
- use boom shrouds, low drift nozzles, anti-drift agents and leave an untreated buffer when applying pesticides; and/or
- use BMPs to reduce the amount of pesticide used;
- maintain riparian buffer areas around seasonal/permanent wetlands and waterways.

Changes in market demand and farm characteristics, such as size and enterprise type, have put pressure on producers to intensify production. As consumer demand for products with environmental attributes increases, producers must be more aware of the relationship between agriculture and the environment. Environmental indicators provide the baseline for measuring changes in the environment from agriculture. While producer awareness of management practices that sustain or improve the surrounding environment has increased from 1981 to 2006, large regional discrepancies in Canada still exist (Eilers et al., 2010). Also, considering the trends in agricultural intensification, if it is to be assumed that demand for food, fiber, and fuel continues to increase, then the potential for environmental degradation from agricultural practices may increase as well. To avoid this and to mitigate further damages, policy intervention and producer education of BMPs may be necessary.

2.4 Policies Influencing Beneficial Management Practice Adoption in Canada

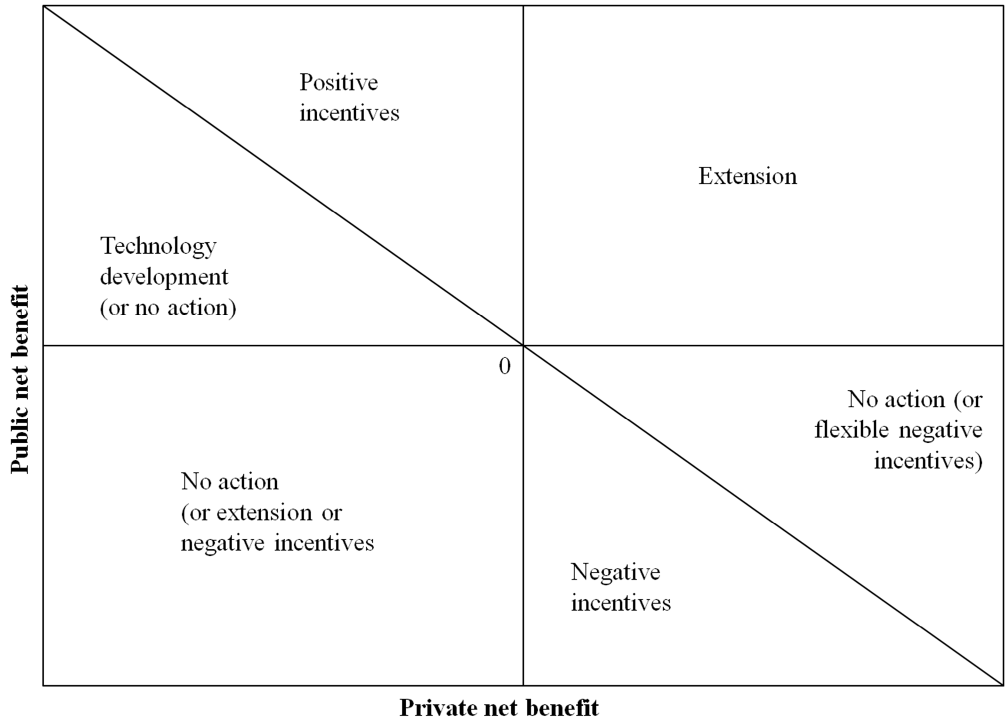
The solutions for many problems of environmental conservation require changes in land management at the private owner level (Pannell, 2008). Environmental issues have become one of the main factors driving policy decisions at the international, national, and provincial levels as human actions are linked to climate change and global warming (Toma and Bouma Management Consultants, 2007). Policy mechanisms to encourage change include programs and incentives that educate, increase awareness, provide regulation, subsidize, or use technology transfer for private land owners (Pannell, 2008). Farmers, as private landowners, are environmental stewards (AAFC, 2011). Producing primary products in a manner that is beneficial for the environment meets consumer demands and helps preserve agricultural lands for future use in the provisioning of food, fiber, and fuel. This section discusses the framework for environmental policy development by Pannell (2008). This is followed by a brief review of policies, programs, and legislation relevant for BMP adoption decisions by cropping operations in Alberta.

2.4.1 Pannell Framework for Environmental Policy Development

Policymakers have multiple policy mechanisms available to them for encouraging agricultural producers to make environmentally beneficial land use decisions. These include extension (i.e., information or education), regulation, and economic instruments (e.g., subsidies, taxes). The optimal choice of policy depends on a number of factors. One possible framework for examining this question is provided by Pannell (2008). Pannell's framework suggests that policy decisions should be made based on the relative levels of private net benefits and public net benefits associated with the resulting land use change or production practice, where private benefits represent the direct impact on the agricultural producer and public benefits correspond to the effect on society as a whole. Both private and public benefits may be positive or negative (i.e., the net effect may be a cost).

The resulting policy framework is illustrated in Figure 2.4 (Pannell, 2008). Figure 2.4 may be considered as four quadrants, defined in terms of the level of private net benefits (horizontal axis) which may be positive (right hand quadrants) or negative (left hand quadrants), and public net benefits (vertical axis) which may be positive (upper quadrants) or negative (lower quadrants). Pannell's policy framework would suggest that the appropriate environmental policy depends on whether public/private benefits are positive/negative as well as the relative absolute magnitude of those benefits.

Figure 2.4 – Classes of policy mechanisms for different levels of public and private benefits



Source: adapted from Pannell (2008)

A full discussion of this framework is provided in Pannell's (2008) paper. However, two examples are provided here to illustrate its use. First, suppose a particular land use change results in both positive private benefits and positive public benefits. This policy framework indicates that the appropriate policy response is "extension". In other words, all that is required for producers to adopt this practice or land use change is information or education, since it is in their best interests to adopt. Conversely, suppose a particular production practice generates positive public net benefits, but these come at a net cost to producers; that is, private benefits are negative. If the positive public net benefit is greater, in absolute terms, than the negative private net benefit, policy intervention through positive incentives (e.g., subsidies) to encourage adoption of the production practice is justifiable. If the opposite is true, then the optimal policy response may be no action; that is, recognize that the benefits from the production practice are outweighed by the costs to producers and accept that the practice is unlikely to be adopted.[6]

2.4.2 Policy Incentives for Cropping Operations

Growing Forward is an initiative between Canada's federal, provincial, and territorial governments to support the development of a profitable, innovative and competitive agricultural sector (AAFC, 2011). This program is in effect from 2008 to 2013. Goals of the program include supporting the agricultural sector to improve risk management, response of the sector to market demands, and to contribute to the well-being of Canadians (AAFC, 2011).

[6] A fuller discussion of the framework, along with extensions that reflect costs and timing of adoption for land use change, is provided in the original Pannell (2008) paper.

Growing Forward uses many national and regional plans and policy programs to achieve the program goals. *Growing Forward* policy programs specifically related to Alberta crop producers to protect environmental resources include the Cover Crop Protection Program (CCPP), Integrated Crop Management Plan, Prairie Shelterbelt Program (PSP), and Water Management. These programs use incentive mechanisms, such as cost-share programs or direct government assistance. Governments and industry work collaboratively under Growing Forward to preserve animal and plant resources, and to adapt to environmental challenges that affect production (AAFC, 2011).

CCPP is an initiative to provide financial assistance to Canadian agricultural producers who are unable to seed crops due to spring flooding or excessive moisture (AAFC, 2011). Eligible applicants can apply for federal assistance of up to $15 per acre to help offset the costs of improving and protecting flood-damaged soil until another commercial crop can be planted (AAFC, 2011). The CCPP improves short term cash flows for affected producers, but also minimizes further soil erosion risk by enabling insured producers to re-seed affected lands (AAFC, 2011).

The Integrated Crop Management Plan assists producers in developing plans that optimize the use of crop inputs while minimizing the impact on the environment (AAFC, 2011). The Integrated Crop Management Plan is managed by Alberta Stewardship Plans. Under this program producers are able to adopt Stewardship Programs under a 50/50 cost-share to a maximum value of $20,000 (AARD, 2010-d).

The PSP provides tree and shrub seedlings for establishment of shelterbelts and other agroforestry, conservation and reclamation projects on agricultural lands (AAFC, 2011). Tree and shrub seedlings are an incentive to producers adopting beneficial management practices and environmental stewardship (AAFC, 2011). The PSP aims to improve the performance of the agricultural sector by helping to achieve the social, economic and environmental benefits of agroforestry systems, such as shelterbelts (AAFC, 2011). As discussed previously, shelterbelts conserve soil and water, manage snow and wind, improve air quality, stabilize crops, and enhance habitat for wildlife (AAFC, 2011).

Agricultural activities can have an impact on Canada's water resources and Growing Forward programs will help to minimize those impacts, including initiatives to understand the agriculture sector's on-going water requirements (AAFC, 2011). The purpose of the Water Management Program is to provide incentive for the creation of a long term water management plan at the farm level (AARD, 2010-e). Water management can also be considered a risk management tool during periods of drought. This program provides financial assistance for producers towards specified improvements to support water security. Improvements available for the cost share program include the addition of wells, dugouts, dams, irrigation sources for cropping, livestock watering, cisterns, and water treatment, among others (AARD, 2010-e).

2.4.3 Extension Programs for Cropping Operations

Agricultural extension programs are policy mechanisms that provide information to producers (e.g., about available land management practices). Examples of land use extension include education, technology transfer, and communication to land owners in general (Pannell, 2008). As compared to other mechanisms, such as subsidies or land grants, extension is a relatively cheap policy instrument that educates land owners about land management practices (Pannell, 2008). However, extension alone is only effective in reducing environmentally adverse land management practices if the private costs of land use change are less than the benefits. Pannell (2008) suggests that extension policies are effective when public net benefits are highly positive and private net benefits are slightly positive (i.e., when private net benefits are highly positive no action is required since land owners would readily adopt practices in this category).

Sustainable Agriculture Environment Systems (SAGES) is also a program developed by *Growing Forward*. SAGES is an extension type policy mechanism. The goal of this initiative is to respond to water and climate changes in agricultural systems. SAGES benefits producers through knowledge and development and is designed to accelerate the creation of BMPs, offer policy options and a better understanding of impacts and adoption opportunities (AAFC, 2011).

EFPs are also a type of extension policy where education is the driving mechanism to promote land use change. For EFPs in Alberta producers discuss environmental concerns with a resource specialist and complete self assessments and the resulting farm plan individually (Alberta EFP, 2011). Throughout the process producers participating in this program have access to expert knowledge for suggestions in the EFP to mitigate risks in production. EFP are put into action by producers through adoption of BMPs according to the individual's priorities, as outlined in the plan. The EFP program benefits producers by providing technical assistance in developing management practices that minimize agricultural or environmental risk, assists producers in understanding impacts of agricultural practices, and educates producers on minimizing environmentally adverse effects from agriculture on the environment.

2.4.4 Regulations for Cropping Operations

This section discusses regulations for producers as it relates to environmentally friendly management practices. While there are many federal acts for mitigating environmental impacts, the most relevant to cropping agriculture are the *Fisheries Act* and the *Pest Control Products Act*. The *Pest Control Products Act* outlines responsible uses of pesticides for Canadian producers, including safe application and precautionary procedures. Adoption of crop rotations with fewer herbicide requirements may reduce the amount of chemical introduced into the ecosystems. The *Fisheries Act* prohibits any person from depositing anything that may have harmful effects of fish into any type of water that may be fish habitat (AARD, 2004-a). This includes any creek, river, stream, lake, or slough where fish may be present, whether the body of water is permanent or temporary (AARD, 2004-a). Damaging effects include the application of manures or chemicals near waterways as there is a chance these inputs could enter the aquatic ecosystem. Water bodies that contain fish species are also prohibited from being altered in any way, such as through drainage. Adoption of buffer strips around water bodies containing fish species is a practice that may prevent contaminated runoff or chemical leaching into fish habitat.

Relevant provincial legislation specific to cropping operations in Alberta include the *Agricultural Operation Practices Act* (AOPA), *Environmental Protection and Enhancement Act* (EPEA), *Natural Resources Conservation Board Act* (NRCBA), *Soil Conservation Act*, and *Water Act*. The AOPA is a set of standards for management practices for producers. The act focuses on nuisance and livestock and manure standards. AOPA is administered by the Natural Resources Conservation Board (NRCB) and due to the nature of the act deals mainly with livestock operations. However, manure application to crop land is also included, as there are setback requirements for injected or incorporated manures near bodies of water (AARD, 2004-a). Adoption of buffer strips around water bodies assures that a minimum amount of land does not receive manure application and differentiates the land from cropland for area to be treated. Surface application of manures requires a farther setback distance as there is increased risk of nutrient runoff (AARD, 2004-a). AOPA also specifies that operators applying over 500 tonnes of manure annually are required to perform soil testing and maintain nutrient management records (AARD, 2004-a).

The EPEA regulates the sale, use, application, handling, storage, transport, and disposal of pesticides (AARD, 2004-a). This act deals with source point pollution and outlines how the crop sector can manage pollution using environmental farm plans and identification of risk areas (Toma and Bouma Management Consultants, 2007). The EPEA prohibits operators from releasing any amount or concentration of a substance into the environment that cause or may cause adverse effects on the environment (AARD, 2004-a).

The *Soil Conservation Act* is intended to ensure good practices are used by operators of farmland and acts to prevent soil loss and deterioration (Toma and Bouma Management Consultants, 2007). This act gives municipalities authority to protect soils (AARD, 2004-a). Landowners are responsible for maintaining the quality of soil when it is in good condition and taking actions to prevent soil deterioration if it is occurring. Practices to ensure soil conservation may include crop rotations, residue management, and shelterbelt adoption to contribute additional organic matter to the soil, provide additional cover, and reduce wind erosion.

The *Water Act* is used to manage the use of water in Alberta (Toma and Bouma Management Consultants, 2007). Under the act approval from Alberta Environment is required for producers to alter the flow or level of water, to change the location or direction of water flow, to cause siltation of water, cause erosion of the bed or shore of water bodies, or to cause an effect on the aquatic environment (AARD, 2004-a). Adoption of buffer strips around riparian and wetland areas protect the surface and can contribute to reductions in sedimentation.

Federal and provincial legislation and policies are important to ensure agricultural producers are operating in ways that are environmentally sound and responsible (AARD, 2004-a). Acts are formed to mitigate or prevent potential environmental impacts from agricultural practices. The Alberta Government has released a series of Environmental Manuals that outline BMPs for several agricultural sectors, including cropping and livestock operations.

2.5 Review of Existing Literature on Analysis of Agricultural Beneficial Management Practice Adoption

The literature review discusses studies that examine the economic factors of on-farm BMP or conservation practice adoption, including simulation analysis. These include studies that develop static and dynamic models to determine the impact of BMP adoption. The current study considers dynamic simulation modelling to estimate the economic impact of BMP adoption on Alberta crop farms. Therefore, studies using similar methodologies or with similar objectives are of interest to this project to identify alternative methods that could be considered and to identify any information gaps in the existing literature.

There are numerous studies on BMP adoption that address water and soil quality. Specific issues addressed include nitrogen leaching, pollution abatement for improved soil and water quality, nutrient management, tillage and biodiversity effects.

Houston and Sun (1999) used results from farmer surveys to develop a multi-objective linear programming model to predict crop yields, water-soil pollution emissions, and farmer’s net returns for peanut and corn crop farms in the coastal areas of Georgia, USA. Their study assumes an objective of minimizing water-soil pollution levels. Farmer attitudes towards voluntary participation in government cost share subsidies for pollution abatement as a BMP are also assessed. It was determined a subsidy of approximately $1.01 per hectare would reduce nitrogen leaching by 2.7%, while net returns were reduced by approximately $4.80 per hectare. As farmer and government costs increase, nitrogen leaching from the crop growth process decreases slightly while environmental benefits increase. In this study reducing nitrogen leaching is costly, but the only control of leaching available is through changes in fertilizer applications. The authors note that stricter nitrogen abatement strategies should also consider crop rotation and other practices. It was further determined in this study that producers voluntarily participating in the subsidy program were more risk averse than average and were more likely to accept partial payments for a change in practices that may lead to lower net returns. This study demonstrates the potential of crop rotations to reduce chemical leaching and how policy can affect producer participation in practices.

Non-linear optimization methods were used in a study by Munoz-Carpena et al. (2008) to investigate the impact of summer cover crops on soil percolation and nitrogen leaching. This study used data for southern Florida sweet corn and hemp crops to develop representative simulation models. The model maximizes plant water and nitrogen uptake to simulate plant stress. After three years with a leguminous summer cover crop, organic matter content increased in corn fields. Both observed and simulated hydraulic changes were most apparent in the top ten centimetres of the soil, where increases in organic matter were also more likely to occur. Corn yields and nitrogen uptake increased when cover crops were adopted. However, nitrogen leaching into shallow aquifers also increased, diminishing water quality. While this study was concerned with biological interactions it also discusses the recommendation of combining cover crop practices with reductions in nitrogen fertilizer application rates to account for net increases in soil nitrogen, which is of interest to the current study as a potential BMP.

A study measuring farm level behaviour in response to non-point source pollution was conducted by Taylor et al. (1992). Five representative farms were defined for different geographical regions in Oregon, USA. The farms had crop mixes that included grass, small grain, vegetable, and berry crops. Non-point source pollution is stochastically modelled and is strongly influenced by weather processes (Taylor et al., 1992). This study used biophysical simulation to generate climate and weather data and optimization to measure changes in farm profit. The models maximize profits under alternative non-point pollution control policies using simulated crop yields under different tillage and soil types. To achieve a 50% reduction in total polluted water, profits were reduced by approximately $10 to $36 per hectare. However, only slight changes in operations (i.e., tillage) or application rates of nitrogen were required to attain 5 to 24% pollution abatement. This study is of interest as, similar to the present study, several representative farms were developed to determine changes in farm profit from adoption of alternative practices, using simulated yields.

A simulation model of beneficial management practices for nitrogen fertilization on cereal and vegetable model farms in Germany was developed by Nendel (2009). Crop, soil, and environmental interactions were simulated to determine net returns and the effect of BMPs. Growing a cereal crop after a shallow-rooted and well-irrigated crop, such as lettuce, extracts nitrogen from the soil from below 90 centimetres. Also in all rotations, almost all nitrogen added as a mineral fertilizer is leached out of the system and the crop nitrogen requirements could be satisfied from mineralized nitrogen from soil organic matter and crop residues. This inclusion of specific crop rotations and crop residues has potential to reduce nitrogen fertilization rates, and increase net returns on the model operations, an outcome that is also explored in this study for cropping operations in Alberta.

BMPs to reduce water pollution from agricultural practices were examined by Centner et al. (1999). Crop yields and nutrient flows to ground and surface waters were simulated over 17 years using weather data and site specific characteristics in Germany and the United States. BMPs examined in this study to reduce erosion included cover crops, contour farming and terracing, conservation tillage, streamside vegetated buffers, filter strips and waterways, pasture management, strip cropping, and stream and water body protection. BMPs to reduce pollution from nutrients included nutrient management, irrigation water management, agricultural waste management systems and composting. The costs of agricultural pollution abatement by reducing irrigation and/or nitrogen fertilizer application rates were found to be significant. As a consequence the practices would likely not be voluntarily adopted. Intercropping was shown to reduce soil erosion and nitrate leaching. Optimal timing and reduced fertilization may increase profits if there were compensation payments provided by the government. This study is of interest as some of the same BMPs are examined in the current study, using similar methods.

Field level simulation models were used by Coiner et al. (2001) to evaluate alternative landscape scenarios in Iowa. The models simulated weather, plant growth, nutrient cycling, hydrology, erosion and sedimentation, and soil temperature for commercial operations. Management of plant materials by tillage, fertilization, irrigation, and conservation practices were also simulated. Results from production, water quality, and biodiversity scenarios were compared with the baseline scenario that assumed the use of conventional tillage. In the production scenario the farms employed conservation tillage, which retains residue cover on the surface of soils, and modification of the crop rotations to incorporate more high value annual crops such as corn and soybean at the expense of alfalfa hay and grass crops. Of the three, the production scenario showed the highest returns to the land due to increased acreage and lower production costs associated with conservation tillage. In the water quality scenario the farms adopted buffer strips around water bodies and modified crop rotations to include more perennial alfalfa and grass crops. The water quality scenario resulted in the lowest returns to the land, but was also the best scenario in terms of the environment as it reduced nitrogen leaching and wind erosion. In the third scenario both water quality and biodiversity were targeted where perennial strip cropping was used to connect buffer strips and riparian areas for wildlife and the farms adopted organic agricultural practices (i.e., commercial fertilizers and chemicals were no longer used). In the biodiversity scenario returns to the land were the second highest and only slightly reduced, despite the fact that land area was reduced. The buffer strip adoption scenario resulted in reduced returns. However, this BMP also reduced nitrogen leaching and wind erosion, which may have long term implications, and may compensate for some of the initial costs associated with buffer strips.

A long term simulation model was used by Tapia-Vargas et al. (2001) to determine the effect of maize production tillage systems on runoff and sediment from agricultural operations located on sloped lands in Mexico. Soil erosion was simulated using soil moisture and runoff variables. Treatments examined included conventional tillage, no till, and no till with varying levels of residue coverage. The scenarios with conventional till and no till without residue had higher levels of runoff and sediment losses, as compared to the scenarios with the combination of no till and residue management. Fu et al. (2006) also simulated soil erosion and sediment yield models to compare no till practices to conventional tillage for farms in Washington, USA, where wheat, barley, and peas were the major crops grown. The models by Fu et al. (2006) yielded similar results as Tapia-Vargas et al. (2001) where there were reductions in soil loss and sediment yield under no-till practices. Both studies provide justification for including residue management as a BMP in the current study.

Matekole and Westra (2009) developed models to simulate surface water, nutrient, pesticide, and sediment runoff quantities. The models were used for an economic analysis of tillage and nutrient BMPs in Louisiana, USA. Farmers applied fertilizers as a type of “pseudo-insurance” against crop losses. However, in the simulation model operations would diversity nitrogen fertilizer application with tillage practices to maximize net returns. Crop acreage and fertilizer management practices were shown as a means of decreasing cropland effluent runoff in the simulated results. Reduced tillage with nutrient management was found to be a cost effective method to reduce nutrient and sediment losses in this study area. In a similar study by Matekole et al. (2009) biophysical economic models were used to evaluate benefits of implementing nitrogen fertilizer application and tillage management BMPs, also in Louisiana, USA. As was the case for the previous study, surface water, nutrient, pesticide, and sediment runoff quantities were simulated in the analysis. This study included the consideration of riparian buffers, such as trees, grasses, and shrubs, that serve as nutrient and sediment filters and help reduce nutrient erosion and sediment loss from cropland into streams and rivers. All scenarios with reduced tillage showed increases in revenue as compared to conventional tillage revenues. The results from this study correspond with the hypothesis that adoption of BMPs may also lead to financial returns to producers. This hypothesis is also explored in the current study.

Khakbazan et al. (2009) developed a dynamic programming model to examine the economic factors associated with yield function, nutrients, and water to connect agro-environmental and economic models. Potato crop rotations under irrigated production in Manitoba were of interest in this study. Khakbazan et al. (2009) compared production costs, yields, and other economic criteria to help in the selection of the best crop rotation for irrigated potato production. Including a potato rotation in these types of models allowed for the evaluation of the sustainability of production systems under a combination of high disturbance and minimal tillage management systems. A model that includes potato yield, growing season precipitation, and fertilizer and irrigation management was adapted from Belcher et al. (2003) in this study to include quantitative relationships found in the literature. Khakbazan et al. (2009) modelled costs as being both dependent on agro-environmental factors, such as fertilizer and yield dependent costs, and on base factors that are static throughout the simulation. Some potato rotations increased soil organic matter, while others slowly depleted the stock.

Cortus (2005) used simulation techniques to investigate the direct farm level impact of wetland drainage. Wetland drainage reduces the amount of EG&S available. However, drainage of wetlands has private benefits, including improved crop yields, increased land value, increased acreage under production, and production of higher value crops, and private costs, including pumping stations, and open ditches. Removing wetlands can be thought of as the opposite of BMP adoption (i.e., the opposite of the current study). Cortus (2005) developed representative farms to model wetland drainage in Saskatchewan crop production. Wetland drainage is economically feasible for Saskatchewan cropping operations, and by extension of the simulation results that it is costly for producers to maintain the current level of EG&S generated by wetlands on the farms.

The objective of the study by Koeckhoven (2008) was to determine the direct farm level impacts of BMP adoption, as is the objective in the current study. Koeckhoven (2008) also used simulation and capital budgeting techniques to determine the impact of BMP adoption. Several BMPs to address water conservation and riparian habitat were examined for a representative mixed (i.e., cattle and cropping activities) farm in southern Alberta. Of practices relevant to cropping agriculture, it was found that the establishment of buffer strips around riparian areas and the adoption of permanent cover were costly for producers in this region, largely due to reductions in the acreage for crop production. It was further concluded that producers may require some type of incentive program to encourage BMP adoption.

Policy is often derived from innovations that decrease environmental damages (Pannell, 1999). As previously mentioned EG&S production can be increased through the adoption of BMPs. Research efforts are increasingly focused on improving and developing practices that reduce harmful impacts on the environment. Financial incentives, such as cost share programs or tax incentives, are often used by governments to share in the risk of uncertainty when adopting new practices and encourage adoption of BMPs (Feather and Amacher, 1994). Programs that rely only on incentives to encourage adoption are costly and adoption is dependent on producer perception (Feather and Amacher, 1994). As a result, programs are developed, but are only adopted by farmers at varying levels. Practices that reveal immediate private benefits, such as no-till technology are widely adopted, while practices where the benefits are not quantifiable for several years, such as biodiversity loss, are adopted at lower rates (Pannell et al., 2006). When benefits are immediately apparent, new practices are perceived as low risk, while the opposite is true for practices that do not have immediately apparent benefits. In designing programs to encourage adoption of BMPs, consideration of the willingness of the producer to adopt must be considered.

According to Pannell (1999) factors that contribute to the willingness of producers to adopt new practices include awareness, feasibility of adoption on a trial basis, and consistency with producer goals. Adoption also depends on personal, social, cultural, and economic factors (Pannell et al., 2006). Farms differ in size, soil fertility, machinery, financial structure, climate, and labour constraints (Pannell, 1999), also contributing to the response of producers towards new farm management practices and policy. In a survey of BMP adoption in Ontario, producers with larger farms and greater farm sales were more likely to practice good environmental management and it was hypothesized that smaller operations lacked the time and money to implement many BMPs (Filson et al., 2009). Most farmers from small to medium operations want the government to pay more than half the cost of BMP adoption (Filson et al., 2009).

Feather and Amacher (1994) develop an adoption model assuming producers are risk averse in investigating the role of information in influencing the adoption of new farm management practices. They find that changing producer perception through educational programs is a more feasible approach as compared to financial incentives to encourage BMP adoption. Deciding whether to adopt an innovation is a risky decision for producers as a choice between alternatives where outcomes are not certain and the attached probabilities may not be known (Greiner et al., 2009). Risk perceptions and preferences influence how information is acquired and the use of trial phases affect the adoption process of farmers (Greiner et al., 2009). As with farm characteristics, farmer risk perceptions and risk management techniques vary regionally and contextually (Greiner et al., 2009).

The program Entry Level Stewardship (ELS) in England demonstrates the shortcomings of only using positive incentive approaches in policy mechanisms. The ELS program attempts to extend the adoption of stewardship practices among agricultural operators (Hodge and Reader, 2009). This program provides farmers with a variety of options and farmers are awarded points that are translated into monetary benefit. While this program does allow for incentives to be targeted for specific benefits and increased the amount of land under stewardship practices, it also implies that payments are necessary to ensure the continuation of stewardship practices (Hodge and Reader, 2009).

Ipe (1998) studied incentive payments to compensate farmers for adopting BMPs. In this study a survey found that farmers have the perception that practices reducing pollution will also increase farm profitability. However, perceived losses from reduction in nitrogen application are significantly higher than the actual losses, resulting in a higher willingness to accept (WTA) incentive payment for reductions in nitrogen application. In the simulated model for incentive payments and WTA, the payments were lower than the actual case. This study also found that risk averse farmers will participate in the program if the payment offered compensates for the loss in potential expected utility due to the reduction in nitrogen application. As farmers become increasingly risk averse, the WTA incentive amount also increases.

Adoption or changes of management practices are typically dependent on the perspective of the producer or land owner (Feather and Amacher, 1994; Greiner et al., 2009). Perspectives vary based on geographical region in both soil and climate characteristics and producer characteristics. Producers are assumed to be risk averse, but the degree of risk aversion may also differ, and policy mechanisms must recognize this fluctuation to be successful. Policy intervention to improve adoption of BMPs does not always require positive incentive, and as previous research has shown, increasing information through extension activities may have a greater impact on adoption. A survey of producers in Ontario finds that farmers prefer voluntary EFP to government intervention and regulation (Filson et al., 2009). In general, adoption of BMPs using negative incentives may initially result in producer opposition, while adoption rates may be low when relying on extension alone.

2.6 Chapter Summary

Responsible agricultural practices have the potential to improve the supply of EG&S. Adoption of BMPs also increases EG&S production. EG&S are beneficial to society and increasing the supply may also create a feedback system where benefits are experienced by producers. In agricultural systems soil and water quality are important factors in maintaining or improving yields and revenue of producers. However, adoption of BMPs to improve the supply of EG&S may not be at the optimal level due to real or perceived costs associated with adoption. Research into agricultural and ecological indicators provides a baseline for determining the net benefit associated with BMP adoption. To determine the optimal amount of EG&S provided by agriculture, policy programs use this information to establish appropriate methods to encourage adoption, including policies of regulation, economic incentives and/or extension.

This study is concerned with a variety of BMPs that primarily affect soil and water quality on agricultural lands. BMPs of interest include crop rotations and non-rotational BMPs to improve soil quality through reduced soil erosion, and improve water quality through reduced nitrogen leaching and soil particle runoff into water bodies. Many studies have examined the effect of altering management practices to improve soil and water quality. Some studies focus on the static assumptions of potential yield improvements and cost savings from BMP adoption while others include dynamic simulation to account for price and yield risk in agricultural production. However, research examining the impact of BMP adoption includes assumptions based on the geographical area as will be the case in this study. Many previous studies employ representative farms that are based on characteristics from actual farms in the area of interest. This approach will be considered, with the use of statistical data for the current study.

This study uses a dynamic approach to modelling price and yield risk and incorporates stochastic methods to estimate potential changes in yields and costs when adopting individual or group BMPs. Increased yields from BMP adoption have the potential to improve producer net income. However costs associated with BMP adoption may include the loss of land previously under production, which may reduce net income. While there are studies relevant to Alberta agriculture, adoption of BMPs may not be analyzed from an economic viewpoint. Some studies use static assumptions, while others do not incorporate several BMPs simultaneously. From the literature review, it is apparent that BMP adoption has the potential to increase or decrease producer net returns. This study aims to quantify the net benefit of adoption for specific BMPs in Alberta.

Chapter 3: The Study Areas

In this chapter the agricultural practices and existing and potential BMPs in Alberta agricultural regions are outlined. Cropping agriculture has a significant impact on the quality of the surrounding environment, specifically on water and soil quality. BMPs that mitigate or decrease the damage to the environment related to agricultural practices include practices that reduce wind and water erosion, reduce water runoff, improve soil organic matter, and generally improve soil health. BMPs that contribute to improving soil and water quality on agricultural lands include zero-tillage or no-tillage practices, residue management, control of crop inputs such as fertilizers, crop rotations, shelterbelts or windbreaks, and buffer zones around wetlands.

Some BMPs have had a significant uptake. For example, practices that are widely adopted in Alberta include zero-tillage or no-tillage, adjustments to crop rotations, shelterbelts to reduce erosion, and residue management. However, producers continue to use significant levels of commercial fertilizers and herbicides in Alberta, while the use of BMPs such as buffer strips around wetlands is quite low. This indicates that reduced water quality from runoff is likely an issue, along with soil quality, due to extensive input use for agricultural production in situations where the nutrients are not used by the crop.

This chapter outlines the methods taken to determine the representative soil zones and municipal districts for analysis. An overview of agriculture is also provided for each region where a representative farm is defined as well as the prevalence of BMP use in the area. Census data from Statistics Canada provide the foundation to define each representative farm and to provide an overview of the agricultural activities and current BMPs in these regions. The agricultural characteristics and the occurrence of BMPs in the areas of interest are examined to confirm the credibility of the attributes of the model farms and adoption of the practices in the analysis.

3.1 Beneficial Management Practices and Environmental Issues in Alberta Crop Production

While agriculture has been an integral part of the Albertan economy for many years, the use of certain practices as explicit BMPs to reduce the environmental impact from agriculture has been relatively recent. In 2004 as a national and provincial initiative AARD and AAFC published Environmental Manuals for agricultural producers. There are manuals specialized for hog, poultry, feedlot, dairy, calf-cow, and crop producers. The BMPs outlined in the manuals for producers correspond with the vision of the Agri-Environment Services Branch (AESB), made up of the Prairie Farm Rehabilitation Administration (PFRA) and Agri-Environmental Policy Bureau (AEPB), which is to integrate environmentally responsible agriculture with competitive agriculture through innovative practices and voluntary stewardship programs (AAFC, 2010-b).

The following sections discuss the BMPs considered to mitigate negative impacts of agriculture on water and soil quality. While there are numerous other BMPs that could be considered the practices discussed represent the scope of this project.

3.1.1 Beneficial Management Practices and Water Quality

Crop production can contribute pollutants to water. Contributing factors are excess nutrients, sediments and pesticides. Water contaminants can be transported to surface water or groundwater through various means. Transport of contaminants to surface waters typically occurs when there is a high risk of soil erosion and runoff into surrounding surface water sources. Contamination of groundwater often occurs when there are high infiltration rates.

Nitrogen and phosphorus are essential nutrients for plant growth and crop production (AARD, 2004-a; McRae et al., 2000). Both are also components of chemical fertilizers, manures and decomposing crop residues. However, after fertilizers are applied to cropland, the residual components can be transported to surface water and groundwater through runoff and leaching. Once nitrogen and phosphorus have reached a source of water, elevated levels of the nutrients decrease water quality by promoting growth of aquatic plants and algae; this process is known as eutrophication (McRae et al., 2000). This effect is particularly observed for phosphorus where after algae and aquatic plants have absorbed the excess phosphorus they begin to decompose. During plant decomposition dissolved oxygen is used which contributes to increased rates of aquatic animal death. While this effect is not as prevalent for excess nitrogen the water soluble form of nitrogen, nitrate, is harmful to humans when consumed in excess. Nitrate can be leached into groundwater beneath lands where intensive agriculture is practised.

Sediment transfer, often due to soil erosion and runoff, to surface waters occurs in a similar manner. Increased sediment in surface water negatively affects the quality of water and is harmful to aquatic species. Sedimentation of surface waters can damage fish eggs and other aquatic larvae (AARD, 2004-a). High levels of sediments suspended in waters also decrease the amount of light penetration which affects the growth of bottom dwelling aquatic plants (AARD, 2004-a). When this occurs there can be an increase in the prevalence of algae, which is similar to the problem of excess phosphorus.

Another contributing factor to decreased water quality in areas of intensive agricultural practices is pesticides. Pesticides can move into surface water or ground water by being dissolved in water, attached to soil particles, or as a result of spray drift (AARD, 2004-a). When pesticides are present in water sources, problems that occur include bio-concentration, where pesticides concentrate in the tissues of affected organisms, and biomagnification, where the concentration of pesticides increases in species as it travels up the food chain (AARD, 2004-a). This is harmful to species diversity surrounding agriculture, but may also be harmful to humans as well.

The quality of water in areas of intense agricultural activity can be improved using BMPs. Many of the problems mentioned above occur due to the transportation of nutrients, sediments and pesticides to water supplies through runoff. Buffers around surface water trap some nutrients, sediments, and pesticides and improve overall water quality. Also areas at higher risk of water erosion contributing to runoff into surface waters typically have low levels of soil organic matter. High levels of soil organic matter hold soil particles together, reducing the risk of erosion, which can contribute to sedimentation and contamination of water bodies. Therefore BMPs such as residue management can improve water quality from runoff.

Crop rotation adjustments as BMPs are also considered. Adding alfalfa hay provides a semi-permanent cover on the land which reduces the amount of runoff that may occur during freeze-thaw cycles in the spring when the land is between annual crops. Also, alfalfa hay and other leguminous crops, including field peas, can fix nitrogen. As a result fewer inputs in the years these crops are grown, and potentially following these crops, are necessary. This reduces the amount of nutrient inputs on the land and as such there is likely a lower incidence of nutrient runoff entering aquatic ecosystems. Alternative crops, such as oats, require fewer herbicide inputs, which decreases the risk of chemicals entering waterways via runoff.

To address the issue of decreased water quality from cropping practices, specifically from nutrients, sediments and pesticides, this study will consider crop rotations, buffer strips, and residue management as mitigating BMPs. Crop rotations will examine the addition of annual and perennial forages, field peas, and oats.

3.1.2 Beneficial Management Practices and Soil Quality

Intensive cropping practices also affect soil quality. Soil quality can be considered in terms of the levels of soil organic matter, soil salinity and soil acidity. A related factor in obtaining reasonable levels of organic matter and good overall soil quality in agricultural soils is erosion. Soil quality is correlated with agricultural production, and as such practices that degrade soil quality contribute to reduced agricultural production.

Soils that are high in organic matter have their soil particles held together better. This reduces the risk of erosion from both water and wind (AARD, 2004-a). Crop rotations that contain perennial forages, especially legumes (e.g., alfalfa), result in soils with higher levels of organic matter due to increased levels of retained residue. Crop rotations where summerfallow frequently occurs reduce soil organic matter over time because less plant residue is returned to the soil (AARD, 2004-a). Including crops that improve soil organic matter reduces erosion to an extent. However, wind erosion can be reduced further using shelterbelts and windbreaks while water erosion can be reduced using surface residue management. Additionally, practices such as no-till or zero-till seeding techniques can improve soil organic matter and reduce erosion.

Plant growth is affected by the salinity and acidity of soils as these issues affect the ability of the plant's roots to function efficiently (McRae et al., 2000). While soil salinity is somewhat naturally occurring, poor management practices can intensify this problem (AARD, 2004-a). High soil salinity results in poor plant growth due to excess salts in the plant's root zone. While also affecting plant growth, soil acidity inhibits the ability of microorganisms in the soil, such as nitrogen fixing bacteria that are present on leguminous plants (AARD, 2004-a). Fertilizer application can increase the acidity of the soils, so reducing inputs by including more crops that are able to provide a supply of nitrogen for subsequent crops, such as alfalfa hay and field peas, is beneficial.

In the Brown soil zone there is a lower level of soil organic matter relative to the level in the Black and Dark Grey soil zones. Therefore BMPs of interest include practices that both reduce erosion and improve soil organic matter. This study considers the adoption of on-farm shelterbelts to reduce wind erosion and crop residue management to reduce water erosion over cropland. This study also considers adding perennial forages and legumes, such as alfalfa hay and field peas, to the crop rotations to improve the soil organic matter and reduce inputs. Additional changes in crop rotations to improve soil health include reducing or eliminating summerfallow and including a legume green manure as a partial or complete replacement, as is appropriate for each region.

3.2 Cropping Agriculture in Alberta

The number of farms in Alberta decreased from approximately 58,000 in 1981 to 49,431 farms in 2006. This trend was not specific to Alberta as the number of farms in Canada decreased by almost 18,000 from 2001 to 2006 (Statistics Canada, 2001 and 2006). In general the trends seem to indicate an increase in the number of small and large farms (under 30 hectares and over 450 hectares) with fewer medium-sized farms. Farms classified as oilseed and grain operations made up 27% of farms in Canada and 25% of farms in Alberta. Alberta's oilseed and grain sector constituted 20% of the Canadian sector in terms of the number of farms. When considering land under crop production in 2006 Alberta represented 35% of all land in crops in Canada. In 2008 farm cash receipts from all cropping activities in Alberta made up 47% of all farm cash receipts, as compared to 44% for livestock operations (AARD, 2009-a). Due to the increased occurrence of large crop farms and the importance of the cropping sector in Alberta's economy this analysis will focus on commercially sized cropping operations in Alberta.

While there has been an increase in the number of large operations the majority of farms in Alberta are still less than 162 hectares (400 acres). Table 3.1 shows the distribution of farm size for operations with land in crops and/or summerfallow in 2006 in Alberta. Farms with over two million dollars in gross farm receipts only made up 1.2% of all operations in 2006. The majority farms gross less than $250,000. There were a total of 41,934 farms with gross farm receipts under $250,000 and 7,497 farms with gross farm receipts over $250,000. The distribution of farm gross receipts is given in Table 3.2.

Table 3.1 – Farms with land in crops and/or summerfallow in Alberta, by size (2006)

Farm acreage	Number of farms (% of total)
Under 130 acres	12,301 (29.6%)
130 to 399 acres	13,036 (31.3%)
400 to 1119 acres	10,240 (24.6%)
1120 + acres	6,047 (14.5%)
Total	41,624

Source: Statistics Canada (2006)

Table 3.2 – Distribution of Alberta farms, by gross receipts (2006)

Gross farm receipts	Number of farms (% of total)
Under $10,000	9,791 (19.8%)
$10,000 to $24,999	8,720 (17.6%)
$25,000 to $49,999	7,170 (14.5%)
$50,000 to $99,999	7,448 (15.1%)
$100,000 to $249,999	8,805 (17.8%)
$250,000 to $499,999	4,333 (8.8%)
$500,000 to $999,999	1,871 (3.8%)
$1,000,000 to $1,999,999	688 (1.4%)
$2,000,000 and over	605 (1.2%)
Total	49,431

Source: Statistics Canada (2006)

According to the 2006 Canadian Census of Agriculture (Statistics Canada, 2006), adoption of practices that are beneficial for the environment among farm operators has been increasing as they are often practices that are also economically beneficial to the producer. In 2006 almost 60% of Alberta farms reported participating in crop rotation practices (Statistics Canada, 2006). Crop rotations have been proven to improve soil health and yields. In addition, 50% of farms reported having shelterbelts or windbreaks on their farms and almost 20% reported having buffer zones around wetlands (Statistics Canada, 2006). Table 3.3 displays practices and number of farms participating in soil conservation practices in Alberta and Canada, as reported in 2006. In 2006 over 50% of the land that was seeded in Alberta had the residue incorporated into the soil or left on the surface (Statistics Canada, 2006). Almost 30% of farms used no-till seeding, which accounts for almost 50% of the land that is seeded in 2006 (Statistics Canada, 2006). In regards to reducing chemical inputs, two-thirds of farms used herbicides and over 75% of farms used commercial fertilizers in 2006, as compared to 71 and 77% of farms in 2001, respectively (Statistics Canada, 2006). Additional tillage practices and land input statistics for Alberta in 2006 are provided in Table 3.4.

Table 3.3 – Number of farms participating in soil conservation practices in Alberta and Canada (2006)

Soil conservation practice	Number of Alberta farms (% of total)	Number of Canadian farms (% of total)
Crop rotation	29,332 (59.3%)	141,322 (61.6%)
Ploughing down green crops	2,803 (5.7%)	24,192 (10.5%)
Windbreaks or shelterbelts	24,810 (50.2%)	84,722 (36.9%)
Buffer zones around water	9,147 (18.5%)	44,988 (19.6%)
Total farms	49,431	229,373

Source: Statistics Canada (2006)

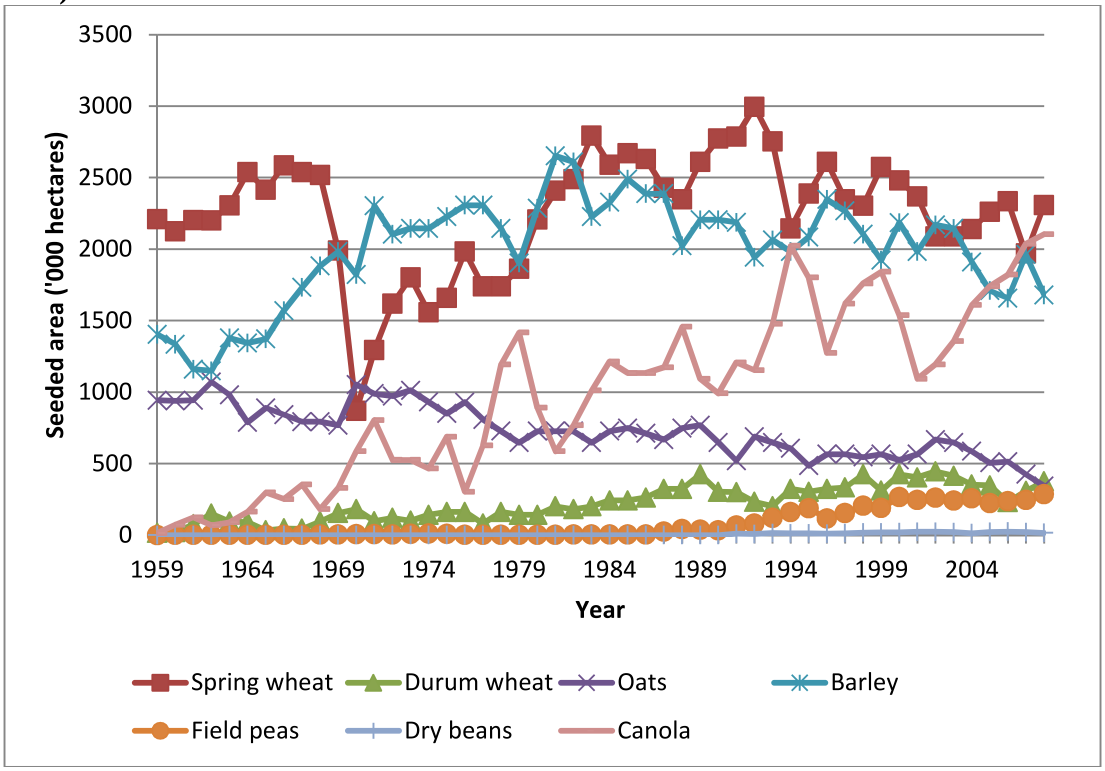
Table 3.4 – Frequency of use of specific tillage practices and crop inputs in Alberta (2006)

Practices and inputs	Number of farms (% of total)	Hectares (% of total)
Most crop residue tilled into soil	15,930 (51.8%)	1,857,391 (24.5%)
Most crop residue retained on the surface	8,956 (29.1%)	2,098,535 (27.7%)
No-till or zero till	9,121 (29.7%)	3,622,275 (47.8%)
Herbicides	20,482 (66.7%)	6,417,539 (84.7%)
Insecticides	2,895 (9.4%)	493,226 (6.5%)
Fungicides	2,309 (7.5%)	653,146 (8.6%)
Commercial Fertilizer	23,443 (76.3%)	6,965,232 (91.9%)
Total land for seeding	30,725	7,578,202

Source: Statistics Canada (2006)

Of all agricultural land (i.e., land used for livestock, perennial and annual crops, summerfallow, or pasture) in Alberta, 45.6% was seeded to crops with an additional 4.3% allocated to summerfallow in 2006. Spring wheat, barley, canola, and alfalfa make up the four crops with the highest acreage seeded in 2006 with approximately 2.3, 1.7, 1.6, and 1.6 million hectares seeded, respectively. The fifth highest acreage was land allocated to summerfallow in 2006 with 0.9 million hectares. Historically spring wheat and barley have been the highest seeded crops in Alberta as shown in Figure 3.1. Figure 3.1 shows the crops that are considered in the crop rotations for this project with the exception of alfalfa hay. The trend in tame hay production has generally been positive from 1960 to 2001 with 2.3 million hectares of land seeded to hay in 2001 and only 0.9 million hectares seeded to hay in 1960 (Statistics Canada, 2001). Canola has gained popularity since it was introduced in the 1970s. Durum wheat is grown primarily in southern regions of Alberta and so is not one of the major crops in terms of total provincial acreage. However, it is a significant crop in southern Alberta. From the historical data shown in Figure 3.1 the area devoted to crops such as field peas and dry beans is increasing while the acreage of land seeded to oats has been decreasing. In 2006 there was approximately 0.5 and 0.2 million hectares of land seeded to oats and field peas in Alberta, respectively. In the same year there was approximately 25,000 hectares of land seeded to dry bean varieties. Beans represent a smaller portion as compared to other crops since they are produced using irrigation technology.

Figure 3.1 – Historical acreage ('000 of hectares) of selected crops in Alberta (1959 – 2008)



Source: Statistics Canada (2009)

3.3 The Representative Regions

Representative regions are chosen primarily on the basis of Statistics Canada census data and opinions from agricultural experts in Alberta. Regions chosen as representative include soil zones with significant agricultural production and municipal districts within these regions. This section will discuss how the representative regions are determined and the agricultural characteristics of the representative regions. Representative regions are chosen from the regions illustrated in Figure 3.2. This section provides the foundation for determining the representative farms to be modelled. The process to define representative farms begins by characterizing the areas by soil zone. Following this, distinguishing agricultural production traits in the representative counties[7] are determined. Specifically, size of farms and common crops grown in each region are examined, which are discussed in Chapter 5 to further determine representative farm characteristics.

3.3.1 Soil Zones

The primary criterion used in defining representative farms for this study is soil zone. Alberta has several soil zones (see Appendix A), and in defining the representative farms it is important to begin characterizing based on soil zones. Alberta is a relatively large province and contains many types of soils that differ based on climatic, vegetative,

[7] Rural municipalities in Alberta are referred to by a variety of terms, including County, Municipal District (M.D.), and Special Area. The term "county" is used in this discussion as a general term to refer to all of these.

and hydrological factors (AARD, 2009-b). Human activities, such as cropping agriculture also impact the formation of soils. Different soil formation factors, temperature, and precipitation across Alberta result in soils that differ in organic material and vegetative cover.

The southeast corner of the province is generally characterized by a semiarid climate and short grass prairie vegetation (AARD, 2009-b). In this area organic matter is mainly added to the soil from plant roots, giving the soils a Brown colour that is indicative of organic material in the upper layers of soil (AARD, 2009-b). Further north and west in Alberta there is increased moisture levels, contributing to higher yielding grasses and higher organic matter contents (AARD, 2009-b). In this area darker brown and black soils are characteristic as there are increased levels of organic matter added to the soils from increased plant growth (AARD, 2009-b). Farther north and west, there are lower temperatures and natural grasslands that are mixed with deciduous trees. Lower temperatures mixed with increased organic material from tree litter and grasses form black soils in these regions (AARD, 2009-b). In the area known as the Peace Lowland, which covers the north western part of Alberta, there is a transition of deciduous trees to coniferous forest, characterizing this area with grassland and forest vegetation (AARD, 2009-b). In forested areas organic matter from leaves results in leached upper soil layers that are low in organic matter, and therefore light grey in colour (AARD, 2009-b).

In general, Mixed Grasslands are dominated by Brown Chernozemic soils, Moist Mixed Grasslands are dominated by Dark Brown Chernozemic soils, and Fescue Grasslands and Aspen Parklands are dominated by Black Chernozemic soils (AARD, 2009-b). These soils are well to imperfectly drained, making them suitable for crop production. In the Boreal Transition (i.e., forest soils) Luvisolic soils and Chernozemic soils are common with a leached grey colour (AARD, 2009). The soils in this region are also well to imperfectly drained (AARD, 2009-b).

The links between the soils and natural vegetation in the areas is indicative of the type of agricultural production that occurs in these regions. In the Brown soils there is little organic matter on the surface and vegetation grown is short with less residue remaining after crop harvest. Here there is less soil organic matter available to form soil aggregates and risks such as soil erosion are higher. In the Black soils higher agricultural production is possible due to increased precipitation and lower temperatures, which is more favourable to growing conditions. This results in more residues potentially being returned to the soil, increasing organic matter and improving soil aggregation. Due to the interspersion of coniferous and deciduous trees and grasslands in the Grey soils, with lower average temperatures, the large amount of organic matter that is produced does not decompose as quickly as in the Black soils. While production is high in this region, leaching from excess organic matter produces the distinctive grey soil colour.

The soil zones that have significant proportions of crop production activities are chosen to define the representative farms. Specifically, farms are defined for the Brown, Dark Brown, Black and Dark Grey soil zones. The Grey soil zone is not included as there are limited cropping operations in this region. In particular, of the four counties considered from the Grey soil zone, an average of less than 30% of farm land was used for crop production.

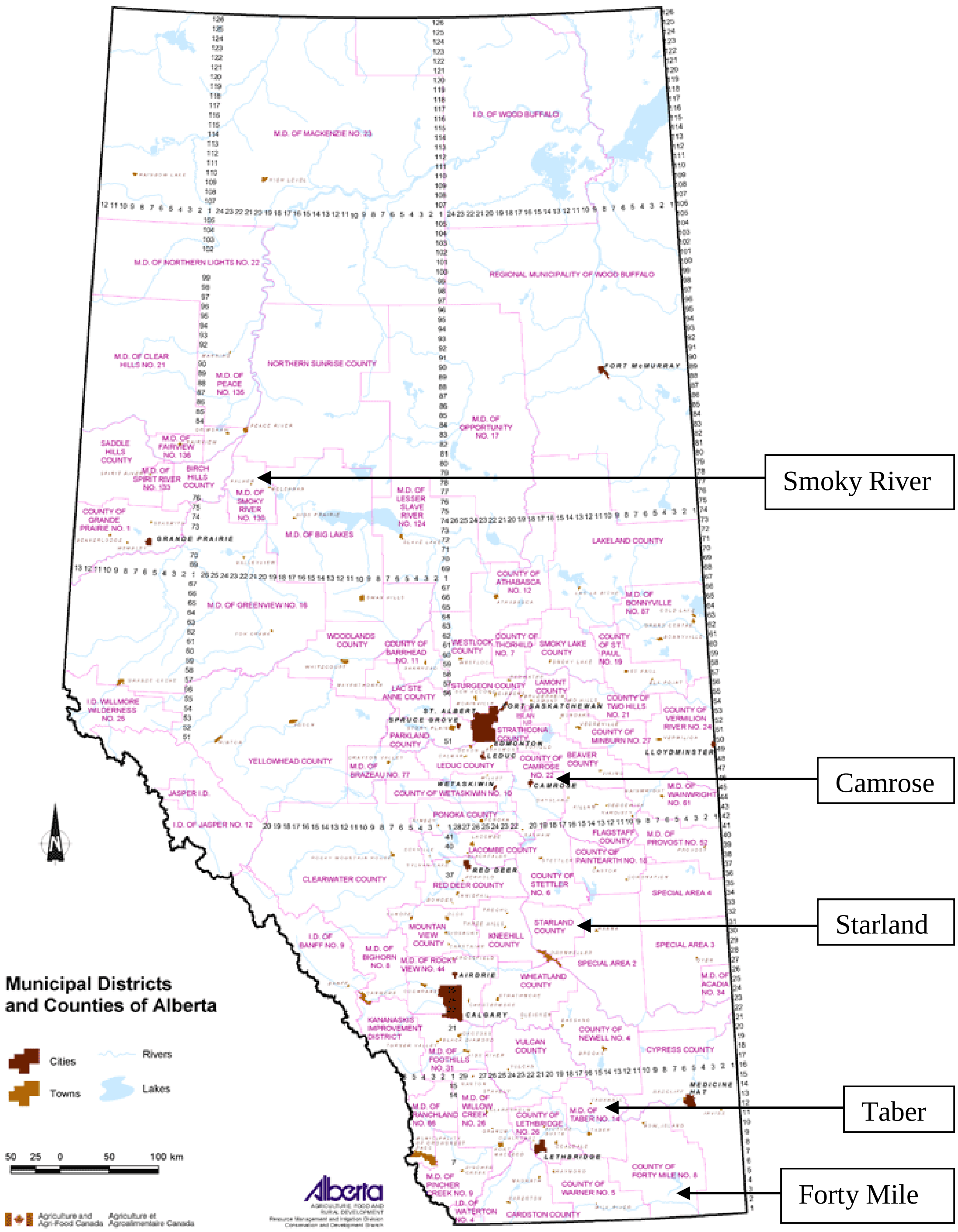
3.3.2 Representative Counties

To further refine the areas and farms used to define the representative farm in each soil zone, a representative county for each soil zone is chosen based on Census data. If at least (approximately) 70% of a county is deemed to be within the boundaries of a particular zone, it is included as being part of that soil zone and is taken into consideration when choosing the location of the representative farms. Any counties that were more "evenly split" between soil zones were excluded from further consideration. The counties included in the analysis by soil zones are provided in Appendix B.

From the remaining counties, representative counties in each soil zone were then chosen based on the relative significance of crop production, as measured by the proportion of agricultural land devoted to crop production. Using data from the 2006 Census of Agriculture, total area of farms, land in crops, land in summerfallow, tame or seeded pasture, and natural land for pasture are used to calculate an approximate percentage of agricultural land allocated to crops and pasture for each county in each soil zone (Table 3.5). Selection was also narrowed by accounting for counties in close proximity to metropolitan areas, and the presence and prevalence of irrigated crop production. Irrigated production is considered as Alberta has the most land area under irrigated production, at over 0.5 million hectares, of all provinces in Canada (Toma and Bouma Management Consultants, 2007).

From the 2006 Census of Agriculture data it was determined that average farm size in counties that are in close proximity to large metropolitan areas is smaller than in counties without large metropolitan areas. It is speculated that this is most likely due to the higher incidence of small hobby farms and acreages in these areas. Therefore, counties that were in close proximity to large cities were excluded from the analysis. Counties and Municipal Districts (M.D.) of Alberta are shown in Figure 3.2.

Figure 3.2 – Municipal Districts and Counties of Alberta



Source: *Adapted from* AARD (2005-b) *with permission from Alberta Agriculture and Rural Development.*

It was determined that the representative farm for the Brown soil zone should be located in either the M.D. of Taber or the County of Forty Mile. In those two counties, 53 and 41% of the agricultural land is in crops, respectively. Of the total area of crops, approximately 14.2% is in irrigated production in the County of Forty Mile, while approximately 44.8% of total crop area is irrigated in the M.D. of Taber. Therefore to fully represent the Brown soil zone, two representative farms are defined; an irrigated farm in the M.D. of Taber and a dryland farm in the County of Forty Mile.

In the Dark Brown soil zone the County of Lethbridge has the highest proportion of land (70%) in crops. However given the presence of the City of Lethbridge within this county, it was excluded from consideration. Starland County, with 62% of farm area devoted to crops, was instead chosen as the representative county for the Dark Brown soil zone. Starland County was chosen over Wheatland County, which had a slightly higher (approximately 66%) proportion of land in crops, because of the higher proportion of irrigated acres (5% versus 0.1% in Starland County) in Wheatland.

In the Black soil zone Sturgeon County has the largest proportion of land in crops with approximately 71% in crops and 19% in pasture. However, as Sturgeon County is close in proximity to the metropolitan area of Edmonton, Camrose County was chosen as the representative county, as it was the next best alternative with approximately 69% of land in crops and 22% in pasture.

The Dark Grey soil zone is made up of two ecoregions[8]: Dry Mixedwood and the Peace River Parkland. In the Dry Mixedwood region Westlock County and County of Two Hills have the highest proportion of land in crops with 57% each. In the Peace River Parkland the M.D. of Smoky River has the highest proportion of land in crops at 82%. Only one representative county is chosen for the Dark Grey soil zone, and since there is an overall higher proportion of land in crops in the Peace River Parkland as compared to the Dry Mixedwood region, the M.D. of Smoky River is chosen as the representative county for this soil zone.

[8] An ecoregion is a distinct region defined by its ecology, including environmental conditions and natural features.

Table 3.5 – Counties and acreage of farm land (in hectares) included in choosing representative farms for each soil zone with significant cropping activities, 2006[a]

Soil Zone	County / Municipal District	Total area of farms	Area in crops and summerfallow	Area in pasture (tame and natural)
Brown	Special Area 2	836,627	196,746 (23.5%)	614,122 (73.4%)
	Special Area 3	700,475	312,964 (44.7%)	374,381 (53.4%)
	County of Newell No. 4	584,440	153,465 (26.3%)	417,681 (71.5%)
	County of Forty Mile No. 8	708,451	383,533 (54.1%)	317,760 (44.9%)
	Cypress County	999,472	229,687 (23.0%)	756,925 (75.7%)
	M.D. of Taber	403,702	241,841 (60.0%)	154,699 (38.3%)
Dark Brown	Special Area 4	401,445	155,078 (38.6%)	234,081 (58.3%)
	County of Lethbridge	296,865	237,226 (79.9%)	52,610 (17.7%)
	Vulcan County	529,712	382,039 (72.1%)	140,855 (26.6%)
	Wheatland County	456,502	333,944 (73.2%)	114,080 (25.0%)
	Starland County	248,301	173,503 (69.9%)	67,311 (27.1%)
	County of Paintearth No. 18	319,966	165,110 (51.6%)	141,835 (44.3%)
	M.D. of Provost No. 52	361,597	168,391 (46.6%)	181,369 (50.2%)
Black	Cardston County	363,438	189,918 (52.3%)	167,085 (46.0%)
	M.D of Pincher Creek	271,796	86,722 (31.9%)	172,553 (63.5%)
	M.D. of Foothills	370,081	162,933 (44.0%)	197,065 (53.2%)
	M.D. of Rocky View No. 44	435,626	245,340 (56.3%)	175,272 (40.2%)
	Red Deer County	407,584	249,931 (61.3%)	137,701 (33.8%)
	Lacombe County	279,310	172,041 (61.6%)	92,198 (33.0%)
	Leduc County	228,363	150,219 (65.8%)	62,445 (27.3%)
	County of Camrose No. 22	336,112	243,427 (72.4%)	74,815 (22.3%)
	Beaver County	291,272	190,986 (65.6%)	85,673 (29.4%)
	Minburn County No. 27	287,193	199,112 (69.3%)	72,167 (25.1%)
	Vermilion River County No. 24	555,652	314,230 (56.6%)	215,155 (38.7%)
	Strathcona County	103,709	64,645 (62.3%)	30,016 (28.9%)
	Sturgeon County	202,168	151,968 (75.2%)	38,534 (19.1%)
	Flagstaff County	399,313	290,036 (72.6%)	87,824 (22.0%)
	M.D. of Wainwright	387,159	212,335 (54.8%)	156,641 (40.5%)
Dark Grey	Lac Ste. Anne County	238,048	112,716 (47.4%)	104,130 (43.7%)
	County of Barrhead No. 11	212,370	115,111 (54.2%)	77,973 (36.7%)
	Westlock County	278,818	177,448 (63.6%)	83,925 (30.1%)
	County of Thorhild No. 7	156,695	92,051 (58.7%)	50,711 (32.4%)
	County of St. Paul No. 19	335,195	143,176 (42.7%)	168,340 (50.2%)
	Athabasca County No. 12	280,259	141,248 (50.4%)	102,266 (36.5%)
	Two Hills County No. 21	229,129	151,416 (66.1%)	62,977 (27.5%)
	M.D. of Smoky River	257,959	220,386 (85.4%)	20,068 (7.8%)
	Birch Hills County	192,277	124,669 (64.8%)	47,467 (24.7%)
	M.D. of Spirit River	68,890	58,067 (84.3%)	4,914 (7.1%)

Soil Zone	County / Municipal District	Total area of farms	Area in crops and summerfallow	Area in pasture (tame and natural)
	County of Grande Prairie No. 1	461,377	272,744 (59.1%)	143,419 (31.1%)
	M.D. of Fairview	130,976	92,577 (70.7%)	29,620 (22.6%)

[a] The values in parentheses are the percentages of total farm area for each type of use. The percentages do not sum to 100% because other land use, such as land for tree production, is not included in the analysis.
Source: Statistics Canada (2006)

The following sections provide summary agricultural statistics for the representative counties in each soil zone. Cropping management and land use practices are also reviewed. As noted earlier, these are later used (in Chapter 5) to define the characteristics for the representative farms that are modelled in the BMP analysis.

3.3.2.1 Municipal District of Taber

The Municipal District of Taber, in southern, Alberta and has a total area of 4,204 square kilometres with a population of 6,280 people in 2006. Common crops grown in this region include spring wheat, durum wheat, barley, canola, potatoes, and alfalfa (Statistics Canada, 2006). Of the representative regions identified for this study Taber is the second largest county in terms of total land and total agricultural land. Approximately 30% of all agricultural land in Taber is under irrigated production, which represents almost 45% of all land in crops in the district. As discussed earlier in this chapter, for this reason the farm that is developed to be representative of this region is assumed to use irrigated production practices.

The distribution of farms by gross farm receipts in the M.D. of Taber is provided in Table 3.6. The trend here is similar to the overall trend for farm receipts and number of farms in Alberta with a slightly higher, as compared to other regions in Alberta, percentage of farms with gross receipts exceeding half a million dollars. The number of farms participating in various soil conservation practices is provided in Table 3.7. Three quarters of farms in the M.D. of Taber use crop rotation as a soil conservation management tool, while over one quarter of all farms had shelterbelts or wind breaks on the farm in 2006. Table 3.8 outlines the tillage practices and land inputs of this region. Less than 65% of agricultural land had residue incorporated into the soil or left on the surface. Figure 3.3 shows the susceptibility of soils to wind erosion[9]. The M.D. of Taber is classified as having moderate to severe wind erosion risk. As such practices such as adopting shelterbelts and retaining crop residue may significantly impact future soil health and yields in this area.

[9] Wind erosion risk is determined based on soils, landscapes and climate. Information on wind speed, soil resistance to movement and available moisture are used to estimate the long term risk of wind erosion on bare, unprotected soils (AARD, 2005).

Table 3.6 – Distribution of farms by gross receipts, Municipal District of Taber (2006)

Gross farm receipts	Number of farms (% of total)
Under $10,000	54 (7.0%)
$10,000 to $24,999	86 (11.2%)
$25,000 to $49,999	68 (8.9%)
$50,000 to $99,999	105 (13.7%)
$100,000 to $249,999	182 (23.7%)
$250,000 to $499,999	129 (16.8%)
$500,000 to $999,999	68 (8.9%)
$1,000,000 to $1,999,999	37 (4.8%)
$2,000,000 and over	39 (5.1%)
Total	768

Source: Statistics Canada (2006)

Table 3.7 – Number of farms participating in soil conservation practices, Municipal District of Taber (2006)

Soil conservation practice	Number of farms (% of total)
Crop rotation	575 (74.9%)
Ploughing down green crops	25 (3.3%)
Windbreaks or shelterbelts	203 (26.4%)
Buffer zones around water	86 (11.2%)
Total farms	768

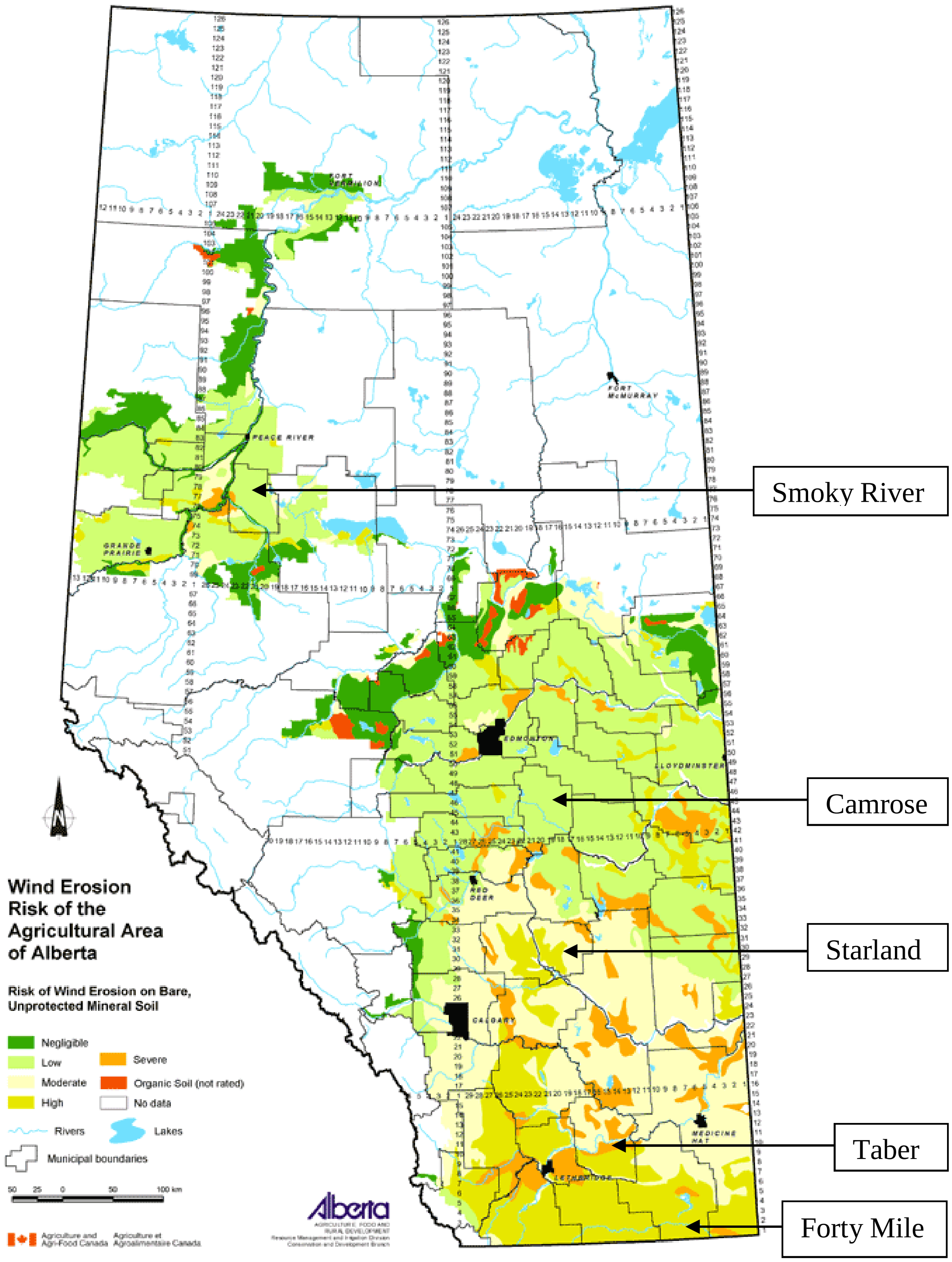
Source: Statistics Canada (2006)

Table 3.8 – Frequency of use for specific tillage practices and land inputs, Municipal District of Taber (2006)

Practices and inputs	Number of farms (% of total)	Hectares (% of total)
Most crop residue into soil	395 (65.2%)	83,430 (41.5%)
Most crop residue retained on the surface	205 (33.8%)	45,917 (22.8%)
No-till or zero till	131 (21.6%)	71,821 (35.7%)
Herbicides	499 (82.3%)	181,385 (90.2%)
Insecticides	205 (33.8%)	38,715 (19.2%)
Fungicides	192 (31.7)	45,399 (22.6%)
Commercial Fertilizer	517 (85.3%)	181,581 (90.3%)
Total land for seeding	606	201,167

Source: Statistics Canada (2006)

Figure 3.3 – Wind erosion risks in Alberta.



Source: *Adapted from* AARD (2005-b) *with permission from Alberta Agriculture and Rural Development.*

3.3.2.2 County of Forty Mile

The County of Forty Mile is in south eastern Alberta and lies along the Canadian and United States border (Figure 3.2). The total area of this county is 7,230 square kilometres with a population of 3,414 in 2006. Total agricultural land in this county is 7,047 square kilometres. According to Statistics Canada (2006) common crops grown in this district include spring wheat, durum wheat, oats, barley, and field peas.

The distribution of gross farm receipts in 2006 for Forty Mile is provided in Table 3.9 with the majority of farms in this region being between $100,000 and $500,000 of gross receipts. The number of farms using selected soil conservation practices, tillage practices and land inputs are provided in Tables 3.10 and 3.11. As shown in Figure 3.3, the wind erosion risk for the County of Forty Mile is moderate to severe, making this an interesting region to study for the adoption of practices such as shelterbelts and crop residue management. In 2006 approximately one quarter of farms in this region reported having shelterbelts or windbreaks while less than 50% of land had residue incorporated or retained on the surface.

Table 3.9 – Distribution of farms by gross receipts, County of Forty Mile (2006)

Gross farm receipts	Number of farms (% of total)
Under $10,000	31 (5.1%)
$10,000 to $24,999	51 (8.5%)
$25,000 to $49,999	46 (7.6%)
$50,000 to $99,999	81 (13.5%)
$100,000 to $249,999	187 (31.1%)
$250,000 to $499,999	116 (19.3%)
$500,000 to $999,999	46 (7.6%)
$1,000,000 to $1,999,999	20 (3.3%)
$2,000,000 and over	24 (4.0%)
Total	602

Source: Statistics Canada (2006)

Table 3.10 – Number of farms participating in soil conservation practices, County of Forty Mile (2006)

Soil conservation practice	Number of farms (% of total)
Crop rotation	486 (80.7%)
Ploughing down green crops	16 (2.7%)
Windbreaks or shelterbelts	167 (27.7%)
Buffer zones around water	64 (10.6%)
Total farms	602

Source: Statistics Canada (2006)

Table 3.11 – Frequency of use for specific tillage practices and land inputs, County of Forty Mile (2006)

Practices and inputs	Number of farms (% of total)	Hectares (% of total)
Most crop residue into soil	241 (47.2%)	66,810 (24.1%)
Most crop residue retained on the surface	183 (35.8%)	65,289 (23.6%)
No-till or zero till	203 (39.7%)	145,017 (52.3%)
Herbicides	411 (80.4%)	254,436 (91.8%)
Insecticides	70 (13.7%)	13,965 (5.0%)
Fungicides	121 (23.7%)	36,753 (13.3%)
Commercial Fertilizer	404 (79.1%)	230,557 (83.2%)
Total land for seeding	511	277,116

Source: Statistics Canada (2006)

3.3.2.3 County of Starland

The County of Starland is located in south-central Alberta and has a total area of 2,558 square kilometres and a population of 2,371 people in 2006. In 2006 crops were planted on over 60% of the land. In this region the crops that are most commonly grown include spring wheat, barley, canola, alfalfa, and field peas (Statistics Canada, 2006).

The distribution of farm gross receipts for Starland County is provided in Table 3.12. Most farms in this region have gross receipts between $25,000 and $500,000. Tables 3.13 and 3.14 provide information regarding soil conservation practices, tillage and land inputs in this region. Most farms use crop rotations as a soil conservation technique, but only 2.2% plough down green crops. Over a third of farms have shelterbelts or windbreaks and almost one third of the acreage seeded to crops had residue incorporated or left on the surface of the soil. According to Figure 3.3 the wind erosion risk for Starland County falls in the moderate to severe category. Therefore the analysis of management techniques to reduce soil erosion from wind may have economic importance for this region.

Table 3.12 – Distribution of farms by gross receipts, County of Starland (2006)

Gross farm receipts	Number of farms (% of total)
Under $10,000	28 (7.7%)
$10,000 to $24,999	43 (11.8%)
$25,000 to $49,999	48 (13.2%)
$50,000 to $99,999	61 (16.8%)
$100,000 to $249,999	89 (24.5%)
$250,000 to $499,999	58 (15.9%)
$500,000 to $999,999	26 (7.1%)
$1,000,000 to $1,999,999	4 (1.1%)
$2,000,000 and over	7 (1.9%)
Total	364

Source: Statistics Canada (2006)

Table 3.13 – Number of farms participating in soil conservation practices, County of Starland (2006)

Soil conservation practice	Number of farms (% of total)
Crop rotation	280 (76.9%)
Ploughing down green crops	8 (2.2%)
Windbreaks or shelterbelts	139 (38.2%)
Buffer zones around water	65 (17.9%)
Total farms	364

Source: Statistics Canada (2006)

Table 3.14 – Frequency of use for specific tillage practices and land inputs, County of Starland (2006)

Practices and inputs	Number of farms (% of total)	Hectares (% of total)
Most crop residue into soil	93 (31.6%)	20,255 (13.5%)
Most crop residue retained on the surface	75 (25.5%)	27,418 (18.3%)
No-till or zero till	157 (53.4%)	102,160 (68.2%)
Herbicides	242 (82.3%)	135,743 (90.6%)
Insecticides	13 (4.4%)	1,997 (1.3%)
Fungicides	32 (10.9%)	17,137 (11.4%)
Commercial Fertilizer	247 (84.0%)	140,993 (94.1%)
Total land for seeding	294	149,833

Source: Statistics Canada (2006)

3.3.2.4 County of Camrose

The County of Camrose is located in central Alberta, south east of Edmonton (Figure 3.2). The County of Camrose has a total area of 3,332 square kilometres with a population of 7,160 people in 2006. Of all agricultural land in this county almost 70% was under crop production in 2006. Crops that make up the bulk of cropping activities in this region include spring wheat, canola, barley, alfalfa, and field peas (Statistics Canada, 2006).

The 2006 distribution for Camrose County farm gross receipts is shown in Table 3.15. The majority of farms have gross receipts below $250,000, indicating that farm size in this area may be slightly smaller as compared to the representative counties previously discussed. Table 3.16 shows the number of farms using various soil conservation practices. Most farms use crop rotations for soil conservation and over half have windbreaks or shelterbelts on the farm. Tillage practices and land inputs for Camrose County are provided in Table 3.17. Over half the acreage seeded used no-till or zero-till technology in 2006. Erosion risk by wind is classified as low in this region (Figure 3.3).

Table 3.15 – Distribution of farms by gross receipts, County of Camrose (2006)

Gross farm receipts	Number of farms (% of total)
Under $10,000	164 (14.3%)
$10,000 to $24,999	191 (16.6%)
$25,000 to $49,999	173 (15.1%)
$50,000 to $99,999	156 (13.6%)
$100,000 to $249,999	257 (22.4%)
$250,000 to $499,999	147 (12.8%)
$500,000 to $999,999	39 (3.4%)
$1,000,000 to $1,999,999	16 (1.4%)
$2,000,000 and over	6 (0.5%)
Total	1149

Source: Statistics Canada (2006)

Table 3.16 – Number of farms participating in soil conservation practices, County of Camrose (2006)

Soil conservation practice	Number of farms (% of total)
Crop rotation	829 (72.2%)
Ploughing down green crops	34 (3.0%)
Windbreaks or shelterbelts	633 (55.1%)
Buffer zones around water	213 (18.5%)
Total farms	1,149

Source: Statistics Canada (2006)

Table 3.17 – Frequency of use for specific tillage practices and land inputs, County of Camrose (2006)

Practices and inputs	Number of farms (%of total)	Hectares (% of total)
Most crop residue into soil	317 (37.3%)	39,664 (18.8%)
Most crop residue retained on the surface	275 (32.4%)	58,322 (27.6%)
No-till or zero till	345 (40.6%)	113,030 (53.6%)
Herbicides	677 (79.7%)	182,936 (86.7%)
Insecticides	46 (5.4%)	6,023 (2.9%)
Fungicides	82 (9.7%)	17,798 (8.4%)
Commercial Fertilizer	716 (84.3%)	198,161 (93.9%)
Total land for seeding	849	211,016

Source: Statistics Canada (2006)

3.3.2.5 Municipal District of Smoky River

The M.D. of Smoky River is located in north western Alberta. This district covers an area of 2,843 square kilometres and had a population of 2,442 people in 2006. Of the total land area 2,459 square kilometres is agricultural land and 82% of the agricultural land was seeded as crops in 2006. Common crops grown in this region include canola, spring wheat, alfalfa, oats, and barley (Statistics Canada, 2006).

The distribution of farm gross receipts for the M.D. of Smoky River in 2006 is given in Table 3.18. The majority of farms in this area have gross receipts between $50,000 and $500,000. The number of farms using selected soil conservation practices is provided in Table 3.19. The number of farms and acreage of land under certain tillage practices and land inputs is provided in Table 3.20. According to Figure 3.3 the wind erosion risk in the M.D. of Smoky River is low with the exception of one small section on the central western edge of this district that has severe erosion risk. However, 42% of producers in this region indicated the presence of shelterbelts or windbreaks on the farms. There is also over half of all hectares seeded where residue is incorporated into the soil or retained on the surface in this region.

Table 3.18 – Distribution of farms by gross receipts, Municipal District of Smoky River (2006)

Gross farm receipts	Number of farms (% of total)
Under $10,000	35 (9.0%)
$10,000 to $24,999	53 (13.6%)
$25,000 to $49,999	34 (8.7%)
$50,000 to $99,999	51 (13.0%)
$100,000 to $249,999	104 (26.6%)
$250,000 to $499,999	66 (16.9%)
$500,000 to $999,999	33 (8.4%)
$1,000,000 to $1,999,999	8 (2.0%)
$2,000,000 and over	7 (1.8%)
Total	391

Source: Statistics Canada (2006)

Table 3.19 – Number of farms participating in soil conservation practices, Municipal District of Smoky River (2006)

Soil conservation practice	Number of farms (% of total)
Crop rotation	324 (82.9%)
Ploughing down green crops	33 (8.4%)
Windbreaks or shelterbelts	164 (41.9%)
Buffer zones around water	59 (15.1%)
Total farms	391

Source: Statistics Canada (2006)

Table 3.20 – Frequency of use for specific tillage practices and land inputs, Municipal District of Smoky River (2006)

Practices and inputs	Number of farms (% of total)	Hectares (% of total)
Most crop residue into soil	122 (39.4%)	26,344 (16.3%)
Most crop residue retained on the surface	115 (37.1%)	64,193 (39.8%)
No-till or zero till	129 (41.6%)	70,756 (43.9%)
Herbicides	257 (82.9%)	150,057 (92.6%)
Insecticides	83 (26.8%)	26,854 (16.6%)
Fungicides	22 (7.1%)	11,709 (7.3%)
Commercial Fertilizer	274 (88.4%)	161,971 (100.4%)
Total land for seeding	310	161,294

Source: Statistics Canada (2006)

3.4 Chapter Summary

A range of locations is considered for this project in an effort to provide a study that is representative of commercial cropping operations in Alberta. Areas are chosen based on the suitability of cropping operations to the climate and region characteristics. Summary statistics for each of the representative counties are provided in Table 3.21. Crop production is important in all five counties, with 53, 41, 62, 69, and 82% of agricultural land being in crops in 2006 for the districts of Taber, Forty Mile, Starland, Camrose, and Smoky River, respectively.

Table 3.21 – Agricultural characteristics of the representative Municipal Districts and Counties

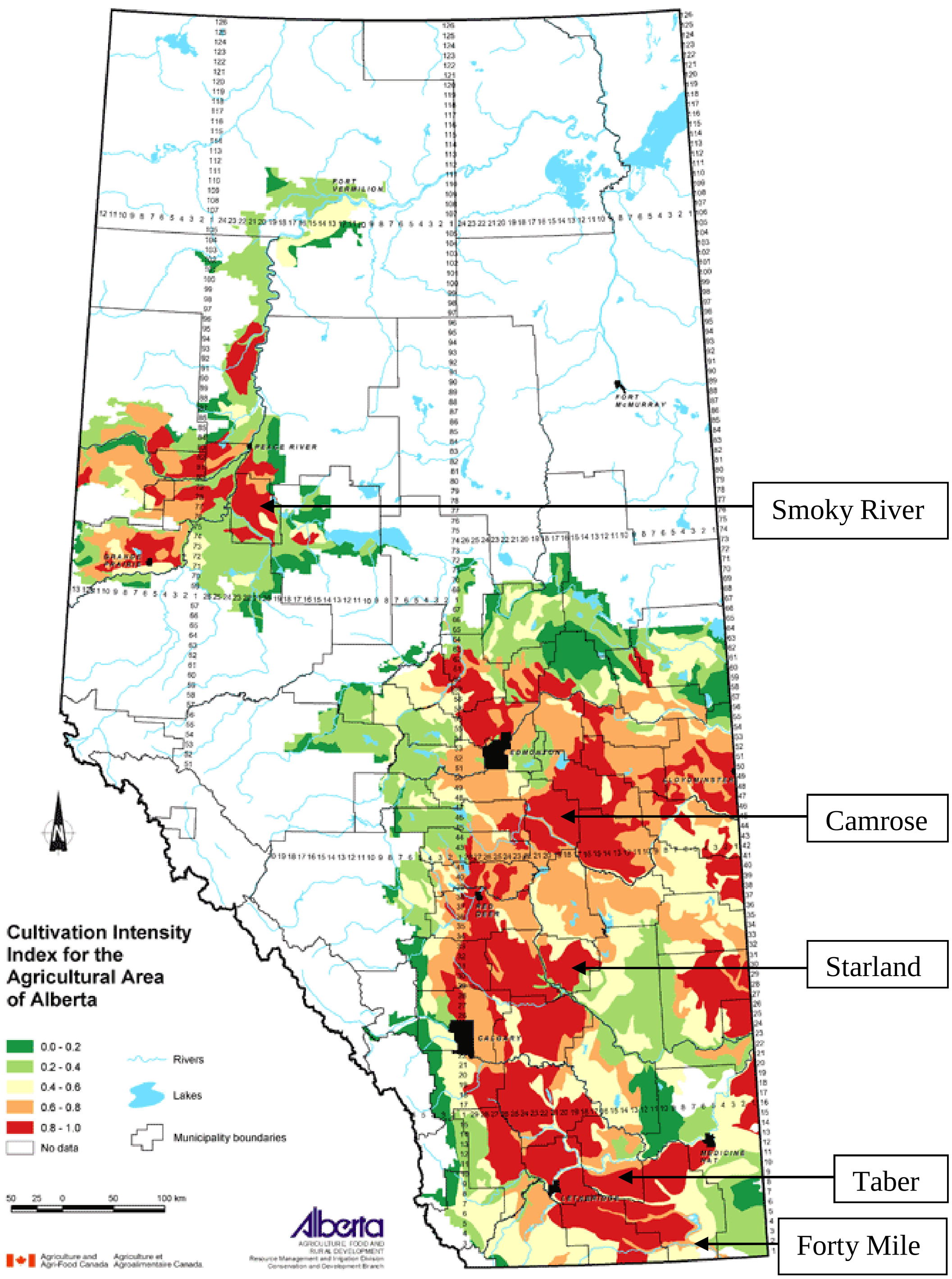
Municipal District	Number of farms	Number of farms with crops	Total agricultural area (ha)	Land in crops (ha)	Land in summer-fallow (ha)
Taber	768	661	403,157	213,705	23,048
Forty Mile	602	548	704,708	287,654	95,990
Starland	364	332	263,093	162,599	19,546
Camrose	1,149	1,001	337,830	233,059	3,461
Smoky River	391	358	245,906	200,971	4,862
Alberta	49,431	41,172	21,095,393	9,621,607	906,347

Source: Statistics Canada (2006)

Figure 3.4 illustrates the cultivation intensity index for different areas of Alberta. The cultivation intensity index measures the frequency with which different cultivation management practices (i.e., no-till, conservation tillage, conventional tillage, and summerfallow) are used. As such, the index provides a proxy of the degree to which crop production practices increase or decrease susceptibility to wind and water erosion on agricultural land (AARD, 2005-a). Higher values represent greater cultivation intensity and greater potential for erosion. According to Figure 3.4, regions chosen as representative of agriculture in Alberta have moderate to high cultivation intensity. Therefore producers in these regions could benefit from the introduction of BMPs.

The information discussed in this chapter will be used as a starting point for defining characteristics such as farm size and crop rotations for the representative farms. The environmental issues discussed in this chapter also provide the starting point for determining relevant BMPs for analysis of the representative farms.

Figure 3.4 – Cultivation intensity in Alberta.



Source: *Adapted from* AARD (2005-b) *with permission from Alberta Agriculture and Rural Development.*

Chapter 4: Capital Budgeting and Simulation Analysis

This chapter discusses the capital budgeting and simulation theory used to analyze the costs and benefits of BMP adoption in this study. The benefits of using capital budgeting techniques for analyzing BMP adoption are discussed, with the benefits of using NPV analysis specifically for this study. Simulation techniques are used in conjunction with capital budgeting as it incorporates crop yield and price risk and allows for flexibility in modelling BMP adoption relationships. This chapter also discusses the structure of the simulation model used to analyze BMP adoption on the representative farms.

4.1 Capital Budgeting

Capital budgeting is a planning process used to determine if a long-term investment is financially acceptable. For this study it is assumed that producers make decisions to maximize wealth. Therefore, a financially acceptable investment is one where wealth in increased. The feasibility of BMP adoption is considered in the wealth maximization and capital budgeting frameworks because some of the BMPs examined in this study, such as shelterbelt adoption, perennial forages, and buffer strips around wetlands, may be considered long term investments.

Copeland and Weston (1988) stated that for a capital budgeting technique to be consistent with wealth maximization, it should be consistent with the following four criteria:

(1) All cash flows are considered.
(2) The cash flows are discounted at the opportunity cost of capital.
(3) The capital budgeting technique should select the project, from mutually exclusive projects, that maximizes wealth. [10]
(4) Projects should be able to be considered independently from all others.[11]

Four capital budgeting techniques commonly used in investment analysis are payback period (PP), accounting rate of return (ARR), internal rate of return (IRR), and net present value (NPV). Copeland and Weston (1988) provide an explanation and discussion regarding the calculations, assumptions and advantages/disadvantages associated with these four methods. Of the four, only NPV meets all four of the criteria outlined above. Therefore NPV analysis is used for simulation analysis in this project and is further discussed in the following section. Representative farms used NPV analysis to determine if BMP adoption is feasible over an infinite amount of time.

4.1.1 Net Present Value

NPV is defined as the present value of future cash flows minus the costs of investment (Ross et al., 2003). Present values are calculated by discounting future cash

[10] Mutually exclusive projects are a set of projects from which only one project can be chosen, thus excluding the other options (Copeland and Weston, 1988).
[11] The fourth criterion is known as the value-additivity principle and implies that if the value of separate projects is known then the sum of the projects results in the value of the firm (Copeland and Weston, 1988).

flows using the opportunity cost of capital, or discount rate. In this way, time value of money[12] is accounted for in evaluating investments.

Projects with positive NPV are deemed to be "acceptable" in that they will result in increased wealth. If two mutually exclusive investments are being compared, the one with the greatest NPV will result in the greatest increase in wealth. NPV is calculated using equation 4.1 from Copeland and Weston (1988):

$$\text{NPV} = \sum_{t=0}^{N} \frac{CF_t}{(1+r)^t} - I_0 \tag{4.1}$$

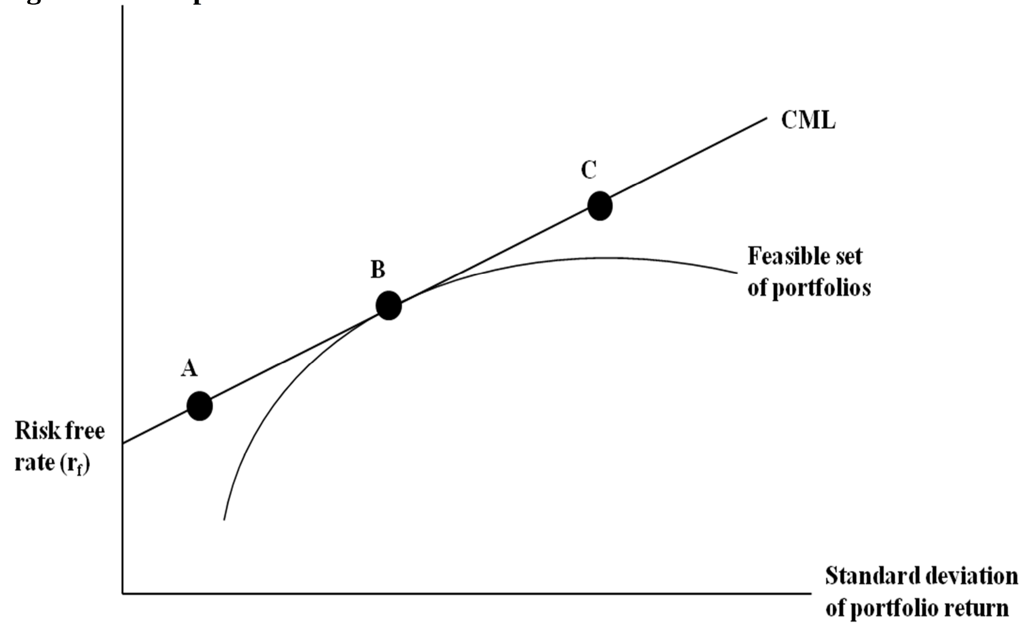
In equation 4.1 Copeland and Weston (1988) define CF_t as the net cash flow in a time period t, I_0 as the initial cash expenditure, r as the market discount rate, and N as the number of years considered for the investment. The discount rate should reflect the market-determined opportunity cost of capital in order to be consistent with the wealth maximization principle (Copeland and Weston, 1988). In situations where cash flows for potential investments are uncertain, the discount rate should also reflect the level of risk. NPV analysis also allows for the possibility of changes in the opportunity cost over the course of the investment (Copeland and Weston, 1988). In other words, if the discount rate changes from one period to the next, cash flows can be discounted accordingly.

As noted above, discount rates reflect the relative riskiness of an operation. Adoption of BMPs is an investment decision that may be risky for producers. Adoption will only occur if the expected return from adoption is sufficiently high to compensate for risk (Ross et al., 2003). Therefore, the discount rate used in NPV analysis should reflect the level of risk involved in investment in the project, in this case BMP adoption.

One approach to determine the appropriate discount rate to use in NPV analysis when cash flows are risky is to use the Capital Market Line (CML). The CML method has been employed for this purpose in farm-level studies by Cortus (2005), Koeckhoven (2008), and Yang (2009). The CML is a line that represents risk efficient combinations of a market portfolio and a risk-free asset. Figure 4.1 illustrates an example of a CML.

[12] The time value of money refers to an assumption regarding investor preferences; that is, all other things being equal, an investor prefers to receive returns (i.e., positive cash flows) earlier rather than later. The discounting done in NPV calculations puts all cash flows associated with an investment on an equivalent time basis.

Figure 4.1 – Capital Market Line



Source: adapted from Ross et al. (2003)

In Figure 4.1, the feasible set represents all feasible combinations of risky portfolios, also known as the efficiency frontier. As shown in Figure 4.1, there is a positive relationship between expected return and risk (i.e., standard deviation of returns). Given a risk-free investment or asset, with return, r_f, there is only one portfolio on the frontier that is optimal, at point *B*. Portfolio *B*, referred to as the market portfolio, is located where the feasible set is tangent to a straight line drawn from the risk free rate, and the optimal investment occurs. This line is the CML. Given the opportunity to invest in combinations of the market portfolio and the risk-free investment, investors will choose some point on the CML, based on their level of risk aversion. In Figure 4.1 point *A* contains a greater proportion of the risk-free investment, as compared to point *C*, and has a lower level of both expected returns and risk. Investors who choose point *A* are more risk averse than investors who choose point *C*.

As discussed by Cortus (2005) and Koeckhoven (2008), the CML may be used to determine an appropriate discount rate for use in the NPV analysis; that is, one that reflects the riskiness of farming operations and activities.[13] In particular, if information is known concerning the rate of return for the risk-free investment, expected return and risk for the market portfolio, and the level of risk for the investment being evaluated, equation 4.2 (from Sharpe et al., 2000), may be used to calculate the level of expected returns that would be required (i.e., the opportunity cost) for the investment to be efficient.

$$\bar{r}_p = r_f + \left[\frac{\bar{r}_m + r_f}{\sigma_m}\right]\sigma_p \qquad (4.2)$$

In equation 4.2, $\bar{r}_p$ is the required expected return for the investment (i.e., the discount rate), r_f is the market risk-free rate of return, $\bar{r}_m$ is the expected return from the market portfolio, σ_m is the standard deviation of the market portfolio, and σ_p is the standard

[13] The discussion provided by both Cortus (2005) and Koeckhoven (2008) is based on Sharpe et al. (2000).

deviation of returns or cash flows for the investment. The $\left[\frac{\bar{r}_m + r_f}{\sigma_m}\right]$ term in equation 4.2 represents the slope of the CML.

In the Cortus (2005) and Koeckhoven (2008) studies, the "investment" being considered is the farm operation itself, and σ_p is determined by simulating performance of the farm and calculating the resulting volatitily. The rate of return of government treasury bills is often used as the risk-free rate (Ross et al., 2003). The return on an index of stocks, such as the Toronto Stock Exchange (TSX) index is a good proxy for the optimal market portfolio, and is used by Cortus (2005) and Koeckhoven (2008) in their analyses.

4.2 Modelling Techniques for Agricultural Systems

This study uses cash flow NPV analysis to investigate the "investment" problem of BMP adoption on Alberta cropping operations. Even with available information the logistics and mechanics of model development can be complex for modelling agricultural systems (Mayer et al., 1998). Therefore alternative modelling techniques are examined for possible use in developing the representative farm models. Models developed for agricultural systems vary from sub-farm, whole farm, to regional, national or even international industry levels (Mayer et al., 1998). At the farm level, individual operations may be viewed as independent units and modelled accordingly (Mayer et al., 1998). Agricultural systems also have a range of management decisions available to the operator. In some cases these decisions may be difficult to model, such as cropping strategies (Mayer et al., 1998). Thus, there are still decisions to be made regarding the type of modelling system that most accurately fits the characteristics of the farms and the feasibility of the investment being made. Alternative approaches that may be considered for use in modelling agricultural systems include mathematical optimization, simulation techniques, and hybrid optimization/simulation techniques.

4.2.1 Mathematical Optimization

The goal of optimization is to find the combination of factor levels that minimizes or maximizes a specific objective or goal (April et al., 2003). Often, this is done within a constrained optimization framework; that is, the objective is optimized subject to a set of constraints that may reflect technical, economic or policy considerations, for example. Constrained optimization methods include linear programming and all the derivatives of this method, including integer programming and nonlinear programming (e.g., quadratic programming). Using these methods, systems are modelled through the specification of mathematical equations and constraints (Mayer et al., 1998). Examples of recent applications where agricultural systems are modelled using constrained optimization methods are Wilson and Dahl (2006), Wagner et al. (2007) and Muñoz-Carpena et al. (2008).

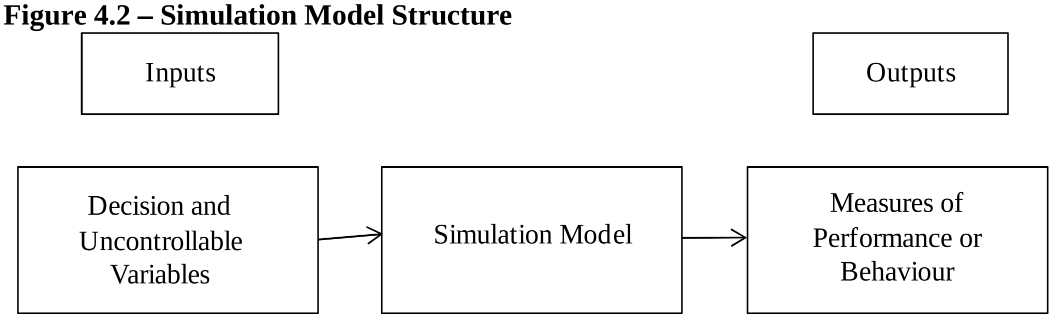
Mathematical programming models can be adapted to incorporate sources of risk in agricultural production (e.g., quadratic programming, stochastic programming). However, these models tend to be fairly rigid in terms of structure (e.g., often constraints must be linear inequalities). As a result these tools are often not a sufficient modelling technique when risk should be modelled in a system, such as for agricultural systems (Musshoff and Hirschauer, 2009). To realistically model agricultural systems, detailed variables are necessary, and even with detail, some of the mathematical programming methods have difficulty dealing with extreme behaviour and interactions of variables (Mayer et al., 1998).

4.2.2 Simulation Analysis

Evans and Olson (2002, p. 2) defined simulation as “the process of building a mathematical or logical model of a system or a decision problem, and experimenting with the problem to obtain insight into the system’s behaviour or to assist in solving the decision problem.” Simulation models are useful for representing agricultural systems as they can be used to test hypotheses and explore alternative management scenarios in agriculture, which aids in the development of innovative practices and policy and extension (Bechini and Stöckle, 2007).

Simulation models may be static or dynamic over time and may contain deterministic or stochastic variables (Carson, 2003). A static model considers only one period in time while a dynamic model may evolve over time. Deterministic models do not contain random variables, while stochastic models allow for one or more parameters to be random. A simulation model is often thought of as a mechanism that converts input parameters into output performance measures (April et al., 2003). The typical structure of a simulation model is provided in Figure 4.2.

Figure 4.2 – Simulation Model Structure



Source: Cortus (2005) (as adapted from Evans and Olson, 2002)

To demonstrate the mechanics of simulation analysis with an example, a cropping operation is considered, where producers are concerned with returns from production. Decision variables include inputs, such as fertilizers and herbicides, and crops grown and management practices used. Uncontrollable variables include input prices, crop yields, and crop prices. The simulation model would contain distributions from which to draw to simulate outcomes of farm decisions. The simulation model would also contain calculations of net returns from production. For example, if the price of grain grown is $0.20 per kilogram, 100,000 kilograms are produced, and the variable costs of production were $0.08 per kilogram of grain, then the net returns for the grain production would be $12,000. With stochastic simulation costs, prices, and yields of grain may vary, according to a distribution. Measures of performance from the simulation model would be net returns (i.e., outputs) from crop production. If the simulation is stochastic, it may be repeated to produce a distribution of outcomes, from which producers can determine the best set of decisions for crop production (Cortus, 2005).

Simulation analysis is an advantageous method of modelling agricultural systems because it allows for flexibility to model complex relationships. Many relationships in agricultural production are non-linear, but can still be estimated using distributions with stochastic parameters, an approach that is feasible with simulation analysis. However as agricultural models are made more flexible they typically become more complex and it is difficult to develop models that are realistically flexible. Also, with simulation analysis there is no guarantee of an optimal solution being found. However, with the ability to predict a distribution of outcomes it is likely that the optimal solution is represented within the range of outcomes that are calculated from simulation analysis.

4.2.3 Hybrid Analysis

A third type of modelling approach that may be used for agricultural systems, as outlined by Mayer et al. (1998), considers optimization combined with simulation analysis; that is, a hybrid approach. Studies considering simulation with optimization are becoming more popular (April et al., 2003; Musshoff and Hirschauer, 2009; Srivastava et al., 2003) as they allow for dynamic modelling with flexible model structure, while still providing an optimal solution. In developing these types of systems, first the simulation model is built and tested, followed by model optimization (Mayer et al., 1998). Different optimization methods may be used when combined with simulation analysis, such as any of the mathematical programming techniques identified earlier. However, in designing hybrid models simplifications are frequently made when complexities in the stochastic variables are encountered, such as non-normally distributed variables (Musshoff and Hirschauer, 2009). While this method may produce accurate results in many cases, there are still shortcomings in the design and technology available in modelling agricultural systems. In order to achieve more accurate results in simulation optimization the use of genetic algorithms may be necessary (Musshoff and Hirschauer, 2009).

4.3 Conceptual Representative Farm Model

This section provides the reasoning for choosing simulation analysis for the present study. Simulation analysis is the best choice for modelling the farm systems because flexibility in variables is permitted as BMPs are adopted. Crop prices, yields and BMP effects can be modelled assuming non-linear distributions, which is more realistic. The simulation analysis in this study will be stochastic to account for risks in agricultural production, including price and yield. The analysis will also be dynamic so that the time element of BMP adoption decisions is considered in the calculations and comparisons of NPVs.

4.3.1 Monte Carlo Simulation

This study considers stochastic simulation in order to incorporate uncertainty and risk using random variables. In particular, Monte Carlo simulation is employed. Monte Carlo simulation uses repetitive random sampling from one or more parameter distributions to compute outcomes that are dependent on the values selected for the distributions (Vlahos, 1997). This study uses the Microsoft Excel add-in program *@RISK*© (Palisade Corporation, 2007) for Monte Carlo simulation, which is relatively simple to use as an addition to Excel spreadsheets and is powerful enough to compute up to 10,000 iterations per simulation.[14] Since Monte Carlo simulation is based on random sampling, results may contain sampling errors (Evans and Olson, 2002). However, increasing the number of iterations for results minimizes this error (Evans and Olson, 2002).

Stochastic model inputs are predefined distributions, and outcomes from Monte Carlo simulation analysis are also distributions. For the purposes of this study the outcome that is used as a measure of wealth for cropping operations is NPV. NPV

[14] An iteration is a set of random draws from a pre-defined probability distribution which are then used to calculate model variables. Monte Carlo programming is an iterative process in that these draws and resulting calculations are repeated to create a distribution of model outcomes.

outcomes from BMP adoption are compared in terms of differences in means and standard deviations associated with distributions of performance measures. In particular, crop yields and prices are modelled stochastically and used to calculate distributions of NPVs for the representative crop farms.

4.3.2 Capital Budgeting and Simulation Analysis

When used alone NPV analysis provides a static result. If this number is positive, then the investment is worthwhile; that is, it adds to wealth. By adding simulation analysis to traditional NPV analysis, the results are in the form of probability distributions. Static values can be misleading when it comes to investment decisions that are potentially risky, whereas probability distributions provide the likelihood of an outcome. Investment decisions have some uncertain properties that can be measured as risk. Typically there is incomplete knowledge of an investment when the investment decision is made. Monte Carlo simulation with NPV analysis allows for investment decisions to become calculated risks, rather than educated guesses (Vlahos, 1997).

It should be pointed out that using NPV analysis and simulation analysis may lead to confusion in how risk is accounted for within the model. In NPV analysis risk is accounted for using the discount rate, while in Monte Carlo simulation risk and uncertainty are accounted for through the specification of stochastic parameters (Trigeorgis, 1996). It may initially be thought that this may be double counting risk in investments. However, it is still preferable to use a distribution of outcomes in NPV analysis, as compared to a static value (Trigeorgis, 1996; Vlahos, 1997).

4.3.3 Representative Farms Simulation Model Structure

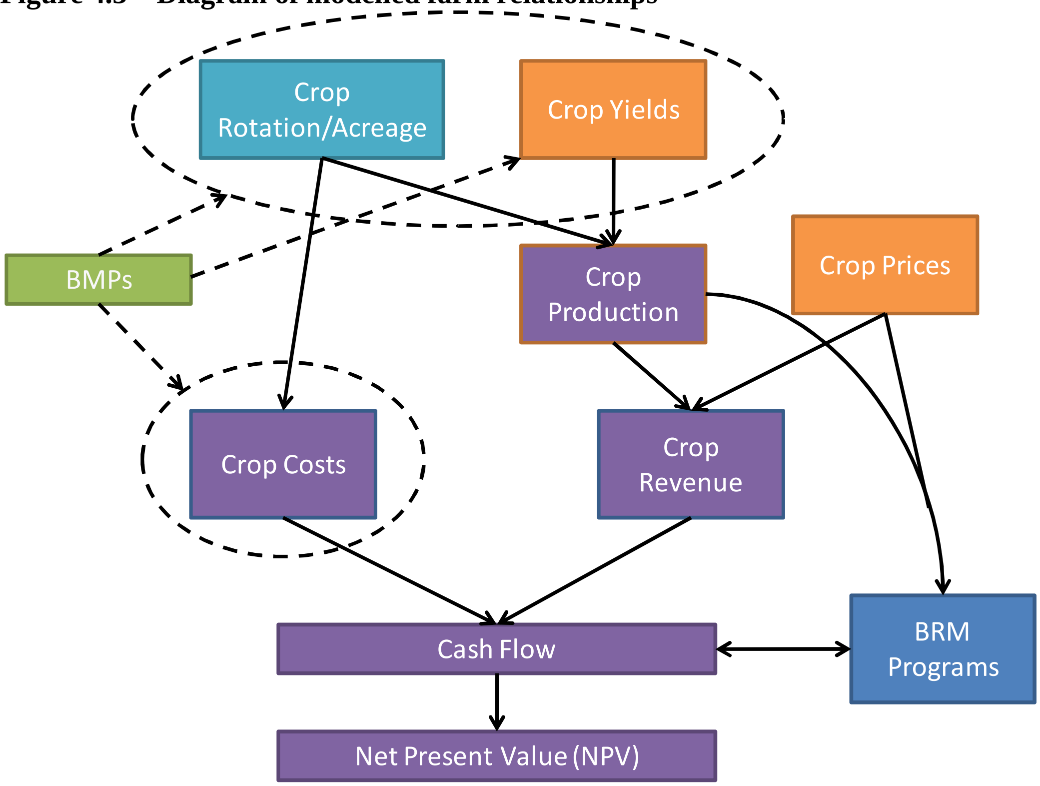
In this study cropping operations consider adoption of BMPs based on wealth maximization. NPV from baseline scenarios are compared to NPVs after BMP adoption. If BMPs produce a net positive effect then the practices are considered beneficial for the operation. Conversely, practices where net losses are observed are considered to result in a net cost for producers and would likely not be adopted without incentives. Cash flow and stochastic simulation are combined in this study to develop representative, farm-level models for cropping operations. Monte Carlo simulation is used, which allows incorporation of historical price and yield models to model uncertainty and risk of these variables. Monte Carlo simulation is also used to account for uncertainty effects from BMP adoption.

To begin, simulation models are developed that incorporate representative farm characteristics such as location, size, crop choice, and crop yields. Input costs such as seed, fertilizer, and herbicides, are added to the models according to the choice in crops grown and area of land allocated to each crop. There are many risks associated with agricultural production. Stochastic crop yield and price models are developed using historical data, accounting for risk from weather (i.e., weather affects yields) and markets. These stochastic yield and price models are incorporated into the farm level simulation models and used to determine net revenue of the operations. Agricultural risk is also incorporated via the discount rate, as cash flows are discounted in NPV analysis.

In modelling BMP adoption, both rotational and non-rotational BMPs are considered. Rotational BMPs affect the amount of land allocated to certain crops, and therefore affect the revenue of the farms. There are also yield effects from adoption of most cropping BMPs. These yield effects affect crops following BMP crops and are modelled stochastically. The yield effects are drawn from distributions with minimum and maximum values, as determined from the literature. Non-rotational BMPs do not result in any change in crop rotations. However, in some cases adoption results in a change in total land available for crop production (e.g., establishment of a buffer strip). More information on BMP yield and acreage effects is provided in Chapter 5. In some cases effects from BMP adoption evolve or develop over time and in many cases all costs and benefits of BMP adoption are not apparent after just one period. Therefore dynamic modelling that considers many time periods is used to determine if BMP adoption is feasible.

Figure 4.3 is a schematic of the modelling techniques for the representative farms. Crop yields and prices are variables that are measured stochastically. It should also be noted that subsequent crop yield from BMP adoption are modelled stochastically. Business Risk Management (BRM) programs include AgriStability, AgriInvest, and crop insurance programs. Variables directly affected by BMP adoption include crop acreage, crop yields, and crop costs, as indicated by the dashed circles in Figure 4.3. The remaining boxes in the schematic including crop production, crop costs, crop revenues, cash flow, and NPV make up the basics of the cash flow relationships.

Figure 4.3 – Diagram of modelled farm relationships[a]



[a] The dashed circles enclose those parts of the model that are directly affected by adoption of BMPs.

4.4 *Chapter Summary*

This chapter discusses the various techniques used in farm level analysis as well as the specific capital budgeting and simulation models used to determine economic viability of BMP adoption. It is argued that NPV analysis is the most appropriate capital budgeting technique to determine if BMP adoption is an economically feasible investment. Simulation analysis is used with NPV analysis to improve the ability of the models to predict outcomes. Simulation analysis models economic and ecological interactions of variables. Simulation, specifically stochastic and dynamic simulation, allows for a distribution of NPV outcomes. NPV alone only provides a single, static result. This may result in some investments being considered, even though they may be risky when modelled with simulation techniques. Cash flows are built in Microsoft Excel and discounted. Stochastic variables are built into the models, using the add-in software *@RISK*, to account for further uncertainty in agricultural production.

Chapter 5: The Representative Farms and Simulation Model

The details of the simulation models developed to analyze the economic costs and benefits of the impact of introducing BMPs on commercial crop farms in Alberta are discussed and explained in this chapter. The simulations are run through the use of dynamic Monte Carlo modelling. Each representative farm is simulated over multiple years, with a subset of parameters being stochastic. The farm models are created in Microsoft Excel© and are simulated using @*RISK*©, which is an Excel add-in program from Palisade Corporation (2007). This program allows the models to be run through time while incorporating uncertainty with stochastic variables. In this study risk enters the analysis through stochastic crop yields and prices, as well as with the discount rate in NPV analysis. In each year of the simulation, random draws are made for each yield and price variable. Multiple iterations of the multiple year simulation are then done in order to obtain distributions of relevant outcomes.

The time horizon used for the BMP analysis is 40 years. A 40-year simulation model is chosen due to the long term nature of some of the BMPs, which are discussed later in this chapter. For example, it takes many years for shelterbelts to achieve sufficient growth to have an impact of crop yields due to reduced water supply near the trees and reduced soil erosion farther away from the trees.

Simulations are run for each representative farm first assuming no BMPs are implemented. They are then re-run for implementation of individual BMPs to determine the impact on farm performance. Finally combinations of BMPs are modelled to compare the effects of joint implementation of BMPs on each farm.

The structure of the individual farm remains relatively constant over time. In particular, the assumption is made that once producers have decided upon a machinery complement, production practices, crop insurance, safety net programs, and crop rotations, these decisions do not change over time. Crop rotation is a BMP that is analyzed in the models. However, once it is decided to implement a BMP crop rotation, this rotation is maintained through the entire simulation time horizon.

The Net Present Value (NPV) for each farm is calculated over a period of 40 years and is used to compare the costs and benefits before and after BMP adoption. The comparison of NPV in each case (without BMPs, individual BMPs, and BMP combinations) provides insight for the economic feasibility of the adoption of BMPs on commercial crop farms in Alberta.

5.1 Representative Farm Characteristics

This section discusses the characteristics that are representative of a typical farm in each region of interest. The representative farms considered for this study are commercial crop farms in Alberta. Farms are defined based on size as well as types of crops typically grown in each region. Commercial cropping operations have land bases that are larger than for an "average" farm (i.e., as would be suggested from Census data) and this is reflected in the representative farms for this project. The information presented in this chapter is determined using Census of Agriculture (2006 and 2001) data and expert opinion from Alberta Agriculture and Rural Development (AARD).

5.1.1 Farm Size

Farm size (i.e., hectares of land per operation) was determined based on the assumption that the modelled farms should be representative of commercial operations in each of the counties being used in the analysis. According to AARD (1999-a) commercially viable farms are at least 648 hectares (1600 acres). On this basis it was assumed that all representative farms will be at least this large. Using 2006 Census of Agriculture data, farms classified by total farm area are separated into the following four categories: 648 to 906 hectares (1600 to 2239 acres), 907 to 1165 hectares (2240 to 2879 acres), 1166 to 1425 hectares (2880 to 3519 acres), and 1426 hectares (3520 acres) and greater. These categories are chosen as they include farms that meet the minimum size requirement and they correspond to groupings in the Statistics Canada census data. The proportion of each grouping, relative to the total number of "commercial sized" farms in each County/Municipal District is used to determine the size of farm that is most common among commercial operations (Table 5.1).

Table 5.1 – Distribution of farms by size, representative Alberta counties (2006)

	Numbers of Farms				
Farm Size (hectares)	Taber	Forty Mile	Starland	Camrose	Smoky River
648 – 906	54	50	47	79	39
907 – 1165	24	64	34	28	30
1166 – 1424	14	42	28	13	14
1425 +	57	128	34	24	29
Total Commercial Farms	149	284	143	144	112
Total Farms	768	602	364	1149	391

Since there are two representative farms in the Brown soil zone and they represent different types of production practices, separate farm sizes for the irrigated and dryland Brown soil zone farms are determined based on the appropriate county data. In the M.D. of Taber, where the irrigated Brown soil zone farm is located, approximately 52% (54 and 24 farms) of commercial operations are in the smaller two size categories and approximately 48% (14 and 57 farms) are in the larger two size categories. Therefore the farm size for the Brown soil zone irrigated farm is set at 1036 hectares (i.e., 2560 acres or 16 quarter sections). Conversely, in the County of Forty Mile approximately 60% (42 and 128 farms) of commercial operations are in the larger two size categories and only 40% (50 and 64 farms) are in the smaller two size categories. The acreage for the farm in the dryland Brown zone is thus set at 1295 hectares (i.e., 3200 acres or 20 quarter sections).

In establishing representative farm size in the other soil zones (i.e., Dark Brown, Black and Dark Grey), individual Counties/Municipal Districts and the overall average farm size for the soil zone is considered. In the Dark Brown soil zone and in Starland County approximately 57% and 43% of commercial farms are in the lower two and upper two size categories, respectively. However, the decision is made to have the farm in Starland County, where the Dark Brown farm is located, the same size as the dryland Brown soil zone farm at 1295 hectares (i.e., 3200 acres or 20 quarter sections). This decision was made to allow for easier comparisons between farms in the Brown and Dark Brown soil zones and is justified on the basis that if the smallest size category (i.e., 648-906 hectares) is excluded from consideration, the distribution of farms in the other three size categories is relatively even. In the Black soil zone, approximately 74% of farms are in the smaller two size categories, while only 26% are in the larger two soil categories. Therefore, the size of the representative farm in Camrose County (i.e., Black soil zone) is set at 1036 hectares (i.e., 2560 acres or 16 quarter sections). In the Dark Grey soil zone and in the M.D. of Smoky River approximately 38% of farms are in the larger two size categories and 62% of farms are in the smaller two size categories. Therefore the representative farm in the Dark Grey soil zone, in the M.D. of Smoky River is set at 777 hectares (i.e., 1920 acres or 12 quarter sections).

5.1.2 Crop Production and Rotation

An important consideration in defining the representative farms for this study is the set of crops to be produced and the associated crop rotations. According to the 2006 Census of Agriculture there were 2,334,512, 1,657,062, and 1,646,468 hectares of spring wheat, barley, and canola, respectively, grown in Alberta. These represent the top three annual crops under production in terms of area. However, growing conditions (i.e., soil quality, temperature and moisture conditions, etc.) vary across the province and so it might be expected that typical crop rotations will also vary for the representative farms. Crops and associated rotations are therefore chosen based on a) crop area in each representative county and soil zone using 2001 and 2006 Census of Agriculture data, and b) expert opinion from AARD.

Table 5.2 provides a summary of areas grown for common crops in each representative county, based on 2006 Census of Agriculture data. As is evident from the values in Table 5.2, in several of the counties alfalfa hay and other tame hay represent a significant proportion of crop area. It is likely that most of this hay production occurs on farms that have cattle. Since this study focuses on operations where the primary source of revenue is from sale of annual crops, hay is not considered for the baseline representative rotations.[15]

The information in Table 5.2 may be used to identify the "top" annual crops for each representative county, defined in terms of area grown. In the Municipal District of Taber the top four crops by area are spring wheat, barley, durum wheat, and canola. For the County of Forty Mile, the predominant crops grown, on an area basis, are spring wheat, durum wheat, oats, barley, and field peas. In the County of Starland spring wheat, barley, and canola represent the most prevalent crops. The same three crops (i.e., spring wheat, barley and canola) are also the top annual crops grown in the County of Camrose, with field peas and oats having smaller but still significant areas. Finally, canola and spring wheat are the dominant annual crops grown in the Municipal District of Smoky River, with oats and barley representing lesser (but still significant) areas.

[15] While hay is not part of the base rotations for any of the representative farms, it is included in the crop rotation BMPs for some of the farms, as a cash generating activity.

Table 5.2 – Areas of crops grown in representative counties in 2006

Crop	Taber	Forty Mile	Starland	Camrose	Smoky River
	Acreage (ha)[a]				
Alfalfa and alfalfa mixes	14,311	12,145	11,763	19,261	34,412
All other tame hay and fodder	4,585	4,564	4,424	11,591	6,450
Barley	29,382	28,329	30,011	33,619	7,785
Canola	17,505	8,117	28,227	72,266	76,447
Chick peas	3,980	7,041	N/A	N/A	N/A
Dry field peas	8,553	24,332	6,137	8,594	3,864
Durum wheat	20,643	46,155	550	N/A	N/A
Mixed grains	641	538	950	3,802	N/A
Oats	2,055	37,084	3,465	6,743	8,266
Other dry beans	8,228	6,545	N/A	N/A	N/A
Potatoes	14,538	1,263	3	N/A	N/A
Spring wheat	64,044	122,957	72,964	72,336	51,910
Sugar beets	8,416	N/A	N/A	N/A	N/A
Other crops	12,644	13,081	3,532	3,115	1,869

[a] N/A is used to denote crops for which acreages are not available due to the crop not being grown in the area or only being grown by a small number of producers (i.e., withheld due to confidentiality).

Source: Statistics Canada (2006)

As noted earlier, expert opinion from AARD is also used to establish crop rotations for the representative cropping operations. Expert opinion (Bergstrom, 2009) indicates that typical crop rotations for Alberta crop farms are comprised of approximately one-third wheat, one-third canola, with the remaining one-third being some combination of barley, peas, silage/forages, and specialty crops. As well, farms typically alternate cereals and broadleaf annuals from year to year within individual fields (Bergstrom, 2009) as a method to deal with potential diseases and reduced yields that may be associated with continuous cropping practices. Besides these general patterns, AARD crop experts also made suggestions as to the specific crops to include for farms in Southern Alberta, including the Brown soil zone irrigated and dryland farms, and the Dark Brown soil farm (Dunn, 2009).

One other source of information taken into account when deciding on crop rotations is the USDA's Crop Sequence Calculator (CSC) (USDA ARS, 2008). The CSC utilizes information on crop production, economics, plant diseases, weeds, water use, and surface soil properties to generate advice/recommendations for producers to use in evaluating risks associated with different crop sequences (USDA ARS, 2008). Research for the CSC was done at the Northern Great Plains Research Laboratory in Mandan, North Dakota from 1998 to 2005. The results provided by the CSC that are taken into consideration for the crop rotations include a) trends towards lower yields when a crop is grown on the residue from the same crop (i.e., two or more subsequent years of the same crop in the same field), and b) trends towards higher cereal grain yields and net returns when a cereal crop follows a pulse or oilseed crop.

A summary of the resulting base crop rotations for each of the representative farms is provided below. In presenting the crop rotation, abbreviations are used for each crop, as follows:

B	-	Barley
C	-	Canola
DB	-	Dry Beans
DW	-	Durum Wheat
SF	-	Summerfallow
SW	-	Spring Wheat

5.1.2.1 Brown Soil Zone – Irrigated Farm

For the irrigated farm in the Brown soil zone, the base rotation is a four-year rotation consisting of SW – C – DW – DB. This rotation was constructed based on AARD expert opinion (Dunn, 2009). This rotation is somewhat consistent with 2006 Census data, as spring wheat, durum wheat, and canola were the first, third, and fourth with respect to crop areas in the district (Table 5.2). However, Census data would suggest that the rotation should include barley (second greatest area), while dry beans are the ninth most commonly grown crop in Taber.

Table 5.2 includes crop areas for all farms in Taber, both irrigated and dryland production. It was suggested by expert opinion (Dunn, 2009) that barley is not as commonly grown using irrigated technology, whereas in Alberta dry beans are typically only grown using irrigation practices. As a consequence, it was deemed to be a reasonable assumption that the farm representative of irrigated production in the Brown soil zone would contain dry beans and so the suggested rotation was used.

5.1.2.2 Brown Soil Zone – Dryland Farm

The base rotation for the dryland farm in the Brown soil zone was an eight-year rotation consisting of SF – SW – C – DW – SF – B – C – SW. As with the irrigated farm, this rotation is based on expert opinion (Dunn, 2009). Dunn (2009) had indicated that actual rotations in this area would not include barley and would have a smaller proportion of summerfallow than is incorporated into the representative farm rotation. However, Census data (Table 5.2) suggest that barley is frequently included in crop rotations, and approximately one quarter of land used for cropland in this region is allocated to summerfallow. On the basis of Census data evidence, the eight year rotation provided above is used for this farm.

5.1.2.3 Dark Brown Soil Zone

For the Dark Brown soil zone the base rotation is a four year rotation consisting of SW – C – B – SF. Again, opinion from AARD (Dunn, 2009) suggested that summerfallow should be reduced or excluded for the rotation for this farm and that barley should perhaps be replaced with winter wheat. However, as was the case for the Brown soil zone farm, Census data indicate a significant portion of cropland was allocated to summerfallow in 2006. Barley had the second greatest area among annual crops in Starland, after spring wheat. As a result, the four year rotation provided above is used for this farm.

5.1.2.4 Black and Dark Grey Soil Zones

The base rotation for the Black and Dark Grey soil zones is a five-year rotation consisting of SW – C – B – SW – C. This is consistent with the 2006 Census of Agriculture data, as spring wheat, barley, and canola are the most common crops in the representative counties for these soil zones. The rotation is also consistent with the recommended alternating pattern of cereal/broadleaf crops. It was suggested by AARD expert opinion (Bergstrom, 2009) that field peas should be included in the base rotation in the Black soil zone. However, peas have a significantly lower area of production than the other three crops in the County of Camrose (Table 5.2). As a result, field peas are included only as part of a BMP crop rotation, as discussed later in this chapter.

5.1.2.5 Crop Rotation Summary

The crop rotations for each representative farm are "combined" with the area of cropland discussed earlier in this chapter (i.e., farm size), to arrive at the areas of crops grown each year by each farm. The area allocated annually for each crop is given in Table 5.3. Since they are grown in rotation, the crops grown on specific fields will change from year to year. However, the total area for each crop on each representative farm is assumed to be constant each year.

Table 5.3 – Annual crop production (in hectares) for base crop rotation, by representative farm

Crop	Irrigated, Brown Soil	Dryland, Brown Soil	Dark Brown Soil	Black Soil	Dark Grey Soil
Barley	0	162	324	208	155
Canola	259	324	324	414	311
Dry Bean	259	0	0	0	0
Durum Wheat	259	162	0	0	0
Spring Wheat	259	324	324	414	311
Summerfallow	0	324	324	0	0
Total	**1036**	**1295**	**1295**	**1036**	**777**

5.1.3 Machinery Complements

Each of the representative farms is assumed to have a machinery complement that is unique to farm location and size, and types of crops grown. The complement is defined in terms of the types and sizes of individual pieces of machinery required to complete cropping operations such as tillage, seeding, harvesting, etc. Activities associated with the machinery complement contribute to farm cash outflows and thus need to be considered explicitly within the modelling process. In particular, day-to-day use of machinery results in variable costs associated with fuel use, maintenance and repairs.[16] As well, machinery replacement decisions result in significant net cash outflows although these are irregular in terms of timing.

Modelling replacement decisions for farm machinery is problematic as factors such as economic feasibility would need to be considered in terms of the timing of the decisions. However, if machinery replacement or maintenance of the machinery asset base is not considered, the ability of producers to maintain normal cropping activities would be impaired. A compromise is used in this simulation analysis; specifically, a constant annual cost is calculated to account for machinery replacement. This annual value is the amount required to maintain the machinery complement at its initial asset value (i.e., at the beginning of the simulation time period). Similar approaches have been used in previous studies with cash flow modelling structures (Cortus, 2005; Koeckhoven, 2008). Other variable costs associated with machinery, such as repairs, are accounted for

[16] Besides these costs, there would be additional potential machinery-related cash outflows in the form of debt servicing or lease payments. However, these are not explicitly considered in the analysis.

using input costs per crop per hectare, and are discussed in the crop input costs section of this chapter.

In order to determine the annual machinery maintenance cash flow amount, machinery complement information is required. This includes the types and sizes of machines present on each representative operation, the machinery book value as of the beginning of the simulation time period, and the annual loss in value (i.e., depreciation rate). This information is used to calculate the annual cash flow that is treated as a proxy for machinery replacement expenditures.

Alternative methods have been used to construct machinery complements. These include using optimization methods, an existing machinery selection algorithm, or expert opinion of farmers in each area obtained through focus groups. However, there are limitations associated with each of these approaches. According to Parmer et al. (1996) optimization methods are time consuming as the typical practice is to vary one parameter, such as crops grown, at a time. As well, optimization techniques do not easily account for weather uncertainty, which can affect scheduling of field operations (Parmer et al., 1996).

Machinery selection algorithms are designed to select the "best" complement while considering constraints such as cropping sequence, acreage, soil type, weather conditions, labour availability and others (Rotz et al., 1983). However, the resulting machinery complement may not be optimal again because of weather uncertainties (Parmar et al., 1996; Rotz et al., 1983).

The machinery complements that are arrived at using optimization or selection algorithm methods tend to be smaller (i.e., smaller machinery sizes) than actual machinery sets observed to be used by producers. That farmers tend to purchase larger equipment and machinery bases than would be suggested by these models is seen as a risk management strategy to account for uncertainty in weather and timeliness of operations (Rotz et al., 1983). Using producer focus groups to obtain expert opinion concerning optimal machinery size would address that limitation. However, this method is time consuming and relatively expensive. As a result, an alternative approach is taken in this study. In particular, given the required field operations for each representative farm, appropriate machine types and sizes are identified in a somewhat ad hoc fashion. Adjustments are made to allow for different soil zones, weather patterns, crops in rotation, farm size, and time available to perform cropping operations. This approach to designing representative machinery complements is consistent with what has been used in other recent studies, such as Cortus (2005) and Koeckhoven (2008). The resulting machinery complements are then validated using expert opinion from AARD cropping specialists (Papworth, 2010).

In developing the machinery complements, the assumption is made that the farms use no-till practices. In particular, seed and fertilizer are placed in the soil with minimal disturbance to the previous year's stubble. Reducing soil disturbance allows for benefits such as reduced soil erosion, conservation of soil moisture and reduced likelihood of the emergence of weed species in the crop (AARD, 2004-a). One pass that places both the seed and fertilizer in the soil also improves the timeliness of seeding (Rotz et al. 1983) allowing more time to be allocated to other practices. Gray et al. (1996) also note that by reducing seeding time, machinery depreciation is slowed due to reduced hours on the tractors. As discussed earlier, no-till practices are recognized as a type of cropping BMP and so it would be possible to model this as one of the BMP scenarios in the current analysis. However, the number of producers using no-till or zero-till production practices has increased over time to a point where it may almost be considered the standard practice. In Alberta the use of no-till or zero-till seeding practices has increased from 27% of total land for seeding in 2001 to 48% of total land for seeding in 2006. In some specific regions of the province, this percentage is greater than 50%, as suggested in the discussion of representative counties in Chapter 3.

In developing machinery complements for each farm it is assumed that there are time constraints to cropping operations such as seeding, spraying and harvesting. Assumptions are made regarding the amount of time that is possible for each practice taking uncertainties such as weather into consideration. The size of implement required to complete the activity in the allocated time is determined next, beginning with the seeding implement. Cortus (2005) and Koeckhoven (2008) observed, based on information from sources such as the AARD Machinery Cost Calculator (2008) and SAF Farm Machinery Custom Rates (2008), that seeding implements require the most tractor horsepower. Therefore the size of the tractor (i.e., horsepower) is based on what is needed for the size of the seeding implement that allows for completion of seeding in a timely manner. Equation 5.1, from Edwards (2009) is used to calculate the required seeding implement width. Equation 5.2 (Edwards, 2009) is then used to calculate the required tractor horsepower. Determination of implement width and tractor horsepower requires some information about soil type and typical field efficiencies for different operations. Field efficiency represents the degree (in percentage terms) of maximum theoretical capabilities of machinery that is achieved in practice, accounting for overlap, slowing for turning in fields, and minor repairs. The assumed values used in these calculations are provided in Tables 5.4 and 5.5.

$$\text{Implement Width} = \frac{\text{Farm size (ha)} * 10}{\text{Available time (hr)} * \text{speed}\left(\frac{\text{km}}{\text{hr}}\right) * \text{Efficiency coefficient}} \tag{5.1}$$

$$\text{Tractor Horsepower} = \frac{\text{Implement width(ft)} * \text{Speed}\left(\frac{\text{km}}{\text{hr}}\right) * \text{Draft}\left(\frac{\text{lb}}{\text{ft}}\right) * \text{Soil factor}}{375} \tag{5.2}$$

Table 5.4 – Values for soil factors

Soil Type	**Type of Tractor**[a]		
	2WD	*4WOA*	*4WD*
Firm soil	1.64	1.54	1.52
Tilled soil	1.75	1.61	1.56
Sandy or Soft soil	2.13	1.82	1.67

[a] 2WD, 4WOA and 4WD refer to two wheel drive, four wheel drive with optional assist, and four wheel drive tractors, respectively.
Source: Edwards (2009)

Table 5.5 – Values for field efficiency

Field Efficiency	**Range**	**Efficiency Used**
Tillage	70 - 85	0.8
Planting	65 - 85	0.75
Harvesting	60 - 80	0.7
Spraying	50 - 70	0.65

Source: Powell (2000)

Soil factor values represent index values reflecting the relationship between soil type/condition and tractor horsepower requirements. As indicated in Table 5.4, horsepower requirements increase with less firm soil. The representative farms in the

Brown and Dark Brown soil zones are assumed to have sandy or soft soil.[17] Given that these farms are also assumed to have a four wheel drive tractor, a soil factor value of 1.82, as determined by Edwards (2008) for sandy or soft soils, is used in the tractor horsepower calculation. For the farms in the Black and Dark Grey soil zones it is assumed that soil is tilled. The Black soil zone farm is assumed to have a four wheel drive tractor, while the Dark Grey soil zone farm is assumed to have a four wheel drive tractor with optional assist. It was decided to use the tilled coefficients in estimating soil factors on the farms in the Black and Dark Grey soil zones as a middle ground between the coefficients since the referenced study from which these values were obtained was based on conditions in Iowa. Differences may be apparent for soils in Alberta, so to avoid going from one extreme to the other, from sandy to firm soil, the tilled coefficient is used even though the present analysis assumes no-till seeding technology is used.

Similar methods are used to determine the size of combine harvester, swather and harrows. The approximate time available to harvest is estimated based on the soil zone. The speed of the equipment is then used to determine the width of the combine header, swather header and harrow. The combine header width is used to choose the size of combine. This is done using SAF (2008) Farm Machinery Custom Rates, which places combines in Classes 5 to 7+ based on grain hopper size and horsepower. Additional equipment added to the machinery complement include farm and grain trucks, grain auger, different combine headers for certain crops, and machinery for specialty crops such as dry beans.

After the machinery complements are built according to the above criteria, opinion from farmers and government analysts is considered and changes are made regarding the size and type of machinery. For instance, it is suggested (Papworth, 2010) that farmers would only own a self propelled, high clearance sprayer if more than 4,047 hectares are sprayed annually. As a result, it is assumed that custom spraying is used by all representative farms. The machinery complements for each representative farm are provided in Table 5.6.

Once the machinery complement for a representative farm is established, the book value at the beginning of the simulation period is determined. As discussed earlier, this represents the machinery asset value to be maintained through the simulation analysis. To establish this value, the age of each piece of machinery as of the beginning of the simulation period is required. For the purposes of this study, machinery for each farm is assumed to be five years of age. [18]

Given the machinery age, two alternative approaches are considered for calculating the initial machinery book values. The first approach involves obtaining new machinery values and depreciating them to five years of age. New machinery values are taken from SAF (2008) *Farm Machinery Custom and Rental Rate Guide 2008-09.* These values are depreciated to five years of age using depreciation rates of 8.5% for combines, 5.5% for tractors, and 7.5% for all other machinery (Unterschultz and Mumey, 1996). The annual average reduction in market value for irrigation systems is assumed to be 10% (MSUE, 2009).

These machinery book values are compared to results using machinery prices available for used machinery in Alberta through *IronSearch.com,* a web site for North American used machinery. A simple linear relationship between machinery price and

[17] Soft or sandy soil is assumed in the Brown and Dark Brown soil zones as these regions have lower soil aggregates and lower soil organic matter, as compared to Black and Dark Grey soil zones (AARD, 2004).

[18] In practice, the machinery present on any particular farm will vary in age. However, in defining the representative farms it was decided to use five years as an average, for reasons of simplicity.

machinery characteristics such as total machine hours, year of production, and horsepower is estimated using the linear regression function in Excel. The regression results are used to predict prices for machinery assumed to be present on the representative farms. These values are then compared to values obtained using the depreciated values based on Saskatchewan Agriculture and Food new machinery prices.

Only slight differences were apparent between the estimated book values calculated using the two methods. Therefore the estimates based on SAF (2008) new machinery values are used in the simulation analysis. The annual machinery replacement/maintenance cash flow expenditure per year is calculated by summing the total book value of the machinery and multiplying by an assumed depreciation rate of 8%. The complete list of all machinery and combined annual costs of machinery, assuming an average age of five years, are provided Table 5.6 and 5.7. Original new machinery values and initial simulation period book values are provided in Appendix C.

Table 5.6 – Machinery complement for the representative farms

Soil Zone	Powered Equipment		Drawn Equipment		Attachments & Misc. Equipment	
	Description	**Size**	**Description**	**Size**	**Description**	**Size**
Brown, irrigated	4WD Tractor	325 h.p.	Air Hoe Drill	40 ft.	Bean Windrower	6R 30"
	S.P. Swather	24 ft.	Harrows	50 ft.	Combine header - pick up	14 ft.
	Combine	Class 7	Bean Rod Cutter	6R 30"	Combine header - flex	30 ft.
	Grain Truck 1	350 h.p.			Combine header - bean pick up	22 ft.
	Grain Truck 2	350 h.p.			Grain Auger	10 "
	Farm Truck	3/4 ton				
Brown, dryland	4WD Tractor	425 h.p.	Air Hoe Drill	50 ft.	Combine header - pick up	14 ft.
	S.P. Swather	30 ft.	Harrows	60 ft.	Combine header - flex	25 ft.
	Combine	Class 6			Grain Auger	10 "
	Grain Truck 1	350 h.p.				
	Grain Truck 2	350 h.p.				
	Farm Truck	3/4 ton				
Dark Brown	4WD Tractor	425 h.p.	Air Hoe Drill	50 ft.	Combine header - pick up	16 ft.
	S.P. Swather	30 ft.	Harrows	80 ft.	Combine header - flex	36 ft.
	Combine	Class 7+			Grain Auger	10 "
	Grain Truck 1	350 h.p.				
	Grain Truck 2	350 h.p.				
	Farm Truck	3/4 ton				
Black	4WD Tractor	325 h.p.	Air Seeder	50 ft.	Combine header - pick up	16 ft.
	S.P. Swather	30 ft.	Cultivator	50 ft.	Combine header - flex	36 ft.
	Combine	Class 7+	Harrows	80 ft.	Grain Auger	10 "
	Grain Truck 1	350 h.p.				
	Grain Truck 2	350 h.p.				
	Farm Truck	3/4 ton				
Dark Grey	4WOA Tractor	225 h.p.	Air Seeder	40 ft.	Combine header - pick up	14 ft.
	S.P. Swather	24 ft.	Cultivator	40 ft.	Combine header - flex	30 ft.
	Combine	Class 7	Harrows	50 ft.	Grain Auger	10 "
	Grain Truck 1	350 h.p.				
	Grain Truck 2	350 h.p.				
	Farm Truck	3/4 ton				

Table 5.7 – Total annual machinery replacement cost by representative farm

Farm	Irrigated Brown	Dryland Brown	Dark Brown	Black	Dark Grey
per acre	$43.52	$16.82	$17.95	$21.86	$25.64
per hectare	$107.54	$41.56	$44.37	$54.02	$63.35

5.2 Stochastic Simulation Model Parameters

This section provides a discussion of the information, estimations, and calculations involved in developing the simulation model parameters that are assumed to be stochastic for the representative cropping operations. As noted earlier, Monte Carlo simulation techniques are used in this analysis in order to allow for stochastic parameters to be modelled for the representative farms. In this way, the simulation analysis accounts for sources of risk in agricultural production.

Drollette (2009) described risk as the possibility of adverse outcomes due to uncertainty and imperfect information at the time when decisions are made. Major sources of production risk in cropping agriculture include uncertainty regarding weather, pests and disease, and the quality of inputs. There is also often market risk arising from uncertain commodity prices. Moss and Shonkwiler (1993) stated that the distributions of commodity prices and yields that represent risk are critical in firm level analysis. Given their potential importance production and price risks are incorporated in the modelling to examine the impact of cropping BMPs for the representative farms. These stochastic elements interact with other variables in the models including crop insurance, safety net programs, and other costs and revenues. Details on how the yield and price relationships are estimated and validated and then included in the cash flow models are also provided in this section.

5.2.1 Crop and Forage Yield Models

Crop yields are modelled in the simulation analysis using yield distributions that are based on historical crop yield data from the counties used to define the representative farms. Crop yield data (1978 to 2008) for the defined representative counties, were obtained from Agriculture Financial Services Corporation (AFSC) for the crops that are included in the base rotations, discussed earlier in this chapter. The data obtained were for dryland crop production in all counties, except for Taber where the data were for irrigated crop production. Historical yields were also obtained for additional crops that are included in some of the crop rotation BMPs; specifically, alfalfa hay, field peas, and legume green manures. The set of data used in modelling crop yields and a summary of the yield data are provided in Appendix D.

5.2.1.1 Estimation of Crop and Forage Yield Variables

Before the yield data can be used to estimate distribution parameters, they must first be tested for a time trend. Variability in yields over time may arise from production risk, but may also be due to changes in technology or technical change. Year-to-year variability may be overstated if the effects of technical change are not “removed”. This is done by de-trending the yield data. First, the yield data are tested for a time trend using a simple regression of yield (Y) on time (t) as shown in Equation 5.3. A statistically significant positive slope may be an indication of progressive technical change. In that case, the yield data are de-trended using the residuals (i.e., observed minus predicted) from the regression. The residuals are added to the predicted yield value for the base year

(2008) to obtain a de-trended yield series. The year 2008 is used as the base year as it represents the most recent yields available at the time of the analysis. This is important in order to be as consistent (time-wise) as possible with the base year for crop costs. A t-test is used to test for the presence of a time trend, with the null hypothesis that $\beta = 0$ in equation 5.3 (i.e., no time trend).

$$Y_t = \alpha + \beta t + \varepsilon_t \tag{5.3}$$

The time trend results are mixed, with approximately half of the crop yields having a significant positive time trend (i.e., rejection of the null hypothesis using a 5% level of significance). These are durum wheat, spring wheat, canola, and dry beans in the Municipal District of Taber (i.e., irrigated production), canola in the County of Forty Mile[19], spring wheat and canola in the County of Camrose, and spring wheat, barley, canola and oats in the Municipal District of Smoky River. Appendix E contains the coefficient estimates, t-statistics and p-values for all tests. For the purposes of this study when yields are required to be de-trended based on the time trend test results, the 2008 predicted yield values are used as the basis for calculating the de-trended yield series.

Once the necessary time series are de-trended, the yield data are fitted to distributions; that is, the distribution parameter estimates to be used in the simulation model are calculated[20]. This is done using the "Fit Distributions" option in *@RISK*. Goodness-of-fit tests are used to determine the best fitting distributions for a given set of data. A wide range of potential distributions are available for consideration in this analysis, including symmetrical and asymmetrical distributions, truncated distributions, etc.

An obvious alternative to consider for the yield distributions is the normal distribution. However, the assumption of normality in yield data is disputed in the literature. For example, Day (1965), Gallagher (1987) and Moss and Shonkwiler (1993) report findings of skewness and kurtosis in yield data. Just and Weninger (1999), however, state that there is inconclusive evidence for rejecting the assumption of normality for yield distributions. They argue that normality may be falsely rejected due to misspecification of the non-random components, misinterpretation of the statistical significance and the use of aggregate time series data to represent farm level distributions. Just and Weninger (1999) base the rationality of normality on the Central Limit Theorem (CLT), because crop yields are reported as averages, whether it be from one field or one county. Therefore, CLT implies that averages have asymptotically normal distributions under broad conditions.

Besides the potential for skewness and/or kurtosis in crop yield data, an important consideration in modelling crop yield distributions is the fact that the distribution should be truncated at zero; that is, it should exclude the possibility of negative yields. This excludes the normal distribution (along with many other distributions) from consideration. Distributions that have the property of potentially being truncated at zero include the Exponential, Gamma, LogNormal, Triangle, Uniform, and Weibull distributions. These distributions are then considered for possible use in modelling crop yields for the current study.

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[19] The canola yield data for the County of Forty Mile include years where a zero yield is recorded. The zero(s) are assumed to represent missing data and so are removed from the time series prior to testing for the time trend.

[20] An alternative estimation method used in recent studies (e.g., Koeckhoven, 2008; Cortus, 2005) is to use temperature and precipitation data to predict crop yields. Stochastic yields are then based on draws from weather distributions. This approach was examined in the current study, but the resulting estimates were not used due to low statistical significance and poor predictive power.

For the purposes of this analysis goodness-of-fit is established using the Kolmogorov-Smirnov (K-S) test statistic. Small values of the K-S test statistic indicate a better fit with the data. Appendix F provides the K-S test statistics for the best fitting distributions for each crop and representative county. The goodness-of-fit test results indicate that the Weibull distribution is, in most cases, the "best fitting" distribution of those that meet the truncation requirement. The only exceptions to this are durum wheat (i.e., third best fit after the Gamma and LogNormal distributions) and spring wheat (i.e., third best fit after the LogNormal and Gamma distributions) in Taber, and spring wheat (i.e., second best fit after the Gamma distribution) in Smoky River.

Based on these results it was decided to use the Weibull distribution to model crop yields. A single type of distribution is used for all crops and farms in order to be consistent across the crops and to allow comparison between representative farms. The Weibull distribution is characterized by being bound at zero, non-symmetrical, and permits a wide range of skewness and kurtosis. The Weibull distribution is characterized by the probability density function:

$$f(x) = \alpha x^{\alpha-1} \frac{\alpha x^{\alpha-1}}{\beta^{\alpha}} \exp[-(\frac{x}{\beta})^{\alpha}] \tag{5.4}$$

Source: Palisade Corporation (2007)

where α represents the shape parameter and β represents the scale parameter.

Besides the individual crop yield distributions, correlations are also required in order to model stochastic crop yields in the simulation analysis. Environmental factors such as weather affect crops in a similar fashion and as a result it is likely that in many cases yields for crops on a given farm are positively correlated. The program *@RISK* has a built in correlation function that allows for stochastic variables to be correlated in a simulation analysis.[21] However, in order to use this feature, sample correlations between crops are required. Correlation coefficients between crops, based on 2004 to 2006 field level data from Alberta crop insurance risk regions[22], were obtained from AARD. These correlations are used in modelling stochastic crop yields in the simulation analysis, versus correlations based on municipal level yield data, because the modelling is performed at the farm level. As such, correlations calculated at the field level are more appropriate, since the level of aggregation of yield variability is closer in magnitude than is the case for municipal level values. Correlations used for each soil zone are provided in Appendix G.

Crops that did not have data available for a reasonable and/or continuous period of time include field peas, legume green manures, and alfalfa hay. For these crops, variability (i.e., risk) in yields is modelled using the correlation between these yields and a reference crop. In this case, barley is used as the reference crop on all dryland farms as it has been shown to be appropriate for this purpose in previous studies (Koeckhoven, 2008). On the farm using irrigated production, spring wheat is used as the reference crop

[21] The *@RISK* function "CORRMAT" is used to correlate crop yield values that are sampled from different distributions. This function allows the variables to be correlated but still have the uncertainty from the stochastic Weibull distributions. The formulae used in *@RISK* combines the "RISKWEIBULL(a,b)" and "RISKCORRMAT(c,d)" functions where the variables in the latter, c and d are drawn from correlation matrices from AARD.

[22] There are 22 crop insurance risk regions in Alberta (AFSC, 2011). The Brown (irrigated) representative farm is located in crop risk area 2. The Brown (dryland) representative farm is located in crop risk area 3. The Dark Brown representative farm is located in crop risk area 8. Finally, the Black and Dark Grey representative farms are located in crop risk areas 12 and 19, respectively.

since barley is not part of the rotation for this farm. Field-level correlations from AARD (2007-b) are also used for these crops.

The yields for field peas, legume green manures and alfalfa hay (i.e., the unknown crop yields) in any period are based on their average yields, the change in barley (or spring wheat) yield from the previous to the current period and the yield correlations from AARD. Equation 5.5 shows this relationship where $Y_{unknown,t}$ is the calculated yield (in kg/ha) of the unknown crop, $E[Y_{unknown}]$ is the estimated yield of the unknown crop, $\Delta Y_{barley/spring\ wheat}$ is the change in barley (or spring wheat) yield from the previous to current period, and $\rho_{barley/spring\ wheat,unknown}$ is the AARD correlation coefficient between barley (or spring wheat) and the unknown crop. The barley-legume green manure correlation used in the analysis for all representative farms is 0.3. For barley-field peas, correlation coefficients of 0.631, 0.757, and 0.429 are used for Forty Mile/Starland, Camrose and Smoky River, respectively. The yield correlation used for barley-alfalfa/grass hay (and spring wheat-alfalfa/grass hay) for all representative farms is 0.3.

$$Y_{unknown,t} = E[Y_{unknown}] * [1 + (\Delta Y_{barley/spring\ wheat} * \rho_{barley/spring\ wheat,unknown})] \qquad (5.5)$$

5.2.1.2 Maximum Crop Yield Limits

Given the stochastic nature of crop yields in the simulation analysis and the distributional assumption for crop yields, there is potential for simulated crop yields that are unrealistically high. As well, some of the BMPs modelled in this study are assumed to have positive yield effects, as discussed later in the chapter. This also contributes to the possibility of having simulated crop yields that are unrealistic in magnitude, as in some cases the BMPs are considered in combination which further increases the potential for higher yields.

To account and correct for this possibility, a maximum restriction is imposed on final simulated crop yields. Maximum yields are determined using the municipal crop yield data that were available. In each case, the maximum was set at the maximum observed yield from the municipal data, plus one standard deviation from historical yield data to account for increased variability at the farm level. The maximum yields, in kilograms per hectare, are displayed in Table 5.8. Maximum yield for the farm in the Brown soil zone under dryland production is not necessary as it is assumed that of crops adopted as a BMP that may improve subsequent crop yields this representative farm only considers field peas. The potential subsequent yield increase from this crop in this region is maximized at 10%, which is below any set maximum values using the above criteria.

Table 5.8 – Crop yields with maximum restrictions (kg/ha)

Soil zone	Alfalfa Hay	Barley	Canola	Durum Wheat	Spring Wheat
Brown, irrigated	10,500.00	N/A[a]	3,078.96	6,530.47	5,542.48
Dark Brown	6,000.00	4,415.21	2,464.57	N/A[a]	3,644.96
Black	6,358.00	4,786.53	2,900.29	N/A[a]	4,456.14
Dark Grey	5,081.50	4,846.27	2,871.00	N/A[a]	4,618.41

[a] N/A denotes "not applicable" as these crops were not considered in the corresponding soil zone.

5.2.1.3 Validation and Adjustment of Crop and Forage Yield Variables

The estimated crop yield distributions and correlations are tested using *@RISK* to determine if they generate simulated yields that match the historical data in terms of means, variance and correlations. This is referred to as validation of the yield models. To test if the estimated crop and forage yield variables accurately estimate the historical correlations, a simulation is run for each farm using *@RISK*. The model is run for 1,000 iterations and the resulting sample correlations calculated from the simulation results are tested for equivalence with the correlation coefficients obtained from AARD. While the calculated correlation coefficients are not exactly the same as the historical values there is no statistically significant difference (based on a 5% level of significance) between the simulated means of the yield data and the de-trended historical yields, for all districts and crops considered. For all crops in all regions the p-value for t-tests assuming unequal variances between de-trended historical yields and simulated yields was greater than 0.42.

Yield data are often recorded and available at a more aggregate level that may not be representative of farm level yields (Just and Weninger, 1999). This presents a problem in terms of aggregation bias related to yield variability. Farm level yield variability is greater than the variability of yields measured at an aggregate level (Marra and Schurle, 1994). To correct for aggregation bias Marra and Schurle (1994) identify an adjustment process. In their study, which compared farm level and county level yield data, they adjusted the county level variability upwards by 0.1% for each percentage difference in county acreage and average farm acreage within the county. This method is also used by Cortus (2005) and Koeckhoven (2008) to correct for biases in yield variability.

In this study, yields are available at a county level, while the simulation is conducted at the farm level. For the crop yield models in this study the variability is adjusted in a similar manner, but rather than using the total county acreage and total farm acreage, the total acreage grown for each crop and the acreage grown on the representative farms for the same crop is used. Once the appropriate standard deviation is calculated using the Marra-Schurle method the α and β parameters (i.e., the shape and scale parameters) in the Weibull distributions are adjusted in an ad hoc manner so that the variance reflected by the distribution is increased to match the value obtained from the Marra-Schurle adjustment, without changing the distribution mean. Tables 5.9 to 5.13 provide the different standard deviations for each crop in each representative county where “Actual” is the standard deviation calculated from the historical (aggregate) data, “Weibull fitted” is the standard deviation from the original Weibull distribution fitted to the data, and “Marra-Schurle (M-S) Corrected” is the adjusted standard deviation that is used in the analysis.

Table 5.9 – Standard deviation adjustments for estimated crop yields in the Municipal District of Taber

	Crop			
Standard Deviation[a] (kg/ha)	Canola	Dry Bean	Durum Wheat	Spring Wheat
Actual	199.82	1054.24	383.77	337.58
Weibull fitted	195.14	925.72	403.78	384.76
Marra-Schurle (M-S) Corrected	213.41	1092.14	414.61	422.44
% Difference (Fitted and M-S)	9.36%	17.98%	2.68%	9.79%

[a] Actual is the standard deviation calculated from the historical (aggregate) data, Weibull fitted is the standard deviation from the original Weibull distribution fitted to the data, and Marra-Schurle (M-S) Corrected is the adjusted standard deviation that is used in the analysis.

Table 5.10 – Standard deviation adjustments for estimated crop yields in the County of Forty Mile

Standard Deviation[a] (kg/ha)	Crop			
	Barley	Canola	Durum wheat	Spring wheat
Actual	653.49	350.38	606.51	531.35
Weibull fitted	581.86	345.78	564.5	478.27
Marra-Schurle (M-S) Corrected	767.21	358.82	778.83	732.62
% Difference (Fitted and M-S)	31.85%	3.77%	37.97%	53.18%

[a] Actual is the standard deviation calculated from the historical (aggregate) data, Weibull fitted is the standard deviation from the original Weibull distribution fitted to the data, and Marra-Schurle (M-S) Corrected is the adjusted standard deviation that is used in the analysis.

Table 5.11 – Standard deviation adjustments for estimated crop yields in the County of Starland

Standard Deviation[a] (kg/ha)	Crop			
	Barley	Canola	Durum wheat	Spring wheat
Actual	636.71	383.11	670.99	493.21
Weibull fitted	587.33	378.93	646.68	471.62
Marra-Schurle (M-S) Corrected	754.11	416.13	672.60	603.87
% Difference (Fitted and M-S)	28.40%	9.82%	4.01%	28.04%

[a] Actual is the standard deviation calculated from the historical (aggregate) data, Weibull fitted is the standard deviation from the original Weibull distribution fitted to the data, and Marra-Schurle (M-S) Corrected is the adjusted standard deviation that is used in the analysis.

Table 5.12 – Standard deviation adjustments for estimated crop yields in the County of Camrose

Standard Deviation[a] (kg/ha)	Crop			
	Barley	Canola	Oat	Spring Wheat
Actual	733.65	354.31	651.18	543.87
Weibull fitted	654.35	310.12	594.77	471.92
Marra-Schurle (M-S) Corrected	766.63	367.35	627.05	559.10
% Difference (Fitted and M-S)	17.16%	18.45%	5.43%	18.47%

[a] Actual is the standard deviation calculated from the historical (aggregate) data, Weibull fitted is the standard deviation from the original Weibull distribution fitted to the data, and Marra-Schurle (M-S) Corrected is the adjusted standard deviation that is used in the analysis.

Table 5.13 – Standard deviation adjustments for estimated crop yields in the Municipal District of Smoky River

Standard Deviation[a] (kg/ha)	Crop			
	Barley	Canola	Oat	Spring Wheat
Actual	535.37	285.84	670.70	515.27
Weibull fitted	501.45	297.92	621.98	512.51
Marra-Schurle (M-S) Corrected	527.34	375.16	663.51	603.24
% Difference (Fitted and M-S)	5.16%	25.93%	6.68%	17.70%

[a] Actual is the standard deviation calculated from the historical (aggregate) data, Weibull fitted is the standard deviation from the original Weibull distribution fitted to the data, and Marra-Schurle (M-S) Corrected is the adjusted standard deviation that is used in the analysis.

Mean yields in the Weibull distributions were also affected slightly by adjusting the standard deviations. Table 5.14 provides the yield mean for each relevant crop by county, the adjusted mean from standard deviation corrections, and the associated Weibull shape (α) and scale (β) parameters.

There is no single "best" method for estimating yield models and correcting for potential biases. Rudstrom et al. (2002) noted that detrending yield data may influence estimates of yield variability. Just and Weninger (1999) also suggested that de-trending may introduce skewness and non-normal kurtosis. It is not known whether this is an issue for the yields used in the present study. However a consistent approach is used to generate yield distributions for use in the simulation analysis. As such, this allows for consistent comparisons between farms and BMP scenarios.

Table 5.14 – Crop yield means from historical data, Weibull distribution crop yield means, and Weibull parameters, by county and crop

County	Crop	Yield Mean (kg/ha)[a]	Weibull Mean (kg/ha)	Weibull α	Weibull β
Taber	Canola	2560.56[b]	2562.31	16.16	2647.40
	Dry Bean	5423.67[b]	5443.56	6.91	5823.20
	Durum wheat	5433.37[b]	5426.37	16.55	5602.60
	Spring wheat	5120.04[b]	5109.35	16.35	5277.20
Forty Mile	Barley	2260.45	2258.52	4.39	2478.30
	Canola	938.79[b]	937.87	2.95	1051.00
	Durum wheat	1970.45	1968.54	3.90	2174.80
	Spring wheat	1835.22	1835.62	4.34	2015.70
Starland	Barley	2656.57	2635.87	5.15	2865.80
	Canola	1272.80	1268.64	3.73	1405.10
	Durum wheat	2295.63	2276.46	3.95	2513.50
	Spring wheat	2369.40	2158.99	5.27	2344.40
Camrose	Barley	2981.82	2971.59	5.22	3228.40
	Canola	1940.66[b]	1933.55	7.36	2061.70
	Oat	2430.41	2411.68	4.61	2639.00
	Spring wheat	3044.40[b]	3036.66	7.61	3232.40
Smoky River	Barley	3556.14[b]	3566.26	8.47	3776.50
	Canola	1830.38[b]	1826.35	7.23	1949.20
	Oat	3536.55[b]	3548.00	6.69	3802.00
	Spring wheat	3088.76[b]	3092.79	7.11	3303.70

[a] Yield means are from historical data and are detrended if a significant trend is present. [b] Denotes crop yields that are detrended prior to further analysis.

5.2.2 Crop and Forage Price Models

Along with crop yields, crop prices are also modelled as stochastic parameters in the simulation analysis. Price data for barley, canola, oats, field peas, dry beans and tame hay were obtained from AARD. Price data for Canadian hard red spring and durum wheat were obtained from the Canadian Wheat Board (CWB) and assumed to be of No. 1 grade with 13.5% protein for both types of wheat. It is assumed that a common crop commodity price is applicable for all crops in all regions of Alberta. As a result the same price data and resulting price models are used for all representative farms.

Price data from 1984 to 2008 are used in estimating the price models. While longer price series are available for some crops, there are limited data available for field peas and dry beans because they have a shorter history of significant production in Alberta. Prior to use in statistical analysis the crop price data were adjusted for inflation using Consumer Price Index (CPI) from Statistics Canada (2009). A summary of crop price data used in this study is provided in Appendix H.

5.2.2.1 Testing for Stationarity

Commodity price data are assumed to be stochastic. Before proceeding to estimate stochastic price models, the price data are tested for stationarity. Stationarity of a stochastic process requires that the variances and autocovariances are finite and independent of time (Verbeek, 2008); stationary price data have the same mean and variance over all time periods. In a stationary model, for example, shocks such as a policy change only have a temporary effect on the underlying trend. Augmented Dickey-Fuller (ADF) tests were used to test for stationarity in the price data. The ADF test examines times series data for the presence of a unit root. If a unit root is present, the data are non-stationary. When unit roots are present in time series data there is a process that is evolving through time. Data stationarity has implications for modelling stochastic prices. In order to accurately model prices using a times series model where current prices are a function of previous prices, prices should be stationary. The alternative, when prices are non-stationary, would be to model prices using a random walk process.

The ADF tests are run using the data analysis and statistical software program, *STATA*. In particular, the ADF tests are used to test for stationarity in the price data, which are transformed using first order differencing. Three versions of the ADF test were run; one assuming no time trend, one assuming a time trend, and one assuming drift[23] (Stock and Watson, 2006).

The results from the ADF test, shown in Table 5.15, suggest that spring wheat, barley, canola, oats, and dry bean commodity prices are stationary for one or more tests assuming no trend, a trend and drift. Conversely, the presence of a unit root (i.e., non-stationarity) is not rejected for durum wheat, field pea, and hay prices.

Table 5.15 – Augmented Dickey Fuller test results for non-stationarity of crop price data

	Test Statistics[a]		
Crop	NO TREND	TREND	DRIFT
Spring Wheat	-3.095**	-2.436	-3.095
Durum Wheat	-2.311	-1.649	-2.311
Barley	-3.618**	-3.286*	-3.618**
Canola	-3.668**	-2.98	-3.668**
Oats	-3.998***	-3.926**	-3.998**
Field Peas	-2.411	-1.096	-2.411
Dry Beans	-3.515**	-3.607**	-3.515*
Alfalfa Hay	-2.482	-2.416	-2.482
1% Crit. Value	-3.750***	-4.380	-4.380
5% Crit. Value	-3.000**	-3.600	-3.600
10% Crit. Value	-2.630*	-3.240	-3.240

[a] ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

[23] For a random walk process with "drift" there is an added upward or downward trend in the process.

While the ADF test results do not rule out non-stationarity for some of the price data, they also do not necessarily mean that the data are, in fact, non-stationary. Most unit root tests have low power against stationarity; that is, stationarity is frequently rejected (Hobijin et al., 2004; Verbeek, 2008). In some cases, this may be due to a lack of enough information in the data to reject the null hypothesis of non-stationarity as opposed to the data truly being non-stationary. This is a known weakness of the ADF test (Verbeek, 2008).

Because of the limitations of the ADF test, the price data are also tested for stationarity using the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Verbeek, 2008). The KPSS test also examines data for stationarity, but the null hypothesis in this case is that the data are stationary. The KPSS test is performed in *STATA* using automatic lag length (bandwidth) selection (lag length=2) and QS kernel.[24] A summary of the test results are provided in Table 5.16. Results from the KPSS test suggest all crop prices, with the exception of field peas, follow a stationary process. The null hypothesis of stationarity is rejected at the 5% level for field pea prices.

Table 5.16 – KPSS test results for stationarity of crop price data

Crop	Test Statistic[a]
Spring Wheat	0.083
Durum Wheat	0.070
Barley	0.067
Canola	0.083
Oats	0.060
Field Peas	0.146**
Dry Beans	0.073
Alfalfa Hay	0.114
1% Crit. Value	0.216***
5% Crit. Value	0.146**
10% Crit. Value	0.119*

[a] ***, **, and * represent statistical significance at the 1%, 5%, and 10% level respectively.

For the purposes of this study crop prices were assumed to follow a stationary process, despite the fact that field pea prices appear to be non-stationary based on both the ADF and KPSS tests. The field pea price results are ignored because a) the null hypothesis is not rejected at the 10% level of significance, b) as with the ADF test, stationarity is sometimes rejected for the KPSS test when in fact the data are stationary (Hobijin et al., 2004), and c) it allows consistent modelling of prices for all crops. Cortus (2005) argues that non-stationary processes can produce wide confidence intervals for price forecasts over long periods of time, resulting in unrealistic simulated price levels. As such the assumption of price stationarity limits the potential for extreme values.

5.2.2.2 Price Model Estimation Procedures

Given the results from the stationarity analysis, crop prices are simulated using time series modelling. In particular, current prices are a function of lagged prices. The

[24] Automatic bandwidth selection is a feature of STATA that automatically determines the maximum lag order of a lagged equation. Kernel estimation is a method to estimate the probability density function of a random variable. The Quadratic Spectral (QS) kernel has been shown to yield more accurate estimates than other kernels in finite samples (Hobijn et al. 2004).

crop price model is estimated using Seemingly Unrelated Regression (SUR) using the software *SHAZAM* (*SHAZAM* User Manual, 2008). Each equation in the SUR model can be estimated independently. However, estimating them as a system allows for consideration that there may be exogenous (i.e., non-modelled) variables affecting all of the dependent variables (i.e., the prices) in a similar way. This would result in error terms for the individual price equations being correlated. SUR recognizes and incorporates the correlation of the errors between the equations. For historical price series this type of estimation is important as it is possible that an event that causes price fluctuations in one crop may also affect other crop prices.

In order to proceed with the SUR estimation, it is first necessary to determine the appropriate number of lagged prices to use as explanatory variables in the price equations. The Akaike Information Criterion (AIC) and Schwarz Criterion (SC) are used to determine the appropriate lag length for each crop price, prior to SUR estimation. AIC and SC are measures of goodness of fit for statistical models used to determine optimal lag length. Each commodity price equation is estimated individually using Ordinary Least Squares (OLS) with one to five lags. A maximum of five lags was chosen as there are only 24 years of price data available. Including too many lags reduces the degrees of freedom, which may cause low model significance. AIC and SC statistics are calculated for each estimation. The results are compared and the optimal lag length is defined by the lowest AIC or SC value. In cases where the two criteria differ in terms of optimal lag length the AIC result is used to determine optimal lag length as it has been shown to be a superior measure in some infinite and finite Vector Autoregression (VAR) models (Kilian, 2001).

The AIC and SC results are shown in Table 5.17. The optimal lag length for spring wheat, durum wheat, barley, and field peas is determined to be three years, while the lag length is two years for the crops canola, oats, and dry beans. Tame hay has an optimal lag length of five years and there is indication that the AIC would decrease further if the equations were estimated with more than five lags. However, due to diminishing degrees of freedom with additional lags it is decided to use five lags for tame hay price.

Table 5.17 – AIC and SC values for lagged price equations

	Lags	1	2	3	4	5
Spring Wheat	AIC	0.00351	0.00264	0.00242	0.00254	0.0027
	SC	0.00357	0.00306	0.00294	0.00324	0.0037
Durum Wheat	AIC	0.00641	0.00533	0.00521	0.00554	0.0059
	SC	0.00707	0.00617	0.00633	0.00707	0.00791
Barley	AIC	0.00147	0.00102	0.00010	0.00108	0.00112
	SC	0.00162	0.00118	0.00121	0.00138	0.0015
Canola	AIC	0.00891	0.00713	0.00753	0.00777	0.00798
	SC	0.00982	0.00825	0.00916	0.00991	0.0107
Oats	AIC	0.00149	0.00132	0.00143	0.00155	0.00156
	SC	0.00164	0.00153	0.00175	0.00198	0.00209
Field Peas	AIC	0.00512	0.00465	0.00453	0.00468	0.00436
	SC	0.00564	0.00538	0.0055	0.00597	0.00585
Dry Beans	AIC	0.00184	0.00158	0.00165	0.00179	0.00113
	SC	0.00202	0.00183	0.00201	0.00229	0.00152
Tame Hay	AIC	0.00093	0.00067	0.00065	0.00056	0.0005
	SC	0.00103	0.00078	0.00079	0.00072	0.00066

The resulting price equations for SUR analysis are provided in Equation 5.6 to 5.13, where P_t^{SW}, P_t^{DW}, P_t^{B}, P_t^{C}, P_t^{O}, P_t^{FP}, P_t^{DB}, P_t^{AH} are the prices of spring wheat, durum wheat, barley, canola, oats, field peas, dry beans, and alfalfa hay respectively. P_{t-n}^{i} is the price in period *t-n* for crop *i*, ε_t^i is the error term in time *t* for crop *i*, and $\beta^i{}_1$ to $\beta^i{}_n$ are the coefficients on the lagged price variables.

$$P_t^{SW} = \beta^{SW}{}_0 + \beta^{SW}{}_1 P_{t-1}^{SW} + \beta^{SW}{}_2 P_{t-2}^{SW} + \beta^{SW}{}_3 P_{t-3}^{SW} + \varepsilon_t^{SW} \tag{5.6}$$

$$P_t^{DW} = \beta^{DW}{}_0 + \beta^{DW}{}_1 P_{t-1}^{DW} + \beta^{DW}{}_2 P_{t-2}^{DW} + \beta^{DW}{}_3 P_{t-3}^{DW} + \varepsilon_t^{DW} \tag{5.7}$$

$$P_t^{B} = \beta^{B}{}_0 + \beta^{B}{}_1 P_{t-1}^{B} + \beta^{B}{}_2 P_{t-2}^{B} + \beta^{B}{}_3 P_{t-3}^{B} + \varepsilon_t^{B} \tag{5.8}$$

$$P_t^{C} = \beta^{C}{}_0 + \beta^{C}{}_1 P_{t-1}^{C} + \beta^{C}{}_2 P_{t-2}^{C} + \varepsilon_t^{C} \tag{5.9}$$

$$P_t^{O} = \beta^{O}{}_0 + \beta^{O}{}_1 P_{t-1}^{O} + \beta^{O}{}_2 P_{t-2}^{O} + \varepsilon_t^{O} \tag{5.10}$$

$$P_t^{FP} = \beta^{FP}{}_0 + \beta^{FP}{}_1 P_{t-1}^{FP} + \beta^{FP}{}_2 P_{t-2}^{FP} + \beta^{FP}{}_3 P_{t-3}^{FP} + \varepsilon_t^{FP} \tag{5.11}$$

$$P_t^{DB} = \beta^{DB}{}_0 + \beta^{DB}{}_1 P_{t-1}^{DB} + \beta^{DB}{}_2 P_{t-2}^{DB} + \varepsilon_t^{DB} \tag{5.12}$$

$$P_t^{AH} = \beta^{AH}{}_0 + \beta^{AH}{}_1 P_{t-1}^{AH} + \beta^{AH}{}_2 P_{t-2}^{AH} + \beta^{AH}{}_3 P_{t-3}^{AH} + \beta^{AH}{}_4 P_{t-4}^{AH} + \beta^{AH}{}_5 P_{t-5}^{AH} + \varepsilon_t^{AH} \tag{5.13}$$

5.2.2.3 Crop Price Model Results and Incorporation

The SUR crop price model results are provided in Table 5.18. All estimated constants are statistically significant at the 1% level. All first lag price coefficients are also significant. However, some lagged prices are not statistically significant. As well, some individual R-squared goodness-of-fit measures are relatively low and range from 0.1249 to 0.6194. However, the overall model R-squared is 0.9358 with a Log-Likelihood

Function (LLF) of 398.50, indicating that together the equations provide a relatively reliable model to predict crop commodity prices.

Table 5.18 – SUR model estimated coefficients

Variable	Estimated Coefficients[a]							
	Spring Wheat	Durum Wheat	Barley	Canola	Oats	Field Peas	Dry Beans	Alfalfa Hay
Lag 1	0.5256***	0.4366**	0.4785***	0.9167***	0.2961**	0.9353***	0.4762***	0.6157***
	(0.2027)	(0.2000)	(0.1241)	(0.1371)	(0.1408)	(0.1410)	(0.0960)	(0.1767)
Lag 2	-0.6901***	-0.5414**	-0.4152***	-0.5677***	-0.3017**	-0.6712***	-0.3475***	0.0074
	(0.1961)	(0.2399)	(0.1309)	(0.1371)	(0.1394)	(0.1820)	(0.0970)	(0.2197)
Lag 3	0.1168	-0.1188	-0.1229			0.1378		-0.3914*
	(0.1854)	(0.2101)	(0.0983)			(0.1240)		(0.2167)
Lag 4								0.0922
								(0.1778)
Lag 5								0.0054
								(0.1378)
Constant	0.2236***	0.2800***	0.1476***	0.2559***	0.1461***	0.1274***	0.1208***	0.0673***
Std. Error	0.0422	0.0636	0.0230	0.0435	0.0323	0.0289	0.0184	0.0148
R-sq'd	0.1918	0.2804	0.4362	0.6194	0.1249	0.6149	0.4839	0.4974

[a] ***, **, and * represent statistical significance at the 1%, 5%, and 10% level respectively.

Annual prices used in the simulation are determined using the estimated SUR system of equations; that is, using lagged prices. The stochastic aspect of the price modelling is introduced through the error term for each equation. The error terms for the commodity price models are estimated in *@RISK* assuming a standard normal distribution (i.e., ~N(0,1)). However, since it is assumed that the price equation errors are correlated, they must be adjusted accordingly and scaled by the standard deviation (Hull, 2003). The error correlations are calculated using the following formulae from Hull (2003):

$$\varepsilon_m = \sum_{k=1}^{k=m} \delta_{mk}\, x_k, \text{ subject to:}$$
$$\sum \delta_{mk}^2 = 1,$$
$$\sum_k \delta_{mk}\, \delta_{jk} = \rho_{m,j} \qquad (5.14)$$

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

There are eight crop prices to be estimated. However, if more than four prices are considered simultaneously, the correlated error equations become extremely complicated to estimate using the above formula.[25] As a result, the crop prices are divided into groups, which are considered separately. The error correlations for crop prices from the SUR estimation are used to decide which crop errors are grouped together to be correlated with

[25] More than four correlated error equations are simple to calculate using the Cholesky Decomposition. However this approach was not used to be consistent with similar previous studies (i.e., Cortus, 2005 and Koeckhoven, 2008).

each other. The correlation estimates are examined and an ad hoc procedure is used to identify sub-groupings where there are strong positive correlations between the error terms for the different crops. These are used as an indication that the exogenous factors tend to have a common effect on the error term in terms of magnitude and sign, and so are likely candidates to have their error terms correlated with each other.

The SUR estimated error correlations are shown in Table 5.19. Based on the correlation estimates, it is decided that barley and oat prices are grouped together and their errors correlated, canola, field pea and dry bean prices represent another grouping for error correlation, spring wheat and durum wheat prices are grouped together, and hay prices will be estimated independently of the other crop prices.

Table 5.19 – SUR estimated error correlations.

	ε^{SW}	ε^{DW}	ε^{BAR}	ε^{CAN}	ε^{OAT}	ε^{FP}	ε^{DB}	ε^{AH}
ε^{SW}	1.0000							
ε^{DW}	0.8539	1.0000						
ε^{BAR}	0.1241	0.4180	1.0000					
ε^{CAN}	0.2682	0.4380	0.3399	1.0000				
ε^{OAT}	-0.0508	0.1940	0.8269	0.0756	1.0000			
ε^{FP}	0.3231	0.3117	0.4237	0.6989	0.0804	1.0000		
ε^{DB}	0.4266	0.4617	0.2808	0.6847	0.0850	0.5312	1.0000	
ε^{AH}	0.0486	0.0543	0.0214	0.0651	0.3554	-0.1111	0.2839	1.0000

Given the sub-groupings identified for the crop prices, the corrected error terms are found by solving for the δ_{mk} terms, as follows:

$$\varepsilon_B = x_B \tag{5.15}$$

$$\varepsilon_O = \rho_{B,O} x_B + \left(\sqrt{1 - \rho_{B,O}^2}\right) x_O \tag{5.16}$$

$$\varepsilon_C = x_C \tag{5.17}$$

$$\varepsilon_{FP} = \rho_{C,FP} x_C + \left(\sqrt{1 - \rho_{C,FP}^2}\right) x_{FP} \tag{5.18}$$

$$\varepsilon_{DB} = \rho_{C,DB} x_C + \left(\frac{\rho_{FP,DB} - \rho_{C,FP}\rho_{C,DB}}{\sqrt{1 - \rho_{C,FP}^2}}\right) x_{FP} + \left(\sqrt{1 - \rho_{C,DB}^2 - \left(\frac{\rho_{FP,DB} - \rho_{C,FP}\rho_{C,DB}}{\sqrt{1 - \rho_{C,FP}^2}}\right)^2}\right) x_{DB} \tag{5.19}$$

$$\varepsilon_{SW} = x_{SW} \tag{5.20}$$

$$\varepsilon_{DW} = \rho_{SW,DW} x_{SW} + \left(\sqrt{1 - \rho_{SW,DW}^2}\right) x_{DW} \tag{5.21}$$

$$\varepsilon_{AH} = x_{AH} \tag{5.22}$$

where subscripts *B*, *O*, *C*, *FP*, *DB*, *SW*, *DW*, and *AH* represent barley, oat, canola, field pea, dry bean, spring wheat, durum wheat, and alfalfa hay commodity price respectively.

5.2.2.4 Validation of Crop Price Models

Since crop prices were assumed to be stationary, simulated results are tested with historical prices to confirm crop prices are modelled accurately and that the assumption of stationarity is reasonable. Historical mean prices (1984 – 2008) are compared with simulated mean prices (40 year simulation period). To compare the results t-tests assuming unpaired samples were conducted for each crop with the null hypothesis that the historical means are equal to the simulated means. Results of the mean prices and t-test p-values are provided in Table 5.20. In all cases the p-value is greater than 0.05 and there is failure to reject the null hypothesis that the means are assumed to be equivalent. Therefore, the assumption of price stationarity is reasonable as there are no significant differences between historical crop prices and simulated crop prices.

Table 5.20 – Comparison of historical price data and @*RISK* simulated values for crop prices ($/kg)

Crop	Historical Mean	@*RISK* Simulated Mean	t-test p-value
Barley	0.1460	0.1390	0.3490
Canola	0.4095	0.3948	0.4235
Dry Bean	0.1517	0.1388	0.1231
Durum Wheat	0.2403	0.2296	0.5084
Field Pea	0.2398	0.2137	0.0826
Hay	0.1087	0.1007	0.1904
Oats	0.1503	0.1452	0.4880
Spring Wheat	0.2244	0.2144	0.3900

5.3 Economic Relationships

The farm simulation models are calculated using cash flow analysis to determine the NPV of each representative farm. A modified net cash flow (MNCF) is calculated annually for each representative farm. The MNCFs are discounted and summed to obtain an NPV for each operation. This section provides an explanation of the cash flow calculations and the connections between revenues and costs in crop production. Revenues arise largely from crop sales which in turn depend on stochastic crop yields and prices and as such annual variability in revenues is expected. The costs associated with crop production include input costs such as seed, fertilizer, fuel, etc. Input costs vary between the farms based on spatial location and are calculated based on average current production costs by soil zone in Alberta (AARD, 2010-b). Other sources of cash flows include crop insurance, the safety net programs AgriStability and AgriInvest, and machinery costs. These are also discussed in this section.

5.3.1 Revenues

Revenues from crop production are calculated from the simulated crop yields and prices. As discussed previously, crop yields are estimated directly from the fitted and adjusted Weibull distributions, incorporating yield correlations between crops. Crop yields are based on independent draws from distributions for each crop in each year for the individual farms. As such annual variability representing crop yield differences due to weather effects is captured. Crop prices, while based on lagged prices, are also stochastic stemming from independent error term draws each year. This introduces further variability into the farm revenue. The bulk of farm revenue is from the sale of crops calculated by multiplying annual crop production in kilograms with commodity price in dollars per kilogram.

Other sources of revenues potentially available to crop producers include payments from safety net programs; specifically, crop insurance and AgriStability and AgriInvest. Payments from these sources are accessible to producers in the event of a significant yield or revenue loss, assuming producer participation in the program(s) in the corresponding year. The calculation of payments from these programs is discussed later in this section.

5.3.2 Input Costs

Input costs for crop production on the representative farms are based on information from Alberta Agriculture's *AgriProfit$* Cropping Alternatives (AARD, 2010-b) program. *AgriProfit$* forecasts are in turn based on current cost of production information obtained from various sources. Input costs relevant to the farms of interest include seed, fertilizer, chemical, trucking and marketing, fuel, oil, and lube, machinery and building repairs, and utilities and miscellaneous costs.

Seed costs in *AgriProfit$* (AARD, 2010-b) are determined from the Alberta Farm Input Prices survey, combined with a seed cost multiplier to account for a blend of certified and common seed that is cleaned and treated (Bergstrom, 2010). Assumptions regarding germination, emergence mortality, and seed spacing are also taken into consideration when determining seed cost. *AgriProfit$* (AARD, 2010-b) assumes a 90-95% germination rate, 3-5% emergence mortality, and nine inch spacing.

Fertilizer costs in *AgriProfit$* (AARD, 2010-b) are based on a blend of nitrogen (N), phosphorus (P), potassium (K), and sulphur (S), abbreviated with NPKS. The price of the fertilizer blend is made up of fall 2009 and spring 2010 prices (Bergstrom, 2010). Prices of \$1.04/kg, \$0.77/kg, \$0.90/kg, and \$0.62/kg for nitrogen, phosphorus, potassium, and sulphur, respectively, are used in the calculations. Chemical costs include pre-seed chemical, in-crop chemical, and/or fungicide/insecticide/pre-harvest/desiccation chemicals that are applied as applicable to the crop and region (AARD, 2010-b).

Trucking and marketing costs are from *AgriProfit$* data and range from \$5 to \$12 per 1,000 kilograms of crop commodity. Other expenses, including fuel, oil and lube, machinery repairs, building repairs, utilities and miscellaneous, and pumping (irrigation only) costs are calculated from *AgriProfit$* data and Alberta Farm Input Prices survey. Many of these input costs vary due to differences in regional farming practices in Alberta and this is accounted for in the different input costs by region, shown in Tables 5.21 to 5.25.

In place of the custom work accounted for by *AgriProfit$* the cost of custom spraying is used in the analysis. This is calculated by multiplying the custom cost of spraying of approximately \$7.34 per hectare (SAF, 2008) by the acreage to be sprayed annually. It is assumed, based on expert opinion (Dunn, 2009), that fields are sprayed an average of two times per year.

The machinery costs provided in Tables 5.21 to 5.25 represent costs for repair and maintenance. Besides these costs, an annual expenditure to account for machinery replacement (i.e., maintenance of the machinery asset base) is also included in the calculation of total crop costs used in cash flow calculations. This expenditure, calculated as the annual amount spent on machinery replacement/maintenance required to offset the loss in value due to depreciation, is discussed earlier in this chapter.

Table 5.21 – Input costs by crop for farm representing Brown soil zone, irrigated production ($/ha)

	Spring wheat	Durum wheat	Argentine Canola	Dry Beans	Alfalfa Hay
Seed	47.81	36.32	73.96	119.52	24.44
Fertilizer (NPKS)	158.14	158.14	192.74	144.55	40.77
Chemical	86.49	86.49	124.79	205.09	5.09
Trucking & Marketing	36.30	40.35	20.16	30.94	39.54
Fuel, Oil & Lube	58.96	60.37	61.78	88.96	92.66
Machinery Repairs	49.54	50.70	48.18	61.78	61.78
Building Repairs	4.94	4.94	4.94	7.41	2.47
Custom Work	7.34	7.34	7.34	7.34	7.34
Utilities & Misc.	48.18	48.18	48.18	210.04	61.78
Irrigation: pumping costs	39.54	39.54	61.78	49.42	63.01
Total	537.25	532.38	643.84	925.04	398.87

Source: AARD (2010-b).

Table 5.22 – Input costs by crop for farm representing Brown soil zone, dryland production ($/ha)

	Spring wheat	Durum wheat	Feed Barley	Canola	Field Peas	Mixed Hay (t)	Summe r-fallow
Seed	37.19	31.78	25.99	59.18	70.28	5.29	0.00
Fertilizer (NPKS)	81.54	81.54	97.60	116.14	33.36	21.00	0.00
Chemical	69.19	69.19	34.59	67.83	58.07	3.41	40.77
Trucking & Marketing	16.14	16.14	20.98	8.40	16.14	14.83	0.00
Fuel, Oil & Lube	26.81	26.81	29.65	31.36	26.81	19.77	19.77
Machinery Repairs	22.24	22.24	21.62	21.00	21.00	18.53	21.00
Building Repairs	2.47	2.47	2.47	2.47	2.47	1.24	1.24
Custom Work	7.34	7.34	7.34	7.34	7.34	0.00	7.34
Utilities & Misc.	21.00	21.00	21.00	21.00	21.00	14.83	9.88
Total	283.92	278.51	261.24	334.72	256.47	98.9	100.00

Source: AARD (2010-b).

Table 5.23 – Input costs by crop for farm representing Dark Brown soil zone, dryland production ($/ha)

	Spring wheat	Durum wheat	Feed Barley	Argentine Canola	Dry field peas	Mixed Hay	Summer-fallow
Seed	37.19	31.78	29.70	73.96	70.28	5.29	0.00
Fertilizer (NPKS)	97.60	97.60	109.96	134.67	33.36	24.71	0.00
Chemical	77.84	77.84	34.59	75.37	95.13	3.41	40.77
Trucking & Marketing	18.16	18.16	22.58	10.08	18.16	17.30	0.00
Fuel, Oil & Lube	27.01	27.01	29.65	33.04	33.36	19.77	19.77
Machinery Repairs	21.62	21.62	21.62	21.62	21.62	18.53	21.00
Building Repairs	2.47	2.47	2.47	2.47	2.47	1.24	1.24
Custom Work	7.34	7.34	7.34	7.34	7.34	0.00	7.34
Utilities & Misc.	24.71	24.71	24.71	24.71	24.71	17.30	9.88
Total	313.94	308.53	282.62	383.26	306.43	107.55	100.00

Source: AARD (2010-b).

Table 5.24 – Input costs by crop for farm representing Black soil zone, dryland production ($/ha)

	Spring wheat	Feed Barley	Milling Oats	Argentine Canola	Dry field peas	Mixed Hay	Alfalfa Hay
Seed	42.50	29.70	26.69	73.96	76.68	5.73	16.93
Fertilizer (NPKS)	130.96	130.96	108.72	181.62	48.18	30.89	28.42
Chemical	86.49	43.24	28.42	75.37	95.13	3.41	4.25
Trucking & Marketing	26.22	29.06	26.29	15.12	20.16	33.36	37.07
Fuel, Oil & Lube	37.07	38.30	33.36	38.30	38.30	33.36	33.36
Machinery Repairs	32.12	32.12	30.89	33.36	33.36	23.47	23.47
Building Repairs	2.47	2.47	2.47	2.47	2.47	1.24	1.24
Custom Work	7.34	7.34	7.34	7.34	7.34	0.00	7.34
Utilities & Misc.	28.42	28.42	28.42	34.59	34.59	17.30	17.30
Total	393.59	341.61	292.6	462.13	356.21	148.76	169.38

Source: AARD (2010-b).

Table 5.25 – Input costs by crop for farm representing Dark Grey (Peace region) soil zone, dryland production ($/ha)

	Spring wheat	Feed Barley	Milling Oats	Argentine Canola	Dry field peas	Mixed Hay	Alfalfa Hay
Seed	37.19	25.99	21.35	59.18	70.28	5.73	16.93
Fertilizer (NPKS)	109.96	109.96	93.90	156.91	38.30	30.89	23.47
Chemical	86.49	43.24	28.42	75.37	58.07	3.41	4.25
Trucking & Marketing	22.19	25.82	22.86	13.44	18.16	25.95	29.65
Fuel, Oil & Lube	26.32	28.17	29.65	33.21	33.73	32.91	33.98
Machinery Repairs	29.65	29.65	24.09	29.65	32.12	18.53	18.53
Building Repairs	2.47	2.47	2.47	2.47	2.47	1.24	1.24
Custom Work	7.34	7.34	7.34	7.34	7.34	0.00	7.34
Utilities & Misc.	24.71	24.71	19.77	24.71	24.71	16.06	16.06
Total	346.32	297.35	249.85	402.28	285.18	134.72	151.45

Source: AARD (2010-b).

5.3.3 Crop Residues

The harvesting of crops grown on the representative farms results in the “production” of residue, which is plant material (i.e., leaves, stalks, roots, etc.) left in the field after the grain is removed. In some cases, crop residue is considered a secondary output from crop production, and may be harvested and sold. In other instances, crop residue is left on the field. Management decisions regarding crop residues vary by producer and by crop.

In this study, residue management practices are determined based on typical moisture conditions for each representative farm, and on expert opinion regarding “normal” actions of producers. For the baseline scenario it is assumed that, where feasible, crop residue is removed from fields (i.e., harvested). Crops for which this is done include barley, durum wheat, oats and spring wheat.[26]

It is further assumed that producers in the southern areas of the province (i.e., Brown and Dark Brown soil zones) retain residue more frequently as compared to producers in the northern areas (i.e., Black and Dark Grey soil zones). This is due to the volume of residue produced as well as typical soil moisture conditions. In modelling whether residue is removed or retained it is assumed that in the Brown soil zone residue of the previously mentioned crops is removed one out of every five years under dryland production and one out of every two years under irrigated production[27]. In the Dark

[26] Other crop residues are assumed to be distributed over the soil during harvest, as the residue itself cannot be harvested.
[27] Higher amounts of residue are produced under irrigated production due to the correlation with crop yields, and as such residues are removed more often under irrigated production.

Brown soil zone residue is removed once every four years. In the Black and Dark Grey soil zones residue is removed once every three years. The residue removed is staggered over time such that each crop with residue available for removal has an equal amount removed over time.

Crop residue production is modelled as a proportion of crop yield. Values are adapted from AARD (2008-c) and are provided in Table 5.26. Costs for baling and removing residue are charged at custom rates of $19.19 (SAF, 2008) per 544 kilogram bale of straw. Producers are assumed to sell all straw baled at $25 per bale (AARD, 2010-c).

Table 5.26 – Crop residue production, by crop and soil zone (kilogram of residue per kilogram of crop yield)

Crop / Soil zone	Brown	Dark Brown	Black/Dark Grey
Barley	0.729	0.833	1.042
Oats	1.030	1.177	1.471
Wheat (durum and spring)	1.166	1.416	1.666

Source: AARD (2008-c)

5.3.4 Crop and Hay Insurance

Crop and hay insurance are risk management tools used by many producers. Participation in these insurance programs assists in offsetting reduced revenue in years when yields are low. In 2008 crop insurance receipts totalled $344.6 million in Alberta, representing 3.2% of total farm cash receipts and 6.7% of crop related cash receipts (AARD, 2009-a). This amount is a significant portion of income for producers, particularly when unexpected weather events occur. Therefore crop and hay insurance are included in the farm simulation modelling and it is assumed that producers (i.e., the representative farms) participate in these programs. The structure of insurance used in the models are production based and follow the structure of AFSC crop and hay insurance programs.

Insurance coverage and premium calculations are individualized to each farm as producers choose a percent of normal yield to be covered, with the options for coverage level being 50, 60, 70, or 80% of the individual normal yield (AFSC, 2011-a). The production based crop insurance provides a yield guarantee and also guarantees a price for yield losses. The program insures against natural perils including drought, excessive moisture, fire from lightning strikes, flood, frost, hail, insect infestations, snow, wind, wildlife invasions and other perils designated by AFSC (AFSC, 2011-a).

In the model there is flexibility for the producer to choose no insurance (0%) or 80% coverage, but once a level is chosen it is implemented for the entirety of the simulation period. For all baseline and BMP scenarios it is assumed producers choose an 80% coverage level; that is, if the simulated yield for a particular crop in a particular year is below 80% of the individual normal yield, an insurance payment is generated. This type of coverage uses spring insurance price (SIP), fall market price, risk area average yields, and actual yields to determine a payment to the producer when there is a shortfall and to determine the cost of crop insurance to the producer. Additional factors affecting crop insurance premiums and payouts are the variable price benefit (VPB) on shortfall, and whether or not the spring price endorsement (SPE) is purchased by the producer. Alberta is divided into risk areas for the purposes of crop insurance coverage and premium calculations. Risk areas examined in this project include 2, 3, 8, 12, and 19 for the counties of Taber, Forty Mile, Starland, Camrose, and Smoky River, respectively. A discussion of the methods used for crop insurance calculations in the models is provided, followed by an example.

For each farm and each annual crop, the basic level of insurance coverage is equal to the insured yield multiplied by the SIP. The insured yield is equal to the risk area average yield multiplied by the coverage level (i.e., assumed to be 80% in the analysis). The insured yield depends on actual historical yields for the farm and "normal" yields in the crop insurance risk area. For simplicity purposes, the risk area average yield for each period is calculated as the average of the actual simulated farm yield for that period and the risk area average yield from the previous period. The risk area average is used alone for the first simulation period.

The spring insurance price (SIP) is a predicted fall market price and is based on historical, current and futures prices of crops (AFSC, 2010-a). The SIP for each crop will vary from year to year in reality. For simplicity, a constant SIP is used; specifically, the SIP for each crop is set at the 2010 value provided by AFSC. SIPs in this period are $0.162, $0.154, $0.140, $0.140, $0.400, $0.165, and $0.675 per kilogram for spring wheat, durum wheat, barley, oats, canola, field peas, and dry beans, respectively.[28]

A crop insurance payment is generated if the actual simulated yield is below the insured yield; that is, if it is less than 80% of the risk area average yield (i.e., given the assumption of 80% coverage level chosen by the producer). The payment is equal to the difference between the insured yield level and actual yield, multiplied by the SIP. A variable price benefit (VPB) on the shortfall is also provided by AFSC. The VPB provides additional compensation to producers in the event that there is a yield shortfall (i.e., a crop insurance payment is generated) and the actual fall price of the insured crop is 10-50% (i.e., the benefit is capped at 50%) above the SIP (AFSC, 2010-a). The VPB is calculated by multiplying the yield shortfall by the difference between the fall price and the spring insurance price. The VPB is incorporated in the simulation analysis by using the difference between the simulated crop price and the SIP.

Producers can opt to purchase additional crop insurance protection, referred to as SPE. SPE provides price protection against price declines during the year; that is, if the fall price is 10-50% (i.e., the SPE payment is capped at 50%) lower than the SIP. If SPE is purchased and the fall crop price is sufficiently below the SIP, an SPE payment is generated. The payment is equal to the difference between the SIP and the actual fall price, multiplied by the actual yield or insured yield (whichever is greater). Producers are assumed to purchase SPE in this study, and so this is incorporated into the simulation calculations for the representative farm models.

To illustrate this with an example, suppose a producer chooses crop insurance level of 80% for 100 hectares of spring wheat with yields of 1,500 kilograms per hectare. The pre-determined risk area average yield is 2,000 kilograms per hectare for the same year. The SIP of spring wheat is $0.162/kg, while the fall market price is $0.200/kg. Production coverage for this producer is 160,000 kg (2000 kg/ha * 80% * 100 ha). The shortfall is calculated by the production coverage minus the producer's actual yield and in this case is 100,000 kilograms. Therefore the crop insurance payment to the producer is $16,200 ($0.162 * 100,000 kg). In addition to this, since the fall market price has increased by approximately 25% the producer receives a payment of the shortfall (100,000 kg) multiplied by the difference in the SIP and the fall market price, an

[28] A comparison of the SIP to the average simulated prices indicates that for some crops (i.e., barley, canola and oats) the two prices are similar. For durum and spring wheat, however, the prices are not as close and there is a significant difference in the case of dry beans. This represents a limitation of the modelling of crop insurance in this study, particularly for the representative farm in the Brown soil zone under irrigated production (i.e., where dry beans are grown).

additional \$3,800 in VPB. By participating in crop insurance the producer has gained additional income of \$20,000. If the fall market price had fallen 10-50% below the SIP then a payment from SPE would be calculated in place of the VPB.

Crop insurance premiums are based on the coverage level for the particular crop, the risk region in which the farm is located, and whether or not SPE is purchased. The premium is equal to the dollar value of the coverage level multiplied by a premium rate. For simplicity purposes, in this study the premium rate is assumed to be 10% for all crops and all representative farms.[29] Of the resulting premium, 40% is assumed to be paid by the producer and included as a cash outflow in the simulation model, as crop insurance premiums are subsidized by the provincial and federal governments. Provincial and federal governments each pay 25% of the total premiums and share 50% of the administration fees. In modelling crop insurance it is assumed that this is approximately 60% of the total, leaving 40% for producers to pay (AAFC, 2009).

Hay insurance is also based on actual production versus coverage level. When yield is below the chosen coverage level a claim is triggered (AFSC, 2010-c). Producers can insure dryland and irrigated hay at 50, 60, 70, or 80% coverage levels and can also select different price options. However, if hay insurance is chosen producers must insure all land that they are using to produce hay. Insurance coverage is initially based on the normal expected yield in the risk area but is adjusted over time to reflect individual yield trends of the producer using a cumulative index based on the risk area average and actual yields (AFSC, 2010-c).

Risk area “normals” are calculated for each region to reflect the amount of hay producers can expect to grow in a normal year (AFSC, 2010-c). Risk area “normals” are estimated to be approximately 10,500, 3,505, 4,250, and 3,825 kilograms per hectare for farms in the Brown (irrigated production), Dark Brown, Black, and Dark Grey soil zones. For this study the risk area “normals” are estimated in an ad hoc manner, based on the actual values that could be expected in each region without causing payments to occur too frequently or infrequently.[30]

For perennial crops AFSC uses an indexing system to stabilize coverage. The cumulative index is the ratio of the index yield divided by the risk area average yield. The index yield has three “levels” calculated to provide stability in insurance coverage. This allows the risk area “normals” to become individualized to the producer over time. Annual yields are capped and cushioned at 1.8 and 0.7 times, respectively, the risk area average times the producer’s cumulative index in the previous period (AFSC, 2010-c). That is, if the ratio of actual yields and the risk area average is less than 0.7, the index is cushioned at 70%, and if the ratio is greater than 1.8, the index is capped at 180%. When the ratio falls in between these ratios the index yield is simply calculated as the average of the actual yield and the risk area average yield. Production coverage for producers is then a function of the cumulative index, the risk area normal, and the coverage level.

Assumptions when modelling hay insurance are that hay is insured at the same level as crops, at 80%, and once this level is decided upon it remains constant for the duration of the simulation. Risk area normal yields are determined from the yield data, while risk area average yields and hay prices are determined within the model. It is assumed that when the producer chooses the 80% hay insurance level the price option is

[29] In fact, the premium rates will vary by crop, risk region and year. For example, the 2011 AFSC premium rates for the crops included in this study and the relevant risk regions for the representative farms vary from 7% to 18% (AFSC, 2011-a).

[30] Risk area “normals” were determined as a simple average of yields from historic data, and adjusted to ensure crop insurance payments did not occur too frequently or not frequently enough, using a trial and error process in the simulation analysis.

$0.099/kg, which is consistent with the AFSC hay insurance program in 2010. These values are assumed to be constant through all years of the simulations for simplicity.

The production coverage is calculated the same way for hay as for crops, using the coverage level, acreage, and risk area average. When yield falls below the production coverage the producer claims the shortfall amount multiplied by the price option chosen. There is also VPB for hay insurance which provides compensation when the yield shortfall is below the insurance coverage and the price has increased during the growing season (AFSC, 2010-c) and is calculated in the same manner as it is for crop insurance.

5.3.5 AgriStability and AgriInvest

AgriStability and AgriInvest are public business risk management programs available to Canadian agricultural producers. Both are joint provincial-federal programs offered through the Growing Forward agricultural policy framework.[31] AgriStability provides protection from larger declines in income while AgriInvest is intended to address smaller fluctuations in income. Both programs are designed to mitigate weather, disease, and market risk. All representative farms are assumed to participate in both AgriStability and AgriInvest.

The principle behind AgriStability is that government and producers share the responsibility for managing income risk. The reference measure of income used in AgriStability is referred to as the production margin (PM). The PM is calculated by subtracting allowable expenses from allowable income. Allowable income is revenue generated from the sale of agricultural commodities. Allowable expenses are those costs directly associated with agricultural production. For the purposes of this study the PM is calculated as the difference between revenue from crop sales and variable costs of crop production.[32]

In each year, the PM is compared to the reference margin (RM). The reference margin is calculated using an Olympic average of the previous five years' PMs, where the minimum and maximum values are excluded from the average. The reference margin is therefore actually a three year average of the production margin. If the PM is less than the RM, there is potential for an AgriStability payment to be triggered. If the deficit is less than 15% (i.e., the PM is at least 85% of the RM), there is no AgriStability payment generated. The principle here is that PMs that are 85-100% of the RM represent normal fluctuations in income. This range of PMs is referred to as Tier 1. Tier 1 deficits are assumed to be addressed by AgriInvest, which is discussed below.

If the PM is less than 85% of the RM, an AgriStability payment is generated. Tier 2 is the range of PMs that are between 70% and 85% of the RM. In Tier 2, AgriStability pays 70% of the difference between the PM and 85% of the RM. PMs that are between $0 and 70% of the RM are in Tier 3. In this tier, AgriStability pays 80% of the difference between the PM and 70% of the RM. Finally, negative PMs are in Tier 4. AgriStability pays 60% of the difference between the PM and $0 in this tier.[33] The maximum annual AgriStability payment cannot exceed $5,000,000 per farm in Alberta.

[31] AgriStability and AgriInvest replaced the Canadian Agricultural Income Stabilization (CAIS) program in 2007-08. CAIS was the business risk management program offered through the previous Agricultural Policy Framework (APF).

[32] Details concerning what constitute allowable income and expenses are provided in the AgriStability Program Handbook (AFSC, 2011-a).

[33] AgriStability coverage for negative PMs is provided as long as the farm has not had negative margins in more than two of the previous five years (i.e., no more than one of the three years used in the Olympic average RM calculation)

The payments associated with the various tiers are cumulative. For example, if a producer PM is in Tier 3, payments for Tiers 2 and 3 are generated. The AgriStability payment structure may be summarized as follows (Schaufele et al., 2010, p. 3):

$$\text{Payment} = \begin{cases} 0, \text{ if PM} \geq 85\% \text{ RM} \\ 70\% \text{ (85\% RM – PM), if } 70\% \text{ RM} \leq \text{PM} < 85\% \text{ RM} \\ 80\% \text{ (70\% RM – PM) + 70\% (15\% RM), if } 0 \leq \text{PM} < 70\% \text{ RM} \\ 60\% \text{ (0-PM) + 80\% (70\% PM) + 70\% (15\% RM), if PM} < 0 \end{cases}$$

The following examples serve to illustrate the AgriStability payment calculations for the various tiers. Suppose a producer has a reference margin of $100,000. AgriStability payments for four alternative production margin scenarios are provided; production margins equal to $90,000, $75,000, $50,000 and -$10,000.

Example 1: Production Margin = $90,000. The producer is in Tier 1. There is no AgriStability payment.

Example 2: Production Margin = $75,000. The producer is in Tier 2. The resulting AgriStability payment is equal to $7,000; that is, 70% of the difference between $85,000 (85% of the reference margin) and $75,000 (the production margin).

Example 3: Production Margin = $50,000. The producer is in Tier 3. The AgriStability payment in this case is equal to $26,500. This includes a $16,000 Tier 3 payment, equal to 80% of the difference between $70,000 (i.e., 70% of the reference margin) and the $50,000 production margin. It also includes a $10,500 Tier 2 payment, equal to 70% of the difference between $85,000 and $70,000 (i.e., the ceiling and floor, respectively for Tier 2).

Example 4: Production Margin = -$10,000. The producer is in Tier 4. Assuming that the producer is eligible for Tier 4 coverage, the AgriStability payment is equal to $72,500. This includes a $6,000 Tier 4 payment, equal to 60% of the difference between $0 and the -$10,000 production margin. It also includes $56,000 Tier 3 payment (i.e., 80% of the difference between the ceiling and floor for Tier 3) and a $10,500 Tier 2 payment (i.e., 70% of the difference between the ceiling and floor for Tier 2).

Fees for participating in AgriStability are $0.0045 per $1 of reference margin, multiplied by 85%. There is a minimum fee of $45. The administrative cost share fee is an additional $55, making the minimum payment for any operation participating in AgriStability equal to $100. In the previous example producer fees would be $437.50 (i.e., [85% * $100,000 * $0.0045] + $55).

As noted above, the representative farms are also assumed to participate in AgriInvest. AgriInvest is essentially a savings program, where producers contribute to an account and their contributions are matched (to a pre-specified limit) by government contributions. Participation in AgriInvest is voluntary and is on at an individual level. AgriInvest accounts can be set up at any Canadian bank and producers manage their accounts individually. The purpose of the AgriInvest program is to provide agricultural producers with a program for managing smaller declines in income (i.e., within Tier 1).

Producers may contribute up to 1.5% of allowable net sales (ANS), where ANS is defined as sales of agricultural commodities minus purchase of agricultural commodities. ANS is capped at $1.5 million per producer for lifetime participation in the program for the purposes of AgriInvest. Producer contributions are matched dollar for dollar by government contributions. Given the ANS cap, the maximum annual matching government contribution is $22,500 (i.e., 1.5% of $1,500,000). Producers may withdraw funds from their AgriInvest account in any year.[34]

[34] Further details concerning AgriInvest are provided in the AgriInvest Program Handbook (AAFC, 2011-a).

Given the flexibility in the AgriInvest program with respect to contribution and withdrawal decisions, some simplifying assumptions were necessary in modelling this program in the representative farm simulation analysis. AgriInvest contribution and withdrawal decisions were linked with AgriStability calculations. This was done to be consistent with the principle behind the AgriInvest program; that is, it is intended to "manage" small fluctuations in income that are not addressed by AgriStability. As a result, contributions and withdrawals were determined based on the production margin (PM) level.

In the simulation models, deposits are made to the producer's AgriInvest account in years when the PM is positive and greater than the RM.[35] For the representative farms it is assumed that when this scenario occurs, the producer deposits 1.5% of the PM into this account. The government deposits a matching amount equal to the producer's contribution, up to $22,500 per year. For example if the PM is $110,000 and the RM is $100,000 the producer would deposit $1,650 in the bank account and the government would match this amount, such that the total deposit to the account is $3,300. The producer deposit is treated as a cash outflow for the purposes of MNCF calculations.

Similarly, if a representative farm's PM in a particular year is less than the RM, and there are funds available in the AgriInvest account, a withdrawal is triggered. The AgriInvest withdrawal is equal to the difference between the PM and the RM, to a maximum of 15% of the RM (i.e., the deficit constituting Tier 1). The withdrawal is limited to the Tier 1 shortfall since it is assumed that AgriStability addresses any additional shortfall (i.e., in Tiers 2, 3 and/or 4). It is assumed that AgriInvest withdrawals only occur when the PM is less than the RM but greater than 85% of the RM. If the calculated withdrawal is greater than the current AgriStability account balance, the withdrawal is limited to the account balance. For example, if the PM and RM for a representative farm are $95,000 and $100,000, respectively, and there are sufficient funds in the AgriInvest account, the producer would withdraw $5,000 from the AgriInvest account to stabilize income. Alternatively, if the RM was $100,000 and the PM was $70,000, the AgriInvest account withdrawal (assuming sufficient funds being available in the account) would be $15,000; that is, the difference between the RM and the Tier 2 ceiling where AgriStability would begin to generate risk management support.

5.4 Beneficial Management Practices

The objective of this study is to determine the direct economic costs and benefits associated with the adoption of on-farm BMPs. This portion of the chapter describes the rationale behind considering the selected practices as BMPs and how they are incorporated into the model farms. There are two main categories of BMPs modelled, rotational BMPs and non-rotational BMPs. All BMPs can be modelled individually or in combination with other BMPs, if applicable to the soil zone. Each BMP is described in terms of adjustments made in the farm models in terms of the incurred costs and associated benefits.

5.4.1 Crop Rotation Beneficial Management Practices

Rotational BMPs are adopted for the potential to improve the health of the soil through reduced erosion, reduced disease cycles, improved crop diversity, reduction of inputs, and an improved nitrogen carrying capacity of the soil. These effects are discussed in the following sections.

[35] In reality an AgriInvest account would collect interest. However, this is not modelled.

5.4.1.1 *Conversion of Cropland to Forage*

The first rotational BMP considered is the addition of alfalfa, a perennial legume forage, to the representative farm crop rotations. This change may be considered as a BMP because of the potential for reduced chemical fertilizer application in subsequent crops. This is due to the nitrogen fixing property of alfalfa, being a legume.

The alfalfa hay BMP is modelled for the representative farms in the Brown (irrigated production only), Dark Brown, Black and Dark Grey soil zones. Alfalfa hay is not considered for the Brown soil zone representative farm under dryland production as alfalfa hay production in this location is not agronomically viable (Bergstrom, 2009).

Since alfalfa is a perennial crop, a decision is required concerning how long (i.e., number of years) to maintain the stand in the rotation before reverting back to annual crops. Alfalfa stand yields tend to initially increase with age before eventually decreasing as the stand ages. Based on information from previous studies (Koeckhoven, 2008; Leyshon et al., 1981) and for reasons related to convenience for modelling in the simulation analysis, three years of alfalfa hay are included in the BMP rotation. After the alfalfa stand is three years of age, yields begin to decline, as compared to the average alfalfa yield for a five year old alfalfa crop (Koeckhoven, 2008; Leyshon et al. 1981).

Results from the previous alfalfa studies in northern Alberta (Hoyt, 1990; Hoyt and Hennig, 1970) are used to determine the duration of the subsequent yield benefit from adopting three years of alfalfa hay into the representative farm rotations, accounting for differences in normal rainfall/soil zones. The assumption is made in the simulation analysis that the yield benefit is observed for the next three crop years following alfalfa hay. While there is potential to have yield benefits beyond three years (e.g., some studies observe yield benefits up to 15 subsequent years), three years is chosen as a reasonable, albeit conservative, estimate.

For all representative farms where the alfalfa hay BMP is modelled, the crops grown in rotation in the three years following alfalfa are spring wheat, canola, and barley (durum wheat for the farm under irrigated production) in years one, two, and three, respectively. Annual crop yield increases attributable to alfalfa are assumed to be stochastic, and vary from year to year. As there is no guidance from the literature regarding the potential trend or distribution of the yield effect, it is modelled assuming a uniform distribution where a draw is taken using the minimum and maximum values shown in Table 5.27, and are adapted from Albertan alfalfa hay studies by Hoyt (1990) and Hoyt and Hennig (1970).

Table 5.27 – Yield increases (%) following alfalfa hay

Subsequent years (crop)		Northern Alberta	Southern Alberta
Year 1 (spring wheat)	Minimum	20%	10%
	Maximum	110%	80%
Year 2 (canola) & Year 3 (barley/durum wheat)	Minimum	14%	4%
	Maximum	104%	74%

The ability of legumes to fix atmospheric nitrogen and make it available for subsequent crops is modelled by yield increases in subsequent crops, but savings from reduced fertilizer savings is also considered. Yield increases and nitrogen cost savings are both modelled as there have been many studies citing the rotational benefits of including leguminous crops (Entz et al., 1995; Hoyt, 1990; Hoyt and Hennig, 1971; Lafond et al., 2007). Considering that many studies cite subsequent benefits from legume crops for up to 15 years, this study considers both a yield and nitrogen impact over only three years.

The average contribution of nitrogen by alfalfa hay is 45 pounds per acre but can be as high as 107 pounds per acre under optimal growing conditions (MAFRI, 2010). A five year stand of alfalfa hay can produce considerable nitrogen benefit for up to the first seven subsequent crops (MAFRI, 2010). While there is evidence that nitrogen application for the first cereal crop following an alfalfa stand is not necessary (MAFRI, 2010), it is assumed that 25% of the normal nitrogen is applied to be realistic with the actions of producers (Hutton, 2010). In the second, third and fourth years following an alfalfa stand it is assumed that 50, 80, and 100% (Hutton, 2010) of the normal amount of nitrogen is applied. These nitrogen savings are quantified through reduced nitrogen fertilizer costs over different subsequent crops and soil zones. These cost savings range from \$6.85/ha to \$36.92/ha, as displayed in Table 5.28. Costs are calculated using *AgriProfit\$* (AARD, 2010-b) nitrogen-phosphorus-potassium-sulphur (NPKS) blend (\$/kg) fertilizer costs and determining the proportion that is nitrogen costs.

Table 5.28 – Nitrogen benefit from reduced fertilizer inputs following alfalfa hay in rotation measured as cost reduction (\$/ha)

Subsequent Year / Crop	1 / Spring Wheat	2 / Canola	3 / Barley (Durum Wheat)
Brown, irrigated	\$36.92/ha	\$30.00/ha	\$9.85/ha
Dark Brown, dryland	\$22.79/ha	\$20.96/ha	\$6.85/ha
Black, dryland	\$30.57/ha	\$28.27/ha	\$8.15/ha
Dark Grey, dryland	\$25.67/ha	\$24.40/ha	\$6.85/ha
N application (as % of normal)	25%	50%	80%

Additional costs of adopting a perennial forage stand include baling and removal of alfalfa hay. These costs are incurred at custom rates so as to not result in additional machinery being necessary. The cost of baling and removal for a 750 kilogram alfalfa hay bale is assumed to be \$19.19 (SAF, 2008). Sale of alfalfa hay is on a per kilogram basis and the price is stochastic, as per the discussion earlier in this chapter.

5.4.1.2 Introduction of Field Peas

Similar to alfalfa hay, field peas are a legume and as such have the ability to fix nitrogen in the soil. Adding field peas to the crop rotations may therefore be considered a BMP because it allows for reduced use of chemical fertilizer. In terms of direct benefits for producers, incorporating field peas also allows for potential yield increases for subsequent crops. Adding field peas to existing crop rotations also increases diversity, which has been proven to improve crop yields within western Canada (Harapiak, 2007).

Field peas are considered a viable crop to adopt in the Brown (dryland), Dark Brown, Black, and Dark Grey soil zones. Field peas are not considered under irrigated production in the Brown soil zone as this crop was only grown on approximately 5% of the land under production in the representative county in 2006 (Statistics Canada, 2006). As a consequence the likelihood of this crop being economically viable is lower.

Field peas are modelled to include direct benefits in terms of both a yield benefit to subsequent crops and reduced nitrogen inputs for crops following field peas. For the representative farms in the Dark Brown, Black and Dark Grey soil zones, the rotation is adjusted such that spring wheat follows field peas. For the farm in the Brown (dryland) soil zone either spring wheat or barley may follow field peas. According to Harapiak (2007) there are differences in yield benefits following field peas that are related to rainfall levels; that is, greater rainfall contributes to greater yield effects. For the purposes of this study, crops following field peas in southern Alberta (i.e., Brown and Dark Brown soil zones) are modelled to have a yield benefit in the range of zero to ten percent while in northern Alberta (i.e., Black and Dark Grey soil zones) the yield benefit is in the range of 20 to 30% (Harapiak, 2007). This assumption is made due to overall lower historical precipitation in southern Alberta, as compared to northern Alberta.

As with the alfalfa BMP, the field pea yield benefit is modelled as being stochastic, as the impact will vary from year to year. Values are drawn from a uniform distribution with the minimum and maximum benefits shown in Table 5.29. A uniform distribution is chosen to draw yield benefits from as there is no indication in the literature concerning the nature of the distribution of the effects, or of trends within this range.

Table 5.29 – Yield increases (%) following field peas

Year 1	Northern Alberta	Southern Alberta
Minimum	20%	0%
Maximum	30%	10%

The nitrogen fertilizer benefit for the crop following field peas in the representative farm rotations is modelled as a reduced fertilizer cost for spring wheat or barley. The cost reduction is given in Table 5.30 and is based on nitrogen application following field peas being 33% of normal application (Harapiak, 2007). Costs are calculated using *AgriProfit$* (AARD, 2010-b) NPKS blend ($/kg) fertilizer costs, based on the proportion of fertilizer made up of nitrogen.

Table 5.30 – Nitrogen benefit from reduced fertilizer inputs following field peas in rotation measured as cost reduction ($/ha)

Soil zone	**Spring Wheat**	**Barley**
Brown, dryland	$17.01/ha	$20.35/ha
Dark Brown, dryland	$20.35/ha	N/A[a]
Black, dryland	$27.31/ha	N/A[a]
Dark Grey, dryland	$22.93/ha	N/A[a]

[a] N/A denotes not applicable for these regions as barley only follows field pea in rotation for the representative farm in the Brown (dryland) soil zone.

5.4.1.3 Partial or Complete Replacement of Summerfallow with Legume Green Manures

Summerfallow is commonly used by producers in southern regions of Alberta to recapture soil moisture loss from continuous cropping (Zentner et al., 2004). However, as discussed in Chapter 2, there are potential negative environmental impacts from this practice, including increased soil erosion, reduced soil organic matter content, etc. One BMP considered in this study is the partial or complete replacement of summerfallow in the rotation with a legume green manure crop. This shift in production practice has the effect of reducing the potentially negative effects of summerfallow. As well, the legume crop fixes nitrogen in the soil, reducing the need for chemical nitrogen application in the subsequent crop. Finally, the green manure crop adds organic matter when incorporated into the soil.

There are several options of crops that may be considered for use as green manure. These include annual crops, winter annual crops, perennial crops and legumes. Potential legume green manure crops include alfalfa, peas, lentils and many types of clover. For this study it is assumed that the legume green manure crop is red clover.

Legume green manures are adopted as a partial or complete replacement for summerfallow in the Brown and Dark Brown soil zones under dryland production. In the Brown soil zone it is assumed that legume green manures only partially replace summerfallow as there is a high proportion of land allocated to this practice in the County of Forty Mile (Statistics Canada, 2006). It is assumed that legume green manures completely replace summerfallow in the Dark Brown soil zone as Statistics Canada (2006) data and expert opinion (Dunn, 2009) suggest this practice is used to a lesser extent in the County of Starland.

As with alfalfa and field peas, incorporating a legume green manure crop into the rotation has two potential effects; a yield effect and nitrogen benefit. The yield effect following legume green manures in rotation may be negative depending on moisture. As noted earlier, one reason for utilizing summerfallow is to allow soil moisture to build up by resting the land. If summerfallow is replaced by a green manure crop and it is a dry year there would be a lower yield for the crop in the following year due to reduced soil moisture content.

For the purposes of this study, a dry year occurs when the simulated yield of a legume green manure is less than the minimum yield from the municipal level data, minus one standard deviation. These numbers are estimated from the available data, as there was a lack of continuous data for legume green manure yields in these regions. In the event of a dry year the resulting yield effect for the subsequent crop is determined based on a draw from a uniform distribution; the minimum value is -16% and a maximum value is zero. The yield effect is measured stochastically to account for year to year differences. A uniform distribution is used as there is no information available regarding the appropriate distribution or of trends within the minimum and maximum yield decrease range. If legume green manure yield is in "normal" (i.e., if it is not a dry year) the yield effect for the subsequent crop is zero. The crop following legume green manures in rotation is always spring wheat for both representative farms on which this practice is adopted.

The nitrogen benefit that occurs following the legume green manure is similar to that discussed earlier for field peas and alfalfa; that is, nitrogen is fixed in the soil and is available for use by the subsequent crop. However, the nitrogen benefit associated with green manure is smaller than for the other two legumes considered in the BMPs previously discussed. Zentner et al. (2004) suggests that the nitrogen benefit to subsequent crops following legume green manures in rotation may not be noticeable until the second time in rotation. For modelling purposes in this study it is assumed that the first time legume green manures occurs in rotation the nitrogen application for spring wheat following the legume will be 97% of what it would be without legume green manures in rotation (i.e., following summerfallow). The second time legume green manures occur in the crop rotation the nitrogen application for the subsequent spring wheat crop is 90% of normal. Following the third (and any additional) occurrence of legume green manure in the rotation the nitrogen application rate for the subsequent spring wheat crop is 81% of normal. The dollar savings per hectare and percent savings for spring wheat are shown in Table 5.31.

Table 5.31 – Nitrogen savings ($/ha) and nitrogen application following legume green manures in rotation.

Number of times in rotation	1	2	3+
Brown, dryland	$0.76/ha	$2.54/ha	$4.82/ha
Dark Brown, dryland	$0.91/ha	$3.04/ha	$5.77/ha
N application (as % of normal)	97%	90%	81%

5.4.1.4 Introduction of Oats

Including oats in a crop rotation is considered a BMP as this crop has lower chemical input requirements (i.e., fertilizer and pesticide), as compared to other annual grains/oilseeds. This effect is modelled directly in terms of the costs of production; that is, the per hectare cost for oats is lower than for wheat, barley or canola. There are no other impacts in terms of the model. Production costs from *AgriProfit$* are used in the models. This BMP is modelled for the representative farms in the more northern soil zones, Black and Dark Grey. According to experts at Alberta Agriculture oats are not commonly grown in southern areas of Alberta due to a higher incidence of weedy species in the rotations during and after oat production (Bergstrom, 2010).

When oats are grown in the Black and Dark Grey soil zones the chemical input costs are $28.42 per hectare for each region. In the Black soil zone chemical costs for spring wheat, barley, canola, and field peas are $86.49, $43.24, $75.37, and $95.13 per hectare, respectively. In the Grey soil zone in the Peace region the chemical costs are the same for all crops except field peas where the cost is $58.07 per hectare due to the reduced nitrogen consideration for field peas. Chemical fertilizer costs for oats are significantly lower than for barley, canola, wheat, and field pea in these regions.

5.4.1.5 Resulting Beneficial Management Practice Crop Rotations

Adoption of each of the rotational BMPs discussed in this section is modelled for the representative farms. Not all BMPs are modelled for all farms, for reasons outlined in the earlier discussion. Combinations of rotational BMPs are also considered; that is, there is the option to adopt one, all, or any feasible combination of the rotational BMPs. For the Brown soil zone (irrigated production) farm the only rotational BMP considered is the addition of alfalfa hay. For the Brown soil zone (dryland production) farm, field pea and legume green manure are both considered. As well, a combination BMP involving adoption of both crops is modelled. For the Dark Brown representative farm, adoption of alfalfa hay, field peas, and legume green manure are all modelled as BMPs, along with combinations of two BMPs and all three crops being simultaneously incorporated into the crop rotation. For the two northern representative farms (i.e., Black and Dark Grey soil zones) alfalfa hay, field peas, and oats are modelled as rotational BMPs. As well, combinations of two of the crop rotation BMPs and all three simultaneously being adopted are also modelled.

Tables 5.32 to 5.35 show the possible rotations for each farm, starting with the base rotation (no BMPs). Each rotation is individually examined and compared to the base rotation. Crop name acronyms are the same as in section 5.1.2 with the addition of “AH” for alfalfa hay, “FP” for field peas, “LGM” for legume green manures, and “O” for oats.

Table 5.32 – Rotations for Brown soil zone farm, irrigated production

Rotation	Crop Rotation[a]
Base	SW – C – DW – DB
Add AH	AH – AH – AH – SW – C – DW – DB – SW

[a] AH = alfalfa hay; C = canola; DB = dry beans; DW = durum wheat; SW = spring wheat

Table 5.33 – Rotations for Brown soil zone farm, dryland production

Rotation	Crop Rotation[a]
Base	SF – SW – C – DW – SF – B – C – SW
Add FP	SF – SW – C – DW – FP – B – C – SW
Add LGM	LGM – SW – C – DW – SF – B – C – SW
Add FP & LGM	LGM – SW – C – B – SF – DW – FP – SW

[a] B = barley; C = canola; DW = durum wheat; FP = field peas; LGM = legume green manure; SF = summerfallow; SW = spring wheat

Table 5.34 – Rotations for Dark Brown soil zone farm

Rotation	Crop Rotation[a]
Base	SW – C – B – SF
Add FP	SW – C – B – FP – SW – SF
Add LGM	SW – C – B – LGM
Add FP & LGM	SW – C – B – LGM – SW – FP – SW – C
Add AH	AH – AH – AH – SW – C – B – SF
Add AH & FP	AH – AH – AH – SW – C – B – FP – SW – SF – SW – C
Add AH & LGM	AH – AH – AH – SW – C – B – LGM – SW – C
Add AH, FP, & LGM	AH – AH – AH – SW – C – B – FP – SW – LGM – SW – C

[a] AH = alfalfa hay; B = barley; C = canola; FP = field peas; LGM = legume green manure; SF = summerfallow; SW = spring wheat

Table 5.35 – Rotations for Black and Dark Grey soil zone farms

Rotation	Crop Rotation[a]
Base	SW – C – B – SW – C
Add FP	SW – C – B – FP – SW – C
Add O	SW – C – B – SW – C – O
Add FP & O	SW – C – B – FP – SW – C – O
Add AH	AH – AH – AH – SW – C – B – C – SW
Add AH & FP	AH – AH – AH – SW – C – B – FP – SW – C
Add AH & O	AH – AH – AH – SW – C – B – SW – C – O
Add AH, FP, & O	AH – AH – AH – SW – C – B – FP – SW – C – O

[a] AH = alfalfa hay; B = barley; C = canola; FP = field peas; O = oats; SW = spring wheat

5.4.2 Non-Rotational Beneficial Management Practices

The purpose of non-rotational BMPs is similar to that of rotational BMPs; that is, to improve soil health, maintain productivity of the land, or provide protection of ecologically sensitive areas. Non-rotational BMPs considered in this project include shelterbelts, buffer strips, and residue management. There is also the additional option to include permanent cover in the buffer strip areas. When used appropriately these BMPs improve soil health by reducing wind and soil erosion. Buffer strips and permanent cover also provide protection for wetlands/riparian areas from runoff of agricultural chemicals from annual crop production (i.e., fertilizer and pesticides). This section provides a discussion of the specific methods and parameters used in modelling adoption of shelterbelts, buffer strips, and residue management as BMPs on the representative farms in terms of their direct effect on farm performance.

5.4.2.1 Shelterbelts

Shelterbelts are established on each representative farm based on the properties of the farm in terms of the potential need. As discussed earlier in Chapter 2, shelterbelts assist in reducing the potential for wind erosion. However, they also have a potential effect (both positive and negative) on crop yields in adjacent fields.

Shelterbelts may be established using a variety of species of trees. In modelling shelterbelt adoption in the current study it is decided to assume that a mix of Caragana and Green Ash trees are used for the shelterbelts. These types of trees are chosen as they are viable shelterbelt species throughout Alberta. Other common shelterbelt species include White Spruce and Scots Pine. However, these trees would not grow well in all regions of Alberta (AARD, 2007-a) and so for simplicity and consistency the Caragana and Green Ash mix is used. The trees are assumed to be planted in a ratio of two Caragana trees for every one Green Ash, with spacing of 60 centimetres between trees (AARD, 2007-a). The average mature heights of Green Ash and Caragana are sixteen and five metres, respectively.

The protection resulting from shelterbelts is dependent on the number of shelterbelts per unit of area, and the height of the trees. Caragana typically grow faster than Green Ash, but eventually Green Ash is the taller of the two species. This is why the combination of these two species is often used for shelterbelts. For simplicity of modelling only the growth of Green Ash is calculated over time and the height of Green Ash trees is used to determine shelterbelt protection. The following growth equation, adapted from Geyer and Lynch (1990), is used to calculate the height (in metres) of the Green Ash trees:

$$\text{Height (m)} = 0.4 + (0.5 * \text{Age}) + (2.5 * (1 - e^{(-0.3 * \text{Age})})) \qquad (5.23)$$

where “Age” is the age of the trees, in years. In the simulation analysis the growth equation is adapted by assuming green ash tree height is “capped” at twenty metres as this is the average maximum height of Green Ash trees. Also it is assumed that shelterbelts do not have an effect on yields until the third year after they are planted. Since the trees are relatively small when they are first planted it would not be reasonable to assume significant protection from wind or competition between trees and crops for water and nutrients until the fourth year from BMP adoption.

Shelterbelts are most effective in dry soil regions where the risk of soil erosion is greater. For this reason representative dryland farm operations in the southern regions of Alberta (i.e., Brown and Dark Brown soil zones) will have more shelterbelts per quarter section as compared to farms in northern areas (i.e., Black and Dark Grey soil zones). In modelling the adoption of the shelterbelt BMP it is assumed that the Brown soil zone (irrigated production[36]) representative farm establishes four shelterbelts per quarter

[36] In calculating the costs of irrigation machinery for the farm in the Brown soil zone under irrigated production it was assumed that centre pivot systems are used. However, adopting shelterbelts would divide the fields in such a way that pivot irrigation is not feasible. While irrigation machinery costs were not recalculated based on this fact, it is noted for future studies.

section while the farm in the same soil zone under dryland production establishes five shelterbelts per quarter section. Since moisture is a component in reducing soil erosion and this is controlled with irrigated production it is assumed that fewer shelterbelts are necessary for the irrigated operation. The farms representing dryland production in the Dark Brown, Black, and Dark Grey soil zones are assumed to plant four, three, and two shelterbelts per quarter section, respectively. The pattern here is to establish fewer shelterbelts for representative farms that are further north, as this is consistent with reduced soil erosion potential due to differences in soil composition, such as soil organic matter.

The shelterbelts are assumed to run the length of each field (i.e., 795 metres), and are twelve metres wide. This width is necessary for appropriate spacing between trees and crops, while allowing for tree growth. The specifications of shelterbelt adoption for each representative farm, including the acreage lost, are provided in Table 5.36. If shelterbelts are adopted, implementation is staggered equally over eight years. It is unlikely that producers would have the resources (i.e., time and money) to establish all shelterbelts in one time period. However, the establishment time would vary from producer to producer. Eight years was chosen as an establishment time that would likely be feasible for most producers.

Table 5.36 – Shelterbelt specifications per region

Soil Zone	Number per quarter section	Number per farm	Total number of trees	Total lost acreage (ha)	Lost acreage as % of total
Brown, irrigated	4	64	84,800	61.1	5.9%
Brown, dryland	5	100	132,500	95.4	7.7%
Dark Brown	4	80	106,000	76.3	5.9%
Black	3	48	63,600	45.8	4.4%
Dark Grey	2	24	31,800	22.9	3.0%

Shelterbelt trees can be obtained at no cost from the Prairie Farm Rehabilitation Administration (PFRA), but there are planting and maintenance costs associated with this BMP. Site preparation and planting is assumed to cost $0.70 per tree. Maintenance of trees is required starting in the year following planting until the sixth year after planting, with the cost being $0.15 per tree per year. Cost estimates are adapted from a study in Indiana, USA (Indiana Woodland Steward, 2010) which assumes machine planting at the rate of $250 to $300 per acre (i.e., $101 to $121 per hectare) with 500 trees planted per acre (i.e., 203 trees per hectare) and additional herbicide costs of approximately $50 per acre (i.e., $21 per hectare). Total establishment costs are $122,960, $192,125, $153,700, $92,220, and $46,110 for the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey representative farms, respectively.

Yield effects from shelterbelts occur in two areas of the field. The first area is directly adjacent to the shelterbelt and covers the area extending out to three times the height of the shelterbelt, including any area that is under three times the height of the shelterbelt (0-3H). In this region there is a yield decrease due to competition of the crops with the shelterbelt trees for moisture and nutrients (AARD, 2004-b). The second area is from three to ten times the height of the shelterbelt (3-10H). In this area there is sufficient wind protection and increased moisture trapping for a yield increase (AARD, 2004-b). As a conservative measure yield effects from shelterbelts, both decreases and increases, are only considered on one side of the shelterbelt. This assumption is reasonable for yield increases as crops would typically only be sheltered in the direction of the prevailing wind. This assumption may be inconsistent for yield decreases directly adjacent to shelterbelts, however to obtain the full effect the resulting yield "cost" could simply be doubled. The yield changes used to model the effect of shelterbelts are based on information from multiple sources, including AARD (2004-b) (see Appendix I), Baldwin (1988), Kort (1988), and Kulshreshtha and Kort (2009). Specifically, yield effects for barley, canola, wheat and hay are estimated from AARD (2004-b). Yield effects for oats are estimated from Kort (1988). Due to a lack of information for a yield effect of shelterbelts on field peas and legume green manures it is assumed that these effects are the same as those for barley. The yield effect for dry beans is only relevant for irrigated production and is estimated from Baldwin (1988). Table 5.37 shows the yield effect of shelterbelts per region and crop as a percent of normal (i.e. without shelterbelts) yields.

Table 5.37 – Yield effect (as % of normal) of shelterbelts for soil zones and regions adjacent to shelterbelts

Soil Zone	Height Category[a]	Barley	Canola	Dry Beans	Field Peas	Hay	Legume Green Manures	Oats	Wheat
Brown	0-3H	61%	57%	76%	61%	76%	61%	51%	62%
	3-10H	112%	112%	116%	112%	116%	112%	104%	109%
Dark Brown	0-3H	62%	58%	-	62%	77%	62%	52%	63%
	3-10H	112%	113%	-	112%	117%	112%	104%	110%
Black	0-3H	61%	57%	-	61%	76%	61%	51%	62%
	3-10H	107%	108%	-	107%	112%	107%	102%	104%
Dark Grey	0-3H	62%	57%	-	62%	76%	62%	51%	62%
	3-10H	108%	109%	-	108%	112%	108%	103%	105%

[a] 0-3H is the area immediately adjacent to the trees extending out to a distance three times the height of the trees, while 3-10H is the area extending from three times the tree height out to ten times the tree height.

5.4.2.2 Buffer Strips

Buffer strips is another BMP modelled in this study. As discussed in Chapter 2, buffer strips can serve as a potential filter in terms of reducing runoff of agricultural chemicals. Buffer strips may be implemented as area of land set aside from agricultural use. Alternatively, they may be implemented as permanent cover; that is, the area may be seeded to permanent forage which is used for hay production.

Buffer strips may be implemented anywhere on the representative farms. However, in this study they are used to provide a buffer around wetlands and associated riparian areas. In particular, it is assumed that two, four, four, six and six percent of land is wetland for the Brown soil zone (irrigated), Brown soil zone (dryland), Dark Brown soil zone, Black soil zone, and Dark Grey soil zone representative farms, respectively. This assumption is made based on information from South Saskatchewan Regions Wetlands (2009). All farm calculations take the area in wetland into consideration and land under production is adjusted accordingly.

The impact of the buffer strip BMP depends not only on the area of wetlands but also the configuration (i.e., shape). For ease of modelling, each quarter section is assumed to have one small circular wetland, of corresponding size, per 64.75 hectares. The impact of the BMP also depends on the buffer strip width. The buffer strips are assumed to be ten metres in width. This width is chosen as it is sufficient to provide riparian protection, and has been used in previous studies of BMPs in wetland areas (Koeckhoven, 2008). As well, in the scenario where the buffer strip is used for hay production, 10 metres is sufficiently wide to accommodate hay harvesting equipment. The total area of land lost due to the adoption of buffer strips for each of the farms is provided in Table 5.38.

Table 5.38 – Wetland characteristics and acreage lost due to wetland adoption

Soil zone	Number of wetlands per farm	Individual wetland radius (m)	Total buffer strip area per farm (ha)
Brown, irrigated	16	64.2	6.96
Brown, dryland	20	90.8	12.04
Dark Brown	20	90.8	12.04
Black	16	111.2	11.68
Dark Grey	12	111.2	8.76

As with the other BMPs the decision to adopt buffer strips or adopt buffer strips and hay the area is made at the beginning of the simulation period (i.e., all land area is converted to buffer strips in year one of the simulation) and this decision is carried on for all forty years of the simulation. If the buffer strip is left idle, there is no implementation cost associated with the BMP, as it is assumed that the land is simply left alone. If the buffer strip is used for hay production (i.e., permanent cover) there is a onetime cost incorporated that is equivalent to seeding the area with hay (i.e., as per the costs provided in Tables 5.20 to 5.24). When the buffer strips are used for hay production, it is also assumed that the crop is custom baled. The cost incurred is $19.19 (SAF, 2008) for baling and removing a 635 kilogram grass hay bale. Costs are incurred at custom rates so the machinery complement does not need to be changed. It is estimated from the limited historical data from alfalfa hay and grass hay, that grass hay price is approximately 60% of the price of alfalfa hay which is determined stochastically. Therefore, it is assumed that grass hay is sold for 60% of the price of alfalfa hay.

5.4.2.3 Residue Management

As discussed earlier, in the baseline scenario post-harvest residue for some crops is removed from fields (i.e., harvested) in some years and “retained” on the field in other years. Residue management may actually be considered as a BMP. The residue management BMP is defined here as the practice of leaving residue on the fields in some years, rather than harvesting it. This practice provides a potential short term benefit of increased soil moisture content while in the long term it may improve soil organic matter (Korol, 2004). This could potentially lead to higher yields in dry years (Huanwen et al., 2004), as compared to no residue management.

For the purposes of the project only the crops barley, durum wheat, oats, and spring wheat are considered for residue management as these crops provide an amount and type of residue that can be harvested. The residue management BMP modelled in this analysis represents exactly the same practices that are assumed to be used in the baseline scenario in terms of the amount of residue removed. For the Brown soil zone, residue of the previously mentioned crops is removed one out of every five years under dryland production and one out of every two years under irrigated production. In the Dark Brown soil zone residue is removed once every four years. In the Black and Dark Grey soil zones residue is removed once every three years. As discussed earlier in this chapter, the differences between the different representative farms (i.e., soil zones) are due to the quantity of residue produced, and expected moisture conditions. The decision rules regarding the pattern of residue management for this BMP are static in the simulation analysis; that is, they do not change over time.

The long term effects of residue management on soil organic content are not modelled in this study. However, the short term effects on crop yield due to soil moisture are explicitly considered in the simulation analysis. The impact of residue management on subsequent crop yields is dependent on moisture conditions; that is, whether it is a "wet year" or a "dry year". A wet year (i.e., greater moisture) results in greater than average residue while in a dry year the opposite is the case. In a dry year, if crop residue is left on the field, there will be a positive effect on the yield of the subsequent crop due to improved soil moisture. However, leaving crop residue on the field in a wet year (i.e., when there is more soil moisture and a greater level of crop residue) can cause problems for the subsequent crop and actually result in reduced yield. Crop residues are correlated with crop yields; if crop yields are high, then residue yields are high. If large amounts of residue are retained on the soil surface there may be less opportunity for the soil surface to warm for germination, and there may also be poor seedling emergence from excessive surface residues (Lafond et al., 1992).

Crop residue production is modelled in the same way as for the baseline scenario (i.e., as a proportion of crop yield). For the purposes of modelling the yield effects associated with the residue management BMP, a wet year is one where the residue (in kg/ha) is greater than the mean residue production level[37] plus one standard deviation. A dry year is one where the residue is less than the mean residue amount minus one standard deviation. If residue is removed in a wet year, a predetermined action that is based on the pattern of residue management for the particular representative farm (discussed earlier), there is no effect on yield. However, if crop residue is retained in a wet year there is a negative effect on the yield for the subsequent crop. If residue is removed in a dry year the subsequent crop will have a reduced yield whereas if the producer retains the residue the subsequent crop will have an increased yield. In both the BMP and baseline scenarios there is potential for yield decreases to occur to the subsequent crops if residue is removed in a dry year. However, in the BMP scenario it is further assumed that subsequent crop yield increases can occur when residue is retained in dry years and that crop yield decreases can occur when residue is retained in wet years.

Yield effects (positive and negative) associated with residue management are assumed to be stochastic. The effects are modelled using draws from uniform distributions. Minimum and maximum values of residue effects are provided in Table 5.39. These values are adapted from studies by Lafond et al. (1992 and 2009). The crops affected by these yield effects are dependent on the specific crop rotations for the representative farms. Information indicating the crops following barley, durum wheat, oats, and spring wheat in rotation is provided earlier in this chapter (Tables 5.31 to 5.34).

Table 5.39 – Minimum and maximum values of crop yield changes (as % of normal) from retaining or removing residue in dry and wet years

Yield effect from residue decision	Minimum	Maximum
Low residue (dry year), retain residue	0%	3%
Low residue (dry year), remove residue	-3%	0%
High residue (wet year), retain residue	-12%	0%
High residue (wet year), remove residue	0%	0%

The effect of the residue management BMP on farm performance is assessed by comparing the BMP simulation results with results for a revised baseline scenario. In

[37] The mean value of residue production is the level associated with the average crop yield for the particular representative farm.

particular, the baseline scenarios for the representative farms (i.e., with no BMP adoption) are re-simulated, assuming that residues for the relevant crops (i.e., barley, oats, durum and spring wheat) are removed (i.e., harvested) every year. This revised baseline simulation is required, as the original baseline scenarios included residue management practices that are identical to the residue management BMP, without the yield effects modelled for the BMP. The revised baseline allows for a more appropriate comparison, in order to determine the economic impact of the BMP. The negative yield effects associated with residue removal in dry years is modelled in the revised baseline analysis. Results from the residue management BMP are compared to both baseline scenarios.

5.4.3 Beneficial Management Practices Adoption Sensitivity Analysis

The yield benefits associated with the BMPs modelled in this analysis are estimates based on previous studies, some of which are from outside of Alberta, and on expert opinion. Given the resulting uncertainty regarding the actual effects that might occur with adoption of the BMPs sensitivity analysis is done on the yield effects as well as other relevant factors associated with the BMPs modelled in this study. It is expected that if yield benefit estimates are increased (decreased) the value of the firm (i.e., the net benefits associated with the BMP) will increase (decrease) accordingly. This pattern is also expected for sensitivity analysis on nitrogen savings estimates associated with crop rotation BMPs.

The yield benefit to crops during the first year after an alfalfa stand is broken up is assumed to be from 10% to 80% in Southern Alberta and 20% to 110% in Northern Alberta. The second and third years after an alfalfa stand show benefits of 4% to 74% in the south and 14% to 104% in the north. Sensitivity analysis is done on each estimate (minimum or maximum value) individually. The analysis examines changes at intervals of 0.05 to a maximum of 0.15 differences in either direction. In addition to the yield benefit following an alfalfa stand there is a nitrogen benefit where nitrogen is applied as a percent of normal for the first three years following the stand. Sensitivity analysis is done on these estimates at 5% increments to a maximum of 15% in either direction.

Sensitivity analysis is conducted in a similar manner for yield effects and nitrogen savings following field peas. Sensitivity of results to changes in the yield benefit following field peas is tested individually for the maximum and minimum values that are used in the draw from a uniform distribution using 0.05 increments up to 0.15 differences in both directions. Sensitivity to changes in the nitrogen benefit following field peas is also tested using 5% increments up to a difference of 15% in both directions.

Sensitivity analysis on legume green manure yield and nitrogen benefits is also done in a similar fashion as for alfalfa hay and field peas. For the yield effect, which is conditional on previously mentioned assumptions, the effects of changes to minimum and maximum values are tested individually at 0.05 increments up to 0.15 differences in both directions. Sensitivity of results for the nitrogen benefits, which vary with the number of times green manures are in rotation, are also tested at 5% increments in either direction up to 15%.

Sensitivity analysis is also conducted for parameters associated with the non-rotational BMPs. Shelterbelt yield estimates are tested using sensitivity analysis on both areas adjacent to the trees (i.e., the areas in which yields are negatively and positively affected, respectively), independently. Estimates of the yield effects are changed in increments of 0.05 up to differences of 0.15 from the original value for each crop. Buffer strip sensitivity analysis includes testing the impact of increasing the width of the strip in increments of two metres up to a difference of six metres when buffer strips are adopted with the option to harvest hay. The same analysis is used when buffer strips are adopted without the adoption of hay in the buffers in addition to a decrease in buffer strip width by two and four metres. Sensitivity analysis is also conducted with respect to the proportion of land assumed to be wetlands. Specifically, alternative scenarios where wetlands make up 2, 4, 6, or 8% of total land are examined. Finally, the yield effects following residue management are tested in a similar manner as for the other yield effects, with minimum and maximum yield effects being changed in increments of 0.05 each, to a maximum change of 0.15 for distributions of the yield effects as appropriate. For example, in the case of a dry year where residues are retained, there are yield increases possible, so sensitivity analysis tests the effect of further yield increases from the upper value of the distribution, which is 0.03 in this case, but not changes to the lower value of the distribution, which is zero in this case.

Analyses of different discount rates used in the models are examined at 8% and 12% with base rotation results compared to the adoption of field peas. Sensitivity analysis is also performed on the type of starting crop price method used, including the five, ten, and historic average of crop prices for the base rotation, alfalfa hay in rotation, and adoption of shelterbelts. Sensitivity analysis is performed on including or excluding safety net programs with the base rotation results compared to scenarios that consider adoption field peas and shelterbelts.

5.5 Simulation and Cash Flows for Beneficial Management Practices Analysis

This section discusses how the cash flow simulation models are used for the economic analysis of BMP adoption. As discussed earlier in the chapter, there are five representative farm models developed and used in this study. These farm models are analyzed independently using Monte Carlo simulation. Each farm is initially simulated assuming a set of baseline crop rotations and production practices. Performance for the farms is then again simulated, assuming adoption of one or more rotational or non-rotational BMPs, as discussed earlier in this chapter.

An annual modified net cash flow is calculated and used in an NPV analysis to compare farm performance for the various BMP scenarios to the baseline scenario (i.e., no BMP adoption) for the farms. BMPs affect the cash flow structure of the farms. The acreage available for crop production changes with adoption of some of the BMPs (e.g., buffer strips, shelterbelts). Management of residue affects the input costs and yields of subsequent crops which affects the revenue of the farm. The rotational BMPs affect the pattern of crops grown and, in some cases, crop yields and input costs.

Adoption of BMPs is evaluated by comparing NPVs between scenarios for each of the representative farms. In each case, the NPV for the BMP scenario is compared with the BMP for the baseline scenario. If the difference between the two NPVs is positive, the BMP provides a net benefit to the producers, in that adoption results in improved cash flows and increased value or wealth. If the difference is negative, adoption of the BMP represents a net cost to the cropping operation, and would result in decreased value or wealth.

5.5.1 Discount Rate

The discount rate used for Monte Carlo simulation studies varies depending on the type of firm being analyzed. Typically, the discount rate incorporates the relative riskiness of the business, as discussed in Chapter 4. The Canadian Treasury Board uses a discount rate of 8%, calculated as a weighted average of the interest rate on domestic savings, the interest rate of a postponed investment, and the marginal cost of foreign borrowing (Treasury Board of Canada Secretariat, 2007). This rate was re-estimated, using the same criteria, from the 10% rate calculated in 1998.

Recent studies, similar to the current study in that they have examined adoption of environmental practices by agricultural firms, have used a discount rate of 10% (Cortus, 2005; Koeckhoven, 2008). The default discount rate for this study is 10%. However, sensitivity analysis is conducted with respect to the value of the discount rate. In particular, the NPV results for the baseline and BMP scenarios are also analyzed using discount rates of 8% and 12%, to determine if discount rate has an effect on the feasibility of BMP adoption.

5.5.2 Simulation Model Iterations

As discussed previously, Monte Carlo simulation is an iterative process that uses random draws from pre-specified distributions to model stochastic parameters. The result of this process is a distribution of results. When using Monte Carlo simulation a decision is required in terms of the number of iterations to use in the analysis. There is a tradeoff involved in making this decision. When more iterations are used, more confidence can be placed in the "accuracy" of the distribution of results; that is, a greater opportunity for the simulation results to accurately represent the outcome. However, when using *@RISK* as more iterations are added to each simulation the time for each simulation increases. Due to the many simulations that will be done on five models the number of iterations will be chosen so as to maximize modelling efficiency while still providing accurate results.

A t-test was performed comparing model results using 1,000 iterations with model results using 10,000 iterations. A paired t-test with the hypothesis that results from models simulated with 1,000 iterations and 10,000 iterations would be equal was not rejected ($p = 0.76$, $df = 4$). This is expected to hold across all other scenarios and 1,000 iterations will be used for all baseline and BMP analyses.

5.5.3 Net Present Value Calculations and Beneficial Management Practices Adoption Assessment

Net present value is calculated using cash flows associated with crop input costs, crop and forage revenues, machinery costs, and revenues and expenditures for AgriStability, AgriInvest and crop insurance programs. In the case of BMP scenarios, cash flows associated with adoption (e.g., revenues from hay production, costs of establishing shelterbelts, etc.) are also incorporated into the NPV calculations.

As noted earlier, a forty year time horizon is used for the simulation analysis. The forty years of cash flows are used to calculate an NPV in perpetuity ($NPV_{perpetuity}$). The use of a perpetuity NPV measure assumes there is no end to the cash flows; that is, they continue into perpetuity. This approach is used as some of the BMPs (e.g., crop rotations shelterbelts) require several years before the effects on farm performance are fully realized, and the impact of the BMPs continue beyond the end of the simulation time horizon. The calculation used for the NPV with perpetuity is given in equation 5.24:

$$NPV_{Perpetuity} = \sum_{t=0}^{40} \frac{C_t}{(1+r)^t} + \left(\frac{C_{40}}{r} * \frac{1}{(1+r)^{40}} \right) \tag{5.24}$$

where C_t is the net cash flow for year t (t = 0 to 40) and r is the discount rate. The first term in equation 5.24 is the summation of discounted cash flows over the 40 year time horizon. To this is added the perpetuity present value; that is, an estimate of the present value of cash flows beyond year 40. The cash flow in the year 40 is divided by the discount rate (r) to obtain a year 40 perpetuity present value, which is then discounted to a present value.

For further comparison of the results of BMP adoption the NPVs are converted to an annualized value per hectare. The annualized values are useful for comparison of scenarios for individual farms, as this calculation converts the NPVs to values that may be compared to estimate annual net benefits or costs per hectare for the various BMP scenarios. This computation also allows for a more direct comparison between representative farms for individual BMP scenarios.

The formula to annualize NPV with perpetuity is shown in equation 5.25:

$$A = NPV_{Perpetuity} * r \tag{5.25}$$

where A is the annualized NPV, $NPV_{Perpetuity}$ is the original NPV in perpetuity and r is the discount rate. Equation 5.25 is essentially the (rearranged) formula for a perpetual annuity; that is the present value of a constant stream of future returns that extends into perpetuity. In this case, the present value is the NPV from the simulation analysis, and the calculation provides the (constant) annual cash flow that would generate it.

The annualized present values are then used to calculate the annual change in farm performance/value resulting from a particular BMP scenario; that is, the difference between the annualized NPVs. This difference is then converted to a per hectare value. The specifics of this calculation depend on the type of BMP under consideration. In the case of rotational BMPs, the change in practice affects the whole farm since the overall crop rotation is adjusted. This is also true for the residue management BMP. For these scenarios, therefore, the annualized NPV difference is divided by total farm acreage to determine the annual net benefit or cost per hectare. For other non-rotational BMPs such as shelterbelts and buffer strips, the effect is to reduce the area available for regular annual crop production. For these BMP scenarios, the annualized NPV difference is divided by the farm acreage affected by the particular BMP to establish the net benefit or cost per hectare.

5.6 Chapter Summary

Stochastic, dynamic simulation models are used to examine the feasibility of the adoption of several rotational and non-rotational BMPs on five representative commercial crop farms in Alberta. Decisions regarding farm size, structure, and other characteristics are based on 2001 and 2006 Statistics Canada data, data from AARD and AFSC, and opinions from experts in these areas.

Stochastic variables in the model include crop and forage prices and crop and forage yields. The stochastic variables are based on historical price and yield data obtained from AARD and AFSC. Prices are assumed to be provincial in nature and are therefore common for all representative farms. However, yields are specific to each region. Several of the yield effects from BMP adoption also use stochastic draws from uniform distributions. The stochastic variables generate final yields and revenues for each operation.

The models are built to be flexible in the adoption of individual and combinations of BMPs. The BMPs considered include adding alfalfa hay, field peas, legume green manures, and oats to the rotation based on the feasibility of the soil zone, and adding shelterbelts, buffer strips, hay in the buffer strips, and management of residues on all representative farms. For each farm, NPV analysis is employed to compare the adoption of these BMPs to a baseline scenario. Sensitivity analysis is also used to validate some of the estimates used in the models and to examine the feasibility of adoption under differing circumstances; that is, for alternative values of key parameters.

Chapter 6: Results and Discussion

This chapter provides a discussion of the results from the model farm simulations that were presented in Chapter 5. The direct economic impact of BMP adoption is presented and explained along with sensitivity analysis for a subset of model variables. The value for each representative farm after adopting one or more BMPs, as proxied through an NPV calculation, is compared to a reference result for each farm. Summary results from the simulations are provided in tabular form in this chapter, but more complete results are available in Appendix J.

6.1 Baseline Scenario Results

Baseline scenarios are simulations modelled for the representative farms, assuming that none of the BMPs are adopted. Baseline results are determined using the base crop rotations that were presented and discussed in sections 5.1.2.1 to 5.1.2.5. The baseline results for each farm are used as the basis for comparison when one or more BMPs are adopted and also for comparison in sensitivity analysis.

Mean and standard deviation NPV[38] values for the reference farm simulations are shown in Table 6.1. The annualized mean values of the farms on a per hectare basis (i.e., from Equation 5.33) are also provided. The measure of NPV for the farms can be considered as a modified wealth measure for the operations but does not represent wealth in terms of equity or net worth. As discussed in the preceding chapter, this is due to the use of modified net cash flows (MNCFs) in the NPV calculations. MNCFs do not include all cash flows that would be relevant for equity calculations. The type of analysis in this study does not consider capital structure in terms of the method of financing farm assets as either debt or equity. However, higher mean NPV amounts do indicate greater wealth for the operation.

The annualized mean NPVs for the operations are approximately \$236, \$65, \$85, \$274, and \$311 per hectare for the farms located in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively. The highest wealth value per hectare is on the farm with the smallest acreage and furthest north in the province. As compared to other farms located in the southern (i.e., in the Brown and Dark Brown soil zones) regions of the province the farm with irrigated production has the highest wealth due to higher value of crop production under irrigation. The irrigated farm also grows dry beans, which are of higher value and are not considered on the dryland farms. Of the southern farms under dryland production the farm in the Dark Brown soil zone has a higher wealth value per hectare due to higher crop yields in this region relative to those for dryland production in the Brown soil zone. Comparing the results of the farm in the Dark Brown soil zone with the farms in the Black and Dark Grey soil zones a large gap in value that is partially due to the amount of canola, a higher value crop, grown in the base rotations is present. In the Dark Brown soil zone canola is grown on one quarter of the land under production, while in the Black and Dark Grey soil zones it is grown on two fifths of the land[39].

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[38] The NPVs presented and discussed in this chapter are "in perpetuity"; that is, they are calculated using an infinite time horizon. The calculation of NPV with perpetuity is provided in Chapter 5, section 5.5.3.

[39] It should be noted that the degree of intensity of canola production for the Black and Dark Grey farms (i.e., two of every five years) results in greater risk in terms of disease problems for this crop. However, this risk factor was not explicitly incorporated into the analysis due to lack of ability to quantify the impact on yield distributions.

When comparing the standard deviations of the NPVs for the representative farms it is also important to consider that a number of factors affect this variability measure. For example, economic theory suggests that variance of returns generally increases with greater levels of expected returns. As well, each farm may be considered as a "portfolio" of crop enterprises. As the number of enterprises in the portfolio increases, all else being equal, NPV variability would tend to be lower. The pattern of NPV standard deviations in Table 6.1 is somewhat consistent with these considerations. For example, the irrigated Brown soil zone farm has the second greatest mean NPV and the highest standard deviation while the Dark Brown farm has the second lowest mean NPV and standard deviation. The number of crop enterprises in the portfolio for each representative farm is likely not a major factor, as the farms either have three or four risky crop enterprises each (i.e., as discussed in Chapter 5, not including summerfallow).

However, there are some significant deviations from the expected pattern. For example, the dryland Brown soil zone farm has the second highest standard deviation but also has the lowest mean NPV. Historical yields in this area have more variability as compared to other regions due to extreme differences in temperature and precipitation events. The naturally occurring variability in weather in this region is hypothesized to be the cause of the high variability calculated in the model. While it is not explicitly modelled, the soil in southern Alberta is more prone to erosion due to lower soil moisture levels and lower soil organic matter levels. Extrapolating from this, yields may vary more from year to year due to faster annual depletion of the soil under poor growing conditions, as compared to areas with higher levels of soil organic matter and soil moisture. The other significant exception to the expected pattern is the Dark Grey representative farm which has the third highest mean NPV but the smallest standard deviation. While there is no obvious explanation for this result, it may be the case that the opposite situation exists from the dryland Brown soil zone farm; that is, crop production is less risky in this region.

One other result with respect to the NPV standard deviations is worthy of note here. The farm in the Brown soil zone under irrigated production has the highest standard deviation. This is somewhat surprising as a common assumption is that there is less variability in income with irrigated production since the input of water is controlled by the operator (i.e., less yield risk). However, specifics of irrigation practices are not directly modelled in the analysis as there is no allowance for more irrigation water to be used in years where seasonal rainfall is lower and other events such as yields and costs associated with irrigation may be indirectly affecting this value.

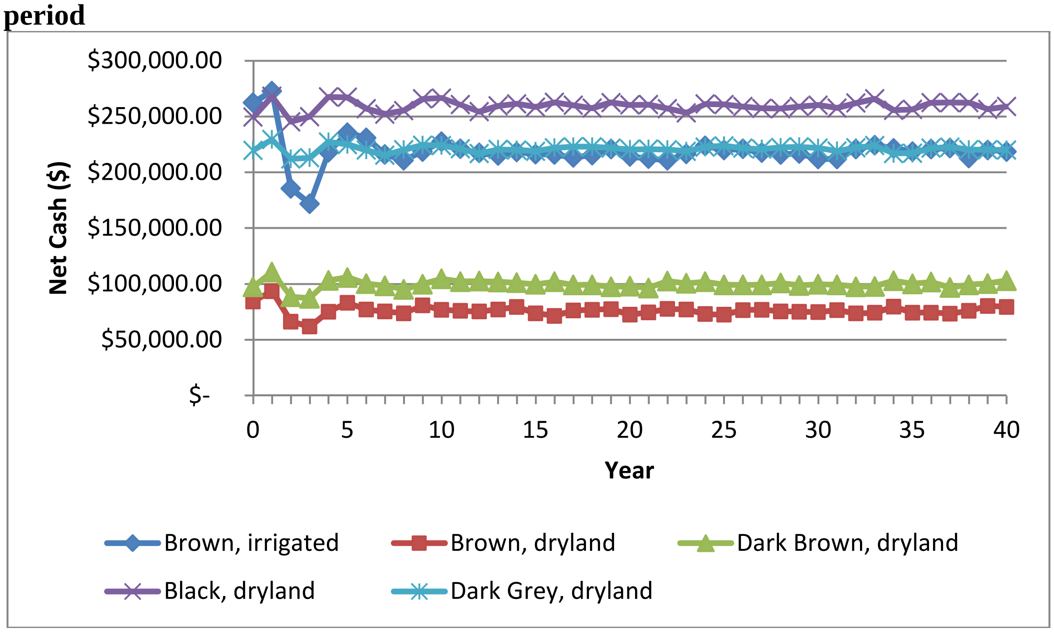
Table 6.1 –Baseline results of the representative farms for the variable NPV

Soil zone, production	Mean NPV	Standard deviation NPV	Farm hectares	Annualized mean NPV per hectare
Brown, irrigated	$2,441,735	$424,010	1,036	$235.69
Brown, dryland	$845,707	$346,840	1,295	$65.31
Dark Brown, dryland	$1,094,775	$297,373	1,295	$84.54
Black, dryland	$2,841,695	$330,860	1,036	$274.29
Dark Grey, dryland	$2,419,362	$229,890	777	$311.37

Figure 6.1 shows the average annual cash flows of the simulation for the representative farms over the forty year time period. Over the forty years the average cash

flows are approximately $219, $76, $100, $259, and $221 thousand for the farms in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively. The overall trends between farms in average annual cash flow is consistent with the trends in perpetual wealth of the operations as discussed above. The average annual cash flows slightly decrease initially, in years two to four of the simulation. Further examination of the cash flows with static assumptions conclude that in these years average simulated crop prices of barley, durum wheat, and spring wheat are slightly lower than for other years, resulting in lower revenues. For example in year two of the simulation average spring wheat price is $0.19 per kilogram, while the 2008 and 31 year average prices were $0.32 and $0.22 per kilogram, respectively. In years three and four average simulated barley price was $0.13 per kilogram, while the 2008 and historic average prices were $0.21 and $0.15 per kilogram, respectively. The effect is elevated for the farm under irrigated production since there is a greater proportion of wheat (spring and durum) grown. All other expenses and revenues are relatively consistent. It is hypothesized that due to the nature of the price models using lagged variables and a 2008 starting price, the first several years of the simulation are more variable than subsequent years.

Figure 6.1 – Modified net cash flows for representative farms over the 40 year time period



6.1.1 Validation of Representative Farm Models

Simulation models are used in this study to predict the quantitative costs and benefits of BMP adoption. It is impossible to model all possible actions and events that can occur on cropping operations, but stochastic simulation analysis is employed to account for potential variability in outcomes. However, models are not useful for use in decision making unless they accurately represent and reproduce behaviours that occur in real systems (Macal, 2005). Many land use models use parameter sensitivity and error propagation, but do not consider full model validation (Kok et al., 2001). This is in part due to the objectives of the studies, to explore future scenarios that do not currently exist, and therefore do not have a benchmark for comparison (Kok et al., 2001). Verification and validation of models ensures some credibility is accounted for in modelling social systems (Macal, 2005), such as in agricultural production.

Verification ensures that models are programmed correctly and perform as intended (Macal, 2005). Verification for this study is done using price and yield model comparisons to historical data. Sensitivity analysis of input and BMP parameters, discussed later in this chapter, also ensure verification of model specifications. However, these tests do not ensure that the farm models are accurately and correctly reflective of real farms in the areas of interest. Verification improves the degree of statistical certainty, but Macal (2005) notes that no computational model will ever be guaranteed to be completely error free.

Ideally, validation of the representative farm models discussed in this project would be through comparison of the model farms to real farms in the respective areas, of the same size and crop characteristics. However, the real world system does not exist in this case, or in many cases of simulation analysis (Macal, 2005). Therefore, there are associated practical difficulties in validating models (Kok et al., 2001).

Chapter 4 discusses the benefits of using NPV analysis with Monte Carlo simulation as the method to determine costs and benefits of BMP adoption on agricultural operations. This provides basis for techniques validation in theory, but does not ensure validation of the complex relationships modelled. Koeckhoven (2008) uses simulation output to validate similar farm level models. It is suggested that the cash rental rate of land can be determined by half of the contribution margin (direct revenue minus direct expenses) to account for the possibility of renters to profit from agricultural activities on the land (Koeckhoven, 2008). Koeckhoven (2008) also suggests that the annualized cost is a good approximation of the contribution margin for crop production. Table 6.2 compares the annualized NPV per hectare and half the contribution margin, in year 40, per hectare, to land rental rates, by soil zone, in Alberta. Land rental rates were obtained for the year 2010 from AARD (2011-b). Comparing the contribution margin estimate to the Alberta land lease rates in 2010, the values are within the range for rental rates for the farms in the Brown (irrigated), Brown (dryland), and Dark Brown soil zones. However, the contribution margin values are higher than the rental rates for the farms in the Black and Dark Grey soil zones. A similar pattern is apparent when comparing the annualized NPV per hectare to the rental rates, with the exception of the farm in the Brown (dryland) soil zone, where the annualized value is lower than the rental rate range.

Table 6.2 – Comparison of annualized NPV and half of the contribution margin in year 40 to land rental rates in Alberta, per hectare

Soil zone	Annualized NPV	Half of Year 40 Contribution Margin	Rental Rates (2010)[a]		
			Minimum	Maximum	Average
Brown, irrigated	$235.69	$236.44	$123.50	$741.00	$226.42
Brown, dryland	$65.31	$103.53	$81.51	$160.55	$124.07
Dark Brown, dryland	$84.54	$101.90	$81.51	$160.55	$124.07
Black, dryland	$274.29	$221.16	$46.31	$197.60	$124.19
Dark Grey, dryland	$311.37	$228.08	$34.58	$185.25	$124.71

[a] Rental rate values obtained from AARD (2011-b), Custom Rates Survey.

An alternative method to comparing annualized values and the contribution margin (net of the amount assumed to be profit) is to compare the total value of the operations (i.e., NPV with perpetuity) per hectare to farmland values. This type of comparison uses revealed preference theory to assume that there is a relationship between land property prices and the property characteristics (Swinton et al., 2007), in this case the ability of the land to support agricultural production. Farmland values, specifically for grain production, were obtained by Farm Credit Canada (FCC) from September 2009 to September 2011 (FCC, 2011). Table 6.3 provides the comparison of NPVs obtained from the simulation models and farmland values for crop land. Farmland values are reported by county or municipal district and were determined based on the representative counties for each corresponding representative soil zone, as defined in Chapter 3. Comparing the NPV results with farmland values it appears that the simulation values under estimate the value of land for farms in the Brown (irrigated and dryland), Dark Brown, and Black soil zones. The NPV per hectare of the farm in the Dark Grey soil zone is within the range of farmland values in this soil zone. It should also be noted that the NPV per hectare for the farm in the Black soil zone is close to the range of farmland values in this region.

Table 6.3 – Comparison of NPV and farmland values, per hectare

Soil zone	NPV	Farmland Values (2010-11)[a]		
		Minimum	Maximum	Average
Brown, irrigated	$2,356.89	$5,607	$12,842	$9,609
Brown, dryland	$653.06	$1,162	$5,513	$2,822
Dark Brown, dryland	$845.39	$2,116	$5,004	$3,574
Black, dryland	$2,742.95	$2,818	$6,472	$4,800
Dark Grey, dryland	$3,113.72	$2,108	$3,467	$2,642

[a] Farmland values obtained from FCC (2011).

While it is difficult to validate simulation models due to simplifying assumptions made that are not realistic, the combination of land rental rates and farmland values results in the models being consistent with at least one approach, and that these models are useful in predicting the costs and benefits of BMP adoption. It is assumed that the separate verification and sensitivity analysis, as presented later in this chapter, of BMP parameters retains the validation of the representative farm models.

6.2 Crop Rotation Beneficial Management Practices Results

This section presents and discusses results for the rotational BMPs. Alfalfa hay is added to rotations on the irrigated farm in the Brown soil zone and on the dryland farms in the Dark Brown, Black, and Dark Grey soil zones. Field peas are added to rotations on all farms under dryland production. Legume green manures are added to rotations as a partial or complete replacement for summerfallow on dryland farms in the Brown and Dark Brown soil zones. Oats are added in rotations on farms in the Black and Dark Grey soil zones. Rotations that combine the BMP crops are also examined in this section. See section 5.4.1 for an explanation of each alternative rotation in terms of its role as a BMP.

As noted earlier, the BMPs are compared to the baseline scenario using the NPVs calculated from the simulation analysis. In the case of the rotational BMPs the annualized mean NPV per hectare from the baseline scenario (i.e., $A_{Baseline}$ in Equation 6.1) is subtracted from the annualized mean NPV per hectare for the particular BMP (i.e., A_{BMP}).

The difference represents the effect (positive or negative) of the BMP, expressed in annual terms per hectare of the farm. Positive (negative) values represent a positive (negative) impact of the BMP on farm wealth. The difference is then divided by the baseline annualized mean NPV per hectare to express the difference in percentage terms (Equation 6.1).

$$[(A_{BMP} - A_{Baseline})/A_{Baseline}] * 100\% \qquad (6.1)$$

6.2.1 Alfalfa Hay

When alfalfa hay is added to rotations there is a reduction in the percentage of other crops grown. Specifically, there are approximately 378, 533, 365, and 274 hectares of land converted from crop production to forage production when a three year alfalfa hay stand is adopted in rotation for farms in the Brown (irrigated production), Dark Brown, Black, and Dark Grey soil zones, respectively. As discussed in Section 5.4.1.1 other effects of adopting three year stands of alfalfa include nitrogen fixing benefits in soil and improved yields in subsequent crops after the stand has been terminated.

The mean NPV of the farms increases when alfalfa hay is adopted in rotations due to beneficial assumptions made for subsequent crop yields and input costs. The average price of alfalfa hay is lower than the average price of all grain and oilseed crops considered in the analysis, but alfalfa hay produces relatively higher yields per hectare for all crops except for barley production in the Dark Grey soil zone. Also, per hectare direct expenses for alfalfa hay production is lower for all other crops considered in the baseline and alfalfa hay rotations. The net effect is that average cash inflow per year and per hectare for alfalfa hay is lower on all farms when compared to the crops being replaced (i.e., reduced in acreage) to adopt alfalfa hay in rotation, including barley, canola, durum wheat, and spring wheat. The results in terms of increased mean NPV (i.e., from increased net cash for the entire simulation period) for the representative farms are therefore due to the yield and nitrogen benefits for crops following alfalfa hay in rotation.

Table 6.4 displays the mean and standard deviation values for the NPV variable and calculates the mean as an annual value per hectare of farm land. In the fifth column of this table the annual value of the operation with the BMP is compared with the annual value from the baseline scenario, column five in Table 6.1. The results show that the addition of alfalfa hay has the strongest effect on the farm situated in the Dark Brown soil zone with a difference in the mean value of the farm after adoption of approximately $63 per hectare per year. This is an increase of 75% as compared to the base rotation. The second strongest effect is seen on the farm in the Brown soil zone under irrigated production. Here the present value of the farm is approximately $2.8 million with a standard deviation of approximately $0.4 million. Compared to the base rotation adding alfalfa hay on the irrigated farm in the Brown soil zone increases the annual mean value of the operation by 15%. Adding alfalfa hay to the farms in the Black and Dark Grey soil zones changes the value of the farms by approximately $48 and $32 per hectare per year, respectively. The percent change as compared to the base rotations on these farms are 17% and 10% for the Black and Dark Grey farms. In terms of differences between farms, a larger benefit from adding alfalfa hay is apparent for the farm located in the Dark Brown soil zone as compared to the other areas and is partly due to the way alfalfa hay fits in the rotations and replaces other crops and practices. In the Dark Brown soil zone alfalfa hay fits into the rotation as three years of alfalfa followed by the base rotation. Therefore, summerfallow occurs less frequently in the crop rotation, which improves the revenue generated by the farm, as this is a practice that does not generate revenue.

For all farms adding alfalfa hay increases the mean value of the operation. However the standard deviation of each operation is reduced when alfalfa hay is added to rotation. Standard deviation decreases by 15, 26, 29, and 26% for the farms in the Brown (irrigated), Dark Brown, Black, and Dark Grey soil zones. The lower standard deviation indicates that the range of outcomes is closer to the mean outcome after alfalfa is added to rotation, as compared to the base rotation. It appears that adding alfalfa hay somewhat reduces the uncertainty of production among producers in all relevant soil zones and production types. The reductions in standard deviation are also attributed to the standard error of alfalfa hay in the SUR model for price estimates in Chapter 5. Table 5.18 provides the standard error estimates, with the estimate for alfalfa hay being the lowest of all crops in the model.

As discussed earlier for the baseline results, the cropping operations may be considered to have a portfolio of risky cropping enterprises. One factor affecting the variability of portfolio returns is the number of "assets" included in the portfolio. In particular, as the number of assets increases (all else being equal) the portfolio variance decreases. With this rotational BMP, an additional crop enterprise is added to the portfolio. Therefore, it might be expected that NPV variability would decrease. As well, portfolio variability is affected by the correlation between returns for the portfolio assets. In the case of alfalfa yields, there is an assumed positive correlation with other crop yields. In modelling alfalfa prices, however, as discussed in Chapter 5 the error term for the alfalfa price equation is not correlated (i.e., correlation equal to zero) with the error terms for the other crop price equations. This contributes to a lower correlation between alfalfa returns and other crop returns, which in turn would result in portfolio variance being reduced from the addition of the alfalfa enterprise.

It should be noted that while reduced risk is observed from the model results this may not occur in reality. In practice, hay production is dependent on many factors. Yields and price are affected by adverse weather during harvest of hay as rain at certain times may decrease the quality of hay and decrease the price, while lack of precipitation may also result in only one cut of hay, where the model always predicts two cuts of hay.

Table 6.4 – Results of NPV variable for alfalfa hay rotation on representative farms

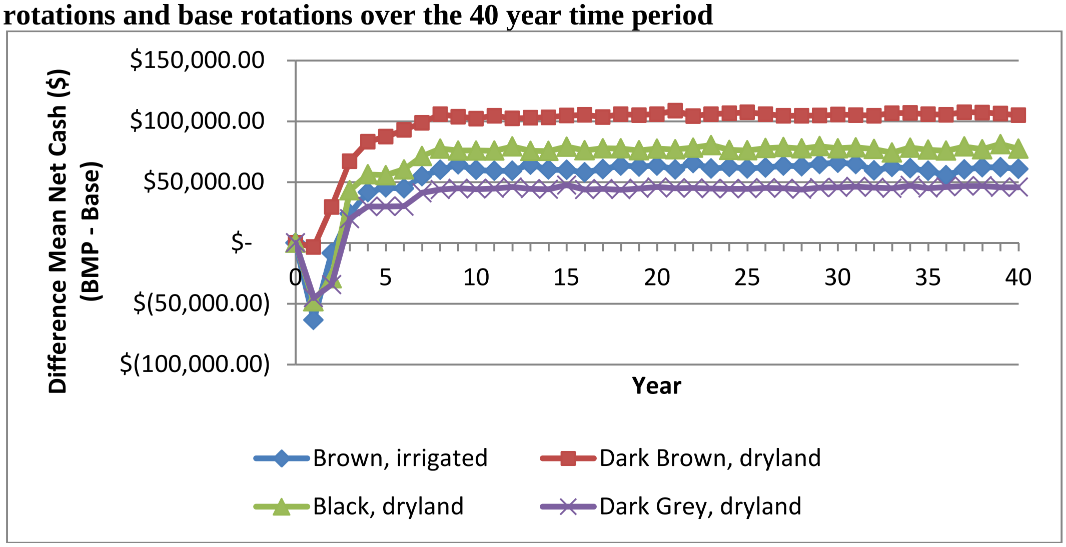
Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Brown, irrigated	$2,814,897	$359,244	$271.71	$36.02	15%
Dark Brown, dryland	$1,917,264	$221,454	$148.05	$63.51	75%
Black, dryland	$3,336,329	$236,190	$322.04	$47.74	17%
Dark Grey, dryland	$2,668,590	$170,301	$343.45	$32.08	10%

The modified net cash flow difference between the base rotation and adoption of alfalfa hay in rotation over the forty year period for all representative farms is shown in Figure 6.2. Since BMPs are adopted starting in time equals one at time zero the difference between adopting BMPs and the base scenario is zero. Initially, the difference in cash flows between the alfalfa hay BMP and the base scenario is negative for most of the representative farms. This result is caused by a combination of two factors. First, as discussed earlier, while the expected cash flow associated with alfalfa hay is positive, it is less than the corresponding cash flow per hectare for other crops in the rotation. Since the benefits of adopting alfalfa hay in rotation are not apparent until the initial alfalfa stand is “broken” and the land is seeded to a different crop, the resulting difference in net cash flow is negative. As well, the cash flow for the first year of alfalfa in rotation is lower than for the remaining duration of the stand since there are establishment costs associated with this crop. As the stand is established net cash flows from alfalfa hay increase and stabilize. For these reasons, in the first year after alfalfa hay is adopted most of the farms have a negative difference when compared to the base rotations. After the initial period of low cash flows the difference between the alfalfa hay adoption and the base scenario becomes positive and stabilizes at approximately 62, 105, 77, and 45 thousand dollars for the farms in the Brown (irrigated), Dark Brown, Black, and Dark Grey soil zones.

The exception to this pattern is the Dark Brown soil zone farm. There is no initial decrease in expected cash flows from adoption of alfalfa hay on this representative farm. This difference is caused by the impact of reduced frequency of summerfallow when alfalfa is added to the rotation. The increased revenue from more land under production compensates for the initial drop in expected cash flow from alfalfa hay adoption.

Stabilization of the difference in cash flows occurs as the benefits of having an alfalfa stand in the crop rotation are fully realized. The benefit is largest in the Dark Brown soil zone as there is a larger area affected with this being the largest farm to adopt alfalfa hay in rotation. Also, there is no drop in the difference in mean net cash from the BMP rotation and baseline results on the farm in the Dark Brown soil zone due to the reduction of land allocated to summerfallow when alfalfa hay is adopted (see Table 5.34). The overall effect is the lowest on the farm in the Dark Grey soil zone as this has the smallest area affected by including an alfalfa hay stand in rotation. The farms in the Brown and Black soil zones are the same size and also have approximately the same overall area of land affected by the change in the crop rotation. However the benefits of alfalfa hay are stronger on the irrigated farm due to an expected higher yield with irrigated production. The overall annual cash flow benefit of growing alfalfa hay under irrigation in the Brown soil zone is greater than the benefit of growing alfalfa hay in the Black soil zone where the overall yield benefit for subsequent crops is greater.

Figure 6.2 – Modified net cash flow difference between adopting alfalfa hay in crop rotations and base rotations over the 40 year time period



6.2.2 Field Peas

Similar to alfalfa hay, when field peas are added to the base rotation there is a decrease in the percentage of other crops grown due to land base constraints. Field pea production is assumed to use approximately 155, 207, 162, and 122 hectares of land on dryland farms in the Brown, Dark Brown, Black, and Dark Grey soil zones, respectively. Benefits of adopting field peas in crop rotations include reduced nitrogen fertilizer costs in the subsequent crop and a yield benefit for the subsequent crop.

Overall, when field peas are adopted into the rotations the value of the farms is increased. Table 6.5 displays, for each representative farm, NPV means and standard deviations, mean annualized NPV per hectare, and the percent difference in the annual value relative to the baseline scenarios. The addition of field peas increases the annual value of the farm in the Brown soil zone by $42 per hectare, a 65% difference from the base rotation. In the Dark Brown soil zone adding field peas increases the value of the farm by $28 per hectare per year, which is a 33% increase from the base rotation. In the Black soil zone the addition of field peas actually decreases the annual per hectare value of the farm by $2, which is a 1% difference as compared to the base rotation. However this is largely due to the reduction of acreage allotted to crops with higher production value such as canola. In the Dark Grey soil zone adding field peas to the crop rotation increases the annual wealth value of the farm by $5 per hectare which is a 2% increase as compared to the base rotation in this soil zone.

Similar to adding alfalfa hay to the rotation, adding field peas to rotations decreases the standard deviation of the NPV variable for all farms examined. However the effect is smaller here. Adding field peas to the rotation decreases the standard deviation by 1%, 7%, 10% and 6% for the farms in the Brown, Dark Brown, Black and Dark Grey soil zones. Adding field peas to the rotation slightly reduces the uncertainty of production. This effect is most noticeable on the farm in the Black soil zone for which adding field peas did not result in an increased value of production. Similar to the effect observed in alfalfa hay the decrease in standard deviation is likely due to increased diversification in the crop portfolio, resulting in decreased risk.

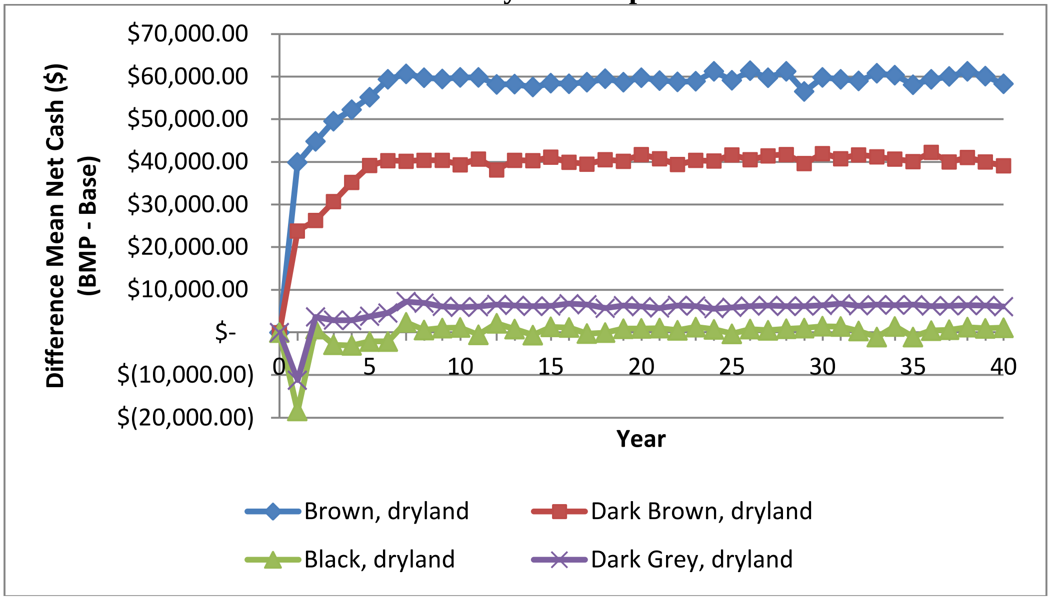
Table 6.5 – Results of NPV variable for field pea rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Brown, dryland	$1,394,374	$344,382	$107.67	$42.37	65%
Dark Brown, dryland	$1,459,713	$276,665	$112.72	$28.18	33%
Black, dryland	$2,823,872	$299,176	$272.57	-$1.72	-1%
Dark Grey, dryland	$2,457,592	$216,222	$316.29	$4.92	2%

The modified net cash flow difference between adopting field peas in rotations and the base rotations is shown in Figure 6.3. For the farms in the Brown and Dark Brown soil zones the benefit of adding field peas to rotations is immediately positive. This is due to reductions in the acreage of land allocated to summerfallow for these farms. The full effect of adding field peas to the southern soil zones is apparent after ten years when the mean net cash differences between the field pea BMP and the baseline rotation are approximately $59,000 and $41,000 per year for the Brown (dryland) and Dark Brown soil zone farms, respectively.

For the farms in the Black and Dark Grey soil zones there is an initial drop in net cash the first year field peas are adopted. This is due to the reduction in acreage available for higher value production crops such as canola. As well, yield and input cost benefits of field peas to subsequent crops do not occur until the second year field peas are in rotation. After year ten the benefit of adopting field peas, as compared to the base rotation, on net cash stabilize at approximately $625 and $6,230 per farm and per year for the farms in the Black and Dark Grey soil zones, respectively.

Figure 6.3 – Modified net cash flow difference between adopting field peas in crop rotations and base rotations over the 40 year time period



6.2.3 Legume Green Manures

Legume green manures are added to rotations for the southern Alberta dryland farms as a complete or partial replacement for summerfallow. In the case of the Brown (dryland) soil zone farm, prior to adopting this BMP there were approximately 310 hectares per year of land under summerfallow. The BMP results in this being reduced by half, to approximately 155 hectares. The other 155 hectares previously allocated to summerfallow practices are seeded to a legume green manure. For the Dark Brown soil zone farm, there were approximately 310 hectares of summerfallow in the base rotation. Adoption of this BMP results in all of this being seeded to legume green manures; that is, summerfallow is reduced to zero.

Having land under summerfallow has some costs, but there are typically higher costs associated with land seeded to legume green manures. The benefits of seeding land to legume green manures are outlined in section 5.4.1.3. However, the simulation results indicate that the costs of adopting legume green manures into the rotations outweigh these benefits, given the assumptions of the models. The mean and standard deviation values for NPV, the mean annualized NPV values per hectare, and the percentage change in the mean annualized values for this BMP are shown in Table 6.6. The addition of legume green manures to the rotation results in average annualized values of approximately $60 and $74 per hectare for the farms in the Brown and Dark Brown soil zones, respectively. These represent reductions of 8% and 12%, respectively, compared to the base rotation. Changes to the standard deviation as a result of adding legume green manures are minimal and do not present any significant change in uncertainty as compared to the base rotation.

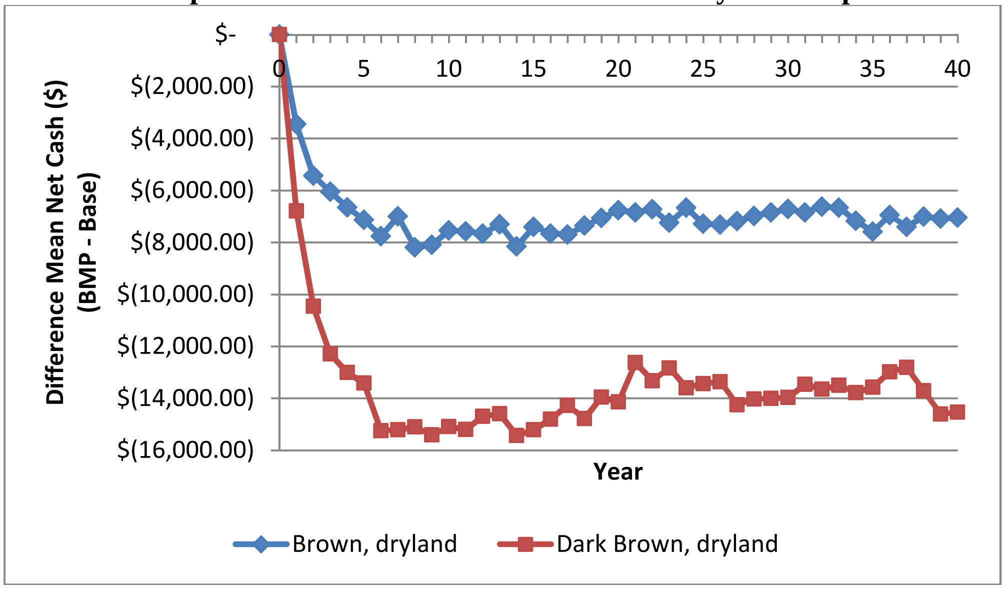
The benefits associated with this BMP are reduced nitrogen costs in subsequent years. It is assumed that the benefit to subsequent crops increases with the number of times legume green manures is present in rotation with benefits occurring from reduced input costs for nitrogen fertilizer. Conversely, the conversion from summerfallow to legume green manure results in a net increase in crop costs; that is, additional costs of seeding and ploughing legume green manures are greater than the costs associated with summerfallow being replaced. As well, legume green manures may deplete more soil moisture, as compared to summerfallow, and as such there is potential for a yield decrease in subsequent years. The simulation results indicate that the net effect of these changes is “negative” in terms of reduced cash flow and wealth. It should be noted that the model does not consider other long term benefits of legume green manures, such as improved soil organic matter content from reduction in summerfallow and increased residue returned to the soil. Incorporating these longer term effects of green manure would increase the potential for improvements in farm wealth as a consequence of adopting this type of BMP.

Table 6.6 – Results of NPV variable for legume green manures rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Brown, dryland	$778,252	$345,417	$60.10	-$5.21	-8%
Dark Brown, dryland	$962,575	$296,480	$74.33	-$10.21	-12%

The annual difference in the modified net cash flow between the base rotation and adding legume green manures to rotation is shown in Figure 6.4. The effect of adding legume green manures to rotation, as compared to the base rotation, is negative for both farms in all forty years considered. The full effect of adding legume green manures is evident after approximately twenty years. It takes longer for the full effect of legume green manures to be seen due to the increasing benefits with the number of times it occurs in rotation. The average difference between the base rotation and legume green manures rotation in terms of annual cash flows is approximately -$7,000 and -$14,000 for the farms in the Brown and Dark Brown soil zones. The negative impact is stronger on the farm in the Dark Brown soil zone since all summerfallow in rotation is replaced with legume green manures on this farm. The negative impact is amplified from the assumption that there is potential for yield losses in crops following legume green manures due to potential soil moisture depletion in dry years. The initial decline in cash flow from adoption of this BMP is due to the transition of land away from summerfallow to legume green manures in rotation, which are associated with higher input costs.

Figure 6.4 – Modified net cash flow difference between adopting legume green manures in crop rotations and base rotations over the 40 year time period



6.2.4 Oats

Oats are added to rotations only in the northern (i.e., in the Black and Dark Grey soil zones) soil zones. When oats are adopted in rotations, 162 and 122 hectares per year of land are cropped as oats on the Black and Dark Grey soil zone farms, respectively. With the addition of oats, there is a proportionate reduction in the area for the other crops in rotation for the two farms; barley, canola, and spring wheat crops. Unlike the previously discussed BMPs which affect subsequent crops in terms of nitrogen requirements and/or yields, oats is considered a BMP simply due to the reduction in inputs, specifically chemical fertilizer and herbicide, necessary for this crop. As compared to spring wheat and barley, the fertilizer cost for oats is approximately $21 and $16 per hectare less in the Black and Dark Grey soil zones, respectively. Per hectare cost for chemical herbicide is approximately $28 for oats in the Black and Dark Grey soil zones, while it is approximately $86 and $43 per hectare for spring wheat and barley, respectively, in the same areas.[40]

Results for the representative farms that adopt oats into the rotation are shown in Table 6.7. Mean NPVs after adopting oats are approximately 2.5 and 2.4 million dollars with standard deviations of approximately 0.3 and 0.2 million dollars for the Black and Dark Grey soil zone farms, respectively. These represent reductions in both mean and standard deviation as compared to the baseline results. The annualized mean NPV of the farm in the Black soil zone after adopting oats is $246 per hectare. This represents a decrease of $29 per hectare per year, or a 10% reduction when compared to the base rotation. For the Dark Grey soil zone farm the annual mean NPV after adopting oats is approximately $305 per hectare, which is $6 per hectare per year lower, or a 2% reduction, when compared to the base rotation. The decreased mean NPV values are due to reduced net cash flows associated with oats relative to the crops being replaced in the rotation. In other words, lower revenues generated by including oats outweigh the input

[40] As noted in Chapter 5, oats should only be grown on fields where wild oats are not problematic as there are no herbicides available for control of wild oats when oats are grown.

cost reductions associated with this crop. The decrease in variance is likely attributable to two factors. First, lower expected returns tend to be associated with lower variability. Secondly, there is increased diversification in the portfolio of crop enterprises.

Table 6.7 – Results of NPV variable for oats rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Black, dryland	$2,545,356	$309,612	$245.69	-$28.60	-10%
Dark Grey, dryland	$2,372,483	$217,208	$305.34	-$6.03	-2%

The annual difference in the mean modified net cash flow between the base rotation and adding oats to rotation is shown in Figure 6.5. The effect of adding oats to the rotations on the farms in the Black and Dark Grey soil zones is negative in all simulated years. As noted earlier, while the costs of growing oats is slightly less than other crops this benefit does not seem to outweigh the lost extra revenue associated with the other crops from the base rotation. On the farm in the Black soil zone the effect is a loss of approximately $32,000 per year. On the farm in the Dark Grey soil zone the effect is a loss of approximately $5,000 per year.

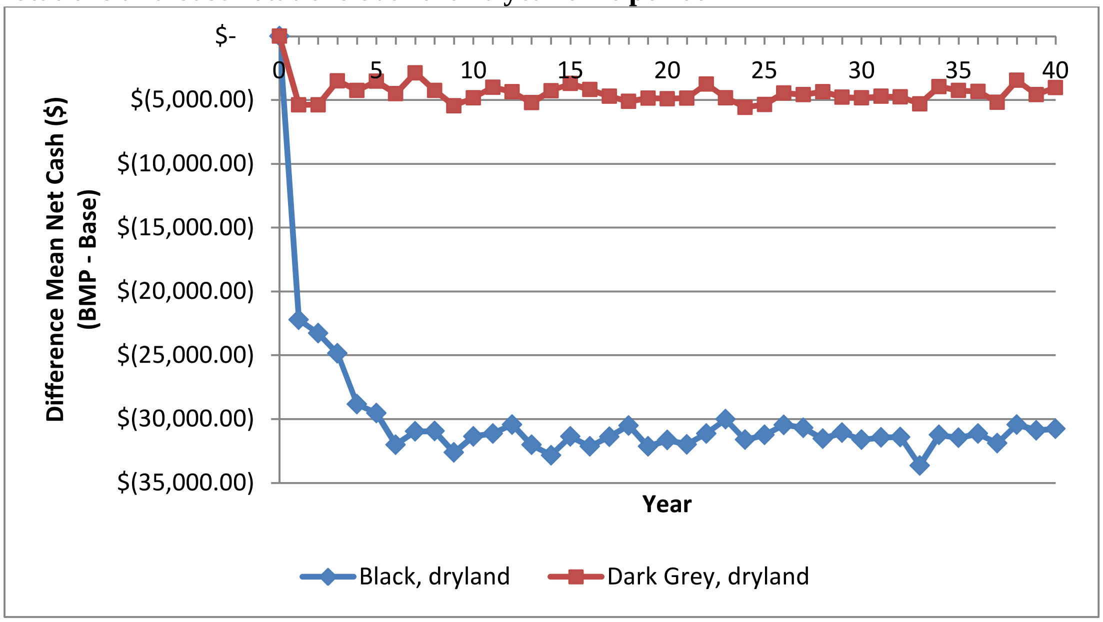
If the results for the two farms are compared, it appears that the impact of adopting oats is more significant (i.e., more negative) for the Black soil zone farm than for the Dark Grey soil zone farm. Part of this is due to the difference in costs associated with oats. Direct expenses from growing oats are approximately $241 and $201 per hectare on representative farms in the Black and Dark Grey soil zones, respectively, and this contributes at least in part to the differences in simulation results between the two farms.

Besides the differences in costs per hectare, however, much of the difference between the Black and Dark Grey soil zone farms is due to assumptions made about the oat yields. Chapter 5 (Section 5.2.1.1) provides an explanation and justification for detrending procedures used for the yield data to account for changes in crop technology over time. As discussed in Chapter 5, the oat yield data for the representative municipal district in the Dark Grey soil zone had a significant trend and so the oat yield data were detrended prior to estimating the yield distribution for the simulation model. Conversely, there was no significant trend in the oat yield data for the Black soil zone and consequently no detrending procedure was used. One outcome from detrending the oat yield data for the Dark Grey soil zone was a higher average yield than for the original data series. In particular, the resulting average was significantly higher as compared to the overall average in the Black soil zone. From the original municipal level data mean oat yields were approximately 2,431 and 2,817 kilograms per hectare in the Black and Dark Grey soil zones, respectively. After detrending, the average for the Dark Grey soil zone was approximately 3,537 kilograms per hectare.[41] This difference in average yield contributes significantly to the relative impact of adopting oats for the two farms. With an average yield similar to the original value for the Dark Grey soil zone farm (i.e., before

[41] Municipal level averages prior to detrending are provided in Appendix D, Table D.6. Detrended and fitted yield averages are available in Table 5.14.

correcting for the time trend), the impact on average modified net cash flows would be approximately $13,000. While this would still result in the net (negative) impact of adopting oats being smaller for the Dark Grey soil zone farm than for the Black soil zone farm, the difference between the farms would be much smaller.

Figure 6.5 – Modified net cash flow difference between adopting oats in crop rotations and base rotations over the 40 year time period



6.2.5 Combinations of BMP Crops

In this section the results from the combination of one or more rotational BMPs will be discussed. Combinations of BMP crops are examined to determine potential complementary effects of the crop rotation BMPs. Different combinations are possible in each soil zone, as shown in Tables 5.31 to 5.34.

6.2.5.1 Alfalfa Hay and Field Peas

Rotations that include alfalfa hay and field peas are possible for representative farms in the Dark Brown, Black, and Dark Grey soil zones under dryland production. Field pea production is not considered under irrigated production and alfalfa hay is not considered in the Brown soil zone under dryland production, for reasons discussed earlier. The areas allocated for alfalfa hay in rotations for the Dark Brown, Black, and Dark Grey soil zone farms are 339, 325, and 244 hectares, respectively. Field peas account for approximately 113, 108, and 81 hectares of land on the Dark Brown, Black, and Dark Grey soil zone farms, respectively.

Mean and standard deviation of NPV results, annualized mean value, and comparison of the change in annual value to the baseline results from the farms that adopt alfalfa hay and field peas in rotations simultaneously are provided in Tables 6.8. The annualized NPV per hectare in the Dark Brown soil zone is approximately $198 per hectare when alfalfa hay and field peas are added to rotation. This is a difference from the base rotation of approximately 135% as a benefit to the producer. The standard deviation of this variable also decreases with this rotation by approximately $173,000. For the farm in the Black soil zone the annual value of the farm increases by over $30 per hectare to approximately $305 per hectare when alfalfa hay and field peas are included in the rotation. The standard deviation of this farm also decreases by approximately $120,000 when these two crops are included, as compared to the base rotation. On the farm in the Dark Grey soil zone adding alfalfa hay and field peas increases the value of the farm by almost $20 per hectare as compared to the base rotation. The standard deviation of this value also decreases on this farm by approximately $130,000 as compared to the base rotation.

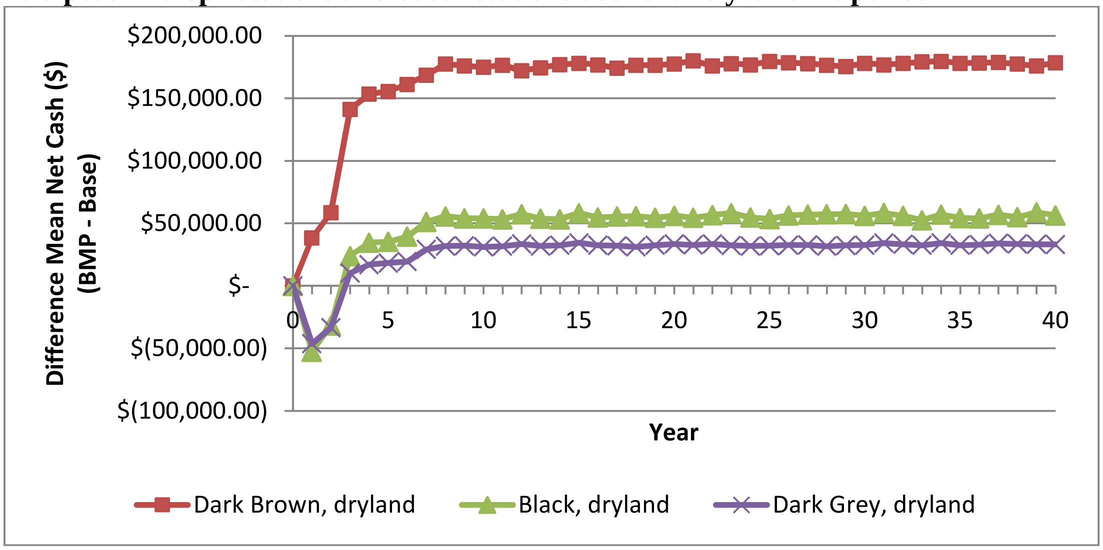
For all farms that consider adding alfalfa hay and field peas simultaneously the mean value of the operation increases while the standard deviation decreases. As previously mentioned the decrease in standard deviation may simply be due to assumptions in the models. The increases in the annual mean values from adding two BMP crops are consistent with the findings of the individual BMP crops. On the farms representative of the Black and Dark Grey soil zones adding both alfalfa hay and field pea results in an annual value of the operations in between the higher value when only alfalfa hay is adopted and the lower value when only field pea is adopted. This result is consistent with land restrictions as the benefits reflect the tradeoffs of land allocated for each crop in rotation. Conversely, for the Dark Brown soil zone the benefit seems large and additive. However, while there are still land constraints, as for the other two farms considered for this rotation, when both field peas and alfalfa hay are adopted land is no longer allocated for summerfallow on the representative farm in the Dark Brown soil zone. The seemingly additive effect of field pea and alfalfa hay on the farm in the Dark Brown soil zone occurs due to all land having crops harvested every year, whereas when these BMPs are considered individually there is still land allocated to summerfallow, a practice where revenue is not generated.

Table 6.8 – Results of NPV variable for alfalfa hay and field peas in rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Dark Brown, dryland	$2,568,349	$250,880	$198.33	$113.79	135%
Black, dryland	$3,155,688	$227,461	$304.60	$30.31	11%
Dark Grey, dryland	$2,570,017	$167,861	$330.76	$19.39	6%

The annual difference in the forty year modified net cash flows between adding alfalfa hay and field peas and the base rotation is shown in Figure 6.6. Adding these two crops to the base rotation is beneficial for all three farms considered. In the Dark Brown soil zone the benefit of adding the two crops is immediate and averages approximately $177,000 in the last 30 years of the analysis. The instantaneous positive effect is due to land being allocated to crops instead of summerfallow, where revenue is nonexistent. In the Black and Dark Grey soil zones the initial impact of adding field peas and alfalfa hay is negative. This is in contrast to the farm in the Dark Brown soil zone because summerfallow practices do not occur on these farms (i.e., in the Black and Dark Grey soil zones) in the baseline or any other rotation (i.e., all land is always used for cropping practices). However, as stated previously when the crop effects where discussed individually, once the yield and nitrogen benefits of these crops begin to take effect the impact is positive. The annual benefit of alfalfa hay and field peas in rotation in the Black and Dark Grey soil zones is approximately $56,000 and $33,000, respectively, for the last 30 years of analysis, as compared to the base rotation.

Figure 6.6 – Modified net cash flow difference between adopting alfalfa hay and field peas in crop rotations and base rotations over the 40 year time period



6.2.5.2 Alfalfa Hay and Legume Green Manures

The addition of alfalfa hay and legume green manures simultaneously to the base rotation only occurs on the farm situated in the Dark Brown soil zone. Adoption of legume green manures only occurs on representative farms in the Brown and Dark Brown soil zones under dryland production, and alfalfa hay is not adopted as a BMP on the farm in the Brown soil zone under dryland production. When alfalfa hay and legume green manures are added to the base rotation approximately 414 and 138 hectares are allocated to alfalfa hay and legume green manures, respectively.

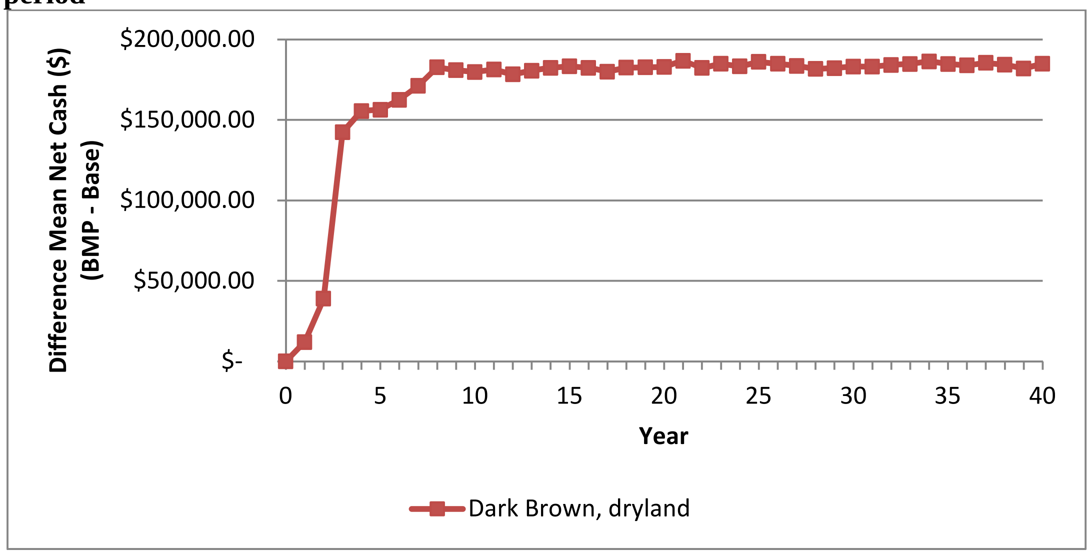
The mean NPV of the farm is approximately $2.6 million with a standard deviation of approximately $0.25 million after alfalfa hay and legume green manures are adopted in rotation. The results of the NPV variable, the annualized value, and comparison with baseline results are shown in Table 6.9. When compared to the base rotation this rotation increases the annual mean NPV of the farm by approximately $113 per hectare. The standard deviation of this variable also decreases by approximately $48,000. As compared to the base rotation the mean value of the farm is increased by 134%. While legume green manures are not a cash crop there is a yield and nitrogen benefit for subsequent crops and there is no longer any land allocated for summerfallow. With more land under production overall the annual benefit of this rotation is positive and is greater than considering alfalfa hay alone in this region, but slightly less than when alfalfa hay is adopted with field peas. When alfalfa hay is adopted alone summerfallow is still part of the crop rotation, but when alfalfa hay is adopted with legume green manures or field peas, summerfallow is not present in the rotation. While the adoption of legume green manures in rotation provides benefits to subsequent crops there is no revenue benefit, as there is when field pea is adopted.

Table 6.9 – Results of NPV variable for alfalfa hay and legume green manures in rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Dark Brown, dryland	$2,562,013	$249,690	$197.84	$113.30	134%

The difference in the annual modified net cash flows over 40 years is shown in Figure 6.7. Adding alfalfa hay and legume green manures to the farm in the Dark Brown soil zone results in immediate benefits. The average cash flow difference between this BMP rotation and the base rotation for the last 30 years considered is approximately $183,000. This is consistent with the changes in allocation from summerfallow for this rotation and the benefits from adopting a forage crop with annual crop production.

Figure 6.7 – Modified net cash flow difference between adopting alfalfa hay and legume green manures in crop rotations and base rotations over the 40 year time period



6.2.5.3 Alfalfa Hay and Oats

Adding alfalfa hay and oats to the base rotation can occur on the farms in the Black and Dark Grey soil zones. As previously mentioned oats are only adopted as a crop BMP on farms in the Black and Dark Grey soil zones. Including alfalfa hay in rotation is also adopted on these farms as a BMP. When this rotation occurs there are 324 and 108 hectares of land allocated to alfalfa hay and oats, respectively, for the Black soil zone farm and 243 and 81 hectares of land allocated to alfalfa hay and oats, respectively, for the Dark Grey soil zone farm.

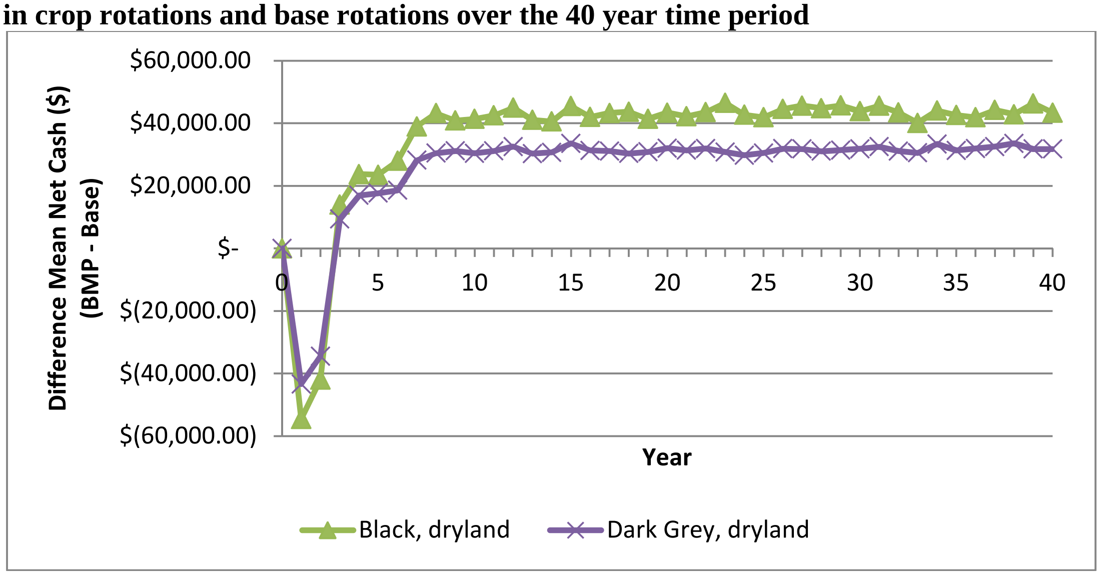
The mean and standard deviation results of the NPV variables for the farms are provided in Table 6.10. The annualized mean NPV of the farms are approximately $294 and $330 per hectare with standard deviations of approximately $0.24 and $0.17 million for the farms in the Black and Dark Grey soil zones, respectively. The annual value of the farms increases by approximately $20 and $18 per hectare for the farms in the Black and Dark Grey soil zones, respectively, when alfalfa hay and oats are added to the crop rotation, as compared to the base rotation. The increase in mean value on the farms is due to alfalfa hay in rotation. The increase is less than when alfalfa hay is added alone as including oats in the rotation slightly decreases the value of the farm, as discussed in section 6.2.4.

Table 6.10 – Results of NPV variable for alfalfa hay and oats in rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Black, dryland	$3,044,274	$237,405	$293.85	$19.55	7%
Dark Grey, dryland	$2,562,102	$169,710	$329.74	$18.37	6%

The annual difference in the modified net cash flows of the farms considered when adopting alfalfa hay and oats to rotation as compared to the base rotation is shown in Figure 6.8. The initial impact of adding these two crops to rotations in the Black and Dark Grey soil zones is negative. However once the yield and nitrogen benefit following alfalfa crops occurs the impact is positive. From years 11 to 40 of the cash flow analysis the average annual benefit of alfalfa hay and oats is approximately $43,449 and $31,535 for the farms in the Black and Dark Grey soil zones, respectively. The individual patterns from alfalfa hay alone and oats alone are apparent with a sharp decrease in value for the first two years of adoption and then an increase that is due to the adoption of alfalfa hay.

Figure 6.8 – Modified net cash flow difference between adopting alfalfa hay and oats in crop rotations and base rotations over the 40 year time period



6.2.5.4 Alfalfa Hay, Field Peas and Legume Green Manures

Alfalfa hay, field peas and legume green manures is adopted in the same rotation on the representative farm in the Dark Brown soil zone. This is the only representative farm where simultaneous adoption of these BMP crops occurs in the simulation models. Alfalfa hay is adopted on farms in the Brown (irrigated), Dark Brown, Black, and Dark Grey soil zones. Field peas are adopted on all dryland farms. Legume green manures are adopted on farms in the Brown (dryland) and Dark Brown soil zones. Therefore, the only representative farm that considers alfalfa hay, field peas and legume green manures is in the Dark Brown soil zone. For this BMP rotation approximately 339, 113, and 113 hectares of land per year are allocated to alfalfa hay, field peas, and legume green manures, respectively.

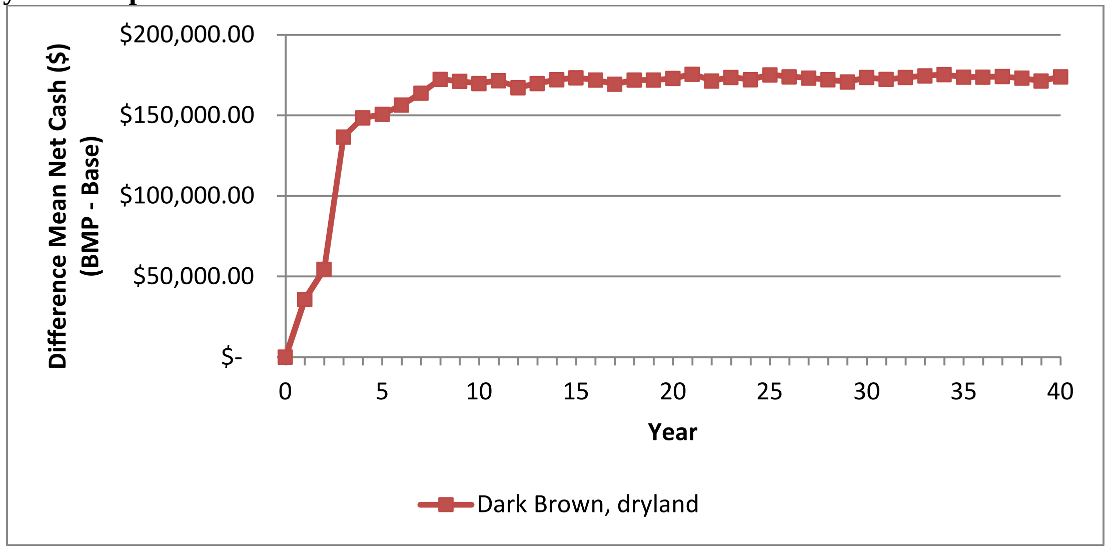
Simulation results for the NPV variable, including mean, standard deviation, annualized mean per hectare, and comparison of the mean with baseline results are provided in Table 6.11. The mean NPV of the farm for this rotation is approximately $2.5 million with a standard deviation of $0.25 million. When compared to the baseline results this BMP rotation increases the mean value of the operation by approximately $110 per hectare per year, a 131% difference. This value is greater than when alfalfa hay or field peas are adopted alone on this farm, but lower than when alfalfa hay and field peas are adopted simultaneously. The effect of including legume green manures slightly decreases the annual mean value of the farm per hectare as there is no revenue benefit of including this crop in rotation and there is potential for subsequent yield decreases.

Table 6.11 – Results of NPV variable for alfalfa hay, field peas, and legume green manures in rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Dark Brown, dryland	$2,523,564	$249,851	$194.87	$110.33	131%

The annual modified net cash flows of the difference between adopting alfalfa hay, field peas, and legume green manures and the base rotation is shown in Figure 6.9. The average impact of adopting this BMP in rotation is approximately $173,000 per year greater than the base rotation. The pattern of annual net cash flows is dominated by the effects of alfalfa hay and field peas with a strong increase immediately after this rotation is adopted. Annual increases are relatively strong until the fourth year when the full impact of adopting alfalfa hay occurs. The effect of legume green manures in the rotation is only seen if compared to alfalfa hay or field peas alone or in combination in the Dark Brown soil zone, with the effect slightly dampening these stronger impacts. Since the model does not consider other long term benefits of improved soil organic matter content the overall effect of legume green manures in this rotation lowers the annual cash flow slightly as compared to crop rotations without legume green manures in this region.

Figure 6.9 – Modified net cash flow difference between adopting alfalfa hay, field peas, and legume green manures in crop rotations and base rotations over the 40 year time period



6.2.5.5 Alfalfa Hay, Field Peas and Oats

BMP rotations that include adding alfalfa hay, field peas, and oats to the base rotation occur on the representative farms in the Black and Dark Grey soil zones. As previously mentioned, oats are only considered in rotation as a BMP on farms in the Black and Dark Grey soil zones. Alfalfa hay and field peas are also considered as a BMP on these farms, making the combination of these crops feasible in these locations. In the Black soil zone there are approximately 292, 97, and 97 hectares of land allocated to alfalfa hay, field peas and oats for this BMP rotation. In the Dark Grey soil zone there is proportionately less land allocated to these crops at 219, 73, and 73 hectares, respectively.

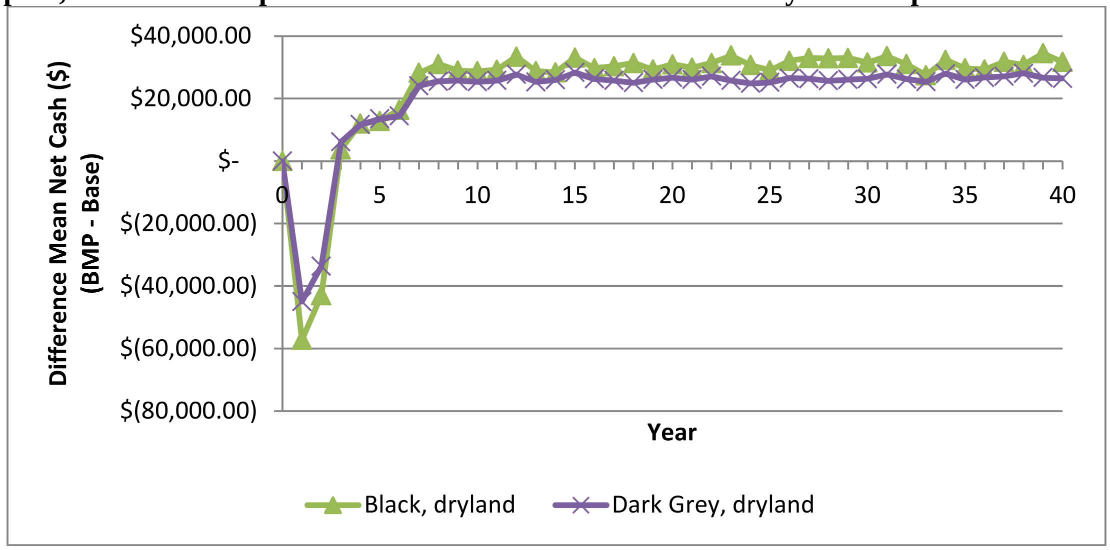
The results of the values of the two farms considered for this BMP rotation are provided in Table 6.12. The mean NPV of the farms increases by 4% for both farms as compared to the base rotation. The standard deviations are approximately $0.23 and $0.16 million for the representative farms in the Black and Dark Grey soil zones, respectively. The annual mean value of the Black soil zone farm increases by approximately $10 per hectare. In the Dark Grey soil zone the representative farm annual mean value increases by approximately $13 per hectare as compared to the base rotation. The increase in mean values is due to the inclusion of field peas and alfalfa hay into the rotation. However this impact is "dampened" by the effect of oats which has a negative effect on NPV. The resulting annualized value is less than the individual effect of including alfalfa hay in rotation but greater than the individual effect of including field peas in rotation. As more crops are included in rotations in these soil zones there is less land available for higher value crops such as canola.

Table 6.12 – Results of NPV variable for alfalfa hay, field peas, and oats in rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Black, dryland	$2,944,221	$225,512	$284.19	$9.90	4%
Dark Grey, dryland	$2,522,781	$163,807	$324.68	$13.31	4%

Figure 6.10 shows the difference in the modified net cash flows between adopting this BMP rotation and the base rotation for 40 simulation years. There is an initial decrease in cash flows; however the average difference from years 11 to 40 is approximately $31,000 and $26,000 for the farms in the Black and Dark Grey soil zones, respectively. The initial decrease occurs when the crops alfalfa hay and field peas are examined independently and there is a consistent decrease when oats are adopted independently so this effect is expected. It is also expected that the alfalfa hay effect will dominate the field pea and oat effects as there is more acreage of land allocated to this crop due to the logistics of incorporating a three year forage stand in a crop rotation. Therefore the increase due to alfalfa hay dominates and the benefits are apparent with a positive net cash flow after three years for both farms considered. This positive impact increases until approximately the eighth year in rotation.

Figure 6.10 – Modified net cash flow difference between adopting alfalfa hay, field peas, and oats in crop rotations and base rotations over the 40 year time period



6.2.5.6 Field Peas and Legume Green Manures

Rotations that consider adding field peas and legume green manures at the same time occur on the farms in the Brown and Dark Brown farms under dryland production. This crop combination is only viable on these farms since they are the only two that consider legume green manure adoption for complete or partial replacement of summerfallow. For both representative farms the land allocated to each of the crops (i.e., field peas and legume green manure) is approximately 155 hectares.

When field peas and legume green manures are adopted in crop rotations the mean NPV of the farms increases on the representative farms considered. The results of the mean and standard deviation of the NPV variable and the comparisons of these values to the base rotation are provided in Table 6.13. The mean value of NPV is approximately $82 and $121 per hectare per year for the farms in the Brown and Dark Brown soil zones, respectively. As compared to the base rotation this is an increase of approximately $15 and $36 per hectare per year for the farm in the Brown and Dark Brown soil zones, respectively.

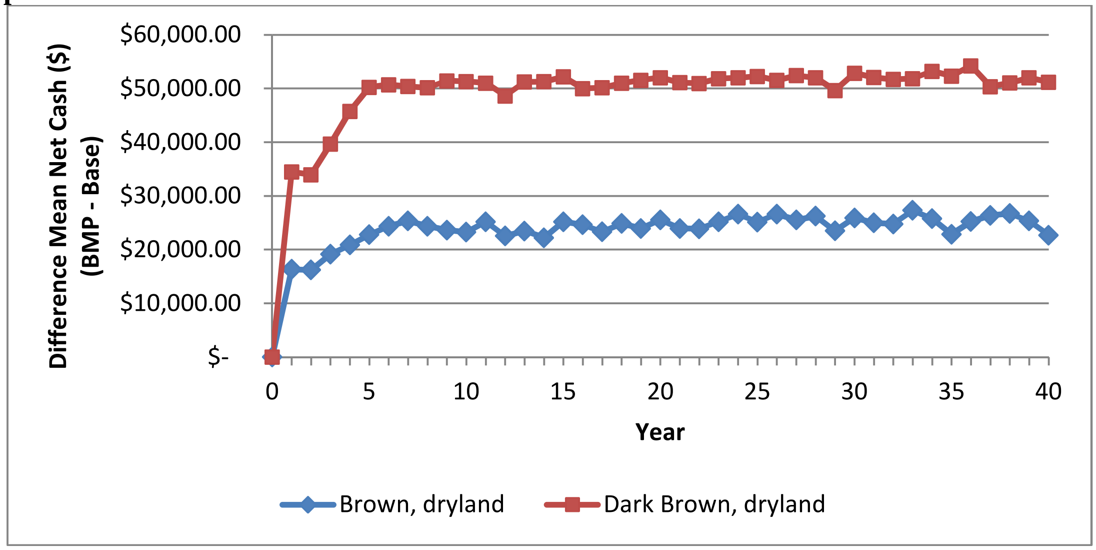
The $15 increase on the farm in the Brown soil zone is expected as it is less than the increase that occurs when field peas is adopted in rotation independently, which accounts for the minimizing effect legume green manures has due to higher costs as compared to summerfallow. The $36 increase on the farm in the Dark Brown soil zone is higher than the effect when field peas are adopted in rotation independently in this region. This relationship occurs because when field peas are added to rotation independently in the Dark Brown soil zone there is still summerfallow practice. When both field peas and legume green manures are added to rotation there is no longer any summerfallow in the Dark Brown soil zone. This allows more land to be allocated overall to revenue producing crops, while still having some land allocated for legume green manures. In the Brown soil zone, under dryland production, when both field peas and legume green manures are adopted in rotation simultaneously there is still land allocated for summerfallow.

Table 6.13 – Results of NPV variable for field peas and legume green manures in rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Brown, dryland	$1,068,009	$307,636	$82.47	$17.17	26%
Dark Brown, dryland	$1,563,429	$310,093	$120.73	$36.19	43%

Figure 6.11 shows the 40 year simulation results of the difference in the modified net cash flow for the BMP rotation and the base rotation. The annual benefit of including field peas and legume green manures in rotation in the soil zones are approximately $23,000 and $49,000 for the Brown and Dark Brown soil zones. As mentioned in the previous paragraph the effect of this BMP crop rotation seems greater in the Dark Brown soil zone as compared to the Brown soil zone. However this effect is due to logistics in land allocation for crops in this BMP rotation. The general pattern in net cash difference for this BMP is similar to the pattern when field peas are adopted independently.

Figure 6.11 – Modified net cash flow difference between adopting field peas and legume green manures in crop rotations and base rotations over the 40 year time period



6.2.5.7 Field Peas and Oats

Field peas and oats added to the base rotation are considered a BMP rotation in the Black and Dark Grey soil zones. Oats are only adopted as a BMP crop on farms in the Black and Dark Grey soil zones. Therefore this combination of BMP crops is only possible in these soil zones. On the representative farm in the Black soil zone there are 139 hectares allocated to each of the two added crops (i.e., field peas and oats). On the representative farm in the Dark Grey soil zone there are 104 hectares allocated for each of the BMP crops.

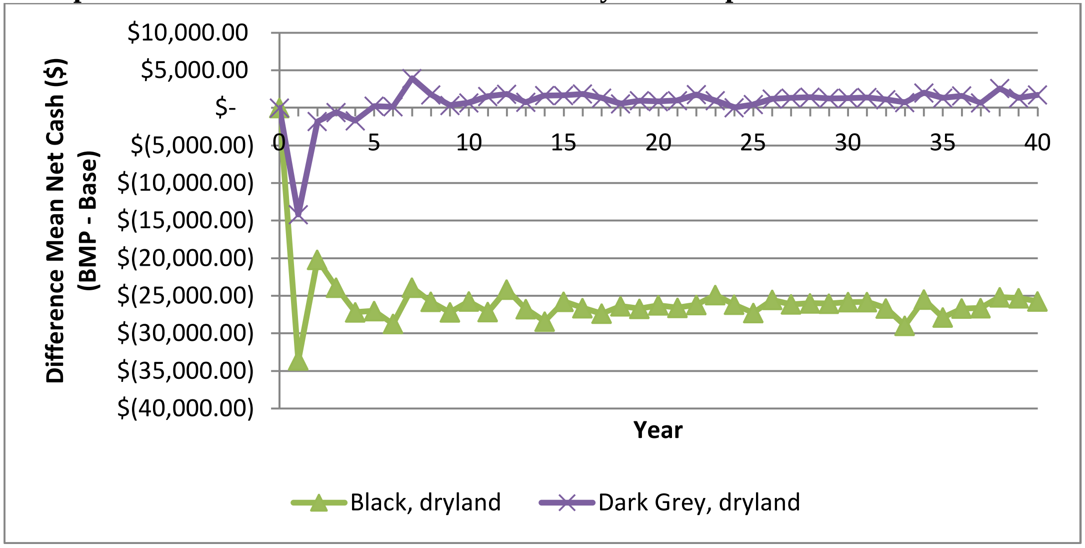
NPV of the farms with the BMP rotation is compared with the base rotation to determine the effect of this rotation. NPV results and comparisons to the base rotation are provided in Table 6.14. This rotation has a negative effect on the value of the operations. The mean values of the operations are approximately $248 and $310 per hectare per year on the farms in the Black and Dark Grey soil zones. This is a decrease in net value from the base rotation of 9% for the farm in the Black soil zone and approximately no change for the farm in the Dark Grey soil zone. As previously mentioned the value of oats as a cash crop is significantly less as compared to crops such as canola. The overall proportion of arable farm land producing canola decreases as other crops are added. The addition of field peas to the farm in the Black soil zone similarly showed a negative impact. The slight positive impact of field peas in the Dark Grey soil zone mitigates the negative effect of oats, making the overall effect of these two crops approximately zero in this location.

Table 6.14 – Results of NPV variable for field peas and oats in rotation on representative farms

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Black, dryland	$2,573,881	$284,952	$248.44	-$25.85	-9%
Dark Grey, dryland	$2,410,627	$205,674	$310.25	-$1.12	0%

The difference in annual cash flows between this BMP rotation and the base rotation are shown in Figure 6.12. In the Dark Grey soil zone the BMP rotation has an average annual effect of approximately $650 for the last 30 years of simulations. However in the Black soil zone the effect on the representative farm is approximately -$25,000 per year. For both farms considered there is a strong negative initial effect which somewhat recovers once the positive effect following field peas occurs. As mentioned in section 6.2.4 the large difference between the two farms may be due to detrending corrections made to the yield data in the representative region in the Dark Grey soil zone. These corrections were not necessary in the area representative of the Black soil zone. Also, costs of producing oats in the Dark Grey soil regions of Alberta are slightly lower as compared to regions in the Black soil zone.

Figure 6.12 – Modified net cash flow difference between adopting field peas and oats in crop rotations and base rotations over the 40 year time period



6.3 *Non-Rotational Beneficial Management Practices Results*

This section presents and discusses results for the non-rotational BMPs that are considered for the representative farms. The BMPs include adoption of shelterbelts, buffer strips with or without hay, and residue management. All non-rotational BMPs are considered for the five representative farms. BMP results are compared to results for the reference farms where there are no BMPs implemented. Adoption of residue management is compared to the baseline scenarios in the same manner as for rotational BMPs, that is, an annualized value per hectare of land over the whole farm is used. For BMPs that consider a reduction in crop acreage, such as adoption of shelterbelts and buffer strips, comparisons with the baseline results will be on a per hectare of crop land lost. In particular, the NPVs for the baseline and BMP scenarios are both converted to an annual basis, $ANPV_{Baseline}$ and $ANPV_{BMP}$, respectively. The difference between these two values is then divided by the hectares of cropland lost due to implementation of the BMP. The resulting value is the annual impact of the BMP per hectare of affected cropland (Equation 6.2).

$$[(ANPV_{BMP} - ANPV_{Baseline})/Hectares\ lost] \tag{6.2}$$

Results for combinations of non-rotational BMPs are also presented and discussed in this section. Results for scenarios where the non-rotational BMPs are combined with rotational BMPs from the previous section are not discussed in this chapter, but a summary of numerical results are provided in Appendix K.

6.3.1 Shelterbelts

Adopting shelterbelts as a BMP reduces total land area available for crop production. Hectares seeded to crops are reduced by 61.1, 95.4, 76.3, 45.8, and 22.9 hectares for the farms situated in the Brown (irrigated production), Brown (dryland production), Dark Brown, Black, and Dark Grey soil zones, respectively. Besides the effect in terms of reduced area for crop production, there are yield effects on land in proximity to the shelterbelts. As discussed in Chapter 5, there are yield benefits from adopting shelterbelts but these are limited to the area of land that is protected by the trees. Closer to the shelterbelts, however, there are yield decreases on land where crops are competing for soil moisture and nutrients with the shelterbelt tree species.

When shelterbelts are adopted on the representative farms the NPV decreases for the reference farms. This is consistent for all five farms. This result is largely due to the relatively high cost of adoption, including planting and maintenance costs, and the loss of cropland. The results of adopting shelterbelts on the mean and standard deviation of NPV of the farms are shown in Table 6.15 and compared as a total to the baseline results. Not surprisingly, the greatest total impact on NPV occurs for those farms with a greater area of land allocated to shelterbelts. The greatest overall cost occurs on the Brown soil zone (dryland) farm, which has the greatest area of land converted due to the higher potential for soil erosion. Conversely, the lowest overall impact is for the Dark Grey soil zone farm. Since there is lower concern for soil erosion in this area, fewer shelterbelts are adopted, and less crop acreage is lost. A similar pattern is present for the other farms in that the relative overall reductions in NPV are consistent with the amount of cropland lost due to shelterbelt adoption. Standard deviations of the NPV values also decrease when shelterbelts are adopted. The decrease is relatively small and is due to the overall decrease in the mean NPV of the operations when shelterbelts are adopted.

However, when considering the cost per hectare of crop land lost the impact is greatest for farms with the lowest potential to see reductions in soil erosion. On the representative farm in the Brown soil zone under irrigated production the annualized cost of shelterbelt adoption is \$317 per hectare of cropland allocated for shelterbelts. On the other representative farm in the Brown soil zone, but under dryland production, the annualized cost is \$195 per hectare of cropland allocated for shelterbelt adoption. In the Dark Brown soil zone the representative farm experiences an annualized cost of \$181 per hectare converted for shelterbelts. On the northern representative farms in the Black and Dark Grey soil zones the annualized cost of adopting shelterbelts is approximately $396 and $411 per hectare of cropland converted to shelterbelts, respectively.

These differences per hectare affected by the shelterbelt BMP are due to two factors. Per hectare costs of establishing shelterbelts are the same for all representative farms, but this is not the case for the yield impacts. When shelterbelts are adopted all farms experience an annual yield loss (i.e., in kilograms per hectare) in the area of land directly adjacent to shelterbelts and a yield benefit on land that is sheltered by the trees, but that is not in direct competition for moisture and nutrients. Farms in the Brown and Dark Brown soil zones experience a slightly higher yield loss in the areas directly adjacent to the trees as compared to the farms in the Black and Dark Grey soil zones. However, the yield benefit in the sheltered area is greater on the farms in the Brown and Dark Brown soil zones, as compared to the farms in the Black and Dark Grey soil zones. The other factor influencing the difference in per hectare results for the representative farms is the difference in value of crop production lost due to reduced crop acreage between the farms; that is, the farms with the higher NPV per hectare for the baseline scenario tend to incur a greater per hectare cost for the shelterbelt BMP.

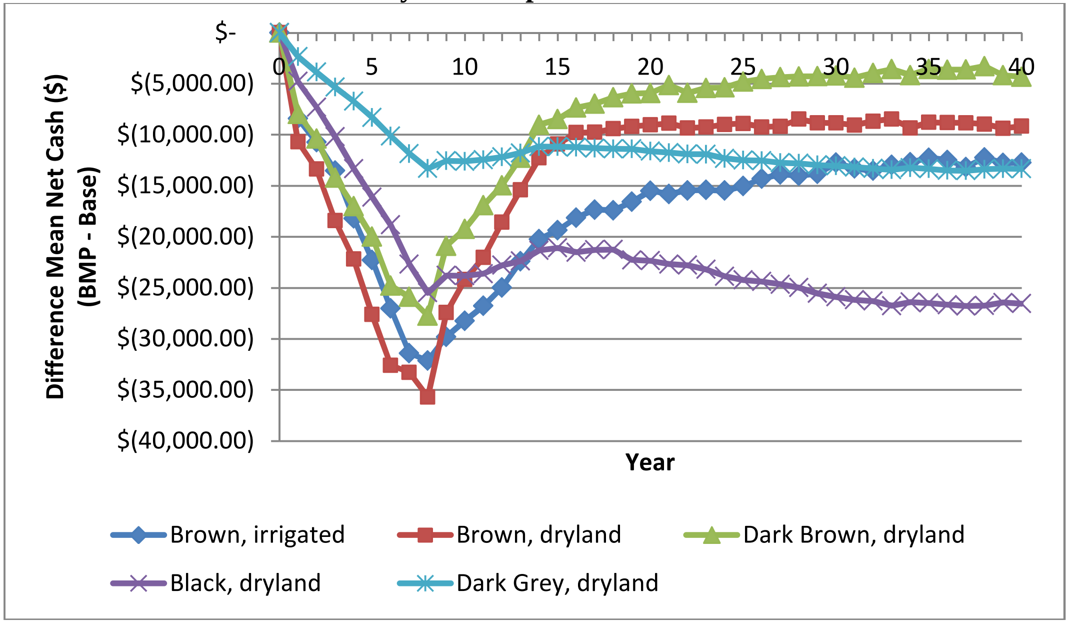
Table 6.15 – Results of NPV variable for representative farms adopting shelterbelts

Soil zone, production	Mean NPV	Standard deviation NPV	Difference in annualized NPV[a]	Annualized difference per hectare lost[b]
Brown, irrigated	$2,248,072	$414,808	-$19,366.30	-$316.96
Brown, dryland	$659,880	$339,125	-$18,582.71	-$194.79
Dark Brown, dryland	$956,363	$292,528	-$13,841.24	-$181.41
Black, dryland	$2,660,446	$324,231	-$18,124.90	-$395.74
Dark Grey, dryland	$2,325,182	$227,062	-$9,418.00	-$411.27

[a] Calculated as the annualized NPV for the BMP scenario minus the annualized NPV for the baseline scenario. [b] Calculated as the difference in annualized NPV divided by the hectares of land lost with shelterbelt adoption.

Figure 6.13 shows the difference in the cash flows between adopting shelterbelts as a BMP and the reference farms over 40 years. The initial cost of adopting the shelterbelts is seen through the significant increasingly negative difference between the BMP and the baseline scenarios until approximately the eighth year of the simulation. This pattern is due to the assumption that for all farms full adoption of this BMP occurs over an eight year period. That is, 12.5% of the total amount of land allocated for shelterbelts is converted per year, for eight years. After the eight year transition period, the differences in cash flows are moderated by lower input costs for the shelterbelts and some yield benefits from adoption. For the farms in the Brown and Dark Brown soil zones the recovery after this period is relatively consistent as there is a stronger yield benefit from shelterbelts in these areas as compared to the farms in the Black and Dark Grey soil zones.

Figure 6.13 - Modified net cash flow difference between farms adopting shelterbelts and baseline results over the 40 year time period



6.3.2 Buffer Strips

Similar to shelterbelts, implementing buffer strips around existing wetlands also removes land from crop production. Therefore adoption of this BMP is also expected to decrease the overall NPVs for the representative farms. As discussed in the previous chapter, a certain amount of wetland is assumed to be present on the representative farms. In particular, 2%, 4%, 4%, 6%, and 6% of the farm area is wetland for the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zone farms, respectively. It is further assumed that there is approximately one circular wetland, of appropriate size based on the above percentages, for every 64 hectares of land.

Before buffer strips are adopted as a BMP the land around the wetland is assumed to be cropped. The buffer strip BMP involves establishing 10 metre wide strips around all wetlands. The resulting loss in land for crop production varies by farm; approximately 6.96, 12.04, 12.04, 11.68, and 8.76 hectares of cropland are lost for the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey representative farms, respectively.

Table 6.16 shows the mean and standard deviation of the NPV for the farms after adopting buffer strips, the difference in mean annualized NPV with buffer strips adopted as a BMP and the baseline results, and the difference in NPV per hectare lost from buffer strip adoption. Overall, adopting buffer strips has a small impact on the overall NPV for the operations. There is approximately a 1% decrease in mean NPV observed for all farms, as compared to the reference farms. There is also a small decrease (i.e., approximately 1%) in the standard deviation for the NPVs, which is also related to the decrease in cropland available for production.

On a per hectare basis, however, the cost of this BMP is more significant. The annualized decrease in mean NPV as a per hectare of land converted to buffer strips ranges from approximately $95 to almost $350. This annual cost per hectare of adoption of buffer strips is proportional to the loss in value from crop production in the cropland allocated to adopt buffer strips. The impact of buffer strip adoption is most costly for the farm under irrigated production in the Brown soil zone. In this region crop yields are higher due to irrigation of crops. When land is removed from production this represents a higher cost per hectare lost. Similarly in the Black and Dark Grey soil zones the cost per hectare is relatively high due to higher production that is assumed to be in the area previously. The annualized cost of adoption per hectare lost is lowest in the Brown soil zone under dryland production and second lowest in the Dark Brown soil zone as yields are also lowest in these areas.

Table 6.16 – Results of NPV variable for representative farms adopting buffer strips without hay

Soil zone, production	Mean NPV	Standard deviation NPV	Difference in annualized NPV[a]	Annualized difference per hectare lost[b]
Brown, irrigated	$2,417,557	$421,760	-$2,417.80	-$347.39
Brown, dryland	$834,301	$344,328	-$1,140.57	-$94.73
Dark Brown, dryland	$1,081,114	$295,249	-$1,366.10	-$113.46
Black, dryland	$2,806,884	$327,738	-$3,481.10	-$298.04
Dark Grey, dryland	$2,389,698	$227,806	-$2,966.40	-$338.63

[a] Calculated as the annualized NPV for the BMP scenario minus the annualized NPV for the baseline scenario. [b] Calculated as the difference in annualized NPV divided by the hectares of land lost with shelterbelt adoption.

The results from adopting buffer strips with hay grown in the buffer areas are shown in Table 6.17. Mean NPVs for the representative farms are still below the baseline scenario values but are greater as compared to when buffer strips are considered without hay (Table 6.16). The change relative to the original buffer strip scenario is due to the income generated from the direct sale of hay produced in the buffer strip area. The annual mean costs of adopting buffer strips with hay are approximately $280, $20, $27, $222, and $277 per hectare for the farms in the Brown (irrigated), Brown (dryland), Dark Brown, Black and Dark Grey soil zones, respectively. When the results are converted to an annualized cost per hectare of land lost from the buffer strips the cost is lower than when hay is not grown and sold. However, the trend is the same with it being most costly on farms in the Brown soil zone under irrigated production and least costly on farms in the Brown soil zone under dryland production. Selling hay from the buffer strips reduces the mean annual cost of adopting buffer strips by approximately $67, $75, $86, $76, and $62 per hectare for the farms in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively.

Table 6.17 – Results of NPV variable for representative farms adopting buffer strips with hay

Soil zone, production	Mean NPV	Standard deviation NPV	Difference in annualized NPV[a]	Annualized difference per hectare lost[b]
Brown, irrigated	$2,422,233	$421,843	-$1,950.20	-$280.20
Brown, dryland	$843,273	$344,247	-$243.37	-$20.21
Dark Brown, dryland	$1,091,522	$295,291	-$325.30	-$27.02
Black, dryland	$2,815,807	$327,866	-$2,588.80	-$221.64
Dark Grey, dryland	$2,395,069	$227,822	-$2,429.30	-$277.32

[a] Calculated as the annualized NPV for the BMP scenario minus the annualized NPV for the baseline scenario. [b] Calculated as the difference in annualized NPV divided by the hectares of land lost with shelterbelt adoption.

The difference in annual cash flows over 40 years between adopting buffer strips and the reference farms is shown in Figure 6.14. Adopting this BMP reduces the annual cash flows by a small amount for all farms. As mentioned above the reduction of cash flows are due to the loss of agricultural land for the buffer strips which affects the revenue from crop sales. The average differences when comparing net cash when buffer strips are adopted and the baseline net cash are approximately -$2,590, -$1,234, -$1,503, -$3,774, and -$3,233 for the farms representative in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively (Figure 6.14). The trend for the farm under irrigated production is slightly different from the others as there is an increase in the difference in modified net cash flows in years three and four of the simulation model before the trend drops again and levels off. This effect is consistent with the trend observed in the baseline modified net cash flows for this representative farm.

The annual cash flow difference between adopting buffer strips with hay and the reference farms is shown in Figure 6.15. As compared to the cash flow differences without hay there is more visible variability from year to year. This occurs because of the variability in hay yields in the buffer strips; when the hay is sold this increases the difference in net cash with and without the option to sell hay from the buffers. Hay crops from the buffer strips are assumed to follow the pattern of alfalfa hay yields at a lower rate. The average difference between adoption of buffer strips with hay and baseline result net cash flows are approximately -$2,111, -$223, -$326, -$2,792, and -$2624 on farms representative of the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones. The average annual cost reduction from incorporating the option to bale and sell the hay ranges from approximately $1,200 on the farm in the Dark Brown soil zone to approximately $500 on the farm representative of the Brown soil zone under irrigated production.

Figure 6.14 - Modified net cash flow difference between farms adopting buffer strips and baseline results over the 40 year time period

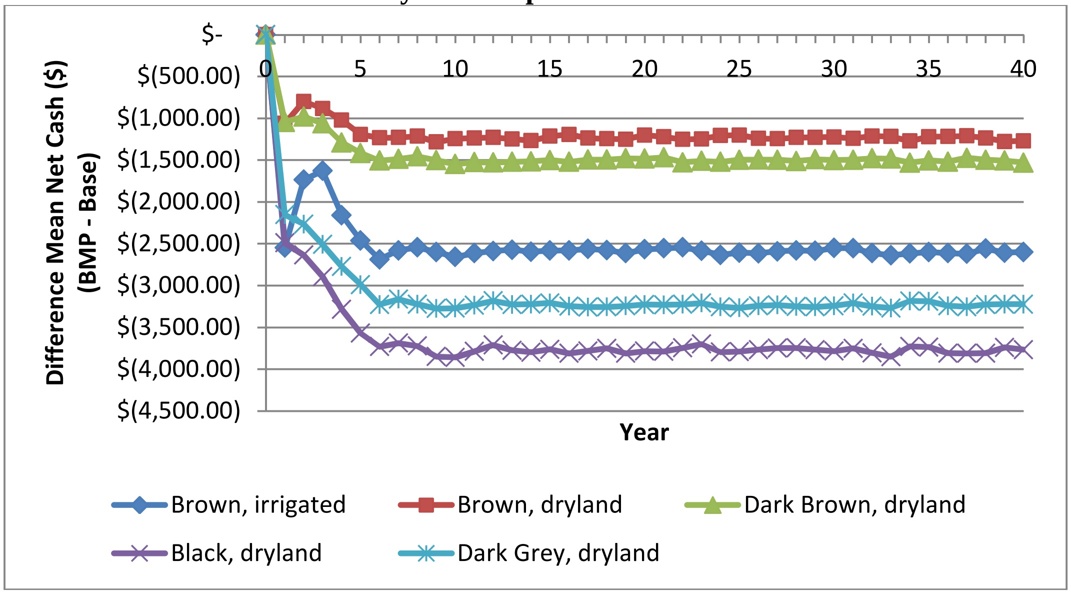
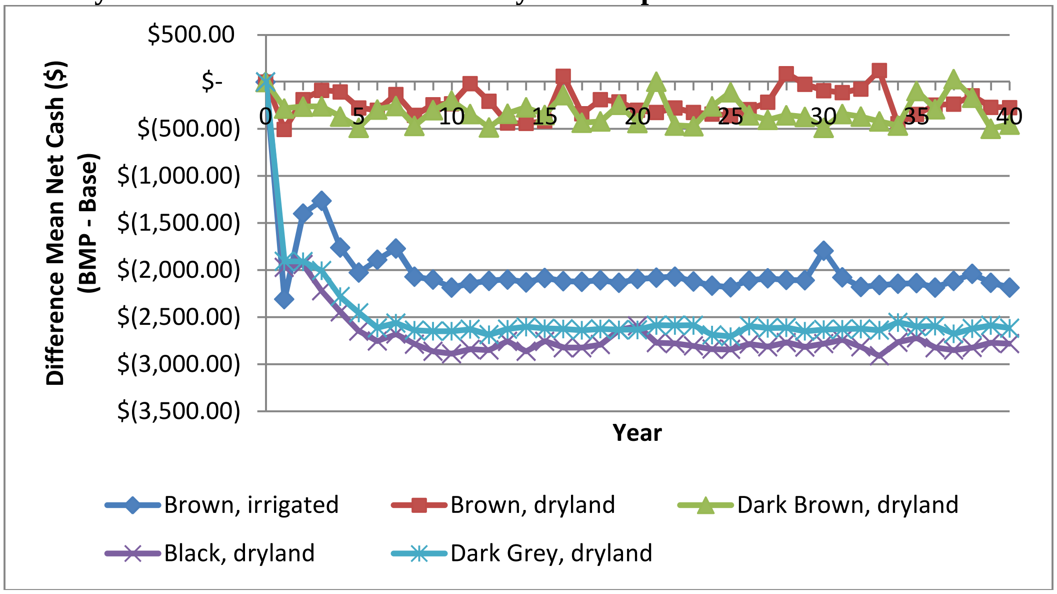


Figure 6.15 - Modified net cash flow difference between farms adopting buffer strips with hay and baseline results over the 40 year time period



6.3.3 Residue Management

As discussed in Chapter 5, an alternative baseline scenario is modelled for the purposes of comparison with results for the residue management BMP. In particular, in this revised baseline scenario wheat (durum and spring) and barley residue is harvested and sold every year. If residues are removed in a dry year[42] then subsequent yields may

[42] A dry year occurs when residue yield is less than the average residue yield minus one standard deviation.

decrease due to reduced ability to retain moisture. The subsequent yield decrease is drawn from a uniform distribution with a minimum value of -0.03 and a maximum value of zero (i.e., the maximum yield loss is 3%). When residues are removed the net benefit from selling the residue for $25 per 544 kilogram straw bale is approximately $5.80. Results from this alternative scenario are provided in Table 6.18. The revised baseline mean NPV values are higher than the original baseline due to the benefits from selling residues each year, which outweigh the potential cost (i.e., reduced yield in the subsequent year) of removing residue in dry years.

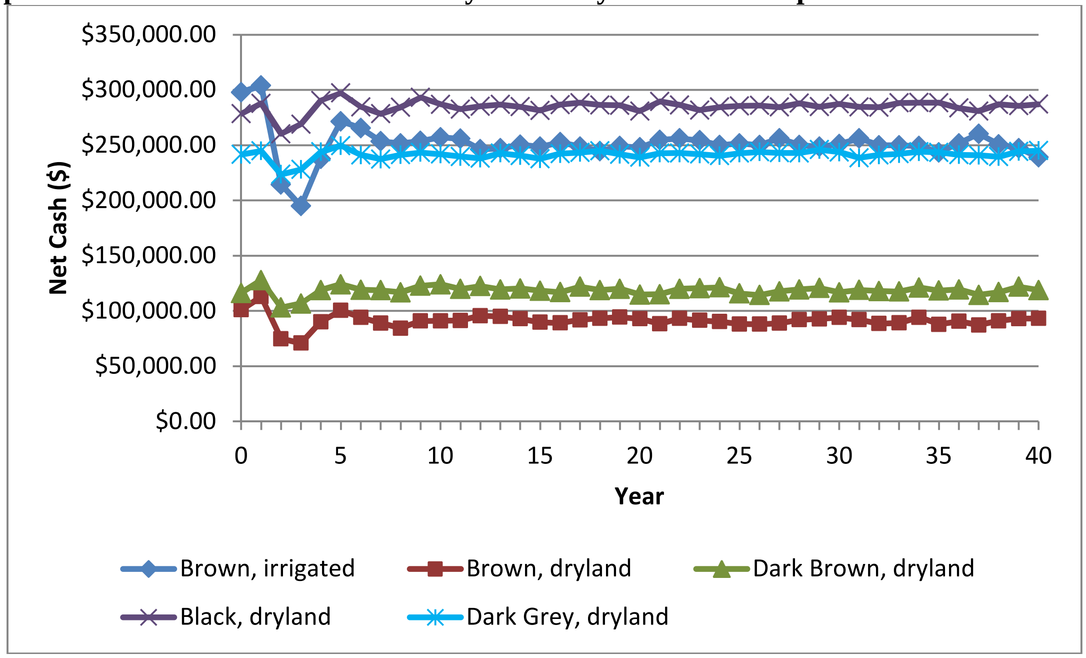
Table 6.18 – Baseline results of the representative farms for the variable NPV with residue removed annually for barley and wheat crops

Soil zone, production	Mean NPV	Standard Deviation NPV	Annualized Mean NPV per hectare	Annualized mean NPV difference per hectare[a]	Percent difference annualized mean NPV per hectare[b]
Brown, irrigated	$2,795,045	$424,532	$269.79	$34.10	14%
Brown, dryland	$1,008,116	$355,382	$77.85	$12.54	19%
Dark Brown, dryland	$1,297,274	$303,678	$100.18	$15.64	18%
Black, dryland	$3,110,800	$358,131	$300.27	$25.98	9%
Dark Grey, dryland	$2,630,588	$239,017	$338.56	$27.18	9%

[a] Calculated as the difference between annualized mean NPV per hectare minus the equivalent value for the original baseline scenario results (i.e., in Table 6.1). [b] Calculated as the percent difference relative to the original baseline scenario.

The annual cash flow pattern from the alternative baseline scenario is similar to the original baseline scenario (i.e., Figure 6.1) and is shown in Figure 6.16. The main difference is higher levels of net cash for all representative farms due to increased revenue from the sale of residue.

Figure 6.16 – Modified net cash flows for representative farms over the 40 year time period with residue removed annually for barley and wheat crops



Adopting residue management as a BMP on the representative farms implies that producers remove and sell residue in some years, while retaining residue to conserve soil moisture in other years. The purpose of retaining residue is to try and preserve soil moisture for use in the subsequent crop. This option applies for residues associated with barley, durum wheat, oats, and spring wheat. Residues for dry beans, canola, and field peas are assumed to always be retained as these crop residues are not easily removed and sold, but rather easily spread over fields. As discussed in Chapter 5, when residue management is adopted as a BMP there is potential for yield benefits. Also, as discussed earlier decisions about removing residue vary by farm but are static for each farm. Residues for the previously mentioned crops are removed every second, fifth, fourth, third, and third year for representative farms in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively. The results for this BMP are compared to the revised baseline[43] results (discussed above) where residues for wheat and barley are assumed to be removed every year.

Results for the residue management BMP are provided in Table 6.19. When compared to the revised baseline scenario net decreases are observed on all representative farms for adoption of residue management as a BMP.[44] The cost of this BMP, on an annual basis per hectare of cropland, ranges from just over $11 to over $26. The greatest numerical decreases are observed for the Black and Dark Grey representative farms. This is due to the higher volume of residue produced on these farms. With adoption of this BMP, there is a greater loss of returns from retaining the residue (i.e., foregone opportunity for sale of straw). In general, the results for this BMP suggest that for all of

[43] In the original baseline scenario there is no financial gain or yield effect from crop residues. In the revised baseline crop residues are sold and yield decreases can occur in dry years when residue is removed. The BMP scenario adds additional yield effect in dry years when residue is retained (yield increase) and in wet years when residue is retained (yield decrease).

[44] When the residue management BMP is compared to the original baseline scenario net increases occur.

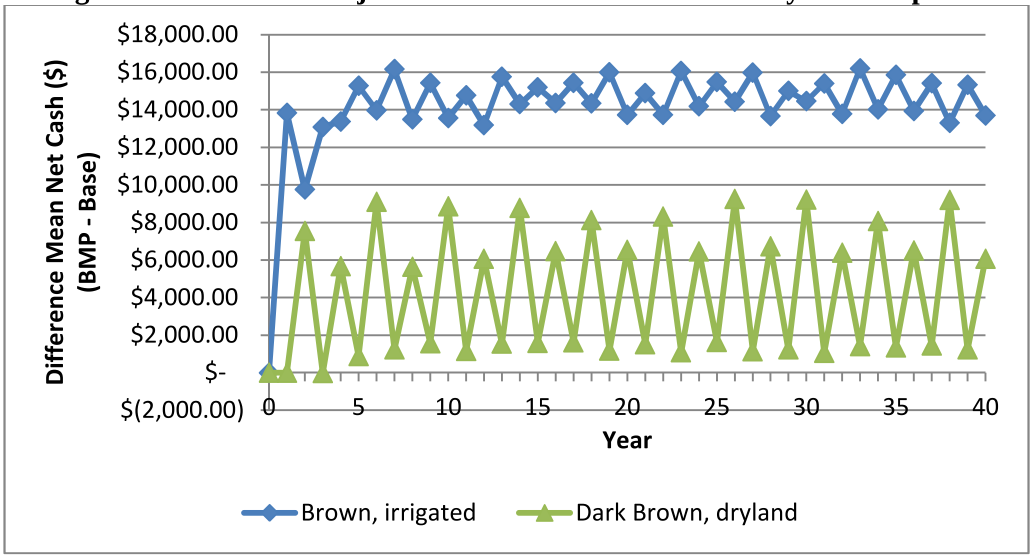
the farms the cost of the foregone opportunity to harvest and market crop residue, combined with the potential for reduced yield in some years (i.e., due to retaining residue in wet years), outweighs any benefits associated with yield increases from retaining residue in dry years.

Table 6.19 – Results of NPV variable for representative farms adopting residue management, as compared to the revised baseline results

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Brown, irrigated	$2,582,058	$424,000	$249.23	-$20.56	-8%
Brown, dryland	$864,268	$343,732	$66.74	-$11.11	-14%
Dark Brown, dryland	$1,133,498	$296,407	$87.53	-$12.65	-13%
Black, dryland	$2,872,261	$318,774	$277.25	-$23.03	-8%
Dark Grey, dryland	$2,427,078	$224,770	$312.37	-$26.19	-8%

Net cash flow differences from the baseline scenario, where barley and wheat residues are removed annually, and residue management as a BMP are shown in Figure 6.17 for representative farms in the Brown (irrigated) and Dark Brown soil zones. The pattern is similar for the other representative farms, and only two are chosen for representation in the figure for simplicity. As can be seen from this figure, the mean annual differences are negative and display significant year to year variability. The negative differences in cash flow are consistent with the earlier NPV results; that is, adoption of this BMP occurs with a net cost to the representative farms. The variability in cash flow differences is likely attributable to the fact that wheat and barley residue is now left on fields in certain years. Therefore, there are reduced cash flows from not selling straw residues. As discussed earlier, the potential for increased crop yields in subsequent years is not sufficient to offset these lost returns.

Figure 6.17 - Modified net cash flow difference between farms adopting residue management and residue adjusted baseline results over the 40 year time period



6.3.4 Combinations of Non-Rotational BMPs

The results from combining multiple non-rotational BMPs are presented in this section. As with the individual BMP scenarios, the NPV results for the combination BMP scenarios are compared with the results from the baseline scenarios. If land that is previously used for cropping purposes is reallocated for a non-rotational BMP (i.e., shelterbelts or buffer strips), comparisons are made using the annualized cost of the BMP per hectare removed from production. The only combination BMP that is examined in this section is simultaneous adoption of shelterbelts and buffer strips. Residue management is not examined in combination with the other two non-rotational BMPs because of the differences in assumptions for the baseline scenario used in the case of residue management.

6.3.4.1 Shelterbelts and Buffer Strips

Results from scenarios adopting shelterbelts and buffer strips and adopting shelterbelts and buffer strips with hay are provided in Tables 6.20 and 6.21. As expected from the results for the individual BMPs, the farm in the Brown soil zone under dryland production shows the largest impact from adoption, while the farm with the least impact from adoption of shelterbelts and buffer strips is in the Dark Grey soil zone. The effect from shelterbelt adoption dominates the buffer strip effect since shelterbelts have significantly higher adoption costs and take relatively more land out of crop production. When hay is grown and sold in the buffer strips the total and annual values of the representative farms increase by approximately 1% (for all farms) relative to the non-hay buffer strip. This reflects the additional revenue generated by the hay production. There is still a net cost to the representative farms, however, relative to the baseline scenarios.

When shelterbelts and buffer strips are adopted simultaneously the amount of land available for crop production is reduced by approximately 68, 107, 88, 57, and 32 hectares on the representative farms in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively. Annualized results are compared with baseline scenario results and divided by the number of hectares lost when adopting shelterbelts and buffer strips. The differences in annualized mean NPV per hectare lost for simultaneous adoption of the two BMPs are consistent with the results for the individual BMPs; that is, the overall effect appears to be additive.

On the farm representative of the Brown soil zone under irrigated production the average annual cost of adopting shelterbelts and buffer strips is approximately $320 per hectare lost without hay and approximately $313 per hectare lost when the option to sell hay grown in the buffer strips is employed. In the Brown soil zone under dryland production the mean annual cost of adoption is approximately $183 and $175 per hectare lost without and with hay sold from buffer strips. When buffer strips and shelterbelts are adopted simultaneously on the farm in the Dark Brown soil zone the mean annual cost of adoption, as compared to the baseline scenario, is approximately $172 and $160 per hectare lost without and with hay sold from the buffer strips, respectively. Similar results occur in the Black and Dark Grey soil zones where the average annual costs are approximately $376 and $391 per hectare lost without hay, and approximately $360 and $374 per hectare lost when hay is sold from buffer strips, for farms in the Black and Dark Grey soil zones, respectively. When considering the impact of the BMPs by the amount of land lost from adoption the impact is greatest for the farms in the Black and Dark Grey soil zones, while the overall impact was greatest for the dryland farms in the Brown and Dark Brown soil zones.

Table 6.20 – Results of NPV variable for representative farms adopting shelterbelts and buffer strips

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare lost (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Brown, irrigated	$2,223,964	$412,282	$214.67	-$319.97	-9%
Brown, dryland	$648,847	$336,682	$50.10	-$183.23	-23%
Dark Brown, dryland	$942,688	$290,370	$72.79	-$172.16	-14%
Black, dryland	$2,625,799	$321,009	$253.46	-$375.60	-8%
Dark Grey, dryland	$2,295,542	$224,880	$295.44	-$391.09	-5%

Table 6.21 – Results of NPV variable for representative farms adopting shelterbelts and buffer strips with hay

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Annualized mean NPV difference per hectare lost (BMP – Baseline)	Percent difference annualized mean NPV per hectare (BMP – Baseline)
Brown, irrigated	$2,228,703	$412,602	$215.13	-$313.01	-9%
Brown, dryland	$657,725	$336,535	$50.79	-$174.96	-22%
Dark Brown, dryland	$953,085	$290,277	$73.60	-$160.39	-13%
Black, dryland	$2,634,503	$321,087	$254.30	-$360.46	-7%
Dark Grey, dryland	$2,301,048	$224,873	$296.15	-$373.70	-5%

Figures 6.18 and 6.19 show the differences in annual net cash flow between farms adopting shelterbelts and buffer strips (without and with hay, respectively) and baseline net cash flows over the forty year simulation period. The shelterbelt effect dominates the trends shown for all farms in both figures as the large initial dip in net cash flows from the high costs of adoption. When buffer strips are adopted with shelterbelts there is a larger net decrease in cash flows as compared to the baseline scenarios as this BMP contributes to land being taken out of production for use as a BMP. When hay is grown and sold in the buffer strips the difference is mitigated slightly by additional annual income.

Figure 6.18 - Modified net cash flow difference between farms adopting shelterbelts and buffer strips and baseline results over the 40 year time period

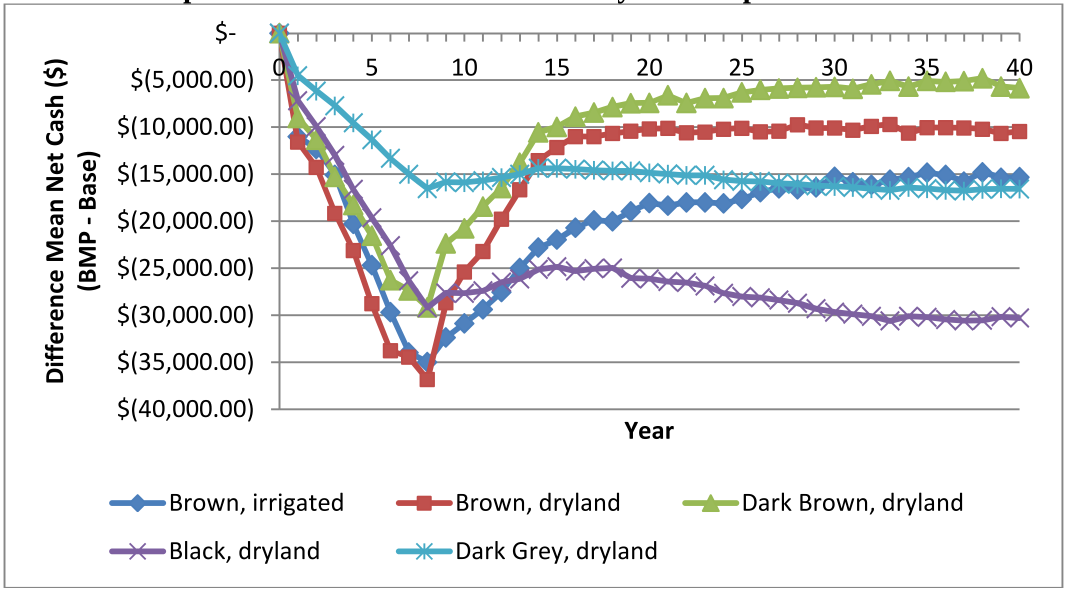
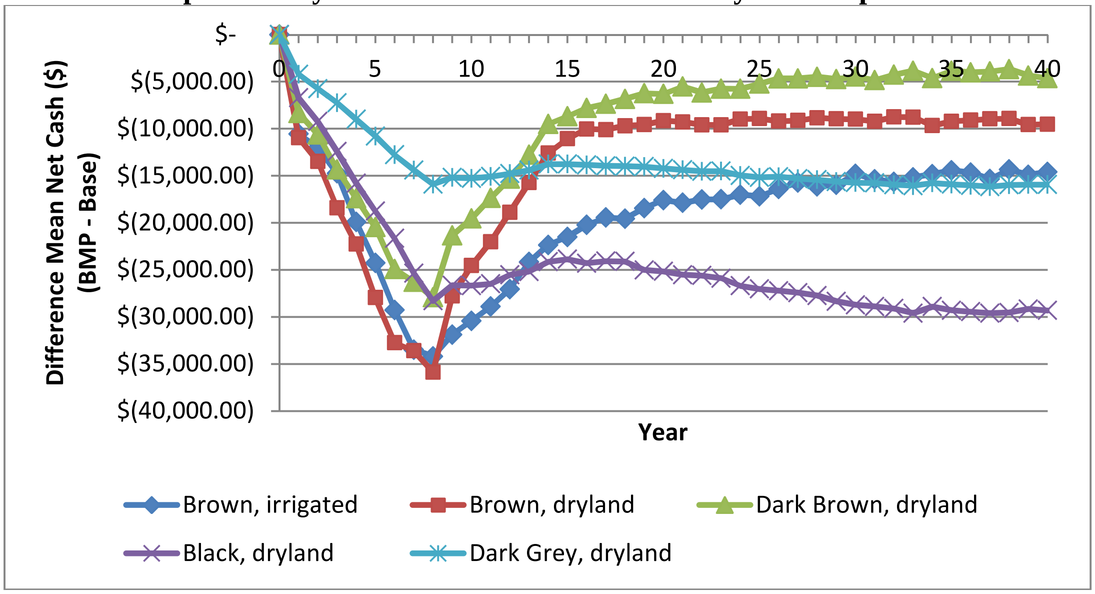


Figure 6.19 - Modified net cash flow difference between farms adopting shelterbelts and buffer strips with hay and baseline results over the 40 year time period



6.4 Sensitivity Analysis

Some of the parameters in the simulation models used in this study are uncertain or unknown. In these cases, sensitivity analysis was performed to determine the effect of these parameters on the NPV of the representative farms. In other words, baseline and BMP scenarios were re-simulated, varying the magnitude of these parameters in order to examine the sensitivity of the BMP results to the parameter values.

In this section results from analysis assuming potential increases or decreases in the input parameters that determine costs or benefits from BMP adoption are discussed. Sensitivity analysis is performed on the yield effect parameters associated with the crop rotation BMPs for alfalfa hay, field peas, and legume green manures. Sensitivity analysis is also done for the magnitude of fertilizer cost reductions following these crops due to nitrogen fixing abilities of the legumes added to rotations. In all cases the sensitivity analysis is done assuming adoption of individual BMPs (i.e., no combination BMP scenarios are considered). Sensitivity analysis is also performed for non-rotational BMP scenarios. In particular, the sensitivity of results to yield change parameters associated with implementation of shelterbelts and introduction of crop residue management are also examined in this section. Sensitivity analysis for the impact of the width of the buffer strips is also examined. For these analyses (i.e., non-crop rotation BMPs), the base crop rotations are maintained in all cases.

6.4.1 Sensitivity Analysis for Alfalfa Hay BMP Parameters

Information from prior literature and expert opinion was used to determine that the addition of alfalfa hay in rotations could result in benefits to subsequent crops from both yield increases and nitrogen fertilizer savings. These effects would be most prominent in the first three subsequent crops, which for the dryland farms are always spring wheat, canola, and barley. On the irrigated farm durum wheat takes the place of barley as the crop grown in the third year after an alfalfa stand. There was significant variability in the values reported or suggested for the magnitude of these effects.

Assumptions were made regarding the scale of the effects and the effects were simulated assuming a uniform distribution with a minimum and maximum possible effect. The sensitivity of the minimum and maximum values for the uniform distributions is analyzed in the following sections.

6.4.1.1 Sensitivity Analysis of Yield Effect Parameters

Yield effects following alfalfa hay stands are calculated based on draws from uniform distributions; that is, the yield effect is assumed to be stochastic. As discussed in Chapter 5, crop yields following alfalfa hay may be increased due to rotational benefits of including perennial legumes in rotation. On farms in the Brown and Dark Brown soil zones the potential yield increase following alfalfa hay is assumed to be between 10 and 80% for the first crop following alfalfa hay, and between 4 and 74% for second and third crops following alfalfa hay. For the Black and Dark Grey soil zone farms the yield increase is between 20 and 110% for the first crop following alfalfa hay, and between 14 and 104% for the second and third crops. In each case the increase is applied to the "normal" yield that is drawn from the particular crop yield distribution for that year.

Sensitivity analysis for these upper and lower limits is performed, with three increases and decreases of 0.05 each on both minimum and maximum values of the uniform distributions. In the following discussion, 'AH Min1' and 'AH Max1', denote the minimum and maximum yield effects, respectively, in the first subsequent year following alfalfa hay, and 'AH Min2' and 'AH Max2' denote the minimum and maximum yield effects, respectively, during the second and third years following alfalfa hay in rotation.

Results from sensitivity analyses are provided for the representative farms in Tables 6.22 to 6.25. Results shown are annualized mean NPV per hectare of land for each farm. Base values for the upper and lower bounds of the uniform distributions for the alfalfa hay yield effects are shown in the second column of each table. The remaining columns provide the mean results for changes in either the upper or lower bound, with the changes ranging from -0.15 to +0.15. For example, when interpreting the change in value for 'AH Min1' for the farm in the Dark Brown soil zone a -0.05 change results in a new lower bound for the distribution equal to 0.09 (i.e., 0.14 minus 0.05) with the upper bound being unchanged from the original value. Changes to the minimum and maximum values from the uniform distributions are examined independent of the other. Sensitivity analysis on the variables that provide the minimum and maximum values for the uniform distributions that determine the yield effect of alfalfa hay on subsequent crops show the largest change per hectare on the farm under irrigated production in the Brown soil zone and the smallest change per hectare on the farm in the Dark Grey soil zone.

Changes to the yield effect limits do not result in significant changes to the NPVs for the representative farms. In particular, sensitivity analysis results in changes in the magnitude of 0% to 4% when the yield effect limits are adjusted up or down between 0.05 and 0.15. On the farm representative of the Brown soil zone under irrigated production the percent change from sensitivity analysis ranged from 0% to 2% when parameters for the first subsequent crop are analyzed and 0% to 3% when parameters for the second and third subsequent years are analyzed. The variables affecting the lower bound of the distribution from which yield effects are drawn had stronger effects in terms of the magnitude of differences from the original alfalfa hay results.

The results from the sensitivity analysis also do not change the overall results, as compared to the baseline results. Adoption of alfalfa hay still results in net positive direct benefits for the representative farms. When potential yield effect distributions include higher boundaries it is expected that the overall value of the operations will increase, and when potential yield distribution include lower boundaries it is expected that the overall value of the operations will decrease. In fact this is the case. That the sensitivity analysis did not change the outcome of the BMP allows greater confidence to be placed in the results for this BMP.

Table 6.22 – Comparison of mean annualized NPV at different rates of yield effects from alfalfa hay, Brown soil zone with irrigated production

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
AH Min1[a]	0.103	$266.11	$268.06	$269.97	$271.71	$273.29	$274.70	$275.87
AH Max1[b]	0.803	$269.28	$270.19	$271.00	$271.71	$272.33	$272.89	$273.40
AH Min2[c]	0.039	$264.30	$267.04	$269.56	$271.71	$273.41	$274.63	$275.43
AH Max2[d]	0.739	$270.35	$270.87	$271.32	$271.71	$272.04	$272.34	$272.60
Baseline	$235.69							

[a] The lower bound of the uniform distribution for the first crop following alfalfa hay. [b] The upper bound of the uniform distribution for the first crop following alfalfa hay. [c] The lower bound of the uniform distribution for the second and third crops following alfalfa hay. [d] The upper bound of the uniform distribution for the second and third crops following alfalfa hay.

Table 6.23 – Comparison of mean annualized NPV at different rates of yield effects from alfalfa hay, Dark Brown soil zone

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
AH Min1[a]	0.103	$145.01	$146.06	$147.08	$148.05	$148.97	$149.84	$150.65
AH Max1[b]	0.803	$145.88	$146.64	$147.37	$148.05	$148.67	$149.26	$149.81
AH Min2[c]	0.039	$142.48	$144.36	$146.22	$148.05	$149.84	$151.57	$153.24
AH Max2[d]	0.739	$143.46	$145.07	$146.60	$148.05	$149.43	$150.74	$151.98
Baseline	$84.54							

[a] The lower bound of the uniform distribution for the first crop following alfalfa hay. [b] The upper bound of the uniform distribution for the first crop following alfalfa hay. [c] The lower bound of the uniform distribution for the second and third crops following alfalfa hay. [d] The upper bound of the uniform distribution for the second and third crops following alfalfa hay.

Table 6.24 – Comparison of mean annualized NPV at different rates of yield effects from alfalfa hay, Black soil zone

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
AH Min1[a]	0.203	$318.30	$319.58	$320.82	$322.04	$323.22	$324.37	$325.48
AH Max1[b]	1.103	$319.37	$320.31	$321.19	$322.04	$322.85	$323.60	$324.31
AH Min2[c]	0.139	$320.35	$320.94	$321.51	$322.04	$322.54	$323.01	$323.44
AH Max2[d]	1.039	$321.16	$321.47	$321.76	$322.04	$322.30	$322.53	$322.76
Baseline	$274.29							

[a] The lower bound of the uniform distribution for the first crop following alfalfa hay. [b] The upper bound of the uniform distribution for the first crop following alfalfa hay. [c] The lower bound of the uniform distribution for the second and third crops following alfalfa hay. [d] The upper bound of the uniform distribution for the second and third crops following alfalfa hay.

Table 6.25 – Comparison of mean annualized NPV at different rates of yield effects from alfalfa hay, Dark Grey soil zone

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
AH Min1[a]	0.203	$339.55	$340.89	$342.18	$343.45	$344.66	$345.85	$346.98
AH Max1[b]	1.103	$340.53	$341.54	$342.51	$343.45	$344.32	$345.17	$345.97
AH Min2[c]	0.139	$341.83	$342.41	$342.97	$343.45	$343.87	$344.21	$344.47
AH Max2[d]	1.039	$342.97	$343.15	$343.31	$343.45	$343.59	$343.71	$343.80
Baseline	$311.37							

[a] The lower bound of the uniform distribution for the first crop following alfalfa hay. [b] The upper bound of the uniform distribution for the first crop following alfalfa hay. [c] The lower bound of the uniform distribution for the second and third crops following alfalfa hay. [d] The upper bound of the uniform distribution for the second and third crops following alfalfa hay.

A final sensitivity analysis is performed assuming that the yield effect for crops following alfalfa hay is zero. The nitrogen fixing ability of legumes has been well established, but the additional yield effect of adding alfalfa hay into the rotation is less certain in the literature. Therefore, a scenario where there is no yield effect is modelled to examine the effect on the results for this BMP. To do this, the parameters described above, including 'AH Min1', 'AH Max1', 'AH Min2', and 'AH Max2' were all set to zero.

The results for this analysis are provided in Table 6.26. The effect of this change is significant in terms of the overall results for the BMP. When there are no yield effects for subsequent crops the only representative farm that experiences an increase in NPV (i.e. net benefit), as compared to the baseline rotation, is in the Dark Brown soil zone. This is due to the decrease in land allocated to summerfallow when alfalfa hay is adopted in rotation, as compared to the baseline results. However, the Dark Brown soil zone farm also displays the greatest decrease in annualized NPV (in percentage terms) relative to the original alfalfa BMP scenario (i.e., a 51% decrease). For the dryland farms examined the annualized difference in value when comparing the two versions of the BMP (i.e., with and without a yield effect and no yield effect for subsequent crops) is approximately $50 per hectare for all three farms, and approximately $70 per hectare for the irrigated farm. The absolute value differences are consistent with the assumptions made in modelling potential yield effects.

Table 6.26 – Comparison of NPV assuming no yield effect from alfalfa hay adoption, by soil zone

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Percent difference annualized mean NPV relative to baseline[a]	Percent difference annualized mean NPV relative to yield effect[b]
Brown, irrigated	$2,077,182	$353,465	$200.50	-15%	-36%
Dark Brown, dryland	$1,267,675	$217,415	$97.89	16%	-51%
Black, dryland	$2,809,712	$236,354	$271.21	-1%	-19%
Dark Grey, dryland	$2,267,027	$169,359	$291.77	-6%	-18%

[a] Percent difference between the BMP of alfalfa hay adoption without a yield effect as compared to the baseline results. [b] Percent difference between the BMP of alfalfa hay adoption without a yield effect as compared to the BMP of alfalfa hay adoption with a yield effect.

6.4.1.2 Sensitivity Analysis of Nitrogen Effect Parameters

Nitrogen effects following alfalfa hay are calculated as the cost savings associated with reduced nitrogen fertilizer application for subsequent crops. Fertilizer savings per hectare are subtracted from the fertilizer costs per hectare used for the baseline scenario (i.e., no alfalfa hay in rotation). Similar to yield effects, nitrogen savings occur for the three crops following alfalfa hay in rotation. The savings are specific to the crop and to the amount of nitrogen assumed to be recovered.

Given fixed crop rotations, the crops following alfalfa are always the same for each farm (i.e., as provided in Tables 5.32, 5.34 and 5.35). Base values for nitrogen savings are provided in the second column in Tables 6.27 to 6.30. As discussed earlier, the base assumption for the alfalfa BMP scenario is that in the first, second and third years following alfalfa hay nitrogen is applied at 25%, 50%, and 80%, respectively, of the normal application rates.

Sensitivity analysis for the fertilizer savings parameter is performed by adjusting the base value up or down in increments of 5% to a maximum of 15%. Sensitivity results are shown in Tables 6.25 to 6.28. In those tables, 'AH Savings 1', 'AH Savings 2', and 'AH Savings 3' represent the cost savings associated with the nitrogen effect in the first, second, and third year following alfalfa, respectively. The second column provides the base value of fertilizer savings in each year following alfalfa hay in rotation. The remaining columns provide the results for changes to the base value of fertilizer cost savings, with changes ranging from -15% to +15%. The last row in each table provides the annualized NPV per hectare for the baseline scenario (i.e., with no BMP adoption) for comparison purposes.

Changes in NPV from varying fertilizer cost savings are relatively small, ranging from $0.01 to $0.03 per hectare per 1% change in fertilizer savings. Unlike the changes in yield effect following alfalfa hay the results from sensitivity analysis on fertilizer savings are symmetrical when increases and decreases to the variables are applied.

Table 6.27 – Comparison of mean annualized NPV at different rates of nitrogen input cost effects from alfalfa hay, Brown soil zone with irrigated production

		Percent Change in Fertilizer Costs from Base Value						
	Base value	-15%	-10%	-5%	0%	5%	10%	15%
AH Savings 1[a]	$36.92	$271.13	$271.32	$271.51	$271.71	$271.90	$272.08	$272.27
AH Savings 2[b]	$30.00	$271.23	$271.39	$271.55	$271.71	$271.86	$272.01	$272.16
AH Savings 3[c]	$9.84	$271.55	$271.60	$271.66	$271.71	$271.76	$271.81	$271.86
Baseline	$235.69							

[a] Fertilizer savings for crops following alfalfa in the first subsequent year. [b] Fertilizer savings for crops following alfalfa in the second subsequent year. [c] Fertilizer savings for crops following alfalfa in the third subsequent year.

Table 6.28 – Comparison of mean annualized NPV at different rates of nitrogen input cost effects from alfalfa hay, Dark Brown soil zone

		Percent Change in Fertilizer Costs from Base Value						
	Base value	-15%	-10%	-5%	0%	5%	10%	15%
AH Savings 1[a]	$22.79	$147.65	$147.78	$147.92	$148.05	$148.18	$148.31	$148.45
AH Savings 2[b]	$20.96	$147.71	$147.83	$147.94	$148.05	$148.16	$148.27	$148.39
AH Savings 3[c]	$6.85	$147.95	$147.98	$148.02	$148.05	$148.08	$148.12	$148.15
Baseline	$84.54							

[a] Fertilizer savings for crops following alfalfa in the first subsequent year. [b] Fertilizer savings for crops following alfalfa in the second subsequent year. [c] Fertilizer savings for crops following alfalfa in the third subsequent year.

Table 6.29 – Comparison of mean annualized NPV at different rates of nitrogen input cost effects from alfalfa hay, Black soil zone

		Percent Change in Fertilizer Costs from Base Value						
	Base value	-15%	-10%	-5%	0%	5%	10%	15%
AH Savings 1[a]	$30.57	$321.57	$321.73	$321.88	$322.04	$322.19	$322.34	$322.49
AH Savings 2[b]	$28.27	$321.64	$321.77	$321.91	$322.04	$322.17	$322.30	$322.43
AH Savings 3[c]	$8.15	$321.94	$321.97	$322.01	$322.04	$322.07	$322.11	$322.14
Baseline	$274.29							

[a] Fertilizer savings for crops following alfalfa in the first subsequent year. [b] Fertilizer savings for crops following alfalfa in the second subsequent year. [c] Fertilizer savings for crops following alfalfa in the third subsequent year.

Table 6.30 – Comparison of mean annualized NPV at different rates of nitrogen input cost effects from alfalfa hay, Dark Grey soil zone

		Percent Change in Fertilizer Costs from Base Value						
	Base value	-15%	-10%	-5%	0%	5%	10%	15%
AH Savings 1[a]	$25.67	$343.07	$343.19	$343.32	$343.45	$343.57	$343.70	$343.83
AH Savings 2[b]	$24.42	$343.11	$343.23	$343.34	$343.45	$343.56	$343.68	$343.79
AH Savings 3[c]	$6.85	$343.36	$343.39	$343.42	$343.45	$343.48	$343.50	$343.53
Baseline	$311.37							

[a] Fertilizer savings for crops following alfalfa in the first subsequent year. [b] Fertilizer savings for crops following alfalfa in the second subsequent year. [c] Fertilizer savings for crops following alfalfa in the third subsequent year.

6.4.2 Sensitivity Analysis of Field Pea BMP Parameters

As was the case for the alfalfa hay BMP, the effects from adding field peas to the representative farm rotations were determined from expert opinion and previous literature. The consensus was that the addition of field peas in crop rotations could result in benefits to subsequent crops from both yield increases and nitrogen fertilizer savings. While there is potential for the benefit of including field peas in rotation that occur for several years after the crop it was determined that these effects would only be modelled for the first year following field peas in rotation. Field peas in crop rotation are followed with spring wheat in all cases except on the farm in the Brown soil zone where it is followed by barley in rotation when field peas are the only BMP crop adopted.

Also similar to the alfalfa hay BMP, there is uncertainty regarding the likely range of values for both impacts resulting from the addition of field peas. Therefore, sensitivity analysis is performed for this BMP. First, the upper and lower bounds on the yield effect are adjusted. Next, the BMP is modelled assuming no yield effect. Finally, the degree of fertilizer cost savings in the subsequent crop is varied up and down.

6.4.2.1 Sensitivity Analysis of Yield Effect Parameters

As discussed in Chapter 5, yield effects following field peas in rotation are determined in the simulation analysis by drawing a value from a uniform distribution. Assumptions were made regarding the scale of the subsequent yield effects. On farms in the Brown and Dark Brown soil zone it is assumed that the minimum and maximum bounds for the yield effect distribution are zero and 0.1, respectively; that is, the yield effect ranges from 0 to a 10% increase. For the Black and Dark Grey soil zone farms the minimum and maximum bounds are 0.2 and 0.3, respectively (i.e., between 20% and 30% increase). The parameters 'FP Min' and 'FP Max' denote the lower and upper distribution bounds for estimating yield effects following field peas in rotation. In the sensitivity analysis scenarios, 'FP Min' and 'FP Max" are adjusted up or down (independently of each other) in increments of 5% (i.e., 0.05) to a maximum change of 15% (i.e., 0.15).

Sensitivity analysis results are provided for farms under dryland production in the Brown, Dark Brown, Black, and Dark Grey soil zones in Tables 6.31 to 6.34, respectively. Results shown are annualized mean NPV of the operations per hectare of land. Base values for the upper and lower bounds of the uniform distributions for the field pea yield effects are shown in the second column of each table. In the remaining columns are the mean NPV results for changes in the upper or lower bound, with the changes ranging from -0.15 to +0.15. For example, when interpreting the change in value for 'FP Min' in the Brown soil zone a -0.15 change results in a new lower bound for the distribution equal to -0.15, with the upper bound being unchanged; that is, the minimum yield change is now -15%. The variable 'FP Min' is not examined with a change of +0.15 as this sets the minimum value greater than the maximum. Similarly 'FP Max' is not examined with a change of -0.15 as this sets the maximum below the minimum value allowed for the distributions.

Changes in mean annual NPV for the farms from sensitivity analysis of the yield increase parameters are relatively small; that is, the NPV values are relatively stable. The NPV changes are symmetrical in terms of increases and decreases for a given increase or decrease in maximum or minimum yield change parameter. Further, the changes result in decreases and increases that represent less than 1% for each 0.01 change in the yield increase parameters. The overall effect of the BMP of adopting field peas in rotation does not change with sensitivity analysis of the yield variables.

Table 6.31 – Comparison of mean annualized NPV at different rates of yield effects from field peas, Brown soil zone with dryland production

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
FP Min[a]	0.000	\$105.07	\$105.92	\$106.80	\$107.67	\$108.55	\$109.44	N/A[c]
FP Max[b]	0.100	N/A[c]	\$105.88	\$106.77	\$107.67	\$108.56	\$109.47	\$110.35
Baseline	\$65.31							

[a] The lower bound of the uniform distribution for the crop following field peas. [b] The upper bound of the uniform distribution for the crop following field peas. [c] N/A denotes that this change is not available to occur as it would cause the minimum (maximum) value to be higher (lower) than the maximum (minimum) value.

Table 6.32 – Comparison of mean annualized NPV at different rates of yield effects from field peas, Dark Brown soil zone

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
FP Min[a]	0.000	\$107.69	\$109.36	\$111.02	\$112.72	\$114.39	\$116.05	N/A[c]
FP Max[b]	0.100	N/A[c]	\$109.37	\$111.04	\$112.72	\$114.38	\$116.02	\$117.67
Baseline	\$84.54							

[a] The lower bound of the uniform distribution for the crop following field peas. [b] The upper bound of the uniform distribution for the crop following field peas. [c] N/A denotes that this change is not available to occur as it would cause the minimum (maximum) value to be higher (lower) than the maximum (minimum) value.

Table 6.33 – Comparison of mean annualized NPV at different rates of yield effects from field peas, Black soil zone

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
FP Min[a]	0.200	$266.23	$268.32	$270.47	$272.57	$274.65	$276.70	N/A[c]
FP Max[b]	0.300	N/A[c]	$268.31	$270.47	$272.57	$274.65	$276.69	$278.67
Baseline	$274.29							

[a] The lower bound of the uniform distribution for the crop following field peas. [b] The upper bound of the uniform distribution for the crop following field peas. [c] N/A denotes that this change is not available to occur as it would cause the minimum (maximum) value to be higher (lower) than the maximum (minimum) value.

Table 6.34 – Comparison of mean annualized NPV at different rates of yield effects from field peas, Dark Grey soil zone

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
FP Min[a]	0.200	$309.77	$311.95	$314.12	$316.29	$318.43	$320.54	N/A[c]
FP Max[b]	0.300	N/A[c]	$311.98	$314.16	$316.29	$318.38	$320.48	$322.50
Baseline	$311.37							

[a] The lower bound of the uniform distribution for the crop following field peas. [b] The upper bound of the uniform distribution for the crop following field peas. [c] N/A denotes that this change is not available to occur as it would cause the minimum (maximum) value to be higher (lower) than the maximum (minimum) value.

For the same reasons outlined in the alfalfa hay BMP sensitivity analysis discussion, sensitivity analysis is also done assuming that the yield effect is zero for crops following field peas. This scenario is modelled by setting the parameters ‘FP Min’ and ‘FP Max’ to zero. The results for this analysis are provided in Table 6.35. As compared to the baseline results, the representative farms in the Brown and Dark Brown soil zones continue to experience increases in NPV from adopting field peas, even with no yield effect. This is due to the decrease in land allocated to summerfallow when field peas are adopted in rotation, as compared to the baseline results. However, when comparing to the base field pea BMP results, there is a 2-3% decrease in NPV of the operations when no subsequent yield effect is assumed.

On representative farms in the Black and Dark Grey soil zones NPV of the operations decreased relative to that of the baseline scenario, when no yield effect is assumed. Not surprisingly, the NPV for these representative farms is lower without a yield effect, as compared to field pea adoption with a subsequent yield effect. This result is expected; when modelling the subsequent positive yield effect, NPV of the operations should be greater than without a subsequent positive yield effect.

Table 6.35 – Comparison of NPV assuming no yield effect from field pea adoption, by soil zone

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Percent difference annualized mean NPV relative to baseline[a]	Percent difference annualized mean NPV relative to yield effect[b]
Brown, dryland	$1,371,136	$343,598	$105.88	62%	-2%
Dark Brown, dryland	$1,416,369	$275,586	$109.37	29%	-3%
Black, dryland	$2,599,584	$293,628	$250.93	-9%	-9%
Dark Grey, dryland	$2,287,175	$211,176	$294.36	-5%	-7%

[a] Percent difference between the BMP of field pea adoption without a yield effect as compared to the baseline results. [b] Percent difference between the BMP of field pea adoption without a yield effect as compared to the BMP of field pea adoption with a yield effect.

6.4.2.2 Sensitivity Analysis of Nitrogen Effect Parameters

Nitrogen effects for the field pea BMP are calculated as the cost savings associated with reduced nitrogen fertilizer application for the subsequent crop. Fertilizer savings per hectare are subtracted from the fertilizer costs per hectare for the baseline scenario (i.e., no field peas in rotation). Similar to the yield effect, nitrogen savings occur for the first crop following field pea in rotation. The savings are specific to the crop and depend on the amount assumed to be carried over and used in the subsequent year. It is assumed that nitrogen is applied at 33% of the normal application rate the year following field peas in rotation.

Sensitivity analysis involved adjusting (i.e., increasing or decreasing) the base value of fertilizer savings for the BMP in increments of 5% to a maximum of 15%. Results are shown in Table 6.36. The second column provides the base value of fertilizer savings in each year following field pea in rotation. The next seven columns provide the results for changes to the base value of fertilizer cost savings, with changes ranging from -15 to +15%. The last column provides the annualized NPV per hectare for the baseline scenario (i.e., with no BMP adoption) for comparison purposes.

When the base value is decreased or increased, the change in mean annualized NPV of the operations decreases or increases symmetrically by $0.02 to $0.04 per hectare for each 1% change in the nitrogen savings variable. However, the annualized NPV per hectare values for each farm are relatively stable over the range of parameter values for nitrogen savings. As well, the overall result for the BMP (i.e., that the field pea BMP generally improves farm performance) is unchanged for any of these sensitivity scenarios.

Table 6.36 – Comparison of mean annualized NPV at different rates of nitrogen input cost effects from field peas

Soil zone	Base value	Percent Change in Fertilizer Costs from Base Value							Base-line
		-15%	-10%	-5%	0%	5%	10%	15%	
Brown	$20.35	$107.33	$107.44	$107.55	$107.67	$107.79	$107.90	$108.01	$65.31
Dark Brown	$20.35	$112.25	$112.42	$112.57	$112.72	$112.87	$113.02	$113.16	$84.54
Black	$27.31	$272.03	$272.20	$272.39	$272.57	$272.76	$272.94	$273.12	$274.29
Dark Grey	$22.93	$315.85	$316.00	$316.15	$316.29	$316.44	$316.59	$316.74	$311.37

6.4.3 Sensitivity Analysis of Legume Green Manure BMP Parameters

In this study the addition of a legume green manure crop as a BMP is considered under dryland production for the representative farms in the Brown and Dark Brown soil zones. As discussed earlier, the addition of legume green manures to crop rotations may result in decreases to subsequent crop yields, but there is also potential for nitrogen fertilizer savings in the subsequent crop (i.e., for one year following the green manure crop). When legume green manures are adopted in crop rotations it is followed with spring wheat in all cases. Assumptions were made regarding the scale of the effects. The yield effects were assumed to be stochastic, with the effect being drawn from a uniform distribution with a minimum and maximum possible effect. Nitrogen savings were deterministic and calculated based on an assumed reduction in nitrogen requirements for the subsequent wheat crop. Sensitivity analyses for these parameters are discussed in the following sections.

6.4.3.1 Sensitivity Analysis of Yield Effect Parameters

The parameters ‘LGM Min’ and ‘LGM Max’ denote the upper and lower bounds for the yield effect in the crop following legume green manure. It is assumed that in a dry year, as discussed in section 5.4.1.3, crop yields following legume green manures in rotation change stochastically, using upper and lower bounds -15.5% (i.e., -0.155) and zero, respectively. However, given the uncertainty associated with these values, sensitivity analysis is performed with three increases and decreases of 0.05 each on the minimum and maximum values for the uniform distributions. The sensitivity analysis is done independently for each; that is, either the maximum value or the minimum value is changed in a particular sensitivity scenario.

Results from sensitivity analyses are provided for farms in the Brown and Dark Brown soil zones in Tables 6.37 and 6.38, respectively. Results shown are annualized mean NPV per hectare of land. Base values for the upper and lower bounds of the uniform distributions for legume green manure yield effects are shown in the second column of each table. The remaining columns provide the mean results for changes in the upper or lower bound, with the changes ranging from -0.15 to +0.15. For example, when interpreting change in value for ‘LGM Min’, a -0.15 change results in a new lower bound for the distribution equal to -0.305, with the upper bound being unchanged.

From the sensitivity analysis it is apparent that there is a larger impact per hectare for the farm located in the Dark Brown soil zone. This is hypothesized to be due to overall higher yields observed in this region, as compared to the Brown soil zone. Overall, however, the mean annual NPVs per hectare are relatively stable over the range of values tested in the sensitivity analysis. Results from sensitivity analysis of yield effects following legume green manures in rotation are also relatively symmetrical for increases and decreases, which is expected given the nature of the changes made in the sensitivity analysis.

Table 6.37 – Comparison of mean annualized NPV at different rates of yield effects from legume green manures, Brown soil zone with dryland production

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
LGM Min[a]	-0.155	$58.39	$58.97	$59.55	$60.10	$60.69	$61.30	$61.85
LGM Max[b]	0.000	$58.42	$58.99	$59.55	$60.10	$60.68	$61.27	$61.85
Baseline	$65.31							

[a] The lower bound of the uniform distribution for the crop following legume green manures. [b] The upper bound of the uniform distribution for the crop following legume green manures.

Table 6.38 – Comparison of mean annualized NPV at different rates of yield effects from legume green manures, Dark Brown soil zone

		Magnitude of Change in Uniform Distribution Maximum or Minimum Values						
	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
LGM Min[a]	-0.155	$70.60	$71.83	$73.09	$74.33	$75.62	$76.89	$78.16
LGM Max[b]	0.000	$70.54	$71.83	$73.08	$74.33	$75.60	$76.88	$78.18
Baseline	$84.54							

[a] The lower bound of the uniform distribution for the crop following legume green manures. [b] The upper bound of the uniform distribution for the crop following legume green manures.

Sensitivity analysis is also done assuming that the yield effect is zero for crops following legume green manures. The variables ‘LGM Min’ and ‘LGM Max’ were set to zero for this scenario and the results are provided in Table 6.39. When compared to the base results for this BMP there is a 3-5% increase in NPV of the operations when no subsequent yield effect is assumed. This is to be expected as there was potential for legume green manures to cause yield decreases in subsequent crops in the base BMP scenario. However, the mean NPVs associated with the no yield effect scenario for this BMP are still lower than the baseline results with no BMP adoption; that is, the benefits from reduced nitrogen costs in the subsequent crop do not outweigh the additional costs of the green manure crop relative to the summerfallow being replaced in the rotation. This outcome improves the confidence of the base model results for this BMP.

Table 6.39 - Comparison of NPV assuming no yield effect from legume green manure adoption, by soil zone

Soil zone, production	Mean NPV	Standard deviation NPV	Annualized mean NPV per hectare	Percent difference annualized mean NPV relative to baseline[a]	Percent difference annualized mean NPV relative to yield effect[b]
Brown, dryland	$801,613	$347,475	$61.90	-5%	3%
Dark Brown, dryland	$1,013,945	$298,474	$78.30	-7%	5%

[a] Percent difference between the BMP of legume green manure adoption without a yield effect as compared to the baseline results. [b] Percent difference between the BMP of legume green manure adoption without a yield effect as compared to the BMP of legume green manure adoption with a yield effect.

6.4.3.2 Sensitivity Analysis of Nitrogen Effect Parameters

Nitrogen effects following legume green manures in rotation are calculated as the cost savings associated with reduced nitrogen fertilizer application for subsequent crops. Fertilizer savings per hectare are subtracted from the fertilizer costs per hectare for the baseline scenario (i.e., no legume green manure in rotation). Nitrogen savings occur in three stages: the first, second and third time legume green manures are in rotation on a single parcel of land. The savings are specific to the crop and to the amount of nitrogen assumed to be recovered and used by the crop. For the subsequent crop, nitrogen is assumed to be applied at 97%, 90% and 81% of the normal application rate following the first, second and third time legume green manures are present in rotation, respectively.

Sensitivity analysis is done on the base value of fertilizer savings by increasing and decreasing the value of savings in increments of 5%, to a maximum of 15%. Results are shown in Tables 6.40 to 6.41. ‘LGM Savings 1’, ‘LGM Savings 2’, and ‘LGM Savings 3’ represent the cost savings associated with the nitrogen effect in the first, second, and third occurrence of legume green manure in rotation, respectively. The second column provides the base value of fertilizer savings in each year following legume green manures in rotation. The remaining columns provide the results for changes to the base value of fertilizer cost savings, with changes ranging from -15% to +15%. The last row in each table provides the annualized NPV per hectare for the baseline scenario (i.e., with no BMP adoption) for comparison purposes.

When the base value is decreased or increased, the change in mean annualized NPV of the operations decreases or increases by $0.01 to $0.02 per hectare for each 1% change in the nitrogen savings variable. The changes are relatively small due to the minor changes associated with the first and second time legume green manures occur in rotation. The third time legume green manures occur in rotation the benefit is more significant but the overall benefit is small since it only occurs for a finite number of years and the future financial benefits of the fertilizer savings are discounted.

Table 6.40 – Comparison of mean annualized NPV at different rates of nitrogen input cost effects from legume green manures, Brown soil zone

		Percent Change in Fertilizer Costs from Base Value						
	Base value	-15%	-10%	-5%	0%	5%	10%	15%
LGM Savings 1[a]	$0.76	$60.09	$60.09	$60.09	$60.10	$60.10	$60.10	$60.10
LGM Savings 2[b]	$2.54	$60.09	$60.09	$60.09	$60.10	$60.10	$60.10	$60.11
LGM Savings 3[c]	$4.82	$60.08	$60.08	$60.09	$60.10	$60.10	$60.11	$60.12
Baseline	$65.31							

[a] Fertilizer savings for crops following legume green manures the first time in rotation. [b] Fertilizer savings for crops following legume green manures the second time in rotation. [c] Fertilizer savings for crops following legume green manures the third time in rotation.

Table 6.41 – Comparison of mean annualized NPV at different rates of nitrogen input cost effects from legume green manures, Dark Brown soil zone

		Percent Change in Fertilizer Costs from Base Value						
	Base value	-15%	-10%	-5%	0%	5%	10%	15%
LGM Savings 1[a]	$0.91	$74.32	$74.32	$74.33	$74.33	$74.34	$74.34	$74.35
LGM Savings 2[b]	$3.04	$74.30	$74.31	$74.32	$74.33	$74.34	$74.35	$74.35
LGM Savings 3[c]	$5.77	$74.28	$74.30	$74.32	$74.33	$74.35	$74.36	$74.37
Baseline	$84.54							

[a] Fertilizer savings for crops following legume green manures the first time in rotation. [b] Fertilizer savings for crops following legume green manures the second time in rotation. [c] Fertilizer savings for crops following legume green manures the third time in rotation.

6.4.4 Sensitivity Analysis of Shelterbelt BMP Parameters

Shelterbelts are adopted on all representative farms, although more shelterbelts are implemented on representative farms assumed to have higher potential for erosion (e.g., farms in the Brown soil zone).[45] Information from prior literature was used to determine that the adoption of shelterbelts could result in yield changes for subsequent crops due to moisture and nutrient competition with the trees (i.e., yield decreases) and reduced erosion in sheltered areas (i.e., yield increases). Based on this literature, assumptions were made regarding the scale of the effects.

The yield effects associated with shelterbelt implementation were simulated assuming a single value for the affected crops on each farm (i.e., the yield effect is deterministic). Possible yield effects range from 51 to 117% of normal yields depending on the crop and the representative farms, with values less than 100% being used for the zone immediately adjacent to the shelterbelt (i.e., yield decreases) and values greater than 100% being used for the area between three and ten times the height of the trees away from the shelterbelt. Specific yield changes, by crop and soil zone are provided in Table 5.37 in Chapter 5.

Sensitivity analysis of the changes to crop yield values is performed with three increases and decreases of 0.05 for each yield change by crop and soil zone. Results from sensitivity analyses are provided by soil zone in Tables 6.42 to 6.46. In those tables, '0-3H' and '3-10H' represent the area in direct proximity to the trees, up to the height of the trees multiplied by three and the height of the trees multiplied by three to ten,

[45] Specific details regarding implementation of the shelterbelts for the representative farms are provided in Chapter 5, and are summarized in Table 5.36.

respectively. Results shown represent differences in annualized mean NPV of the operations per hectare of land converted to shelterbelts; that is, land removed from crop production. Base values for the yield increases from adoption of shelterbelts are shown in the second column of each table. The remaining columns are the mean results for changes in yield effects, with the changes ranging from -0.15 to +0.15. For example, when interpreting the change in value for '0-3H' for the crop canola in the Brown soil zone a -0.15 change results in a new value for the yield effect being 0.416.

Unlike results from the previous analyses, the NPV results are sensitive to adjustments in the yield effects associated with shelterbelt adoption, at least on the basis of a per hectare value. On a percentage basis, the changes per hectare from the base BMP to the adjusted values range from approximately 2% to as much as 86%. The pattern in these sensitivity analysis results suggests that changes to the yield increase in the "outer" range has a greater impact than do changes to yield decreases in the areas immediately adjacent to the trees. This may be due to the fact that a larger area is affected by these changes. The changes also tend to be symmetrical in terms of the impact of an identical percentage increase versus decrease in the parameters.

Despite the greater impact of these parameters on farm performance associated with the shelterbelt BMP, however, the overall result for the BMP is unchanged in all scenarios. Adoption of the shelterbelt BMP represents a significant cost to the representative farms in terms of dollars per hectare affected by the change.

Table 6.42 – Comparison of mean annualized NPV at different rates of yield effects per hectares lost from shelterbelt adoption, Brown soil zone with irrigated production

		Annualized Mean NPV difference per hectare lost[a]						
Area, Crop	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
0-3H Canola	0.566	-$345.18	-$335.75	-$326.15	-$316.96	-$307.62	-$298.36	-$289.42
0-3H Dry Bean	0.760	-$335.32	-$329.19	-$323.15	-$316.96	-$310.54	-$304.49	-$298.61
0-3H Wheat	0.619	-$385.31	-$362.66	-$339.78	-$316.96	-$294.13	-$271.38	-$248.98
3-10H Canola	1.124	-$429.06	-$391.50	-$354.75	-$316.96	-$280.20	-$243.09	-$207.72
3-10H Dry Bean	1.159	-$390.43	-$366.25	-$341.68	-$316.96	-$292.64	-$267.97	-$243.39
3-10H Wheat	1.087	-$589.82	-$498.87	-$407.87	-$316.96	-$226.02	-$134.71	-$45.55

[a] Calculated as the difference in mean annualized NPV from adoption of shelterbelts at different levels of yield effects, divided by hectares lost to cropping activities from shelterbelt adoption.

Table 6.43 – Comparison of mean annualized NPV at different rates of yield effects per hectares lost from shelterbelt adoption, Brown soil zone with dryland production

		Annualized Mean NPV difference per hectare lost[a]						
Area, Crop	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
0-3H Barley	0.611	-$199.59	-$197.96	-$196.45	-$194.79	-$193.22	-$191.46	-$189.91
0-3H Canola	0.566	-$206.13	-$202.18	-$198.48	-$194.79	-$190.94	-$187.11	-$183.36
0-3H Wheat	0.619	-$213.98	-$207.54	-$201.06	-$194.79	-$188.26	-$181.92	-$175.25
3-10H Barley	1.116	-$214.32	-$207.87	-$201.16	-$194.79	-$188.23	-$181.58	-$175.27
3-10H Canola	1.124	-$240.64	-$225.34	-$209.88	-$194.79	-$179.50	-$164.09	-$149.15
3-10H Wheat	1.087	-$272.30	-$246.51	-$220.41	-$194.79	-$168.89	-$143.07	-$117.53

[a] Calculated as the difference in mean annualized NPV from adoption of shelterbelts at different levels of yield effects, divided by hectares lost to cropping activities from shelterbelt adoption.

Table 6.44 – Comparison of mean annualized NPV at different rates of yield effects per hectares lost from shelterbelt adoption, Dark Brown soil zone

		Annualized Mean NPV difference per hectare lost[a]						
Area, Crop	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
0-3H Barley	0.624	-$192.48	-$188.62	-$184.96	-$181.41	-$177.69	-$174.01	-$170.45
0-3H Canola	0.579	-$196.64	-$191.46	-$186.40	-$181.41	-$176.28	-$171.20	-$166.27
0-3H Wheat	0.632	-$195.51	-$190.66	-$186.00	-$181.41	-$176.71	-$172.10	-$167.48
3-10H Barley	1.124	-$225.65	-$211.09	-$196.16	-$181.41	-$166.82	-$152.41	-$138.63
3-10H Canola	1.132	-$241.60	-$221.71	-$201.70	-$181.41	-$161.09	-$141.72	-$122.12
3-10H Wheat	1.095	-$237.80	-$218.84	-$200.33	-$181.41	-$162.90	-$144.59	-$126.68

[a] Calculated as the difference in mean annualized NPV from adoption of shelterbelts at different levels of yield effects, divided by hectares lost to cropping activities from shelterbelt adoption.

Table 6.45 – Comparison of mean annualized NPV at different rates of yield effects per hectares lost from shelterbelt adoption, Black soil zone

		Annualized Mean NPV difference per hectare lost[a]						
Area, Crop	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
0-3H Barley	0.612	-$404.80	-$401.75	-$398.72	-$395.74	-$392.69	-$389.62	-$386.65
0-3H Canola	0.567	-$429.60	-$418.26	-$407.00	-$395.74	-$384.35	-$373.12	-$361.70
0-3H Wheat	0.620	-$425.19	-$415.35	-$405.51	-$395.74	-$385.89	-$376.07	-$366.18
3-10H Barley	1.073	-$432.50	-$420.05	-$407.81	-$395.74	-$383.58	-$371.44	-$359.41
3-10H Canola	1.081	-$532.22	-$486.90	-$440.87	-$395.74	-$350.59	-$305.06	-$259.77
3-10H Wheat	1.044	-$514.27	-$474.57	-$435.02	-$395.74	-$356.23	-$316.99	-$277.44

[a] Calculated as the difference in mean annualized NPV from adoption of shelterbelts at different levels of yield effects, divided by hectares lost to cropping activities from shelterbelt adoption.

Table 6.46 – Comparison of mean annualized NPV at different rates of yield effects per hectares lost from shelterbelt adoption, Dark Grey soil zone

		Annualized Mean NPV difference per hectare lost[a]						
Area, Crop	Base value	-0.15	-0.10	-0.05	0.00	0.05	0.10	0.15
0-3H Barley	0.615	-$421.92	-$418.36	-$414.75	-$411.27	-$407.77	-$404.22	-$400.45
0-3H Canola	0.570	-$443.09	-$432.39	-$421.87	-$411.27	-$400.52	-$389.85	-$379.25
0-3H Wheat	0.623	-$441.12	-$431.05	-$421.17	-$411.27	-$401.41	-$391.45	-$381.19
3-10H Barley	1.078	-$453.91	-$439.76	-$425.50	-$411.27	-$396.83	-$382.41	-$368.04
3-10H Canola	1.086	-$537.90	-$495.91	-$453.74	-$411.27	-$368.67	-$325.91	-$283.81
3-10H Wheat	1.049	-$530.36	-$490.29	-$450.98	-$411.27	-$370.94	-$331.19	-$291.60

[a] Calculated as the difference in mean annualized NPV from adoption of shelterbelts at different levels of yield effects, divided by hectares lost to cropping activities from shelterbelt adoption.

6.4.5 Sensitivity Analysis of Buffer Strip BMP Parameters

In modelling adoption of buffer strip BMPs by the representative farms, key assumptions were made. In particular, it was assumed that the buffer strip width was set at ten metres. As well, the farms were assumed to have a set percentage of land that is wetland. Sensitivity analysis is done for both of these parameters. The buffer strip width is adjusted to determine the cost of additional land taken for buffer strips, with and without hay production. Sensitivity analysis is also performed to determine the effect on the net cost of buffer strip implementation for the representative operations if more or less land is assumed to be wetlands.

As noted above, the base scenario for the buffer strip BMP is a strip that is ten metres wide. For the sensitivity analysis scenarios this is adjusted up and down in increments of two metres. For the case where the buffer strip is retired from production, widths considered are 6, 8, 10, 12, 14, and 16 metres. For the case where the buffer strip is seeded to perennial forage which is harvested as hay, the alternative buffer strip widths considered are 12, 14, and 16 metres.[46] Resulting values for acreage taken out of annual crop production for these sensitivity analysis scenarios are provided by soil zone and buffer width in Table 6.47.

Table 6.47 – Land lost (hectares) due to buffer strip adoption at different buffer widths on representative farms

Buffer width (m)	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
6	4.05	7.07	7.07	6.89	5.17
8	5.49	9.53	9.53	9.27	6.95
10	6.96	12.04	12.04	11.68	8.76
12	8.47	14.60	14.60	14.14	10.60
14	10.02	17.21	17.21	16.64	12.48
16	11.61	19.86	19.86	19.17	14.38

In the baseline analysis it is assumed that the amount of wetland present on the representative farms varies by soil zone. For the purposes of this analysis the farms in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones have 2%, 4%, 4%, 6%, and 6% of land as wetlands in the baseline scenarios, respectively. These values are also varied in the sensitivity analysis for the buffer strip BMP scenarios. On the farm in the Brown (irrigated) soil zone increases to 4%, 6%, and 8% are modelled. On the farms in the Brown (dryland) and Dark Brown soil zones a decrease to 2% and increases of 6% and 8% are tested. On the farms in the Black and Dark Grey soil zones decreases to 2% and 4% and an increase to 8% are tested. Acreages lost from adoption of 10 metre buffer strips are provided in Table 6.48.

Table 6.48 – Land lost (hectares) due to buffer strip adoption at different levels of wetland on representative farms[a]

Percent wetland	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
2%	**6.96**	8.70	8.70	6.96	5.22
4%	9.63	**12.04**	**12.04**	9.63	7.22
6%	11.68	14.60	14.60	**11.68**	**8.76**
8%	13.41	16.76	16.76	13.41	10.06

[a] The base values for each farm are shown in bold print.

[46] Narrower buffer strip widths are not considered for the perennial forage version of the buffer strip BMP due to assumed problems that this would create for navigating forage harvesting equipment.

6.4.5.1 *Buffer Strip Sensitivity Analysis Results - Without Harvested Hay in Buffers*

The first set of sensitivity results are for the buffer strip BMP scenario where land is set aside from any agricultural production. Annualized mean NPV results from sensitivity analysis of adjusting buffer strip widths are provided in Table 6.49. Table 6.50 provides results from the analysis of the difference between adoption of buffer strips and the sensitivity analysis per hectare lost for buffer strip adoption. Comparing results with the baseline results (i.e., without buffer strip adoption) there are very small changes, ranging from approximately $1 to $7 per hectare on the representative farms. In all cases, even a six metre buffer strip around wetlands decreases the annualized mean NPV on all operations. Changes from sensitivity analysis are more apparent when comparing annualized mean NPV per hectare lost from buffer strip adoption to the base BMP value of a 10 metre buffer strip. The results are as expected: more land dedicated to buffer strips results in a negative difference, while less land dedicated to buffer strips result in a positive difference.

Table 6.49 - Comparison of annualized mean NPV at different buffer strip widths

	Annualized Mean NPV per hectare				
Strip width (m)	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
6	$234.34	$64.79	$83.92	$272.32	$309.12
8	$233.85	$64.61	$83.70	$271.63	$308.34
Base BMP Value (10)	$233.35	$64.42	$83.48	$270.93	$307.55
12	$232.86	$64.24	$83.26	$270.22	$306.76
14	$232.36	$64.05	$83.03	$269.51	$305.94
16	$231.83	$63.86	$82.80	$268.77	$305.10
Baseline	$235.69	$65.31	$84.54	$274.29	$311.37

Table 6.50 – Comparison of annualized mean NPV at different buffer strip widths with adoption of buffer strips

	Difference in mean annualized NPV per hectare lost[a]				
Strip width (m)	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
6	$250.65	$66.76	$79.34	$207.96	$235.58
8	$93.98	$25.15	$29.64	$78.03	$88.28
Base BMP Value (10)	$0.00	$0.00	$0.00	$0.00	$0.00
12	-$60.29	-$16.75	-$19.87	-$52.19	-$58.04
14	-$102.91	-$28.48	-$34.39	-$88.54	-$100.48
16	-$135.90	-$37.10	-$44.84	-$116.70	-$132.56

[a] Calculated as the difference in mean annualized NPV from adoption of buffer strips at different buffer strip widths, divided by hectares lost to cropping activities from buffer strip adoption.

Results from sensitivity analysis of the percent of wetlands on each farm are provided in Tables 6.51 and 6.52 as annualized mean NPVs per hectare of farm land and the differences in annualized mean NPV from the base BMP value per hectares lost from buffer strip adoption, respectively. Results from this analysis support the development of the models as increases in percent wetland result in lower mean NPV of the operations, while decreases in percent wetland result in higher mean NPV of the representative farms. Farms with more areas dedicated to wetlands lose more land when 10 metre buffers surrounding wetlands are adopted.

Table 6.51 - Comparison of annualized mean NPV per hectare from adoption of buffer strips at different on-farm wetland percentages

	Annualized Mean NPV per hectare				
Percent wetland	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
2%	$233.35	$66.03	$85.54	$284.07	$322.47
4%	$227.65	$64.42	$83.48	$277.41	$314.91
6%	$222.13	$62.87	$81.50	$270.93	$307.55
8%	$216.71	$61.36	$79.54	$264.54	$300.32

Table 6.52 – Comparison of annualized mean NPV per hectare lost from adoption of buffer strips at different percent of on-farm wetlands

	Difference in annualized mean NPV per hectare lost[a]				
Percent wetland	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
2%	$0.00	$239.47	$305.73	$1,956.73	$2,220.57
4%	-$613.86	$0.00	$0.00	$697.09	$791.05
6%	-$995.37	-$137.54	-$176.22	$0.00	$0.00
8%	-$1,286.21	-$236.98	-$304.48	-$493.74	-$558.52

[a] Calculated as the difference in mean annualized NPV from adoption of buffer strips at different percentages of wetlands, divided by hectares lost to cropping activities from buffer strip adoption.

6.4.5.2 Buffer Strip Sensitivity Analysis Results - With Harvested Hay in Buffers

Annualized mean NPV results from sensitivity analysis of adjusting buffer strip width when adopted with the option to harvest forage in the buffer areas, are provided in Table 6.53. Table 6.54 provides results from the analysis as the difference between adoption of buffer strips with hay and the sensitivity analysis per hectare lost for buffer strip adoption. Comparing results with the baseline results (i.e., without buffer strip adoption) there are very small changes, ranging from less than $1 to approximately $5 per hectare on the representative farms. In all cases, buffer strips around wetlands decrease the annualized mean NPV on all representative farms. Changes from sensitivity analysis are more apparent when comparing annualized mean NPV per hectare lost from buffer strip adoption to the base BMP value of a 10 metre buffer strip. The difference from here however, is that with wider buffer strips there is the opportunity to harvest and sell more hay. Even with this assumption however, it appears that there are diminishing returns to increasing the width of buffer strips.

Table 6.53 – Comparison of mean annualized NPV at different buffer strip widths with adoption of buffer strips with hay

	Annualized Mean NPV per hectare with degree changes				
Strip width (m)	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
Base BMP Value (10)	$233.81	$65.12	$84.29	$271.80	$308.25
12	$233.39	$65.08	$84.25	$271.27	$307.61
14	$232.98	$65.05	$84.21	$270.74	$306.95
16	$232.55	$65.01	$84.15	$270.21	$306.26
Baseline	$235.69	$65.31	$84.54	$274.29	$311.37

Table 6.54 – Comparison of annualized mean NPV at different buffer strip widths with adoption of buffer strips with hay

	Difference in mean annualized NPV per hectare lost[a]				
Strip width (m)	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
Base BMP Value (10)	$67.21	$74.53	$86.45	$76.38	$61.31
12	$4.65	$57.97	$68.30	$24.53	$4.02
14	-$38.25	$46.89	$54.37	-$11.99	-$37.88
16	-$71.62	$38.06	$43.11	-$38.93	-$69.69

[a] Calculated as the difference in mean annualized NPV from adoption of buffer strips with hay at different buffer strip widths, divided by hectares lost to cropping activities from buffer strip adoption.

Results from sensitivity analysis of the percent of wetlands on each farm are provided in Tables 6.55 and 6.56 as annualized mean NPV per hectare of farm land and the difference in annualized mean NPV from the base BMP value per hectares lost from buffer strip adoption, respectively. Results from this analysis are again as expected; increases in the proportion of wetlands result in lower mean NPV of the operations, while decreases result in higher mean NPV of the representative farms.

Table 6.55 – Comparison of mean annualized NPV per hectare from adoption of buffer strips with hay at different percent of on-farm wetlands

	Annualized Mean NPV per hectare with degree changes				
Percent wetland	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
2%	$233.81	$66.52	$86.12	$284.58	$322.88
4%	$228.25	$65.12	$84.29	$278.12	$315.48
6%	$222.85	$63.72	$82.49	$271.80	$308.25
8%	$217.56	$62.33	$80.69	$265.53	$301.12

Table 6.56 – Comparison of annualized mean NPV per hectare lost from adoption of buffer strips with hay at different percent of on-farm wetlands

	Difference in mean annualized NPV per hectare lost[a]				
Percent wetland	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
2%	$67.21	$312.07	$391.86	$2,032.18	$2,282.66
4%	-$548.81	$74.53	$86.45	$772.79	$852.12
6%	-$931.45	-$62.46	-$88.19	$76.38	$61.31
8%	-$1,220.25	-$161.94	-$215.84	-$417.31	-$496.87

[a] Calculated as the difference in mean annualized NPV from adoption of buffer strips with hay at different percentages of wetlands, divided by hectares lost to cropping activities from buffer strip adoption.

6.4.6 Sensitivity Analysis of Residue Management Variables

Adoption of the residue management BMP potentially results in changes to yields for subsequent crops, depending on moisture conditions and whether residue is retained or not. In some cases yields increase while in other cases they may decrease, depending on whether there are moisture deficits or excesses in particular years. Residue management is adopted on all representative farms using equivalent yield change assumptions. Sensitivity analysis is conducted for residue management variables to determine if the bounds on the yield change distributions have a significant effect on the results for this BMP.

The yield effects for this BMP were simulated assuming a uniform distribution, with the lower and upper bounds representing, respectively, the minimum and maximum possible effects. There are three separate yield effect scenarios, a yield increase from retaining residue in dry years ('Dry Increase'), a yield decrease from removing residue in dry years ('Dry Decrease'), and a yield decrease from retaining residue in wet years ('Wet Decrease'). Lower and upper bounds for the uniform distributions from which yield changes are drawn are (0, 0.03), (-0.03, 0), and (-0.12, 0) for 'Dry Increase', 'Dry Decrease', and 'Wet Decrease', respectively. The yield changes represent the percentage change in yield from the value drawn from the yield distributions.

Sensitivity analysis is done by varying the upper or lower bound associated with the uniform distributions for the yield increases/decreases, as appropriate for the parameter. These are done independently with each sensitivity analysis scenario involving an increase or decrease of 0.05, 0.10, or 0.15 for the relevant upper or lower bound. In the case of the 'Dry Increase' distribution, the upper bound is changed to 0.08, 0.13 and 0.18; that is, maximum yield changes of 8%, 13% and 18%. In all cases, the lower bound for the uniform distribution is unchanged at zero. For the 'Dry Decrease' distribution, the lower bound is changed to -0.08, -0.13 and -0.18. Finally, for the 'Wet Decrease' distribution, the lower bound is changed to -0.17, -0.22 and -0.27. In both of these cases, the upper bound for the uniform distribution is left unchanged at zero.

Sensitivity analysis results are provided in Tables 6.57 to 6.59. Results shown are annualized mean NPV of the operations per hectare of land for the residue management BMP. In each table the first column provides the revised bound (upper or lower) used in the particular sensitivity analysis scenario. For example, in Table 6.57 the values 0.08, 0.13, and 0.18 represent the revised upper bounds for the yield increase used in the three alternative scenarios for the sensitivity analysis. The last row in each table provides the base results for the BMP; that is, the mean annualized NPV per hectare generated using the base upper and lower bounds for the yield increase or decrease distribution.

As expected, increasing the upper bound for the distribution of yield increases in dry years results in improved performance (Table 6.57). This is due to the potential for greater crop yield increases in dry years if residue is retained on the field. Also as expected, decreasing the lower bound for yield decreases results in worsened performance. This is true for both yield decreases in dry years when residue is not retained (Table 6.58) and in wet years when residue is retained (Table 6.59). However, in all cases the absolute change in annualized NPV per hectare is relatively small and so it may be concluded that the BMP results are not very sensitive to the assumption regarding the range of yield increases or decreases associated with adoption of this BMP. It should be noted that annualized NPVs per hectare do not change from the baseline results with sensitivity analysis on the "Dry Decrease" variable for the representative farm in the Brown (dryland) soil zone. On this farm, the decision rule is that residues are only removed once every five years. In order for a yield decrease to occur the year would have to be "dry" when residues are removed. Since an effect is not observed it is hypothesized that a "dry" year does not occur on this farm when residues are removed, most likely by coincidence from specifications in the model.

Table 6.57 – Comparison of mean annualized NPV from retention of residue for different yield effect distributions in dry years with yield increases

Dry Increase	Annualized NPV per hectare with degree changes				
Adjusted Distribution Bound	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
Upper Bound					
0.08	$250.18	$67.22	$88.20	$279.62	$314.42
0.13	$251.17	$67.69	$88.86	$282.01	$316.45
0.18	$252.03	$68.15	$89.55	$284.33	$318.45
Base BMP Values[a]	$249.23	$66.74	$87.53	$277.25	$312.37

[a] The lower and upper bounds for the base BMP scenario are 0 and 0.03.

Table 6.58 – Comparison of mean annualized NPV from retention of residue for different yield effect distributions in dry years with yield decreases

Dry Decrease	Annualized NPV per hectare with degree changes				
Uniform distribution range	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
Lower Bound					
-0.18	$246.79	$66.74	$86.83	$273.40	$309.02
-0.13	$247.62	$66.74	$87.06	$274.67	$310.10
-0.08	$248.43	$66.74	$87.31	$275.97	$311.22
Base BMP Values[a]	$249.23	$66.74	$87.53	$277.25	$312.37

[a] The lower and upper bounds for the base BMP scenario are -0.03 and 0.

Table 6.59 – Comparison of mean annualized NPV from retention of residue for different yield effect distributions in wet years

Wet Decrease	Annualized NPV per hectare with degree changes				
Uniform distribution range	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
Lower Bound					
-0.27	$246.84	$65.53	$86.80	$269.84	$302.29
-0.22	$247.59	$65.95	$87.03	$272.17	$305.50
-0.17	$248.38	$66.34	$87.28	$274.65	$308.89
Base BMP Values[a]	$249.23	$66.74	$87.53	$277.25	$312.37

[a] The lower and upper bounds for the base BMP scenario are -0.12 and 0.

6.4.7 Sensitivity Analysis of Discount Rate

Sensitivity analysis is also done on the discount rate of the operations. For the baseline and BMP scenarios a discount rate of 10% is used as this was determined to be the most appropriate for commercial cropping operations and has been used in similar studies (Cortus, 2005; Koeckhoven, 2008). For the sensitivity analysis the results obtained in the baseline scenario are compared with results from the same scenario at 8% and 12% discount rates. Baseline scenarios assume no BMPs are adopted. As expected, using a discount rate of 8% results in an increase in the mean annual value of the operations since future cash flows are discounted to a lesser degree. Conversely, a discount rate of 12% results in decreased mean NPV values for the operations (Table 6.60).

Table 6.60 – Comparison of mean NPV at different discount rates, base rotation

	Mean NPV				
Discount Rate	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
8%	$2,980,586	$1,035,413	$1,345,945	$3,491,476	$2,957,884
10% (Baseline)	$2,441,735	$845,707	$1,094,775	$2,841,695	$2,419,362
12%	$2,081,269	$719,353	$927,760	$2,408,846	$2,056,321

Where the assumption regarding the value of the discount rate may be significant is in terms of the impact on BMP results. In particular, it is useful to know if the choice of discount rate has an effect on whether a particular BMP results in improved or weakened representative farm performance. This would be most likely to happen for BMPs where there is a change in sign over time with respect to the change in cash flow from the baseline scenario; for example, a BMP that initially results in reduced cash flow followed by increased cash flows relative to the baseline. Conversely, the discount rate is unlikely to have an effect on BMP comparisons if adoption results in consistently increased or consistently decreased cash flows relative to the baseline scenario. In this type of scenario, the choice of discount rate will obviously change the NPVs for the various scenarios, baseline and BMP. However, it is likely that the impact of the BMP relative to the baseline will not change in a significant way.

Most of the BMPs considered in this study are consistent with this last case; that is, a consistent pattern of cash flows. As a result it is unlikely that the discount rate will have a significant impact on conclusions from this study. However, to test the impact of the discount rate, sensitivity analysis is done for one rotational BMP, adoption of field peas in rotation.

The impact of the field pea rotational BMP on mean annualized NPV per hectare for the different discount rates is provided in Table 6.61. As can be seen from the results in Table 6.61, varying the discount rate between 8% and 12% has a relatively minor impact on the results for the field pea BMP. As the discount rate increases, the effect is to reduce the annualized benefit associated with the BMP (i.e., smaller positive values or more negative values). However, the general pattern of results, in terms of the absolute magnitude of the impact or the relative effect by farm, is unchanged.

Table 6.61 – Impact of the field pea BMP on mean annualized NPV per hectare, by discount rate[a]

Discount Rate	Brown, dryland	Dark Brown	Black	Dark Grey
8%	$42.95	$28.70	-$1.27	$5.56
Baseline (10%)	$42.37	$28.18	-$1.72	$4.92
12%	$41.84	$27.70	-$2.13	$4.37

[a] These values are calculated as the difference in mean annualized NPV per hectare for the field pea BMP and the baseline scenario, for each farm.

6.4.8 Sensitivity Analysis of Starting Crop Prices

The pattern of simulated prices over time is affected by the choice of starting price in the models. The most recent crop prices available during the analysis were used as the initial prices in all scenarios for this study. For the baseline and BMP scenarios the starting crop prices used are 2008 prices. However, it is also possible to use other historical values, or historical average prices, as the starting values. Therefore, sensitivity analysis is done to examine the impact on model results from choosing alternative starting prices.

The sensitivity analysis for the starting price considers three additional values, all of which are historical averages. Five year and ten year historical averages are used as alternative starting prices, along with a historical average based on the entire time series (1978 to 2008) used to estimate the pricing models. Table 6.62 provides the additional crop price averages used for the sensitivity analysis.

Table 6.62 – Crop prices used for sensitivity analysis of starting crop price in simulation analysis ($/kg)

Crop	2008 Price	Five Year Average	Ten Year Average	1978-2008 Average
Alfalfa Hay	$0.08	$0.08	$0.10	$0.11
Barley	$0.21	$0.14	$0.14	$0.15
Canola	$0.50	$0.36	$0.35	$0.41
Dry Bean	$0.16	$0.12	$0.13	$0.15
Durum Wheat	$0.45	$0.22	$0.22	$0.24
Field Pea	$0.30	$0.20	$0.19	$0.24
Oats	$0.18	$0.14	$0.15	$0.15
Spring Wheat	$0.32	$0.20	$0.20	$0.22

Sensitivity results for crop starting price are provided in Table 6.63. Compared to the original baseline scenario (i.e., using 2008 prices), the use of the historical average starting price scenarios results in lower mean annual NPV values for all representative farms. This is due to the fact that all of the historical average crop prices in Table 6.62 are lower than 2008 prices.[47] However, the impact of starting price is relatively minor, in terms of the change in mean annualized NPV per hectare.

Table 6.63 – Comparison of mean annualized NPV per hectare, assuming different starting crop prices

	Annualized Mean NPV per hectare with alternative crop price scenarios				
Start Price	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
2008 price (Baseline)	$235.69	$65.31	$84.54	$274.29	$311.37
5 year average	$223.90	$62.31	$82.59	$271.09	$308.09
10 year average	$223.81	$62.28	$82.57	$271.03	$308.04
historic average	$224.86	$62.54	$82.80	$271.53	$308.43

To test the effect of starting price on NPV of the operations shelterbelts and alfalfa hay are adopted and different starting prices are compared to the baseline (i.e., using 2008 prices) results. Differences in mean annualized NPV per hectare lost from adopting shelterbelts and the baseline results are provided in Table 6.64. The overall trend is lower NPVs for all farms when the average starting price of crops is lower (i.e., historic prices), and higher values when the starting price is highest (i.e., using the 2008 prices). However, the absolute magnitude of the changes in the per hectare cost of shelterbelt adoption are relatively small (i.e., the differences are all less than $5 per hectare).

Table 6.64 – Difference of mean annualized NPV per hectare lost with adoption of shelterbelts, assuming different start prices[a]

Start price	Brown, irrigated	Brown, dryland	Dark Brown, dryland	Black, dryland	Dark Grey, dryland
2008 price (Baseline)	-$316.96	-$194.79	-$181.40	-$395.74	-$411.27
5 year average	-$313.57	-$195.09	-$180.31	-$392.95	-$409.04
10 year average	-$313.79	-$195.03	-$180.26	-$392.80	-$407.94
historic average	-$311.33	-$194.72	-$181.03	-$392.56	-$408.16

[a] Calculated as the difference from results from shelterbelt adoption and baseline results for each of the different start prices.

[47] The only exception to this is for alfalfa, where the 2008 price is no greater than, and more often less than, the historical averages. However, alfalfa is not included in any of the baseline scenario rotations for the representative farms.

Results from adoption of alfalfa hay, as compared to the baseline values per hectare are provided in Table 6.65. The same trend is apparent as for the shelterbelt BMP, but to a lesser degree. The 2008 price of alfalfa is the same as the five year average price, but lower than the ten year and historic average price. This effect is shown in Table 6.65 as the comparison of BMP to baseline results yields a higher value when using the historic and ten year averages, as compared to the five year average and 2008 start price. However, the effect of the lower starting prices for the other crops outweighs the effect of the higher starting alfalfa prices in these scenarios for the overall NPV of the operations (i.e., without comparison to the baseline).

Starting prices do matter in terms of the simulation results for the baseline scenarios and the BMP adoption scenarios. However, from the sensitivity results shown for the alfalfa hay and shelterbelt BMPs, it may be concluded that their impact is not significant in terms of the overall effect of BMP adoption on farm performance.

Table 6.65 – Difference of mean annualized NPV per hectare with adoption of alfalfa hay, assuming different start prices[a]

Start price	Brown, irrigated	Dark Brown, dryland	Black, dryland	Dark Grey, dryland
2008 price (Baseline)	$36.02	$63.51	$47.74	$32.08
5 year average	$39.50	$63.88	$48.44	$33.01
10 year average	$40.60	$64.37	$48.86	$33.35
historic average	$40.93	$64.50	$48.62	$33.14

[a] Calculated as the difference from results from alfalfa hay adoption and baseline results for each of the different start prices.

6.4.9 Sensitivity Analysis of Safety Net Programs

For all previous scenarios it was assumed that representative farms participate in safety net programs including crop insurance, AgriStability, and AgriInvest. For baseline and BMP scenarios participation in crop insurance at 80% is assumed. Producer participation in safety net programs AgriStability and AgriInvest is voluntary. In the baseline scenarios it is assumed that producers participate in both programs. Sensitivity analysis is performed assuming producers do not participate in any safety net programs for the base rotations on all representative farms. Results from adopting field pea in rotation and shelterbelts are also performed without safety net programs.

Results from sensitivity analysis with and without participation in safety net programs for the base rotations are provided in Table 6.66. On all dryland farms participation in safety net programs increases the mean annual NPV of the operations in all scenarios considered. On the farm in the Brown soil zone (irrigated) participation in safety net programs decreases the mean annual NPV of the operations, as compared to no participation in safety net programs. However, it is assumed that this result is due to measurements in modelling, as AgriStability generally improves the value of the operations. While the difference is not significant (i.e., less than a dollar per hectare) it is thought that the greater benefit from no participation in safety net programs on the irrigated farm is due to higher income in general, due to more control of external risks, such as precipitation, on irrigated operations. For the farm in the Brown soil zone under irrigated production revenues are generally positive. For this farm, AgriStability participation fees outweigh potential payouts from the program for this farm.

Table 6.66 – Comparison of mean annualized NPV with and without safety net programs, base rotation

	Annualized Mean NPV per hectare				
Safety Net Programs	Brown, irrigated	Brown, dryland	Dark Brown	Black	Dark Grey
Yes	$235.69	$65.31	$84.54	$274.29	$311.37
No	$236.49	$47.60	$69.57	$256.18	$295.64

Results from comparison of mean annualized NPV from the baseline scenario and field pea adoption with and without safety net participation are provided in Table 6.67. Generally, participation in safety net programs results in greater net benefits associated with the field pea BMP. In other words, the degree of improvement in performance (i.e., difference in annualized NPV per hectare between the BMP and the baseline) associated with adding field pea is greater with safety net participation than for no participation. In the case of the Black soil zone farm, the field pea BMP still results in a net cost to the producer, but the net cost is reduced (i.e., a smaller negative benefit). These results make sense given the effect of safety net participation is to improve expected performance in general.

The only exception to this result in Table 6.67 is for the farm located in the Dark Grey soil zone. For this farm, the field pea BMP results in improved performance (i.e., a positive net benefit from adoption) with and without safety net participation. However, the net benefit is greater in the case of no participation. It is thought that this result occurs due to yield assumptions for field peas specific to this representative farm. As discussed in Chapter 5, due to a lack of continuous yield data for some crops yield distributions are estimated using correlations and a percent change in yields from a reference crop (i.e., barley on dryland farms). However, an average yield for the unknown crops (i.e., the crops without continuous yield data), in this case field pea, is necessary. The initial "average" is estimated from the small data set that does exist for field pea crops. The estimated "averages" for representative farms that consider field peas are approximately 1,900, 1,700, 1,773, and 2,143 kilograms per hectare for farms located in the Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively. This higher starting average for field pea yields in the Dark Grey soil zone contributes to the benefit of including field peas in rotation in this soil zone. Safety net program payments are made when yields, and therefore revenues are low, so if the estimated yields from including this crop are predicted to be high there may not be benefit from participation.

Table 6.67 – Difference of mean annualized NPV per hectare with and without safety net programs, field pea rotation

	Difference in mean annualized NPV per hectare[a]			
Participation in safety net programs	Brown, dryland	Dark Brown, dryland	Black, dryland	Dark Grey, dryland
Yes	$42.37	$28.18	-$1.72	$4.92
No	$40.11	$27.83	-$2.07	$7.68
Difference	-$2.26	-$0.35	-$0.34	$2.76

[a] Calculated as the difference in mean annualized NPV from field pea adoption with and without safety net participation and the baseline results with and without safety net participation, per hectare of land.

Table 6.68 provides a comparison of the results for shelterbelt adoption with and without safety net participation. The results in Table 6.68 represent the mean cost per hectare taken out of production as a result of establishing shelterbelts. Given that safety net participation generally improves expected farm performance (i.e., as shown in Table 6.66), it is expected that not participating in safety nets would reduce the cost of this BMP due to a lower opportunity cost of foregone crop returns. The expected result occurs for the farms in the Brown (dryland) and Dark Brown soil zones. However, the expected per hectare cost of implementing shelterbelts increases for the other three representative farms. For the farm in the Brown soil zone under irrigated production this result is consistent with the results in Table 6.66 where participation in safety net programs actually decreases the value of the operation as compared to participation.

However, for representative farms in the Black and Dark Grey soil zones the result, that participation in safety nets increases the cost of shelterbelt adoption is not intuitive. Adoption of shelterbelts on farms in the Black and Dark Grey soil zones is costly and decreases farm revenue. This decrease in revenue should trigger safety net payments. The fact that shelterbelt adoption is more viable without safety net participation could be due to the fact that revenue on these representative farms is relatively high, as compared to the other dryland farms. It is hypothesized that the amount of revenue is still sufficiently high when shelterbelts are adopted such that safety net payments are not triggered, and the value of the operations is improved without participation in the programs by saving the associated participation fees.

Table 6.68 – Difference of mean annualized NPV per hectare lost from shelterbelt adoption with and without safety net programs

Participation in safety net programs	Difference in mean annualized NPV per hectare lost[a]				
	Brown, irrigated	Brown, dryland	Dark Brown, dryland	Black, dryland	Dark Grey, dryland
Yes	-$316.96	-$194.79	-$181.41	-$395.74	-$411.27
No	-$331.26	-$176.11	-$176.61	-$415.97	-$439.60
Difference	-$14.30	$18.68	$4.80	-$20.22	-$28.34

[a] Calculated as the difference in mean annualized NPV from shelterbelt adoption with and without safety net program participation and the baseline results with and without safety net participation, per hectare of land lost from shelterbelt adoption.

6.5 Chapter Summary

Many rotational BMPs are beneficial for most farms while some non-rotational BMPs may be costly. Specifically, on farms in the Brown (dryland) and Dark Brown soil zones the addition of alfalfa hay and/or field peas to rotations decreases the amount of land allocated to summerfallow practices and increases land allocated to crops. This improved the value of the operations, as expected. On other representative farms that considered adoption of alfalfa hay into rotation, in the Brown (irrigated), Black, and Dark Grey soil zones, increased NPVs due to the value of alfalfa hay as a crop and potential benefits to subsequent crops following alfalfa hay in rotation also occurred. While there are also potential benefits to crops following field peas in rotation, this crop alone did not improve the mean NPV of the farm in the Black soil and only marginally improved the NPV of the farm in the Dark Grey soil zone. When legume green manures were adopted alone as a partial or complete replacement for summerfallow in rotations on farms in the Brown (dryland) and Dark Brown soil zones decreases in mean NPV of the operations were observed as there are more costs associated with including legume green manures in rotation, as compared to summerfallow practices. Oats were adopted as a rotational BMP on farms in the Black and Dark Grey soil zone as fewer inputs are required for this crop. However, due to lower crop price this BMP resulted in reduced mean NPV of the operations, largely due to reduction of land allocated to higher valued crops, such as canola.

When rotational BMPs are combined some of the individual BMPs that did not seem viable are still beneficial in combinations. When alfalfa hay and field peas are both adopted as BMPs the effect is additive on the farm in the Dark Brown soil zone as these crops completely replace summerfallow practices. This combination was also additive on farms in the Black and Dark Grey soil zones. When field peas were adopted alone in the Black soil zone it was not a viable crop, but with alfalfa hay there is a positive effect on this farm. When alfalfa hay is adopted with legume green manures on the farm in the Dark Brown soil zone summerfallow practices are also phased out and a positive mean NPV is experienced. However, the effect of adding alfalfa hay with legume green manures is lower than adding alfalfa hay with field peas and alfalfa hay with field peas and legume green manures, as less land is dedicated to cash crops.

While adoption of some rotational BMPs reduced the mean NPV of the operations with respect to the baseline results, they did not result in negative mean NPVs. Also, when considering rotational BMPs in combination with others there is potential for increased mean NPVs. These results are encouraging as producer adoption of many of the rotational BMPs examined in this study would require education and involvement of producers, rather than government provided incentives or disincentives; the former being a relatively cheaper policy option.

Adoption of the non-rotational BMPs shelterbelts and buffer strips were more costly for producers due to the allocation of previously cropped land for these practices. Shelterbelts removed significant portions of land from crop production. While shelterbelt adoption reduced the value of the operations as compared to the baseline results, all representative farms still experienced a positive mean NPV. Adoption of buffer strips also resulted in decreased mean NPVs for all representative farms. However, when producers enabled the option to harvest and sell forage from the buffer zones the cost of this BMP decreased. Residue management as a non-rotational BMP increased the mean NPV of the representative farms in all soil zones, relative to the original baseline scenario, but resulted in decreased mean NPVs for all farms relative to the revised baseline scenario where residue is removed every year.

Considering that many of the non-rotational BMPs examined came at a net cost for producers, government involvement in the form of positive incentives for adoption may be necessary. If it is the case that adoption is low for practices that are costly for producers, then it is likely that policy involvement such as incentive mechanisms may be necessary.

There were ten sensitivity analyses performed in total. Some sensitivity analyses were done to expand and test some of the yield and input cost saving assumptions made for BMP adoptions. Others were done to compare how other model assumptions including discount rate, starting crop price averages, and safety net participation affect the value of the operations for baseline and BMP results. For the most part sensitivity analysis of model assumptions did not change the relative outcome of the results. This conclusion offers greater confidence in the ability of the models to predict the effects of BMP adoption of representative farms in Alberta.

Chapter 7: Conclusions and Further Research

A summary of results from the simulation models is provided in this chapter. Following this, conclusions are made based on these results, regarding the feasibility of Beneficial Management Practices (BMP) adoption on representative Alberta crop farms. BMP results from this study are compared to other studies with adoption of similar management practices. This chapter also discusses implications of this research for crop production and policy in Alberta. The chapter concludes with a discussion of limitations and assumptions made in developing the models and potential areas of further research that may be of interest, based on the findings in this study.

7.1 Summary of Results

BMPs have been advocated as a means by which the level of ecological goods and services (EG&S) supplied by agriculture may be increased. However, the societal optimum level of EG&S from agriculture may not equal the amount willing to be supplied by producers. Policy intervention may be necessary to ensure a balance between society and agricultural producers with respect to EG&S production from agricultural practices. Policy decisions might focus on encouraging adoption of BMPs, through extension or incentive policies, to reach the optimum supply of EG&S.

The objective of this study was to quantify and evaluate the economic impact of BMPs for representative Alberta crop farms. To accomplish this, an analysis of the economic costs and benefits associated with BMP adoption on representative Alberta crop farms was undertaken. In particular, this study was performed to determine the direct costs and benefits for Alberta crop farms when BMPs are adopted. The BMPs of interest included adoption of shelterbelts, buffer strips around wetlands, crop residue management, and the introduction of alfalfa hay, field peas, legume green manures as a replacement for summerfallow, and oats in crop rotations. Cost and benefit estimates of adoption of these BMPs were obtained by modelling five farms that are representative of commercial cropping agriculture in Alberta. Farms varied by size and location, but were developed to represent areas where cropping agriculture is significant.

Municipal level crop yields and crop price data from AARD, AFSC, and CWB were used in a Monte Carlo simulation analysis. For baseline and BMP scenarios NPVs with perpetuity were calculated. The impact of risk in agriculture was incorporated in the models using stochastic variables for crop prices and yields. Further to this, stochastic BMP parameters were incorporated to model the effect of shelterbelt, residue management, alfalfa hay, field peas, and legume green manure adoption. Economic and cropping relationships were modelled for the representative farms and the outcome of BMP adoption was assessed through comparisons to the baseline scenarios. All BMP scenarios were compared to the baseline where BMPs were not adopted to determine the potential costs or benefits of BMP adoption for the representative farms. This chapter presents the main findings of the analysis and the implications for producer and policy decisions, model limitations, and further research that could be extrapolated from this study.

7.2 Economic Feasibility of Beneficial Management Practices Adoption

Five farms were modelled to simulate representative regions and cropping operations in Alberta. Farms were located to provide coverage of the major crop producing regions in Alberta; specifically, farms were located in the Brown, Dark Brown, Black, and Dark Grey soil zones. Dryland production was considered in all soil zones and irrigated production was also considered in the Brown soil zone. Farms were further defined by crop rotation. Baseline results were obtained for each farm and the base rotation and further BMP results were compared to the baseline scenarios.

There were four main crop rotation BMPs considered for the five representative farms. Crops considered BMPs for this study include alfalfa hay, field peas, legume green manure, and oats. Considering combination BMPs that include multiple additional crops for each soil zone there were a total of eleven BMP crop rotation scenarios modelled for the five representative farms.

Adding alfalfa hay to the crop rotation may be considered as a BMP because it is a leguminous perennial crop that has potential to increase nitrogen stores in the soil. This may lead to potential yield increases following alfalfa hay from increased nitrogen and a break in annual crop disease cycles. Reduced costs from fewer nitrogen fertilizer inputs following the alfalfa hay stand may also occur. Alfalfa hay was adopted on farms located in the Brown (irrigated production), Dark Brown, Black, and Dark Grey soil zones. The adoption of this rotational BMP proved economically beneficial in all cases. Mean annual benefits were approximately $36, $64, $48, and $32 per hectare for farms in the Brown, Dark Brown, Black, and Dark Grey soil zones, respectively. Benefits from this BMP were attributable to stochastic yield benefits for crops following alfalfa stands, for up to three years. Other benefits contributing to the positive effect of including alfalfa hay in rotation were reduced nitrogen fertilizer costs for crops following alfalfa hay.

Including field peas in the crop rotations may be considered a BMP as this is also a leguminous crop where there is potential for nitrogen and yield benefits for crops following field peas. Fewer inputs are required following field peas and field peas in rotation have potential to break disease cycles in other annual crops. Field peas were adopted as a rotational BMP on all dryland farms in all soil zones considered. The adoption of this BMP also proved relatively beneficial and feasible for producers with mean annual benefits being approximately $42, $28, -$2, and $5 per hectare for farms in the Brown, Dark Brown, Black, and Dark Grey soil zones, respectively. Similar to alfalfa hay the benefit of including field peas in crop rotations was due to potential yield benefits and nitrogen fertilizer savings for the crop following field pea in rotation. Larger benefits from adoption of field peas were observed for representative farms in the southern areas (i.e., Brown and Dark Brown soil zone farms) of the province. This was due to partial replacement of land that was previously under summerfallow practice with field pea. Conversely, the benefits were relatively smaller for farms in the northern soil zones (and negative for the Black soil zone farm) as the adoption of field pea in rotation removes some of the land that was previously used for higher valued crops such as canola.

Incorporating legume green manures into crop rotations may also be considered a BMP as there are similar benefits to alfalfa hay and field peas from this being a leguminous crop. Also, in this study legume green manures were a partial replacement for summerfallow practices. Summerfallow has potential to increase the rate of soil erosion. Reducing this practice by replacing it with an annual crop that is ploughed down, increases soil aggregates and may improve soil quality in the long term. Legume green manures were adopted as a partial or complete replacement for summerfallow on the Brown (dryland) and Dark Brown soil zone representative farms. Adoption of this BMP resulted in a net cost of approximately $5 and $10 per hectare, respectively, for the Brown and Dark Brown soil zone farms. Similar to the alfalfa hay and field pea BMPs, associated with this BMP were nitrogen fertilizer savings for the crop following legume green manures in rotation. However, these savings were outweighed by the fact that growing the green manure crop was more costly (i.e., more input costs) as compared to summerfallow, with no marketable crop being produced. Also there was a potential negative yield effect for the crop following legume green manures in rotation as this crop may compete with future crops for reserved soil moisture, as compared to summerfallow practices.

Oats were adopted as a BMP on farms located in the northern soil zones, Black and Dark Grey. The adoption of oats in rotation was considered a BMP due to reduced inputs during the production year. Adoption of oats in the crop rotations resulted in mean annual net costs of approximately $29 and $6 per hectare, respectively, for the Black and Dark Grey soil zone representative farms. This result occurs because adoption of oats in rotation removed some of the land that was previously cropped as higher valued crops such as canola. The difference in results between the two representative farms was due to a combination of lower input costs for oats in the Dark Grey soil zone as compared to the Black soil zone and higher modelled oat yields for the Dark Grey soil zone.[48]

The rotational BMPs were also modelled in combination with each other; that is, adoption of multiple rotational BMPs. The results from these combination BMPs were generally consistent with the results for the individual BMPs. The benefits from the alfalfa hay BMP typically dominated effects from other rotational BMPs when it was present. When field pea was present in rotation without alfalfa it also typically dominated other crop yield effects, such as from legume green manures or oats. The exception to this was in the Black soil zone where field pea in rotation did not result in economic gains.

Three non-rotational BMPs, adopted by all representative farms, were also modelled in this study. These included shelterbelts, buffer strips around wetlands, and residue management. Buffer strips were examined in two different ways; with the land taken out of annual crop production being left idle or being used for hay production.

Shelterbelt adoption was considered a BMP for this study as there is potential for reduced soil erosion in areas sheltered by the tree species. Reduced soil erosion may improve soil quality and decrease water runoff that may affect water quality in the long term. Adoption of shelterbelts was costly for producers. Land that was previously cropped was “lost” to shelterbelts. That opportunity cost combined with the cost of planting and maintaining the trees until they are mature enough to survive unattended resulted in a net annual cost being associated with this BMP. There were also yield effects for crops in the areas adjacent to the shelterbelts (both positive and negative, depending on distance from the trees). However, these effects were generally outweighed by the other costs noted above. Mean annual costs were approximately $317, $195, $181, $396, and $411 per hectare lost due to shelterbelt adoption on farms representative of the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively.

Buffer strips around wetlands were considered BMPs for this study as water quality is improved by this practice. Buffer strips reduce the amount of soil particles that enter aquatic systems, which improves water quality and may affect aquatic species present in the ecosystem. Adoption of the buffer strip BMP also resulted in a net cost for all representative farms. Adoption costs consisted of the opportunity cost associated with loss of land that was previously being cropped. These costs varied by farm. The mean annual costs for the BMP were approximately $347, $95, $113, $298, and $338 per hectare lost from buffer strip adoption for the farms representative of the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively. The version of this BMP in which hay was produced on the buffer strip area resulted in lower net costs for the representative farms. This was due to the fact that in this scenario

[48] The assumptions made in the analysis that led to the higher modelled yields for the Dark Gray soil zone farm are discussed in Chapter 5.

the buffer strip area was generating returns for the farm. When the option to grow and sell hay for this BMP was employed the cost of the BMP was reduced by approximately $67, $75, $86, $76, and $61 per hectare lost from buffer strip adoption on representative farms in the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively. Even with this adjustment in the BMP, however, there was still a net cost to the farms as the returns from hay production were lower than the foregone returns from annual crop production.

The adoption of residue management was also considered as a BMP for this study. Active residue management has potential to reduce water and soil erosion, particularly on dry soils. Retention of residues in dry years may improve yields as soil moisture is less likely to be evaporated and more organic matter on the surface provides nutrients for crops. However, residue management also entails the removal of residues when they are present in excess. Too much residue may lead to cool spring soils and poor seedling emergence, and thus poor yields. As with the other non-rotation BMPs examined in this study, adoption of residue management also resulted in a net cost to the representative farm operations. While there were potential yield benefits assumed for subsequent crops if crop residue was retained in dry years, there were also potential yield decreases associated with this practice in wet years. As well, the residue (i.e., straw) was assumed to be marketable and so retaining it represents a foregone opportunity for additional returns. The mean annual costs associated with this BMP were approximately $21, $11, $13, $23, and $26 per hectare on farms representative of the Brown (irrigated), Brown (dryland), Dark Brown, Black, and Dark Grey soil zones, respectively.[49]

Sensitivity analysis was conducted for a number of key parameters associated with the various BMPs. This included the nitrogen savings and yield effects for crops following alfalfa hay, field peas, and legume green manures, and the yield effects associated with shelterbelts and residue management BMPs. As well, sensitivity analysis was done for the buffer strip BMP, with respect to the proportion of the farm in wetlands and the width of buffer strips. Finally, the representative farms were modelled varying the discount rate, the starting prices for the pricing equations, and with/without participation in safety net programs. While all of these sensitivity analysis scenarios caused the numerical simulation results to change for the BMPs, they did not fundamentally change the overall impact of the BMP. That is, when the BMPs proved economically beneficial to producers, this also held true when the various parameters were tested. The same proved to be the case for BMPs that resulted in net costs to the representative farms.

7.2.1 Comparison of Selected Results to Other Studies

This section compares BMP results from this study, specifically the adoption of alfalfa hay, field peas, annual cover crops, shelterbelts, and buffer strips, to results from other sources. However, it should be noted that it is difficult to directly compare the economic impacts of BMPs across studies because most studies do not use the same type of analysis or there are differences in the quantification of net benefits from BMPs.

A study of production returns from alfalfa hay under irrigated production was conducted by the University of California Extension (2007) using a hypothetical farm representative of the Butte Valley region of California. Production returns, net of total costs, from alfalfa hay under irrigated production were approximately $160 per hectare (University of California Extension, 2007). This estimate included operating and investment costs, some of which are not included in the current study, where the annual

[49] For reasons provided in Chapter 5, the results for this BMP were compared to a revised baseline scenario.

benefit of including alfalfa hay in rotation, as compared to the base rotation ranged from approximately $32 to $64 per hectare. Specifically, the difference was $32 per hectare under irrigated production. However, the base and BMP rotations in the current study differ and cannot be directly compared due to different proportions of crops grown. However, the farm in the Brown soil zone (irrigated) is the simplest to compare since adopting alfalfa hay in rotation added three years of alfalfa hay prior to the same crops in the base rotation (i.e., see Table 5.32). The average cost of growing crops in the base rotation was approximately $660 per hectare, while the average cost of growing the crops in the alfalfa hay rotation was approximately $548 per hectare. This is a difference of approximately $112 per hectare in cost savings, which can be reasonably compared to the California study (University of California Extension, 2007), since subsequent yield effects were not included in this estimate. Both studies conclude that there are economic benefits to alfalfa hay production.

Harapiak (2007) estimated that the fertilizer benefit of growing field peas would increase economic returns by approximately $84 per hectare, and that field peas provided residual benefit to crops in the range of $74 to $124 per hectare. An approximate estimate from the economic benefit from including field peas in rotation is $183 per hectare (Harapiak, 2007). As previously mentioned, it is difficult to determine the exact benefit of a crop in rotation in the current study since the rotations are altered when the BMP crop is adopted. However, on the representative farm in the Brown soil zone (dryland) field peas directly replaced one year of summerfallow in rotation (i.e., see Table 5.33). The average direct expense for field peas was approximately $257 per hectare. However, there are revenue benefits from replacing summerfallow with field peas. Revenue from field pea was estimated to be approximately $406 per hectare (based on 1900 kg/ha yield, multiplied by $0.21/kg). The approximate, revenue net of direct expenses, benefit of including field peas was $149 per hectare, which would be lower, but still comparable to the estimated benefit by Harapiak (2007).

The University of California Extension (2003) also conducted a study of the production returns from growing an annual cover crop. In this study it was assumed that there is no loss in revenue and the type of cover crop was an oat cereal crop, as compared to the legume crop used in the current study. It was found that cover crops resulted in a short term benefit of approximately $69 per hectare per year, but had a total cost of approximately $363 per hectare per year (University of California Extension, 2003). The net change in income was estimated to be approximately -$294 per hectare. In the current study the representative farm in the Brown soil zone (dryland) directly replaces one year of summerfallow with a legume cover crop (i.e., see Table 5.33). The total direct expenses were found to be approximately $108 per hectare. This is likely not significantly different from the expenses associated with summerfallow, but there were also yield effects (i.e., negative subsequent yields in dry years) from including a cover crop in rotation. In the California study it was assumed that the land was simply not used (i.e., no summerfallow expenses) prior to growing a cover crop, and the cover crop was irrigated (University of California Extension, 2003). Both studies concluded that there are net costs associated with cover crops. The results would be more comparable without the additional costs of irrigation in the California study and with the potential yield decrease effect in terms of economic cost in the current study.

Kort (1988) conducted a review of literature on the economic value of shelterbelts. From multiple sources it was generally found that shelterbelts resulted in increased net economic returns. Several studies examined by Kort (1988) found that shelterbelts paid for themselves in improved yields after 15 to 40 years. A study of Canadian shelterbelts by Nicholaichuk (1980) estimated a net economic return of $3.40 per hectare per year. However, McMartin et al. (1974) conducted a study in North Dakota where yields were collected in fields with existing shelterbelts and found net economic returns to be -$6 per hectare per year. Economic returns from shelterbelts vary geographically and with the reliability of yield estimates from shelterbelt studies. The current study bases yield effects from shelterbelt studies in Alberta. The results are that shelterbelt adoption is costly for producers and ranges from $180 to $411 per hectare per year of crop land converted. The assumptions made for the current study were reasonable in terms of the literature used, and were even thought to be conservative in the estimates. Many past studies concluded that shelterbelts are economically beneficial, however the type of analysis done to confirm these findings differ from that of the current study.

Koeckhoven (2008) used both simulation and NPV analysis to determine the effect of conversion of crop land to permanent forage in riparian areas. This particular BMP is comparable to the buffer strip BMP in the current study. Koeckhoven (2008) estimated the annualized reduction in NPV to be approximately $444 per hectare of crop land converted. This estimate considers NPV with perpetuity and complete protection of the land. The current study estimated the annualized reduction in NPV to range from approximately $95 to $339 per hectare of crop land converted to permanent forage in buffer zones. It should be noted that of the total land converted in Koeckhoven (2008), 155 hectares, approximately 85 hectares is converted to permanent cover and 70 hectares is returned to riparian habitat. In addition, Koeckhoven (2008) includes fencing costs to exclude cattle from the areas. While direct comparisons between the two studies cannot be made, in general, it was concluded from both studies that it is costly for producers to convert crop land to permanent forage.

7.3 Implications for Crop Production and Policy in Alberta

The overall conclusion of this study was that cropping-related BMPs have limited potential for providing direct net benefits to crop producers in Alberta. BMPs that involved removal of land from production (e.g., shelterbelts, buffer strips) were costly for producers. As well, BMPs that changed crop rotations in ways that do not involve adding marketable crops (e.g., green manure) or that did not provide yield benefits or significant cost savings for subsequent crops (e.g., oats), also represented a net cost to producers. The opportunities for direct net benefits arose from adoption of BMPs that involved incorporating marketable crops into rotations that also provided potential nitrogen and/or yield benefits to subsequent crops.

Economic theory suggests that producers, as risk-neutral and price taking firms, minimize costs or maximize profits (Love, 1999). The results and conclusions from this study suggest, then, that the potential for uptake of relevant BMPs by Albertan crop producers is limited. While some or many producers may also incorporate environmental quality considerations in decision making, it is entirely possible that policy intervention will be necessary to encourage Albertan crop producers to adopt BMPs so that a socially optimal level of EG&S production from agriculture is achieved.

As discussed in Chapter 2, the Pannell (2008) environmental policy decision making framework (see Figure 2.4) may be used to assist in guiding decisions regarding policy instruments. What are required to utilize this framework are estimates of public and private net benefits associated with specific land use or production practice changes. The analysis in this study has generated estimates of private (i.e., direct producer) net benefits associated with a specific set of cropping BMPs. If it is assumed that the net public benefits associated with these BMPs (i.e., the societal value of increased EG&S production) are positive, Pannell's policy framework may be used to identify appropriate potential policy instruments.

For those BMPs modelled in this study that resulted in positive net private benefits for the representative cropping operations (i.e., alfalfa and field pea rotational BMPs), Pannell's framework would suggest that extension is the appropriate policy instrument. In other words, information and education should be sufficient to encourage adoption of these production practices.

For the other BMPs examined in this study, the net private benefits are negative; that is, adoption of these BMPs results in a net cost to producers. Based on these results, to improve adoption of shelterbelt and buffer strip BMPs it is likely that positive incentives or technological innovation would be appropriate policy mechanisms. Positive incentives may include direct subsidies or payments to encourage adoption. Conversely, technological innovation as a policy response would depend on the nature of the BMP. Technological innovations could include improved yields for hay or oats, for example, which would help offset the opportunity costs of taking land out of production from other crops. According to Pannell's policy framework, the appropriate choice of policy in this case depends on the relative magnitude of the net public benefits versus the net private costs (i.e., magnitude of the negative benefits). Further research would be required to establish estimates of the value of these public benefits.

Increasing adoption of BMPs results in the provision of EG&S, such as improvements in soil, water, and air quality, that is closer to the societal optimum. For environmental conservation to occur, changes in land practices at the private land owner level are necessary. However, supplying EG&S through BMP adoption is not valued by markets, and as such there is no private incentive for producers/land owners to provide these services. It is also known that there are costs associated with adoption of BMPs to supply EG&S, such as time and/or money. This study aimed to quantify the benefits and costs of BMP adoption. These estimates represent one piece of information that can be used to determine appropriate policy mechanisms to encourage adoption of BMPs.

7.4 Limitations and Assumptions of the Models

It should be noted that the results of this study are specific to the regions of interest, namely four soil zones in Alberta. The models are comprehensive for these regions, but results may not be applicable in other situations. There are limitations associated with the restrictions of defining a finite set of representative farms, when it is generally accepted that cropping agriculture in Alberta is, in reality, heterogeneous. Assumptions were made to specify each farm to the region, including common crops grown and yield of the crops. Results are representative of commercial cropping operations in Alberta, per major cropping soil zone. It should also be noted that assumptions were made to broaden the applicability of the farms to soil zones, rather than smaller, specific agricultural regions in Alberta. In developing representative farm models many assumptions were made, including the percent of wetland in each region, farm size, and crop rotations.

Assumptions made in defining a set of representative farms for this study result in relationships between the magnitude of the net benefit from BMP adoption and assumed farm characteristics. The results of the net benefit of BMP adoption may vary significantly across crop farms in Alberta, but this is not modelled with the use of representative farms with predetermined characteristics. Specifically, it was assumed that each farm had a set percentage of wetland that was realistic for the region of interest with set shape and distribution of wetlands across the farms for simplicity in modelling. In reality, farm profitability would vary if the size or shape of wetlands varied. In addition to this, societal benefit from wetland BMP adoption would vary based on the size of wetland. Assumptions regarding crop rotations for the regions of interest were also made.

Crops in rotation were determined using Statistics Canada data, but assumptions to narrow the number of crops grown were made. Certain crops, such as potatoes and malt barley, were not present in any of the rotations, even though they may be considered on commercial operations in the representative soil zones in reality. Also, once the base or BMP crop rotations were assumed these rotations remained the same throughout the entire simulation. This assumption, of no reversibility in decisions was true for all BMPs considered. Once adoption occurred, the BMP was modelled for the entirety of the simulation period.

While using yield distributions somewhat accounts for risks in agriculture, including crop disease, the probability of crop disease as associated with the assumed crop rotation, was not explored. For example, in the Black and Dark Grey soil zones canola occurs relatively frequently in rotation. In reality producers may break from this rotation if clubroot, a common disease from frequent canola in rotation, occurs. In addition, there are crop diseases associated with pulse crops that were not explored in this study. Yield effects from retaining versus removing or reducing the amount of land under summerfallow practice on representative farms in the Brown and Dark Brown soil zones were also not explored. Considering the popularity of this practice in some areas of Alberta there are likely more involved subsequent yield effects and decisions regarding this practice. It is possible that the decision to allocate land to summerfallow practice is more complicated and may depend on time available for seeding in the spring. In general, yield effects from diseases and cropping practices are highly probable and this study assumes that the effect is modelled in part by the yield distribution. In reality additional disease or cropping practice distributions would better account for these effects.

Many assumptions were made regarding residue management as a BMP. Initially it was assumed that residue was removed at static annual intervals, but no yield impacts were considered in the results. Another baseline scenario was developed where residue was removed each year at custom rates, and sold. Yield decreases were a possibility in dry years for this scenario. In the BMP scenario residue was removed at the same frequency as the initial baseline scenario, but yield increases and decreases were a possibility, as well as the added costs and benefits of baling and sale of the residue. There were challenges in accurately modelling this BMP, and as such assumptions were made in an attempt to quantify the benefits and costs of adoption and compare these to two baseline scenarios.

7.5 Further Research

This study included four major soil zones that are representative of cropping agriculture in Alberta. It would be interesting to expand this study to look at an extended set of representative farms in Alberta where alternative baseline crop rotations and farms of different sizes are examined. These types of expansions to the current study may provide insight to the impact of different farm size on the potential for economies of scale in BMP adoption. Comparisons of different base rotations would also provide further insight on the net benefit of BMP adoption.

This research used dynamic simulation methods and cash flow analysis to determine the net effect of BMP adoption. Future studies could improve upon the predictability of producer decisions by including an optimization portion to the analysis. As previously stated, producers act in a rational manner, where costs are minimized or profits are maximized. Optimization of variables could improve upon some of the assumptions that were made in the models by ensuring some decision variables are optimized for crop production. For example, in this study it was assumed that both baseline and BMP crop rotations are fixed over time. That is, once a crop rotation is decided upon it continues for the entire simulation. Further studies could expand on this assumption by using a long term rotation that is similar to the application in the current study, but allow annual deviations based on market signals that may include yield predictions that are drawn from climate and weather, or price predictions. Another potentially interesting application for BMP adoption decisions, including crop rotations would be to incorporate endogenous producer decisions. Similar decisions were used in the study by Cortus (2005) for drainage decisions, where producer decisions were based on factors within the model. Similar to deviations from crop rotation decisions, BMP adoption decisions may occur due to policy mechanisms or market signals. Endogenous decisions may be particularly interesting for the residue management BMP as a decision rule could be built to determine when residue is removed or retained, based on yield or market signals within the models.

The focus of this study was to quantify the private benefits and costs of BMP adoption, that is, the benefits and costs incurred by producers. In making policy decisions it would be useful to determine the quantitative public or societal net benefits from agricultural BMP adoption. BMPs to improve the provisioning of EG&S have potential external benefits for other agricultural producers, recreational users, wildlife species in the surrounding areas, and nearby municipalities. Estimates of net benefits for these users, especially as it applies to soil and water quality would be a useful extension of this project to determine optimal policy programs (i.e., incentive, extension, or technology based) for increasing BMP adoption. Further research of the willingness to pay or willingness to accept for producers and society for the provisioning of EG&S through BMPs and the evaluation of non-market goods would also aid in the development of efficient policy design.

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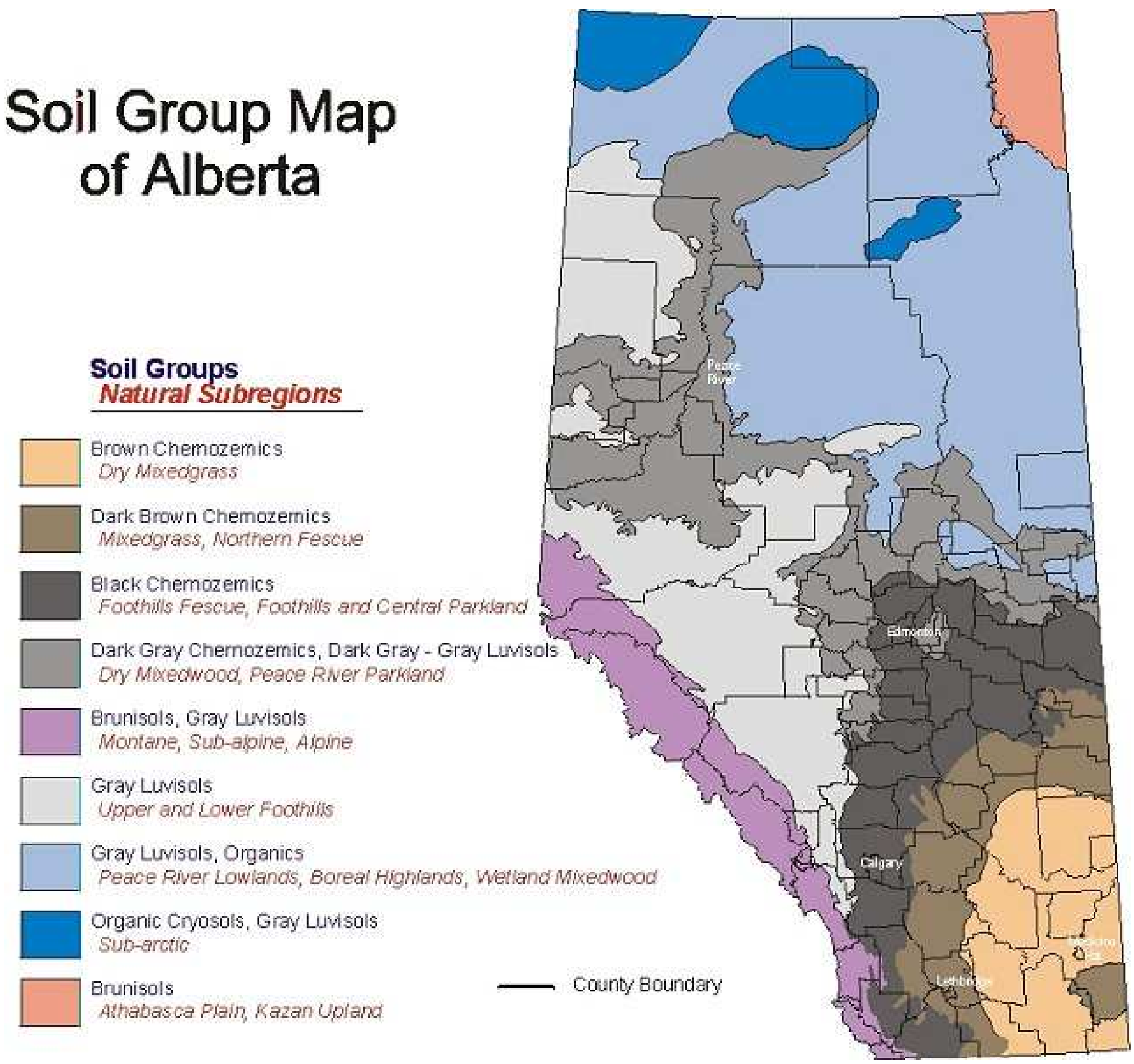
Appendix A: Alberta Soil Zones



Source: *Adapted from* AARD (2005-b) *with permission from Alberta Agriculture and Rural Development*

Appendix B: Counties/Districts Considered in Choosing Representative Farms

Brown	Dark Brown	Black	Dark Grey
Special Area 2	Special Area 4	Cardston County	Lac Ste. Anne County
Special Area 3	County of Lethbridge	M.D. of Pincher Creek	County of Barrhead
County of Newell	Vulcan County	M.D. of Foothills	Westlock County
County of Forty Mile	Wheatland County	M.D. of Rocky View	County of Thorhild
Cypress County	Starland County	Red Deer County	County of St. Paul
M.D. of Taber	County of Paintearth	Lacombe County	Athabasca County
	M.D. of Provost	Leduc County	Two Hills County
		County of Camrose	M.D. of Smoky River
		Beaver County	Birch Hills County
		Minburn County	M.D. of Spirit River
		Vermilion River County	County of Grande Prairie
		Strathcona County	M.D. of Fairview
		Sturgeon County	
		Flagstaff County	
		M.D. of Wainwright	

Appendix C: New and Initial Values of Machinery Complement, by Soil Zone

C.1 – New and initial (book) values of machinery complement in Brown soil zone under irrigated production

Description	Size	New Value	Initial (Book) Value
4WD Tractor	325 h.p.	$200,200	$150,877.03
S.P. Swather	24 ft.	$97,300	$65,890.30
Combine	Class 7	$255,400	$163,804.70
Grain Truck 1	565 h.p.	$87,000	$58,915.28
Grain Truck 2	565 h.p.	$87,000	$58,915.28
Farm Truck	3/4 ton	$38,200	$25,868.55
Air Hoe Drill	40 ft.	$112,800	$76,386.70
Harrows	50 ft.	$11,900	$8,058.53
Bean Rod Cutter	6R 30"	$10,000	$6,771.87
Bean Windrower	6R 30"	$20,000	$13,543.74
Combine header - pick up	14 ft.	$20,900	$14,153.21
Combine header - flex	30 ft.	$38,800	$26,274.86
Combine header - pick up beans	22 ft.	$25,000	$16,929.68
Grain Auger	10 in; 50 - 60 ft.	$9,100	$6,162.40
Conveyor Attachment (beans)	15 in; 60 ft	$17,500	$11,850.77
Start up costs		$1,165,500.00	$688,216.10
Total		$2,196,600	$1,392,618.99
Total per hectare		$2,120.27	$1,344.23
Total per hectare per year (8% depreciation)		$169.62	$107.54

C.2 – New and initial (book) values of machinery complement in Brown soil zone under dryland production

Description	Size	New Value	Initial (Book) Value
4WD Tractor	425 h.p.	$215,600	$162,483
S.P. Swather	30 ft.	$99,500	$67,380
Combine	Class 6	$235,000	$150,721
Grain Truck 1	565 h.p.	$87,000	$58,915
Grain Truck 2	565 h.p.	$87,000	$58,915
Farm Truck	3/4 ton	$38,200	$25,869
Air Hoe Drill	50 ft.	$145,600	$98,598
Harrows	60 ft.	$13,000	$8,803
Combine header - pick up	14 ft.	$20,900	$14,153
Combine header - flex	25 ft.	$30,700	$20,790
Grain Auger	10 in; 50 - 60 ft.	$9,100	$6,162
Total		$981,600	$672,790
Total per hectare		$757.99	$519.53
Total per hectare per year (8% depreciation)		$60.64	$41.56

C.3 – New and initial (book) values of machinery complement in Dark Brown soil zone under dryland production

Description	Size	New Value	Initial (Book) Value
4WD Tractor	425 h.p.	$215,600	$162,483
S.P. Swather	30 ft.	$99,500	$67,380
Combine	Class 7+	$282,000	$180,865
Grain Truck 1	565 h.p.	$87,000	$58,915
Grain Truck 2	565 h.p.	$87,000	$58,915
Farm Truck	3/4 ton	$38,200	$25,869
Air Hoe Drill	50 ft.	$145,600	$98,598
Harrows	80 ft.	$16,500	$11,174
Combine header - pick up	16 ft.	$24,900	$16,862
Combine header - flex	36 ft.	$45,700	$30,947
Grain Auger	10 in; 50 - 60 ft.	$9,100	$6,162
Total		$1,051,100	$718,171
Total per hectare		$811.66	$554.57
Total per hectare per year (8% depreciation)		$64.93	$44.37

C.4 – New and initial (book) values of machinery complement in Black soil zone under dryland production

Description	Size	New Value	Initial (Book) Value
4WD Tractor	325 h.p.	$200,200	$150,877
S.P. Swather	30 ft.	$99,500	$67,380
Combine	Class 7+	$282,000	$180,865
Grain Truck 1	565 h.p.	$87,000	$58,915
Grain Truck 2	565 h.p.	$87,000	$58,915
Farm Truck	3/4 ton	$38,200	$25,869
Air Seeder	50 ft.	$135,300	$91,623
Harrows	80 ft.	$16,500	$11,174
Combine header - pick up	16 ft.	$24,900	$16,862
Combine header - flex	36 ft.	$45,700	$30,947
Grain Auger	10 in; 50 - 60 ft.	$9,100	$6,162
Total		$1,025,400	$699,590
Total per hectare		$989.77	$675.28
Total per hectare per year (8% depreciation)		$79.18	$54.02

C.5 – New and initial (book) values of machinery complement in Dark Grey soil zone under dryland production

Description	Size	New Value	Initial (Book) Value
4WOA Tractor	225 h.p.	$154,100	$116,135
S.P. Swather	24 ft.	$97,300	$65,890
Combine	Class 7	$255,400	$163,805
Grain Truck 1	565 h.p.	$87,000	$58,915
Grain Truck 2	565 h.p.	$87,000	$58,915
Farm Truck	3/4 ton	$38,200	$25,869
Air Seeder	40 ft.	$105,000	$71,105
Harrows	50 ft.	$11,900	$8,059
Combine header - pick up	14 ft.	$20,900	$14,153
Combine header - flex	30 ft.	$38,800	$26,275
Grain Auger	10 in; 50 - 60 ft.	$9,100	$6,162
Total		$904,700	$615,282
Total per hectare		$1,164.35	$791.87
Cost per acre per year (8% depreciation)		$93.15	$63.35

Appendix D: Historical Yield Data

Table D.1 – Data prior to detrending and removal of blank observations, Municipal District of Taber, irrigated production (kg/ha)

Year	Durum wheat	Spring wheat	Barley	Canola	Oat	Dry Bean
1989	3524.16	3183.49	4137.89	1843.96	3216.08	3081.8
1990	3897.03	3109.02	4264.73	2052.27	2794.46	4070.6
1991	3574.64	3576.61	4329.15	1947.05	3281.59	4745.13
1992	2736.95	2886.66	3475.72	1555.54	2233.56	1085.74
1993	4409.84	3726.19	4409.56	2091.96	4852.61	2569.55
1994	3726.9	3435.85	4099.00	1872.67	3179.65	4446.48
1995	4322.18	4300.05	4742.61	2261.44	-	4042.92
1996	3886.71	3818.11	4943.97	2296.39	-	5073.3
1997	4460.33	4105.17	5248.3	2360.18	3563.98	4902.07
1998	4135.2	3847.54	4378.15	2183.58	3791.54	5693.57
1999	4853.26	4711.53	5737.14	2541.73	3341.2	4144.18
2000	4414.99	4067.24	4991.22	2296.65	3343.11	5087.3
2001	4599.83	4206.88	4806.49	1963.59	3141.44	5462.26
2002	4335.82	4213.14	3787.44	2230.32	2752.2	2980.59
2003	4822.03	4644.11	4749.04	2153.6	3664.71	6146.77
2004	5689.24	5310.3	5148.83	2645.27	3090.81	4888.83
2005	5338.22	5237.43	4995.7	2666.54	3336.36	3986.09
2006	5296.13	4849.13	4629.5	2585.03	2649.29	5525.33
2007	4981.4	4975.09	4715.88	2426.83	4139.31	5513.16
2008	5398.12	4542.72	4165.17	2400.43	-	4826.47

Source: AFSC (2009)

Table D.2 – Data prior to detrending and removal of blank observations, County of Forty Mile, dryland production (kg/ha)

Year	Durum wheat	Spring wheat	Barley	Canola	Oat
1978	2244.59	2081.52	2732.87	1427.71	2124.23
1979	1379.60	1235.67	1761.99	1309.73	1016.12
1980	1908.02	1841.57	2476.21	2238.03	1670.07
1981	2218.48	2128.63	2699.85	-	2172.19
1982	1930.90	1856.63	2210.59	1524.69	2034.43
1983	1918.81	1945.28	2377.05	1414.21	1786.16
1984	881.94	928.96	856.53	1027.56	659.72
1985	741.57	812.72	987.00	1187.03	582.27
1986	2145.29	1969.30	2564.76	1700.15	1596.89
1987	2086.94	1872.60	2834.43	1772.40	1726.13
1988	1109.00	840.80	1479.46	1186.46	726.75
1989	1965.66	1862.89	2287.41	994.03	2218.60
1990	1869.09	1828.78	1916.54	898.59	1659.33
1991	2707.11	2511.80	2765.91	1084.17	2722.27
1992	1960.62	1929.83	2504.07	936.66	2627.71
1993	2637.59	2399.42	2887.28	1643.14	3785.58
1994	2035.41	1904.43	2247.44	983.08	2107.19
1995	3105.90	2710.06	2964.92	1455.38	3023.09
1996	1801.81	1790.59	1825.17	1167.48	2046.22
1997	1905.13	1776.89	2127.94	816.39	1675.49
1998	2467.99	2179.97	2505.09	1246.38	2101.71
1999	2416.27	2343.49	2848.32	1438.45	2375.92
2000	1203.73	1201.54	1578.33	726.88	878.26
2001	448.13	439.20	444.26	293.07	279.65
2002	2117.01	1901.09	2219.24	581.34	1944.07
2003	2108.39	2012.00	2311.90	906.25	1494.25
2004	2293.20	2173.11	2768.30	1133.48	2342.78
2005	2478.01	2402.20	3191.66	1260.49	3061.26
2006	2576.89	2232.06	2726.05	1362.65	2576.51
2007	1710.77	1613.16	2092.02	950.93	1301.02
2008	2710.03	2165.67	2881.41	1512.34	1779.99

Source: AFSC (2009)

Table D.3 – Data prior to detrending and removal of blank observations, County of Starland, dryland production (kg/ha)

Year	Spring wheat	Barley	Canola	Oat
1978	1945.64	2609.48	850.26	1517.70
1979	1946.83	2759.20	1150.73	2013.19
1980	2049.76	2420.18	1227.72	2058.23
1981	2096.03	2631.94	1620.19	2032.25
1982	2621.43	3377.34	1750.08	2674.81
1983	2472.86	2986.87	1194.82	2189.95
1984	1705.94	1621.47	952.29	1114.24
1985	1594.27	1878.82	775.25	1335.35
1986	2573.18	3457.08	1640.82	2802.45
1987	1920.36	2959.78	1494.95	2190.22
1988	2196.79	2839.83	1410.38	1824.54
1989	2132.10	2526.17	1014.19	1627.07
1990	2174.37	2761.87	1225.08	1958.70
1991	2173.88	2464.06	1151.79	1592.30
1992	1947.27	2749.86	1142.27	1894.34
1993	1947.40	2728.50	1180.23	2339.48
1994	1823.22	2180.41	1039.31	1672.15
1995	2414.30	2824.04	1403.07	2301.55
1996	2411.68	3101.52	1496.95	1626.04
1997	1826.61	2191.39	975.87	1225.13
1998	2001.40	2549.81	1112.74	2124.97
1999	2849.14	3274.02	1646.16	2843.54
2000	2231.28	2711.90	1285.02	1875.03
2001	1671.62	2004.04	804.38	1348.74
2002	440.81	328.51	231.80	172.82
2003	2365.77	2790.80	993.88	1230.72
2004	2974.30	3512.35	1951.72	2631.72
2005	2578.39	3052.51	1791.25	2183.40
2006	2522.96	2935.91	1591.38	2196.25
2007	2600.67	2462.92	1303.83	2446.40
2008	3041.09	3661.11	2048.44	2251.98

Source: AFSC (2009)

Table D.4 – Data prior to detrending and removal of blank observations, County of Camrose, dryland production (kg/ha)

Year	Spring wheat	Barley	Canola	Oat
1978	1926.30	1767.60	1212.40	1086.01
1979	2294.46	2782.53	1105.73	2576.68
1980	2920.71	3065.63	1436.51	2735.58
1981	2291.48	2799.08	1362.82	2547.36
1982	2242.41	2693.32	1004.24	2431.55
1983	1830.84	1434.27	676.69	1450.32
1984	2631.07	2936.50	1368.44	2180.57
1985	1912.36	2176.09	1064.44	1849.99
1986	2834.38	3684.38	1393.65	2833.22
1987	1943.23	2955.95	1347.98	2507.75
1988	2945.28	3582.44	1428.53	2942.99
1989	2376.76	2849.54	1242.72	2461.40
1990	2728.71	3393.04	1450.06	2708.29
1991	2717.48	2955.43	1358.18	2499.70
1992	2176.44	2799.50	1281.50	2043.60
1993	2760.70	3329.01	1375.96	2722.85
1994	2376.15	2734.25	1175.04	2306.61
1995	2661.75	3507.70	1480.36	2609.17
1996	2967.32	3237.00	1504.66	3002.77
1997	2522.26	2852.54	1483.25	2591.14
1998	2272.14	3100.07	1683.55	2706.51
1999	3148.54	4019.90	1943.87	3242.67
2000	3245.91	3530.77	1748.27	3302.56
2001	3088.96	3576.42	1899.66	2971.29
2002	655.62	532.08	307.30	255.89
2003	2761.29	2921.50	1518.72	2062.20
2004	3315.63	3553.64	2146.42	2802.99
2005	3441.86	3839.27	2440.27	3402.21
2006	2805.81	2846.38	2081.16	1698.16
2007	3018.24	2991.23	1881.82	2434.75
2008	3897.04	3989.53	2393.35	2376.00

Source: AFSC (2009)

Table D.5 – Data prior to detrending and removal of blank observations, Municipal District of Smoky River, dryland production (kg/ha)

Year	Spring wheat	Barley	Canola	Oat
1978	1873.60	2118.89	920.52	2222.45
1979	2469.76	2065.50	607.56	2827.75
1980	2253.48	2454.15	1268.33	2682.59
1981	2265.19	2306.56	1161.52	2162.03
1982	915.82	1288.20	421.43	1229.14
1983	2394.01	2381.47	886.33	3008.54
1984	2086.12	2130.80	1031.06	2634.84
1985	1405.00	1631.72	949.82	1119.57
1986	1480.54	2419.90	1177.70	1694.31
1987	1627.97	1805.26	1165.40	2661.33
1988	2728.09	3011.29	1381.57	3497.41
1989	2259.08	2744.82	1182.77	2962.67
1990	2500.90	2573.75	1007.59	2552.22
1991	2419.31	2564.64	1281.52	2200.88
1992	2008.46	2493.71	1227.23	2508.75
1993	2104.13	2998.79	1180.18	3646.88
1994	1922.25	2841.14	1270.61	2996.92
1995	2832.20	3432.46	1571.30	3408.10
1996	2137.53	1767.57	1048.08	3290.36
1997	2076.13	1828.34	766.80	1491.22
1998	1790.64	2369.50	1203.70	2237.81
1999	1991.56	2390.51	1033.73	2382.04
2000	3638.19	3741.13	1289.19	4169.92
2001	2855.43	3763.92	1570.21	3760.72
2002	2182.70	2838.67	1838.14	2606.95
2003	3282.24	3558.95	1928.95	3739.93
2004	2639.51	3072.58	1950.32	2890.93
2005	3477.22	4147.11	2388.08	3819.03
2006	3587.59	3864.42	1921.77	3891.92
2007	3496.37	4128.49	1897.86	3902.19
2008	3128.65	2924.56	1574.32	3111.99

Source: AFSC (2009)

Table D.6 – Summary yield statistics, prior to detrending

County	Crop	No. of years	Mean (kg/ha)	Standard Deviation (kg/ha)	Variance (kg/ha)	Minimum (kg/ha)	Maximum (kg/ha)
Taber (irrigated)	Spring wheat	20	4137.30	698.92	488490.00	2886.70	5310.30
	Durum wheat	20	4420.10	738.52	545420.00	2736.90	5689.20
	Barley	20	4587.80	532.53	283590.00	3475.70	5737.10
	Canola	20	2218.80	291.96	85240.00	1555.50	2666.50
	Oat	20	2818.60	1333.90	1779300.00	0.00	4852.60
	Dry Bean	20	4413.60	1227.60	1507100.00	1085.70	6146.80
Forty Mile	Spring wheat	31	1835.20	531.35	282340.00	439.20	2710.10
	Durum wheat	31	1970.40	606.51	367850.00	448.13	3105.90
	Barley	31	2260.50	653.50	427060.00	444.26	3191.70
	Canola	31	1167.10	437.74	191610.00	0.00	2238.00
	Oat	31	1874.10	785.65	617240.00	279.65	3785.60
Starland	Spring wheat	31	2169.40	493.21	243250.00	440.81	3041.10
	Barley	31	2656.60	636.71	405390.00	328.51	3661.10
	Canola	31	1272.80	383.11	146770.00	231.80	2048.40
	Oat	31	1912.80	566.67	321110.00	172.82	2843.50
Camrose	Spring wheat	31	2603.60	605.96	367190.00	655.62	3897.00
	Barley	31	2981.80	733.65	538240.00	532.08	4019.90
	Canola	31	1477.30	452.11	204400.00	307.30	2440.30
	Oat	31	2430.40	651.18	424030.00	255.89	3402.20
Smoky River	Spring wheat	31	2381.60	670.25	449230.00	915.82	3638.20
	Barley	31	2698.70	746.16	556760.00	1288.20	4147.10
	Canola	31	1293.70	433.06	187540.00	421.43	2388.10
	Oat	31	2816.50	800.21	640340.00	1119.60	4169.90

Appendix E: Yield Trend Regression Results

Table E.1 – Yield trend regression results[a]

County	Crop	Intercept Coefficient	Year Coefficient	t-stat	p-value
Taber, irrigated	Durum wheat	-208,730	106.7	6.9755	0.0000
Taber, irrigated	Spring wheat	-202,597	103.4	7.6914	0.0000
Taber, irrigated	Barley	-54,991	29.8	1.4892	0.1538
Taber, irrigated	Canola	-69,688	36.0	4.5194	0.0003
Taber, irrigated	Oat[b]	-12,271	7.8	-0.2060	0.8391
Taber, irrigated	Dry bean	-208,072	106.3	2.5314	0.0209
Forty Mile	Durum wheat	-30,726	16.4	1.3664	0.1823
Forty Mile	Spring wheat	-21,370	11.6	1.0948	0.2826
Forty Mile	Barley	-19,389	10.9	0.8234	0.4170
Forty Mile	Canola[b]	37,686	-18.3	-1.3084	0.2010
Forty Mile	Oat	-26,816	14.4	0.9099	0.3704
Starland	Spring wheat	-23,240	12.7	1.3021	0.2031
Starland	Barley	-3,224	3.0	0.2271	0.8220
Starland	Canola	-13,871	7.6	0.9873	0.3317
Starland	Oat	2,093	-0.1	-0.0078	0.9938
Camrose	Spring wheat	-55,966	29.4	2.6457	0.0130
Camrose	Barley	-47,857	25.5	1.7944	0.0832
Camrose	Canola	-60,082	30.9	4.2685	0.0002
Camrose	Oat	-17,166	9.8	0.7464	0.4615
Smoky River	Spring wheat	-91,576	47.1	4.4798	0.0001
Smoky River	Barley	-111,230	57.2	5.2280	0.0000
Smoky River	Canola	-70,018	35.8	6.1292	0.0000
Smoky River	Oat	-92,855	48.0	3.5043	0.0015

[a] Based on the regression $Y_t = \alpha + \beta t + \varepsilon t$, where Y is crop yield and t is time in years. [b] Years where data were not recorded (i.e., a zero value was entered) were removed prior to regression analysis.

Appendix F: Kolmogorov-Smirnov (K-S) test statistics for yield distribution fitting

Table F.1 – K-S distribution fit test statistics for yields under irrigated production in Municipal District of Taber.

Distribution	Durum wheat	Spring wheat	Barley	Canola	Oat	Dry Bean
Weibull	0.1325	0.1487	0.1007	0.1030	0.2036	0.1303
Gamma	0.0947	0.1014	0.1104	0.1135	0.1642	0.1615
Triangle	0.6119	0.6296	0.4105	0.5631	0.3466	0.3200
LogNormal	0.0984	0.1004	0.1164	0.1136	0.1526	0.1779
Expon	0.5586	0.5881	0.5312	0.5650	0.4914	0.4368
Uniform	0.7229	0.7538	0.5787	0.7066	0.4550	0.4855

Table F.2 – K-S distribution fit test statistics for yields under dryland production in County of Forty Mile.

Distribution	Durum wheat	Spring wheat	Barley	Canola	Oat
Weibull	0.1671	0.2134	0.1314	0.0846	0.1281
Gamma	0.2325	0.2827	0.2037	0.0912	0.1767
Triangle	0.2206	0.2880	0.2049	0.1465	0.1021
LogNormal	0.2554	0.3026	0.2292	0.1102	0.2116
Expon	0.3868	0.3944	0.3835	0.3880	0.3237
Uniform	0.3395	0.4087	0.3763	0.2522	0.2073

Table F.3 – K-S distribution fit test statistics for yields under dryland production in County of Starland.

Distribution	Spring wheat	Barley	Canola	Oat
Weibull	0.1046	0.1485	0.0948	0.0906
Gamma	0.1760	0.2392	0.1158	0.1492
Triangle	0.2770	0.2434	0.1662	0.1618
LogNormal	0.2120	0.2693	0.1485	0.1889
Expon	0.4882	0.4425	0.4239	0.4093
Uniform	0.4751	0.4473	0.3340	0.3524

Table F.4 – K-S distribution fit test statistics for yields under dryland production in County of Camrose.

Distribution	Spring wheat	Barley	Canola	Oat
Weibull	0.1237	0.1928	0.1536	0.1736
Gamma	0.2161	0.2865	0.2523	0.2347
Triangle	0.3994	0.3199	0.4121	0.2016
LogNormal	0.2510	0.3158	0.2803	0.2561
Expon	0.5365	0.4657	0.4987	0.4074
Uniform	0.6036	0.5194	0.5496	0.4200

Table F.5 – K-S distribution fit test statistics for yields under dryland production in Municipal District of Smoky River.

Distribution	Spring wheat	Barley	Canola	Oat
Weibull	0.1373	0.1235	0.0876	0.1250
Gamma	0.1334	0.1451	0.1166	0.1771
Triangle	0.2975	0.3557	0.3312	0.2594
LogNormal	0.1437	0.1484	0.1276	0.1860
Expon	0.5001	0.4984	0.4899	0.4395
Uniform	0.5177	0.5572	0.4920	0.4808

Appendix G: Crop Yield Correlations

Table G.1 – Crop yield correlations, Taber (Risk Region B, irrigated)

Crop	Canola	Dry bean	Durum wheat	Spring wheat	Alfalfa hay	Grass hay
Canola	0.41	0.20	0.46	0.46	0.20	0.20
Dry bean	0.20	0.53	0.27	0.27	0.36	0.20
Durum wheat	0.46	0.27	0.49	0.45	0.20	0.29
Spring wheat	0.46	0.27	0.49	0.45	0.20	0.29
Alfalfa hay	0.20	0.36	0.20	0.20	0.49	0.20
Grass hay	0.20	0.20	0.29	0.29	0.20	0.50

Source: AARD (2007-b)

Table G.2 – Crop yield correlations, Forty Mile (Risk Region B, dryland)

Crop	Barley	Canola	Durum wheat	Spring wheat	Field pea	Legume green manure	Grass hay
Barley	0.73	0.55	0.67	0.67	0.63	0.30	0.30
Canola	0.55	0.61	0.54	0.54	0.54	0.30	0.30
Durum wheat	0.67	0.54	0.75	0.75	0.71	0.30	0.30
Spring wheat	0.67	0.54	0.75	0.75	0.71	0.30	0.30
Field pea	0.63	0.54	0.71	0.71	0.81	0.30	0.30
Legume green manure	0.30	0.30	0.30	0.30	0.30	0.70	0.60
Grass hay	0.30	0.30	0.30	0.30	0.30	0.60	0.70

Source: AARD (2007-b)

Table G.3 – Crop yield correlations, Starland (Risk Region B, dryland)

Crop	Barley	Canola	Spring wheat	Field pea	Legume green manure	Alfalfa hay	Grass hay
Barley	0.73	0.55	0.67	0.63	0.30	0.30	0.30
Canola	0.55	0.61	0.54	0.54	0.30	0.30	0.30
Spring wheat	0.67	0.54	0.75	0.71	0.30	0.30	0.30
Field pea	0.63	0.54	0.71	0.81	0.30	0.30	0.30
Legume green manure	0.30	0.30	0.30	0.30	0.70	0.30	0.30
Alfalfa hay	0.30	0.30	0.30	0.30	0.30	0.70	0.60
Grass hay	0.30	0.30	0.30	0.30	0.60	0.60	0.70

Source: AARD (2007-b)

Table G.4 – Crop yield correlations, Camrose (Risk Region C)

Crop	Barley	Canola	Spring wheat	Field pea	Oats	Alfalfa hay	Grass hay
Barley	0.82	0.66	0.77	0.76	0.74	0.30	0.30
Canola	0.66	0.71	0.66	0.67	0.63	0.30	0.30
Spring wheat	0.77	0.66	0.83	0.75	0.72	0.30	0.30
Field pea	0.76	0.67	0.75	0.85	0.73	0.30	0.30
Oats	0.74	0.63	0.72	0.73	0.83	0.31	0.31
Alfalfa hay	0.30	0.30	0.30	0.30	0.31	0.30	0.60
Grass hay	0.30	0.30	0.30	0.30	0.31	0.60	0.70

Source: AARD (2007-b)

Table G.5 – Crop yield correlations, Smoky River (Risk Region D)

Crop	Barley	Canola	Spring wheat	Field pea	Oats	Alfalfa hay	Grass hay
Barley	0.72	0.49	0.59	0.43	0.57	0.30	0.30
Canola	0.49	0.63	0.45	0.42	0.45	0.30	0.30
Spring wheat	0.59	0.45	0.67	0.49	0.55	0.30	0.30
Field pea	0.43	0.42	0.49	0.58	0.48	0.30	0.30
Oats	0.57	0.45	0.53	0.48	0.65	0.31	0.31
Alfalfa hay	0.30	0.30	0.30	0.30	0.30	0.30	0.60
Grass hay	0.30	0.30	0.30	0.30	0.31	0.60	0.70

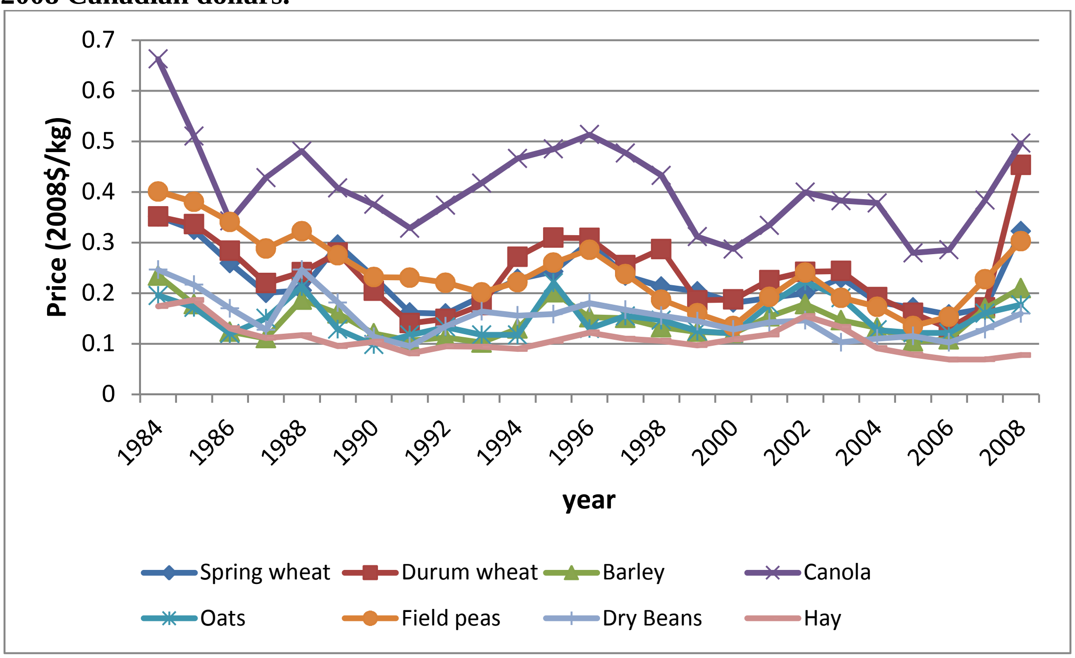
Source: AARD (2007-b)

Appendix H: Crop Price Data Summary

Table H.1 – Summary statistics of commodity price data

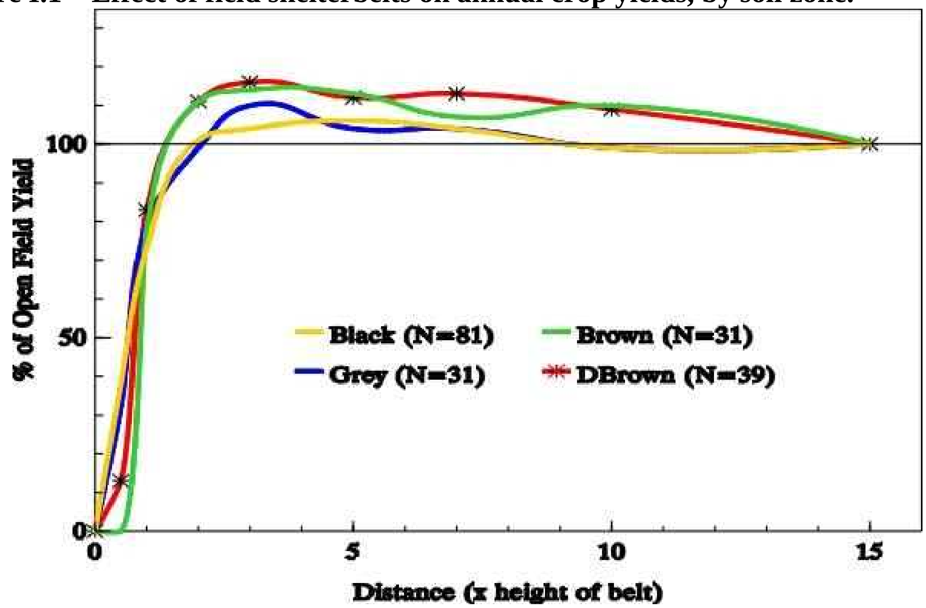
Variable	Obs	Mean	Std. Dev.	Min	Max
Spring Wheat	25	0.224379	0.055807	0.157627	0.351262
Durum Wheat	25	0.240255	0.076039	0.130112	0.45318
Barley	25	0.150305	0.036363	0.098156	0.223464
Canola	25	0.145977	0.036235	0.102252	0.234382
Oats	25	0.409461	0.0891	0.279284	0.66248
Field Peas	25	0.239755	0.071549	0.134798	0.401045
Dry Beans	25	0.151686	0.040432	0.095032	0.246356
Alfalfa Hay	25	0.108697	0.029675	0.068816	0.186363

Figure H.1 – Historical commodity crop prices in Alberta, corrected for inflation to 2008 Canadian dollars.



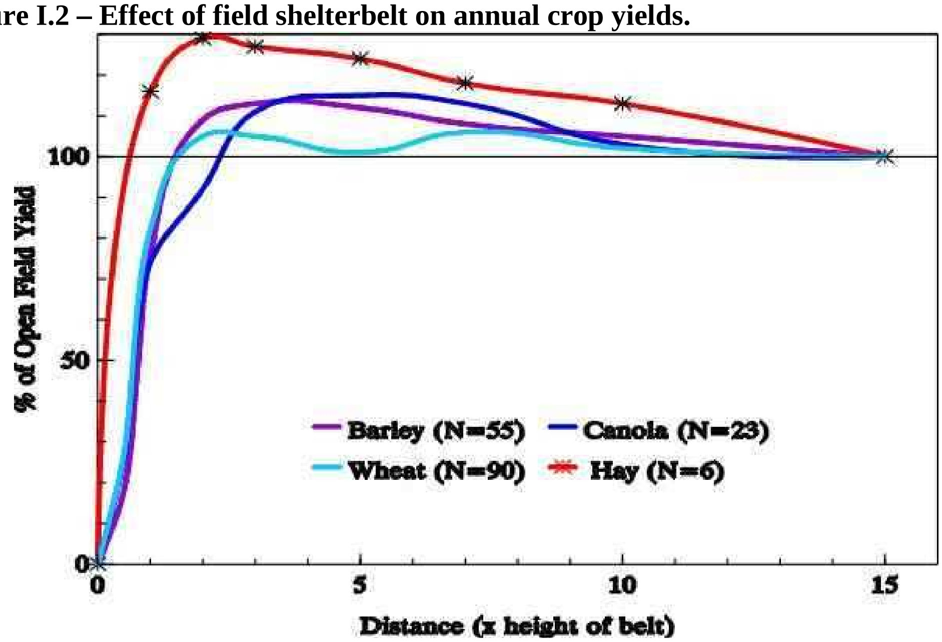
Appendix I: Crop Yields Adjacent to Shelterbelts.

Figure I.1 – Effect of field shelterbelts on annual crop yields, by soil zone.



Source: *Adapted from* AARD (2004-b) *with permission from Alberta Agriculture and Rural Development*

Figure I.2 – Effect of field shelterbelt on annual crop yields.



Source: *Adapted from* AARD (2004-b) *with permission from Alberta Agriculture and Rural Development*

Table I.1 – Effect of field shelterbelt orientation on crop yields

Soil zone/ field direction	Number of sites	Sheltered yield(%)[a]
brown/north	3	95
brown/south	10	98
brown/west	8	97
brown/east	13	110
dark brown/north	9	102
dark brown/south	23	104
dark brown/west	2	110
dark brown/east	3	97
black/north	8	92
black/south	22	99
black/west	10	96
black/east	40	96
grey/ north	7	99
grey/south	15	99
grey/west	1	93
grey/east	8	92

[a] Sheltered yield is the weighted average yield from 0H (height of the shelterbelts) to15H taken as a percentage of open field yield.

Source: AARD (2004-b)

Appendix J: Summary Statistics Tables

Table J.1 – Summary statistics for farm representative of Brown soil zone, irrigated production, baseline rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$272,776	$164,092	-$309,821	$875,756	$45,145	$578,957
Cash Flow Year 2	$185,473	$147,510	-$314,390	$823,725	-$6,609	$447,626
Cash Flow Year 3	$171,880	$140,567	-$332,094	$729,232	-$1,059	$438,387
Cash Flow Year 4	$217,878	$146,102	-$323,746	$984,078	$50,932	$498,134
Cash Flow Year 5	$235,322	$140,005	-$309,182	$794,756	$59,427	$483,846
Cash Flow Year 6	$230,935	$150,817	-$303,993	$806,577	$47,993	$503,163
Cash Flow Year 7	$215,951	$153,589	-$309,531	$797,069	$25,552	$508,592
Cash Flow Year 8	$210,823	$148,565	-$303,612	$868,092	$24,861	$475,937
Cash Flow Year 9	$218,662	$150,668	-$330,325	$848,366	$32,262	$498,318
Cash Flow Year 10	$227,462	$144,092	-$323,815	$957,903	$45,140	$491,865
Cash Flow Year 11	$220,977	$136,059	-$310,976	$762,199	$42,815	$461,469
Cash Flow Year 12	$217,247	$142,002	-$307,149	$868,860	$34,798	$490,468
Cash Flow Year 13	$214,948	$146,796	-$326,754	$752,993	$32,603	$504,784
Cash Flow Year 14	$218,209	$136,569	-$308,840	$729,046	$34,171	$461,255
Cash Flow Year 15	$216,318	$138,899	-$316,082	$861,559	$36,167	$495,147
Cash Flow Year 16	$215,941	$148,535	-$312,494	$925,197	$34,307	$499,864
Cash Flow Year 17	$213,351	$142,459	-$301,220	$806,271	$22,071	$493,589
Cash Flow Year 18	$215,468	$139,866	-$326,533	$834,796	$40,117	$475,977
Cash Flow Year 19	$220,826	$143,295	-$293,493	$790,706	$37,073	$494,046
Cash Flow Year 20	$214,091	$149,343	-$315,203	$1,013,891	$34,609	$482,903
Cash Flow Year 21	$212,239	$143,562	-$328,281	$992,170	$31,555	$482,018
Cash Flow Year 22	$210,728	$146,819	-$308,185	$905,638	$26,557	$480,073
Cash Flow Year 23	$216,657	$144,397	-$327,033	$828,955	$35,228	$490,027
Cash Flow Year 24	$223,730	$154,865	-$326,648	$841,055	$31,430	$501,323
Cash Flow Year 25	$219,910	$144,319	-$322,452	$792,765	$33,482	$479,243
Cash Flow Year 26	$221,062	$144,810	-$334,493	$850,437	$38,570	$482,006
Cash Flow Year 27	$217,538	$139,948	-$322,169	$801,524	$38,714	$470,008
Cash Flow Year 28	$216,036	$138,117	-$331,513	$871,122	$39,649	$470,859
Cash Flow Year 29	$216,888	$144,120	-$309,499	$993,365	$41,626	$487,386
Cash Flow Year 30	$211,856	$138,124	-$298,893	$792,645	$30,802	$465,487
Cash Flow Year 31	$211,987	$145,692	-$324,048	$882,771	$26,942	$470,563
Cash Flow Year 32	$220,796	$141,186	-$316,433	$825,955	$35,369	$466,694
Cash Flow Year 33	$224,386	$150,855	-$332,873	$892,435	$37,678	$524,266
Cash Flow Year 34	$221,401	$148,116	-$302,283	$785,041	$29,437	$500,636
Cash Flow Year 35	$218,652	$152,966	-$311,643	$905,394	$25,164	$487,892
Cash Flow Year 36	$220,682	$141,633	-$325,751	$890,913	$42,567	$492,934
Cash Flow Year 37	$221,689	$151,544	-$315,805	$824,678	$31,748	$509,455
Cash Flow Year 38	$212,892	$137,586	-$324,567	$868,534	$31,644	$460,312

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 39	$219,994	$143,869	-$317,508	$1,031,617	$37,324	$475,276
Cash Flow Year 40	$218,663	$141,785	-$316,879	$782,376	$40,107	$489,898
40 Year NPV	$2,396,562	$421,714	$1,126,172	$4,164,809	$1,699,094	$3,089,488
Perpetuity NPV	$2,441,735	$424,010	$1,207,985	$4,254,192	$1,739,152	$3,127,868

Table J.2 – Summary statistics for farm representative of Brown soil zone, dryland production, baseline rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$93,526	$106,716	-$192,989	$544,018	-$67,939	$293,670
Cash Flow Year 2	$66,312	$105,117	-$140,255	$553,096	-$106,852	$269,030
Cash Flow Year 3	$61,802	$106,043	-$169,575	$598,990	-$108,643	$256,621
Cash Flow Year 4	$75,131	$98,769	-$178,224	$492,589	-$103,288	$258,620
Cash Flow Year 5	$83,062	$107,218	-$159,393	$569,565	-$103,950	$279,457
Cash Flow Year 6	$77,035	$106,792	-$149,072	$576,084	-$106,118	$279,117
Cash Flow Year 7	$75,272	$104,879	-$187,747	$584,862	-$105,590	$267,144
Cash Flow Year 8	$73,655	$101,394	-$161,365	$539,796	-$106,307	$265,292
Cash Flow Year 9	$80,775	$107,081	-$170,811	$532,281	-$103,166	$283,026
Cash Flow Year 10	$76,802	$102,644	-$181,719	$684,108	-$104,044	$260,571
Cash Flow Year 11	$75,846	$103,327	-$191,548	$526,974	-$106,452	$256,048
Cash Flow Year 12	$75,334	$101,590	-$157,086	$488,124	-$107,330	$265,904
Cash Flow Year 13	$77,174	$101,916	-$171,914	$520,309	-$105,705	$271,078
Cash Flow Year 14	$79,229	$101,877	-$177,982	$566,311	-$105,073	$266,303
Cash Flow Year 15	$73,767	$102,987	-$175,515	$456,679	-$104,425	$277,021
Cash Flow Year 16	$71,469	$100,859	-$180,414	$522,315	-$104,737	$257,439
Cash Flow Year 17	$76,134	$106,580	-$166,059	$558,014	-$106,040	$272,850
Cash Flow Year 18	$76,929	$103,359	-$144,970	$556,183	-$105,621	$270,166
Cash Flow Year 19	$77,378	$103,361	-$130,510	$602,838	-$105,597	$263,458
Cash Flow Year 20	$72,398	$105,060	-$206,138	$545,349	-$106,691	$265,124
Cash Flow Year 21	$74,526	$103,778	-$200,517	$442,024	-$103,737	$279,896
Cash Flow Year 22	$77,649	$102,082	-$183,264	$573,497	-$102,949	$269,349
Cash Flow Year 23	$77,136	$103,031	-$133,467	$480,754	-$103,409	$270,751
Cash Flow Year 24	$72,995	$106,650	-$182,570	$579,790	-$106,863	$254,052
Cash Flow Year 25	$72,388	$102,639	-$187,194	$508,342	-$107,223	$267,989
Cash Flow Year 26	$76,513	$102,955	-$170,969	$455,210	-$104,991	$260,214
Cash Flow Year 27	$76,815	$101,677	-$130,278	$556,913	-$101,443	$263,514
Cash Flow Year 28	$75,395	$104,469	-$138,565	$594,341	-$104,484	$267,261
Cash Flow Year 29	$75,189	$101,288	-$157,636	$524,205	-$103,426	$254,548
Cash Flow Year 30	$74,699	$102,149	-$170,990	$488,463	-$105,082	$268,849
Cash Flow Year 31	$76,558	$106,150	-$173,596	$586,588	-$107,004	$260,665
Cash Flow Year 32	$73,587	$101,994	-$169,191	$575,468	-$104,670	$259,490
Cash Flow Year 33	$74,088	$106,532	-$182,290	$669,921	-$105,477	$262,202
Cash Flow Year 34	$79,607	$109,699	-$150,049	$565,723	-$104,728	$277,759

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 35	$74,327	$106,343	-$169,146	$530,843	-$106,938	$271,822
Cash Flow Year 36	$74,211	$101,251	-$145,001	$490,928	-$106,630	$259,819
Cash Flow Year 37	$73,422	$104,980	-$161,960	$535,854	-$106,008	$268,377
Cash Flow Year 38	$75,817	$108,394	-$158,149	$591,449	-$106,575	$288,045
Cash Flow Year 39	$80,305	$105,801	-$144,615	$475,929	-$102,392	$271,253
Cash Flow Year 40	$79,515	$104,026	-$184,410	$611,038	-$106,450	$268,144
40 Year NPV	$828,718	$346,077	-$353,960	$1,861,511	$264,703	$1,402,325
Perpetuity NPV	$845,707	$346,840	-$344,533	$1,916,206	$284,070	$1,414,641

Table J.3 – Summary statistics for farm representative of Dark Brown soil zone, baseline rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$110,723	$88,814	-$121,170	$455,784	-$6,370	$269,222
Cash Flow Year 2	$88,428	$85,460	-$138,477	$460,512	-$22,465	$244,642
Cash Flow Year 3	$87,234	$85,242	-$125,155	$434,413	-$39,438	$233,287
Cash Flow Year 4	$103,113	$86,763	-$127,191	$452,126	-$7,683	$264,278
Cash Flow Year 5	$105,860	$83,718	-$132,157	$484,110	-$10,110	$253,260
Cash Flow Year 6	$100,206	$86,880	-$132,600	$388,228	-$17,145	$256,401
Cash Flow Year 7	$98,373	$89,557	-$139,607	$426,722	-$20,245	$262,776
Cash Flow Year 8	$95,182	$89,293	-$136,922	$528,953	-$27,663	$257,957
Cash Flow Year 9	$99,866	$83,810	-$134,550	$465,581	-$8,124	$248,630
Cash Flow Year 10	$104,555	$85,155	-$141,092	$419,518	-$6,515	$266,915
Cash Flow Year 11	$102,165	$88,249	-$128,679	$422,942	-$17,081	$259,509
Cash Flow Year 12	$102,588	$86,635	-$131,429	$429,397	-$13,858	$271,796
Cash Flow Year 13	$101,784	$86,374	-$173,641	$468,328	-$5,999	$266,017
Cash Flow Year 14	$101,176	$84,601	-$130,459	$418,054	-$13,748	$256,938
Cash Flow Year 15	$99,679	$83,855	-$129,584	$450,428	-$8,996	$260,125
Cash Flow Year 16	$101,956	$89,348	-$128,567	$457,483	-$13,141	$263,267
Cash Flow Year 17	$99,043	$82,751	-$125,833	$454,781	-$10,198	$256,257
Cash Flow Year 18	$99,181	$81,755	-$127,087	$398,996	-$15,967	$241,369
Cash Flow Year 19	$97,427	$80,988	-$123,714	$394,115	-$25,103	$247,157
Cash Flow Year 20	$97,972	$92,232	-$148,634	$466,427	-$25,645	$267,137
Cash Flow Year 21	$96,372	$89,517	-$129,394	$482,991	-$42,095	$256,653
Cash Flow Year 22	$102,471	$86,978	-$134,471	$444,897	-$10,539	$265,687
Cash Flow Year 23	$100,599	$84,142	-$130,593	$523,527	-$15,449	$256,574
Cash Flow Year 24	$101,931	$87,058	-$131,497	$418,448	-$11,206	$262,132
Cash Flow Year 25	$99,300	$85,594	-$129,305	$475,051	-$22,012	$251,597
Cash Flow Year 26	$99,053	$84,852	-$129,872	$411,858	-$16,715	$255,528
Cash Flow Year 27	$99,253	$84,134	-$117,157	$475,439	-$13,098	$245,146
Cash Flow Year 28	$100,850	$88,520	-$139,423	$415,035	-$16,298	$265,300
Cash Flow Year 29	$98,674	$85,514	-$160,741	$409,519	-$13,760	$258,859
Cash Flow Year 30	$99,698	$84,661	-$137,390	$387,003	-$9,623	$261,369

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 31	$99,235	$83,267	-$124,076	$471,215	-$11,863	$248,512
Cash Flow Year 32	$97,566	$83,978	-$130,621	$537,440	-$14,723	$248,925
Cash Flow Year 33	$97,829	$85,139	-$126,667	$463,826	-$14,702	$252,218
Cash Flow Year 34	$102,787	$85,952	-$127,449	$445,266	-$12,557	$259,136
Cash Flow Year 35	$100,156	$90,126	-$137,062	$438,123	-$19,656	$264,957
Cash Flow Year 36	$101,681	$89,419	-$126,045	$410,676	-$18,844	$271,986
Cash Flow Year 37	$96,837	$85,038	-$131,020	$395,358	-$22,473	$258,455
Cash Flow Year 38	$99,254	$88,180	-$135,566	$475,480	-$16,241	$261,900
Cash Flow Year 39	$100,346	$83,691	-$131,618	$427,185	-$8,687	$257,321
Cash Flow Year 40	$102,927	$88,025	-$133,481	$491,714	-$13,000	$263,910
40 Year NPV	$1,071,822	$296,870	$114,010	$1,914,299	$565,954	$1,578,931
Perpetuity NPV	$1,094,775	$297,373	$134,010	$1,955,754	$582,537	$1,601,431

Table J.4 – Summary statistics for farm representative of Black soil zone, baseline rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$268,140	$100,365	$28,899	$763,752	$130,961	$454,868
Cash Flow Year 2	$245,254	$97,432	-$111,323	$610,190	$108,531	$423,696
Cash Flow Year 3	$249,855	$95,929	$44,538	$715,934	$119,570	$429,583
Cash Flow Year 4	$267,546	$97,561	-$113,936	$691,051	$139,002	$445,805
Cash Flow Year 5	$267,201	$94,081	-$110,634	$696,972	$147,158	$445,073
Cash Flow Year 6	$257,011	$94,189	$19,829	$664,078	$129,286	$441,382
Cash Flow Year 7	$252,212	$90,434	-$123,189	$726,728	$125,177	$408,796
Cash Flow Year 8	$255,277	$92,279	-$120,604	$694,131	$125,899	$418,514
Cash Flow Year 9	$265,731	$99,697	-$114,124	$653,501	$130,377	$448,245
Cash Flow Year 10	$266,507	$102,304	$47,728	$779,101	$128,948	$468,448
Cash Flow Year 11	$260,597	$95,711	$25,208	$583,672	$129,525	$447,372
Cash Flow Year 12	$254,255	$95,133	-$133,411	$648,435	$129,909	$424,610
Cash Flow Year 13	$259,531	$98,148	-$110,409	$674,297	$125,239	$449,265
Cash Flow Year 14	$261,378	$94,940	$31,482	$688,418	$131,715	$454,733
Cash Flow Year 15	$258,457	$95,385	$46,750	$651,938	$126,309	$441,800
Cash Flow Year 16	$262,567	$96,489	$46,420	$659,195	$135,922	$444,843
Cash Flow Year 17	$260,116	$96,542	$78,201	$652,687	$133,420	$444,846
Cash Flow Year 18	$257,533	$92,308	$31,131	$682,409	$131,718	$420,800
Cash Flow Year 19	$262,497	$100,571	-$112,971	$789,486	$132,663	$446,653
Cash Flow Year 20	$260,272	$96,300	-$118,908	$726,632	$131,989	$434,154
Cash Flow Year 21	$260,600	$96,667	-$130,506	$601,968	$134,323	$446,659
Cash Flow Year 22	$257,056	$96,385	-$131,166	$654,645	$123,247	$432,338
Cash Flow Year 23	$253,310	$95,194	-$112,606	$639,778	$125,412	$441,031
Cash Flow Year 24	$261,260	$100,410	-$119,663	$577,526	$123,951	$460,376
Cash Flow Year 25	$260,756	$97,535	$34,347	$622,035	$125,124	$449,359
Cash Flow Year 26	$258,896	$94,511	$61,342	$642,595	$129,054	$430,542

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 27	$257,262	$99,585	-$118,255	$744,804	$123,579	$435,269
Cash Flow Year 28	$257,013	$97,439	-$118,959	$728,012	$127,199	$446,415
Cash Flow Year 29	$258,876	$97,420	-$119,011	$692,771	$128,768	$439,012
Cash Flow Year 30	$260,214	$99,160	-$113,242	$707,927	$129,283	$449,597
Cash Flow Year 31	$257,564	$95,608	-$122,046	$625,043	$132,458	$442,447
Cash Flow Year 32	$262,080	$95,728	$45,181	$795,520	$134,024	$440,882
Cash Flow Year 33	$265,838	$98,064	-$133,099	$695,827	$137,182	$446,635
Cash Flow Year 34	$255,604	$91,946	-$120,747	$612,121	$131,721	$428,415
Cash Flow Year 35	$256,287	$98,213	-$116,570	$697,271	$125,054	$453,770
Cash Flow Year 36	$262,378	$100,805	$42,119	$712,641	$132,799	$448,714
Cash Flow Year 37	$262,515	$94,973	-$127,132	$671,791	$131,397	$445,254
Cash Flow Year 38	$262,327	$99,332	-$113,439	$685,068	$132,104	$456,079
Cash Flow Year 39	$256,531	$97,347	-$117,373	$737,084	$126,209	$432,306
Cash Flow Year 40	$258,905	$97,934	-$121,895	$657,617	$125,672	$458,242
40 Year NPV	$2,783,703	$329,635	$1,818,676	$3,908,152	$2,274,507	$3,366,369
Perpetuity NPV	$2,841,695	$330,860	$1,876,053	$3,997,994	$2,339,352	$3,432,523

Table J.5 – Summary statistics for farm representative of Dark Grey soil zone, baseline rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$229,303	$74,688	$76,495	$586,694	$125,934	$377,967
Cash Flow Year 2	$212,039	$71,872	$48,670	$482,706	$115,754	$347,340
Cash Flow Year 3	$213,041	$72,163	$60,369	$659,547	$116,821	$351,817
Cash Flow Year 4	$227,237	$69,142	$47,754	$498,910	$135,516	$358,193
Cash Flow Year 5	$224,933	$63,896	$26,488	$499,901	$137,530	$349,274
Cash Flow Year 6	$219,818	$66,336	$50,279	$580,393	$134,757	$342,117
Cash Flow Year 7	$215,266	$64,287	$53,144	$478,647	$126,984	$347,056
Cash Flow Year 8	$220,196	$66,758	$72,820	$475,671	$129,954	$353,660
Cash Flow Year 9	$224,363	$68,286	$67,959	$521,186	$132,337	$354,156
Cash Flow Year 10	$224,111	$69,763	$69,368	$552,043	$130,675	$356,574
Cash Flow Year 11	$221,000	$66,623	$60,974	$519,271	$130,516	$342,973
Cash Flow Year 12	$216,721	$66,337	$63,166	$541,546	$128,777	$340,093
Cash Flow Year 13	$220,416	$68,626	$21,813	$563,295	$127,634	$348,820
Cash Flow Year 14	$220,081	$66,498	$53,720	$552,411	$125,409	$343,867
Cash Flow Year 15	$218,818	$66,293	$28,609	$468,793	$129,906	$340,501
Cash Flow Year 16	$221,923	$63,560	$61,654	$481,533	$133,442	$337,495
Cash Flow Year 17	$222,908	$70,442	$76,671	$495,526	$129,851	$361,374
Cash Flow Year 18	$222,856	$69,576	$50,538	$521,020	$129,908	$359,399
Cash Flow Year 19	$221,798	$68,871	$62,524	$547,966	$133,944	$360,445
Cash Flow Year 20	$220,455	$67,998	$62,184	$509,482	$129,755	$354,708
Cash Flow Year 21	$220,726	$64,400	$76,832	$500,230	$128,346	$343,277
Cash Flow Year 22	$220,248	$66,485	$58,882	$456,563	$133,900	$347,879

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 23	$218,950	$67,426	$14,805	$531,444	$129,335	$352,846
Cash Flow Year 24	$222,660	$69,728	$65,323	$595,607	$130,410	$359,325
Cash Flow Year 25	$223,748	$70,127	$68,650	$512,687	$128,934	$363,629
Cash Flow Year 26	$221,615	$67,981	$84,199	$474,346	$131,705	$352,675
Cash Flow Year 27	$220,811	$65,350	$74,582	$488,756	$131,449	$345,408
Cash Flow Year 28	$222,254	$69,286	$65,910	$512,457	$129,398	$361,207
Cash Flow Year 29	$222,785	$67,883	$55,902	$503,402	$133,090	$355,560
Cash Flow Year 30	$221,714	$66,561	$72,037	$635,841	$132,368	$356,475
Cash Flow Year 31	$219,007	$66,341	$71,583	$522,437	$127,443	$343,739
Cash Flow Year 32	$222,063	$68,570	$61,718	$546,262	$131,751	$355,884
Cash Flow Year 33	$223,961	$71,788	$65,259	$511,101	$124,094	$366,908
Cash Flow Year 34	$216,888	$63,318	$79,879	$476,442	$132,488	$343,472
Cash Flow Year 35	$217,169	$69,165	$48,585	$511,975	$129,232	$355,409
Cash Flow Year 36	$221,586	$69,401	$66,715	$540,646	$127,833	$348,962
Cash Flow Year 37	$222,565	$69,173	$52,534	$493,014	$126,798	$353,256
Cash Flow Year 38	$220,337	$69,401	$86,813	$514,956	$127,968	$351,369
Cash Flow Year 39	$220,137	$69,073	$66,971	$496,811	$130,005	$355,750
Cash Flow Year 40	$220,072	$69,802	$71,838	$604,945	$126,806	$354,440
40 Year NPV	$2,379,141	$229,095	$1,729,459	$3,165,850	$2,009,232	$2,742,444
Perpetuity NPV	$2,419,362	$229,890	$1,743,034	$3,206,808	$2,042,479	$2,784,193

Table J.6 – Summary statistics for farm representative of Brown soil zone, irrigated production, baseline rotation with residues (barley, durum wheat, and spring wheat) removed annually

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$303,789	$159,407	-$275,411	$889,518	$86,852	$588,092
Cash Flow Year 2	$214,465	$147,841	-$277,948	$861,765	$18,652	$495,567
Cash Flow Year 3	$194,903	$133,233	-$301,522	$839,451	$26,852	$415,100
Cash Flow Year 4	$237,457	$137,730	-$313,067	$828,927	$63,726	$485,554
Cash Flow Year 5	$271,565	$140,724	-$309,527	$834,176	$99,820	$540,742
Cash Flow Year 6	$265,316	$143,314	-$292,302	$937,009	$81,227	$540,014
Cash Flow Year 7	$253,445	$152,581	-$328,314	$806,233	$66,197	$543,878
Cash Flow Year 8	$251,475	$140,565	-$296,396	$752,367	$71,951	$524,100
Cash Flow Year 9	$253,685	$138,340	-$322,083	$817,469	$77,333	$509,863
Cash Flow Year 10	$257,112	$138,705	-$300,110	$853,519	$75,296	$524,399
Cash Flow Year 11	$255,711	$143,086	-$289,888	$830,115	$67,899	$529,435
Cash Flow Year 12	$246,237	$143,914	-$312,257	$751,551	$61,692	$517,418
Cash Flow Year 13	$247,006	$140,949	-$310,008	$795,655	$55,369	$508,478
Cash Flow Year 14	$250,371	$147,093	-$290,313	$961,251	$65,324	$533,758
Cash Flow Year 15	$248,456	$141,953	-$305,115	$906,480	$67,148	$519,342
Cash Flow Year 16	$252,616	$150,856	-$316,752	$793,377	$64,411	$545,733
Cash Flow Year 17	$248,665	$140,935	-$306,673	$929,023	$67,297	$514,565

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 18	$244,512	$140,649	-$300,707	$747,987	$64,352	$497,266
Cash Flow Year 19	$249,027	$140,873	-$297,861	$867,673	$66,304	$506,945
Cash Flow Year 20	$247,860	$137,865	-$293,055	$910,083	$70,971	$495,713
Cash Flow Year 21	$254,717	$152,940	-$304,180	$822,915	$63,003	$529,281
Cash Flow Year 22	$255,968	$145,354	-$301,058	$769,874	$69,889	$538,090
Cash Flow Year 23	$254,266	$146,098	-$360,746	$890,074	$57,312	$526,185
Cash Flow Year 24	$249,973	$143,418	-$332,512	$912,757	$66,436	$524,201
Cash Flow Year 25	$251,535	$141,794	-$300,390	$871,598	$63,084	$506,245
Cash Flow Year 26	$249,974	$141,969	-$291,165	$933,627	$71,842	$500,538
Cash Flow Year 27	$256,076	$145,238	-$299,074	$874,198	$73,501	$523,160
Cash Flow Year 28	$250,149	$139,038	-$60,221	$808,341	$69,470	$521,574
Cash Flow Year 29	$248,540	$141,354	-$291,866	$886,188	$70,532	$519,523
Cash Flow Year 30	$250,952	$141,455	-$298,640	$1,140,463	$64,145	$513,016
Cash Flow Year 31	$256,041	$142,833	-$301,829	$850,385	$59,225	$506,746
Cash Flow Year 32	$249,752	$147,594	-$302,001	$841,224	$61,675	$527,786
Cash Flow Year 33	$249,778	$137,415	-$294,760	$837,218	$67,301	$520,174
Cash Flow Year 34	$249,092	$141,710	-$300,761	$781,752	$63,416	$519,984
Cash Flow Year 35	$243,407	$135,837	-$306,315	$733,319	$67,260	$494,410
Cash Flow Year 36	$251,570	$150,086	-$295,046	$861,661	$62,137	$538,998
Cash Flow Year 37	$260,295	$142,056	-$289,234	$808,257	$72,186	$532,510
Cash Flow Year 38	$250,737	$139,536	-$289,463	$825,126	$63,152	$516,144
Cash Flow Year 39	$247,200	$143,239	-$293,349	$978,387	$60,658	$501,975
Cash Flow Year 40	$238,892	$141,474	-$326,072	$774,184	$54,426	$494,652
40 Year NPV	$2,742,025	$425,079	$1,308,585	$4,308,521	$2,044,242	$3,438,943
Perpetuity NPV	$2,795,045	$424,532	$1,395,286	$4,365,294	$2,111,534	$3,495,768

Table J.7 – Summary statistics for farm representative of Brown soil zone, dryland production, baseline rotation with residues (barley, durum wheat, and spring wheat) removed annually

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$112,850	$119,237	-$175,926	$628,673	-$46,250	$334,041
Cash Flow Year 2	$74,816	$107,110	-$165,710	$571,563	-$105,904	$264,351
Cash Flow Year 3	$70,857	$101,006	-$158,675	$471,096	-$104,066	$257,578
Cash Flow Year 4	$90,171	$99,481	-$177,786	$610,118	-$98,194	$262,213
Cash Flow Year 5	$100,381	$108,610	-$141,938	$599,980	-$100,011	$299,703
Cash Flow Year 6	$94,101	$110,698	-$160,440	$703,096	-$103,199	$293,546
Cash Flow Year 7	$89,002	$105,036	-$175,643	$498,081	-$100,636	$278,316
Cash Flow Year 8	$84,325	$103,237	-$148,972	$515,441	-$105,456	$263,228
Cash Flow Year 9	$90,790	$104,950	-$152,454	$593,482	-$103,034	$280,147
Cash Flow Year 10	$91,060	$102,452	-$206,109	$535,298	-$101,811	$280,484
Cash Flow Year 11	$91,262	$110,671	-$133,322	$566,660	-$103,256	$290,283
Cash Flow Year 12	$95,570	$111,860	-$167,363	$575,894	-$103,605	$304,459

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 13	$94,837	$107,293	-$155,353	$513,760	-$102,290	$300,044
Cash Flow Year 14	$92,889	$107,010	-$181,576	$500,156	-$102,873	$285,080
Cash Flow Year 15	$89,711	$108,600	-$132,740	$543,143	-$104,445	$281,664
Cash Flow Year 16	$89,086	$107,389	-$175,345	$575,924	-$104,243	$276,577
Cash Flow Year 17	$91,927	$107,284	-$150,807	$780,303	-$100,527	$287,085
Cash Flow Year 18	$93,259	$103,623	-$172,819	$481,863	-$99,538	$277,949
Cash Flow Year 19	$94,305	$105,648	-$164,672	$581,106	-$100,515	$292,737
Cash Flow Year 20	$92,923	$112,377	-$152,500	$608,647	-$104,217	$304,607
Cash Flow Year 21	$88,327	$105,520	-$139,049	$523,849	-$102,041	$286,231
Cash Flow Year 22	$93,152	$106,079	-$162,647	$699,171	-$100,306	$275,774
Cash Flow Year 23	$91,463	$102,851	-$139,533	$516,407	-$100,208	$283,496
Cash Flow Year 24	$90,214	$104,354	-$146,497	$569,789	-$102,100	$270,801
Cash Flow Year 25	$88,024	$104,919	-$137,973	$511,399	-$104,389	$284,616
Cash Flow Year 26	$87,909	$103,320	-$151,132	$514,727	-$101,421	$282,719
Cash Flow Year 27	$88,834	$104,869	-$134,662	$532,847	-$103,481	$280,425
Cash Flow Year 28	$91,956	$105,969	-$160,700	$552,221	-$102,525	$294,013
Cash Flow Year 29	$92,725	$107,993	-$135,471	$623,821	-$103,780	$290,230
Cash Flow Year 30	$94,008	$108,199	-$136,157	$713,719	-$101,978	$290,094
Cash Flow Year 31	$91,979	$108,264	-$163,868	$793,529	-$104,879	$279,047
Cash Flow Year 32	$88,565	$104,772	-$190,993	$621,060	-$104,029	$280,542
Cash Flow Year 33	$89,055	$103,100	-$134,157	$513,652	-$101,849	$277,020
Cash Flow Year 34	$94,248	$105,619	-$161,326	$606,318	-$99,824	$289,639
Cash Flow Year 35	$87,737	$110,613	-$141,052	$582,636	-$104,616	$304,273
Cash Flow Year 36	$90,495	$104,060	-$184,149	$551,497	-$102,043	$279,352
Cash Flow Year 37	$87,258	$104,473	-$137,983	$481,214	-$102,848	$287,666
Cash Flow Year 38	$90,954	$108,193	-$178,832	$736,918	-$102,937	$292,386
Cash Flow Year 39	$92,987	$105,451	-$147,907	$518,901	-$102,001	$277,663
Cash Flow Year 40	$93,183	$109,634	-$173,134	$626,192	-$102,106	$295,653
40 Year NPV	$988,197	$354,487	-$153,498	$2,079,334	$400,431	$1,576,159
Perpetuity NPV	$1,008,116	$355,382	-$134,994	$2,112,859	$425,443	$1,599,518

Table J.8 – Summary statistics for farm representative of Dark Brown soil zone, baseline rotation with residues (barley and spring wheat) removed annually

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$127,794	$96,447	-$129,737	$576,652	$6,118	$314,464
Cash Flow Year 2	$103,031	$90,880	-$126,917	$483,370	-$16,237	$256,909
Cash Flow Year 3	$106,691	$91,333	-$124,352	$538,452	-$15,422	$267,124
Cash Flow Year 4	$118,838	$83,596	-$126,787	$529,951	$9,425	$279,419
Cash Flow Year 5	$124,086	$86,706	-$119,814	$475,005	$10,005	$288,676
Cash Flow Year 6	$119,076	$87,654	-$125,425	$426,931	$878	$280,882
Cash Flow Year 7	$118,611	$91,204	-$132,844	$417,254	-$3,767	$280,110
Cash Flow Year 8	$116,857	$89,336	-$130,942	$430,489	$1,480	$284,046

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 9	$122,705	$84,348	-$114,452	$447,745	$10,185	$280,885
Cash Flow Year 10	$124,099	$89,176	-$129,401	$487,080	$13,068	$285,285
Cash Flow Year 11	$119,787	$86,109	-$127,450	$475,020	$5,587	$278,425
Cash Flow Year 12	$122,378	$88,384	-$134,270	$475,867	$7,542	$288,541
Cash Flow Year 13	$119,445	$86,887	-$195,859	$496,237	$7,122	$276,717
Cash Flow Year 14	$120,272	$87,604	-$124,911	$514,705	$7,094	$273,642
Cash Flow Year 15	$118,274	$85,609	-$115,555	$468,406	$8,651	$280,785
Cash Flow Year 16	$116,914	$88,376	-$131,167	$458,761	$4,981	$282,175
Cash Flow Year 17	$121,788	$87,506	-$127,709	$536,927	$8,369	$291,038
Cash Flow Year 18	$118,823	$88,236	-$125,199	$499,888	$5,416	$286,722
Cash Flow Year 19	$120,027	$88,036	-$139,208	$442,051	$8,178	$288,531
Cash Flow Year 20	$114,803	$86,432	-$139,407	$471,150	$5,507	$276,983
Cash Flow Year 21	$115,051	$87,056	-$128,801	$460,992	$286	$278,206
Cash Flow Year 22	$119,974	$89,872	-$136,812	$590,036	$2,224	$287,902
Cash Flow Year 23	$120,537	$84,058	-$128,471	$482,402	$11,772	$274,661
Cash Flow Year 24	$121,267	$90,540	-$125,166	$507,290	$7,263	$302,617
Cash Flow Year 25	$115,761	$85,816	-$131,487	$459,730	$3,998	$273,363
Cash Flow Year 26	$114,271	$85,241	-$139,252	$488,956	$7,075	$266,016
Cash Flow Year 27	$117,688	$86,728	-$127,429	$530,054	$4,463	$264,051
Cash Flow Year 28	$119,398	$87,555	-$148,818	$514,690	$4,515	$279,003
Cash Flow Year 29	$120,724	$88,329	-$139,805	$497,956	$4,726	$277,164
Cash Flow Year 30	$116,793	$83,338	-$136,050	$503,573	$5,769	$267,633
Cash Flow Year 31	$119,024	$89,845	-$135,644	$473,285	$4,341	$290,128
Cash Flow Year 32	$117,932	$90,074	-$132,233	$540,245	-$2,987	$268,635
Cash Flow Year 33	$117,449	$87,822	-$128,791	$467,469	$3,208	$273,030
Cash Flow Year 34	$121,124	$87,609	-$131,905	$450,017	$3,549	$275,807
Cash Flow Year 35	$118,400	$88,570	-$133,885	$510,089	$4,951	$283,158
Cash Flow Year 36	$119,407	$85,279	-$142,401	$407,051	$8,018	$274,240
Cash Flow Year 37	$114,459	$82,500	-$129,662	$458,809	$127	$257,035
Cash Flow Year 38	$116,895	$83,698	-$121,448	$448,829	$4,431	$267,723
Cash Flow Year 39	$121,819	$90,512	-$171,384	$484,479	$5,701	$284,024
Cash Flow Year 40	$118,773	$89,364	-$129,609	$558,829	$2,911	$279,715
40 Year NPV	$1,271,121	$302,509	$305,313	$2,065,753	$735,332	$1,748,660
Perpetuity NPV	$1,297,274	$303,678	$340,269	$2,075,314	$765,143	$1,782,434

Table J.9 – Summary statistics for farm representative of Black soil zone, baseline rotation with residues (barley and spring wheat) removed annually

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$287,824	$110,230	-$120,563	$770,925	$139,907	$494,869
Cash Flow Year 2	$260,227	$100,713	$7,309	$712,130	$124,401	$440,330
Cash Flow Year 3	$268,966	$103,255	$55,123	$665,820	$121,864	$461,718
Cash Flow Year 4	$290,323	$100,509	-$118,292	$675,678	$149,884	$478,533

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 5	$297,216	$99,863	-$119,283	$681,753	$164,676	$498,123
Cash Flow Year 6	$284,576	$94,628	$58,884	$594,460	$157,133	$467,513
Cash Flow Year 7	$278,410	$96,311	$29,212	$691,376	$144,050	$469,709
Cash Flow Year 8	$284,275	$99,256	-$114,823	$632,734	$146,635	$480,671
Cash Flow Year 9	$293,171	$101,439	-$140,447	$721,497	$154,840	$480,976
Cash Flow Year 10	$286,957	$102,012	-$115,303	$747,818	$152,782	$475,152
Cash Flow Year 11	$282,556	$95,492	$54,417	$634,385	$150,975	$467,069
Cash Flow Year 12	$285,137	$97,736	-$115,452	$661,361	$148,352	$464,043
Cash Flow Year 13	$286,820	$96,755	-$111,376	$691,129	$163,032	$464,915
Cash Flow Year 14	$284,659	$94,625	$59,423	$732,858	$156,526	$458,768
Cash Flow Year 15	$281,452	$94,137	$38,245	$636,538	$149,298	$461,255
Cash Flow Year 16	$286,577	$98,106	$30,018	$647,998	$153,794	$485,737
Cash Flow Year 17	$288,285	$97,606	$59,542	$647,368	$158,294	$467,655
Cash Flow Year 18	$286,388	$101,082	-$113,077	$737,465	$147,843	$476,487
Cash Flow Year 19	$286,089	$99,301	-$127,666	$676,763	$151,036	$481,996
Cash Flow Year 20	$280,809	$94,657	-$120,358	$763,500	$152,378	$454,882
Cash Flow Year 21	$289,569	$95,678	-$110,167	$687,816	$158,280	$469,806
Cash Flow Year 22	$286,380	$99,906	-$116,057	$690,222	$155,669	$471,724
Cash Flow Year 23	$281,719	$95,123	$65,924	$769,252	$145,427	$456,544
Cash Flow Year 24	$284,412	$95,474	$70,738	$658,440	$151,135	$461,781
Cash Flow Year 25	$285,519	$99,734	$55,637	$699,499	$151,223	$481,408
Cash Flow Year 26	$285,893	$97,204	-$113,743	$692,394	$149,862	$459,199
Cash Flow Year 27	$284,400	$98,391	$70,502	$783,020	$147,027	$471,382
Cash Flow Year 28	$287,905	$100,056	$18,924	$695,870	$152,378	$476,848
Cash Flow Year 29	$284,676	$94,501	$38,077	$724,467	$152,017	$456,083
Cash Flow Year 30	$287,337	$98,572	$73,025	$754,011	$154,283	$462,513
Cash Flow Year 31	$284,618	$93,789	$56,923	$757,128	$156,032	$463,103
Cash Flow Year 32	$284,352	$95,182	$62,832	$720,013	$158,521	$460,483
Cash Flow Year 33	$288,205	$96,376	-$113,870	$715,435	$157,907	$466,436
Cash Flow Year 34	$288,486	$97,377	-$110,376	$731,684	$158,130	$466,875
Cash Flow Year 35	$288,403	$101,967	-$119,399	$737,825	$151,278	$474,142
Cash Flow Year 36	$283,555	$95,293	$71,496	$698,487	$153,743	$474,265
Cash Flow Year 37	$280,857	$95,269	-$114,272	$621,038	$148,886	$469,070
Cash Flow Year 38	$286,850	$94,123	-$120,627	$607,626	$157,091	$464,674
Cash Flow Year 39	$285,632	$97,053	-$112,311	$661,524	$155,965	$475,732
Cash Flow Year 40	$287,078	$100,758	$66,048	$788,340	$156,417	$487,707
40 Year NPV	$3,047,550	$356,872	$1,975,383	$4,456,629	$2,496,062	$3,635,871
Perpetuity NPV	$3,110,800	$358,131	$2,031,078	$4,495,620	$2,570,998	$3,706,115

Table J.10 – Summary statistics for farm representative of Dark Grey soil zone, baseline rotation with residues (barley and spring wheat) removed annually

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$244,693	$77,755	$92,501	$593,844	$142,136	$398,597
Cash Flow Year 2	$223,619	$71,774	$66,566	$532,136	$123,548	$358,569
Cash Flow Year 3	$227,934	$72,012	$59,841	$504,717	$129,955	$363,417
Cash Flow Year 4	$243,862	$70,658	$88,306	$570,774	$151,078	$376,287
Cash Flow Year 5	$249,586	$68,080	$89,845	$548,063	$151,305	$382,280
Cash Flow Year 6	$241,080	$66,223	$96,485	$538,996	$153,210	$370,077
Cash Flow Year 7	$237,369	$65,976	$79,574	$562,004	$147,378	$354,727
Cash Flow Year 8	$241,329	$71,885	$74,696	$558,941	$146,276	$383,138
Cash Flow Year 9	$243,347	$71,655	$57,199	$548,265	$148,506	$383,356
Cash Flow Year 10	$241,864	$67,727	$91,390	$500,230	$146,919	$368,192
Cash Flow Year 11	$239,699	$65,758	$98,944	$501,382	$148,789	$368,230
Cash Flow Year 12	$238,034	$66,844	$91,802	$556,338	$145,440	$364,722
Cash Flow Year 13	$242,773	$71,191	$96,932	$586,480	$147,058	$385,083
Cash Flow Year 14	$240,540	$68,414	$78,897	$516,465	$146,974	$372,865
Cash Flow Year 15	$237,684	$66,968	$87,149	$563,666	$143,343	$366,169
Cash Flow Year 16	$242,284	$72,150	$75,709	$551,984	$148,468	$383,636
Cash Flow Year 17	$243,229	$70,845	$104,106	$497,287	$147,758	$391,682
Cash Flow Year 18	$244,837	$72,572	$79,702	$612,907	$148,262	$388,950
Cash Flow Year 19	$241,693	$69,116	$91,671	$564,627	$147,301	$364,197
Cash Flow Year 20	$238,994	$66,795	$70,999	$576,591	$152,143	$369,645
Cash Flow Year 21	$242,731	$68,009	$77,864	$578,238	$149,542	$366,738
Cash Flow Year 22	$242,797	$69,585	$82,448	$560,340	$145,945	$374,073
Cash Flow Year 23	$241,829	$69,880	$93,700	$618,842	$149,257	$373,623
Cash Flow Year 24	$240,396	$67,569	$45,816	$525,135	$145,916	$364,405
Cash Flow Year 25	$242,707	$69,040	$82,546	$514,210	$146,175	$372,586
Cash Flow Year 26	$243,889	$68,702	$88,075	$514,623	$151,359	$371,498
Cash Flow Year 27	$242,954	$69,751	$83,949	$518,852	$148,010	$373,683
Cash Flow Year 28	$242,885	$69,892	$80,478	$559,198	$146,578	$379,971
Cash Flow Year 29	$245,926	$70,293	$72,317	$544,929	$153,369	$385,309
Cash Flow Year 30	$243,694	$70,324	$107,036	$638,823	$150,776	$378,569
Cash Flow Year 31	$238,480	$65,391	$90,119	$562,700	$148,427	$365,552
Cash Flow Year 32	$241,116	$69,321	$85,200	$548,840	$147,043	$375,002
Cash Flow Year 33	$242,168	$70,776	$79,240	$682,227	$144,310	$373,431
Cash Flow Year 34	$243,938	$67,449	$67,800	$519,575	$151,745	$363,644
Cash Flow Year 35	$243,470	$68,325	$88,472	$540,577	$148,192	$375,528
Cash Flow Year 36	$241,201	$68,840	$63,287	$524,600	$146,942	$375,150
Cash Flow Year 37	$240,757	$69,570	$66,438	$532,751	$146,766	$374,020
Cash Flow Year 38	$239,505	$65,287	$78,833	$511,116	$148,602	$358,393
Cash Flow Year 39	$244,292	$69,609	$83,848	$551,388	$150,403	$372,547
Cash Flow Year 40	$245,061	$71,723	$98,727	$566,377	$152,238	$388,307

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
40 Year NPV	$2,585,719	$237,750	$1,900,969	$3,365,780	$2,190,719	$2,968,177
Perpetuity NPV	$2,630,588	$239,017	$1,933,697	$3,421,188	$2,244,886	$3,018,088

Table J.11 – Summary statistics for farm representative of Brown soil zone, irrigated production, alfalfa hay rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$209,379	$108,696	-$290,652	$589,895	$48,917	$413,386
Cash Flow Year 2	$177,120	$115,229	-$92,662	$664,595	$21,044	$401,632
Cash Flow Year 3	$195,980	$117,852	-$133,664	$658,238	$33,834	$411,928
Cash Flow Year 4	$259,559	$125,586	-$27,870	$770,111	$90,837	$499,685
Cash Flow Year 5	$280,807	$123,050	$13,811	$700,977	$115,258	$513,383
Cash Flow Year 6	$275,582	$122,214	$954	$793,441	$109,199	$502,362
Cash Flow Year 7	$270,649	$117,331	-$11,879	$708,960	$116,032	$492,344
Cash Flow Year 8	$270,724	$112,823	$46,492	$756,517	$116,125	$493,805
Cash Flow Year 9	$283,155	$116,425	-$286,060	$712,342	$132,846	$502,988
Cash Flow Year 10	$287,458	$109,734	$31,971	$791,889	$135,380	$493,191
Cash Flow Year 11	$280,203	$105,949	$24,741	$731,950	$133,676	$476,541
Cash Flow Year 12	$276,533	$110,708	$33,038	$722,939	$124,986	$486,875
Cash Flow Year 13	$279,216	$108,309	$26,741	$655,483	$133,746	$495,725
Cash Flow Year 14	$278,466	$104,483	$18,548	$770,068	$136,929	$473,900
Cash Flow Year 15	$276,250	$106,032	$21,914	$653,068	$130,022	$479,545
Cash Flow Year 16	$273,892	$112,418	$43,993	$857,545	$122,602	$483,387
Cash Flow Year 17	$274,001	$106,953	$22,985	$703,277	$132,482	$483,142
Cash Flow Year 18	$279,024	$104,463	-$1,408	$695,546	$137,711	$470,727
Cash Flow Year 19	$283,505	$112,218	$13,149	$759,063	$130,984	$496,126
Cash Flow Year 20	$277,601	$113,341	-$279,969	$795,166	$131,566	$482,033
Cash Flow Year 21	$272,592	$110,674	-$7,432	$828,913	$122,357	$478,878
Cash Flow Year 22	$276,355	$111,835	$37,875	$784,656	$129,934	$489,723
Cash Flow Year 23	$277,691	$109,525	$52,322	$773,162	$132,524	$473,054
Cash Flow Year 24	$286,079	$116,993	$47,312	$815,467	$131,541	$504,638
Cash Flow Year 25	$281,041	$107,597	$20,668	$725,837	$131,992	$485,634
Cash Flow Year 26	$283,025	$113,479	$25,209	$779,808	$130,378	$504,191
Cash Flow Year 27	$280,902	$108,679	$47,440	$734,177	$130,103	$495,264
Cash Flow Year 28	$278,976	$107,272	-$22,922	$827,673	$132,955	$489,079
Cash Flow Year 29	$281,739	$114,023	$25,215	$839,265	$132,723	$507,653
Cash Flow Year 30	$277,683	$107,907	$32,734	$713,512	$130,135	$485,887
Cash Flow Year 31	$276,779	$109,015	$19,886	$821,427	$127,030	$479,500
Cash Flow Year 32	$280,305	$107,719	$54,723	$690,651	$127,777	$483,016
Cash Flow Year 33	$286,688	$114,817	$33,711	$853,459	$135,095	$508,553
Cash Flow Year 34	$282,626	$111,457	$19,622	$730,355	$126,090	$497,150
Cash Flow Year 35	$277,801	$111,778	$45,634	$703,982	$129,465	$488,151
Cash Flow Year 36	$276,296	$103,966	$38,545	$643,385	$128,290	$476,139

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 37	$281,922	$114,111	$29,119	$723,289	$129,581	$507,635
Cash Flow Year 38	$275,104	$107,171	-$274,773	$725,415	$124,557	$469,998
Cash Flow Year 39	$282,002	$113,091	$10,722	$813,495	$130,983	$509,796
Cash Flow Year 40	$279,596	$111,652	$2,334	$743,646	$131,581	$493,342
40 Year NPV	$2,761,479	$358,795	$1,549,478	$4,058,104	$2,186,785	$3,354,831
Perpetuity NPV	$2,814,897	$359,244	$1,602,837	$4,135,812	$2,239,055	$3,394,284

Table J.12 – Summary statistics for farm representative of Dark Brown soil zone, alfalfa hay rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$107,296	$61,171	-$71,334	$313,479	$22,356	$214,909
Cash Flow Year 2	$117,938	$68,085	-$57,950	$387,392	$16,772	$234,609
Cash Flow Year 3	$154,424	$72,403	-$7,409	$370,419	$49,676	$279,928
Cash Flow Year 4	$186,344	$78,352	$12,442	$464,454	$75,443	$327,350
Cash Flow Year 5	$193,226	$73,441	$32,763	$472,763	$89,094	$322,949
Cash Flow Year 6	$193,035	$66,745	$41,245	$407,907	$98,620	$313,375
Cash Flow Year 7	$197,184	$62,917	$29,699	$452,649	$109,938	$315,139
Cash Flow Year 8	$200,960	$60,694	$69,759	$445,021	$113,340	$318,540
Cash Flow Year 9	$203,693	$57,017	$33,767	$499,224	$122,784	$308,697
Cash Flow Year 10	$206,746	$60,290	$79,265	$433,473	$120,701	$317,694
Cash Flow Year 11	$206,673	$62,072	$60,865	$444,287	$122,182	$319,898
Cash Flow Year 12	$204,883	$58,653	$41,041	$430,134	$122,063	$315,373
Cash Flow Year 13	$204,579	$61,109	$52,381	$453,360	$121,653	$326,981
Cash Flow Year 14	$204,393	$57,606	$66,323	$452,485	$120,143	$310,448
Cash Flow Year 15	$204,377	$58,716	$71,343	$436,393	$123,058	$316,821
Cash Flow Year 16	$207,131	$61,656	$67,398	$467,355	$121,321	$323,242
Cash Flow Year 17	$202,573	$57,672	$59,760	$461,368	$119,162	$304,039
Cash Flow Year 18	$204,861	$56,756	$71,124	$424,379	$119,199	$306,902
Cash Flow Year 19	$202,492	$57,770	$55,884	$490,960	$120,249	$315,377
Cash Flow Year 20	$203,862	$59,851	$45,134	$503,789	$122,274	$312,063
Cash Flow Year 21	$204,990	$61,027	$49,339	$412,956	$119,422	$321,478
Cash Flow Year 22	$206,726	$62,290	$47,073	$472,468	$122,920	$323,664
Cash Flow Year 23	$206,481	$60,493	$80,140	$431,256	$120,783	$323,475
Cash Flow Year 24	$208,400	$61,967	$65,174	$484,706	$121,086	$329,819
Cash Flow Year 25	$206,682	$59,532	$56,408	$455,915	$123,108	$313,582
Cash Flow Year 26	$204,903	$57,475	$84,576	$455,730	$122,775	$315,706
Cash Flow Year 27	$203,662	$58,311	$73,867	$455,113	$122,339	$310,791
Cash Flow Year 28	$205,408	$60,840	$45,158	$519,554	$123,620	$317,671
Cash Flow Year 29	$203,386	$58,349	$79,343	$424,885	$122,433	$315,617
Cash Flow Year 30	$205,238	$59,780	$76,338	$413,895	$121,515	$312,792
Cash Flow Year 31	$204,297	$57,462	$69,502	$381,241	$117,245	$313,343
Cash Flow Year 32	$202,106	$58,534	$73,791	$477,742	$120,301	$309,422

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 33	$204,483	$59,918	$50,109	$429,593	$119,279	$315,457
Cash Flow Year 34	$209,585	$60,118	$65,531	$451,736	$124,618	$319,237
Cash Flow Year 35	$205,838	$60,203	$62,060	$514,584	$121,164	$322,003
Cash Flow Year 36	$207,034	$60,750	$52,467	$452,694	$124,909	$325,904
Cash Flow Year 37	$204,349	$58,656	$73,656	$475,119	$120,621	$314,089
Cash Flow Year 38	$206,388	$59,209	$64,474	$429,315	$119,145	$317,087
Cash Flow Year 39	$206,549	$58,409	$65,183	$445,684	$128,000	$316,411
Cash Flow Year 40	$207,909	$59,423	$50,196	$413,319	$124,699	$320,346
40 Year NPV	$1,871,163	$221,059	$1,078,574	$2,553,840	$1,513,050	$2,228,685
Perpetuity NPV	$1,917,264	$221,454	$1,121,644	$2,604,555	$1,561,515	$2,278,478

Table J.13 – Summary statistics for farm representative of Black soil zone, alfalfa hay rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$219,934	$60,713	$43,516	$503,875	$120,527	$318,874
Cash Flow Year 2	$216,179	$69,909	$48,615	$479,704	$112,396	$345,810
Cash Flow Year 3	$293,021	$76,752	$106,431	$573,468	$178,156	$425,676
Cash Flow Year 4	$323,776	$80,503	$117,581	$614,857	$204,970	$461,645
Cash Flow Year 5	$322,773	$75,811	$121,918	$580,334	$208,630	$457,386
Cash Flow Year 6	$317,425	$71,377	$150,360	$604,288	$218,452	$449,967
Cash Flow Year 7	$323,632	$63,141	$181,667	$599,994	$233,524	$444,731
Cash Flow Year 8	$332,747	$58,890	$202,582	$589,275	$248,368	$448,926
Cash Flow Year 9	$341,585	$63,121	$196,273	$565,655	$251,904	$465,594
Cash Flow Year 10	$342,371	$61,602	$207,766	$582,579	$256,126	$455,730
Cash Flow Year 11	$336,351	$59,384	$201,853	$598,752	$252,172	$445,509
Cash Flow Year 12	$333,463	$58,281	$162,477	$580,775	$251,755	$440,479
Cash Flow Year 13	$335,186	$60,028	$193,971	$542,945	$248,998	$451,780
Cash Flow Year 14	$336,859	$59,992	$169,584	$581,055	$251,557	$445,573
Cash Flow Year 15	$337,462	$62,841	$166,201	$580,254	$248,141	$457,403
Cash Flow Year 16	$338,560	$60,553	$187,398	$573,494	$256,977	$450,376
Cash Flow Year 17	$337,900	$61,456	$198,920	$548,523	$254,006	$459,009
Cash Flow Year 18	$335,061	$58,525	$196,022	$576,180	$253,255	$444,989
Cash Flow Year 19	$338,482	$60,263	$190,274	$619,357	$253,493	$454,950
Cash Flow Year 20	$337,689	$59,603	$189,142	$651,240	$252,863	$447,936
Cash Flow Year 21	$337,347	$60,380	$187,122	$570,183	$251,973	$450,045
Cash Flow Year 22	$335,242	$59,191	$195,128	$573,843	$250,989	$449,996
Cash Flow Year 23	$333,716	$58,712	$183,261	$552,932	$249,889	$443,035
Cash Flow Year 24	$337,685	$62,243	$166,033	$546,542	$251,531	$457,898
Cash Flow Year 25	$336,744	$60,328	$192,646	$620,251	$254,150	$453,776
Cash Flow Year 26	$336,738	$60,650	$171,152	$568,442	$253,752	$451,765
Cash Flow Year 27	$335,950	$60,657	$188,226	$615,482	$249,983	$443,867
Cash Flow Year 28	$334,622	$59,606	$171,221	$570,942	$247,922	$447,626

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 29	$338,268	$61,177	$172,774	$560,739	$254,007	$453,670
Cash Flow Year 30	$337,973	$61,990	$192,436	$559,531	$251,639	$452,361
Cash Flow Year 31	$336,016	$61,073	$192,718	$593,312	$255,613	$450,116
Cash Flow Year 32	$339,125	$61,458	$202,209	$699,608	$254,686	$458,253
Cash Flow Year 33	$339,982	$60,946	$213,191	$570,838	$260,441	$459,686
Cash Flow Year 34	$333,895	$54,594	$203,913	$561,117	$253,690	$429,279
Cash Flow Year 35	$332,796	$59,132	$189,362	$598,364	$252,767	$442,226
Cash Flow Year 36	$338,111	$63,921	$191,618	$597,700	$249,839	$463,241
Cash Flow Year 37	$341,716	$64,204	$186,229	$627,840	$256,604	$460,537
Cash Flow Year 38	$339,202	$61,405	$178,381	$644,362	$255,182	$455,699
Cash Flow Year 39	$337,611	$61,571	$173,587	$623,883	$249,454	$456,217
Cash Flow Year 40	$336,251	$61,099	$171,796	$636,012	$249,291	$450,648
40 Year NPV	$3,270,135	$235,852	$2,624,569	$4,288,861	$2,879,125	$3,677,006
Perpetuity NPV	$3,336,329	$236,190	$2,687,196	$4,358,125	$2,939,483	$3,749,858

Table J.14 – Summary statistics for farm representative of Dark Grey soil zone, alfalfa hay rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$184,084	$41,466	$69,195	$425,859	$118,121	$255,940
Cash Flow Year 2	$177,653	$47,439	$47,458	$374,283	$108,124	$267,873
Cash Flow Year 3	$232,890	$58,291	$102,477	$483,133	$146,382	$335,348
Cash Flow Year 4	$257,021	$58,067	$108,514	$470,441	$173,710	$357,630
Cash Flow Year 5	$254,904	$53,751	$130,908	$427,682	$174,761	$351,260
Cash Flow Year 6	$249,907	$52,835	$132,547	$439,919	$176,399	$348,312
Cash Flow Year 7	$256,383	$46,872	$149,689	$460,003	$191,554	$339,403
Cash Flow Year 8	$263,951	$45,004	$160,733	$445,404	$200,665	$349,847
Cash Flow Year 9	$269,236	$44,850	$154,491	$422,552	$209,067	$352,544
Cash Flow Year 10	$268,317	$44,700	$161,037	$461,365	$206,136	$348,369
Cash Flow Year 11	$265,697	$43,520	$144,264	$417,816	$203,553	$350,186
Cash Flow Year 12	$262,649	$42,556	$153,181	$449,964	$204,228	$339,952
Cash Flow Year 13	$264,883	$43,334	$158,133	$429,400	$202,354	$343,897
Cash Flow Year 14	$264,127	$43,578	$139,808	$434,347	$203,718	$348,866
Cash Flow Year 15	$266,292	$46,029	$137,174	$473,791	$203,497	$354,798
Cash Flow Year 16	$265,718	$44,155	$150,954	$486,507	$204,944	$348,456
Cash Flow Year 17	$267,390	$46,736	$152,758	$448,120	$201,757	$355,216
Cash Flow Year 18	$266,529	$45,102	$141,586	$462,010	$206,907	$354,035
Cash Flow Year 19	$266,447	$43,580	$166,707	$427,335	$204,270	$346,672
Cash Flow Year 20	$266,339	$45,013	$168,051	$431,031	$204,006	$348,242
Cash Flow Year 21	$265,739	$42,645	$168,552	$417,124	$201,811	$344,091
Cash Flow Year 22	$265,286	$43,897	$168,388	$460,708	$204,369	$350,459
Cash Flow Year 23	$263,518	$42,187	$105,001	$424,378	$203,923	$340,746
Cash Flow Year 24	$267,049	$44,473	$156,696	$439,833	$206,465	$348,474

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 25	$268,174	$45,173	$166,972	$476,897	$205,726	$350,395
Cash Flow Year 26	$266,798	$44,216	$145,641	$455,160	$206,947	$348,835
Cash Flow Year 27	$265,672	$43,356	$155,886	$478,862	$204,191	$343,263
Cash Flow Year 28	$266,144	$42,329	$167,071	$434,924	$204,753	$341,438
Cash Flow Year 29	$268,156	$43,534	$175,287	$459,067	$206,330	$349,173
Cash Flow Year 30	$267,340	$44,566	$177,065	$430,803	$204,078	$349,953
Cash Flow Year 31	$265,306	$43,633	$165,502	$446,941	$205,268	$349,333
Cash Flow Year 32	$267,570	$44,248	$155,841	$477,541	$206,475	$350,863
Cash Flow Year 33	$268,796	$45,726	$141,880	$460,032	$206,897	$359,336
Cash Flow Year 34	$263,997	$41,051	$156,728	$417,646	$203,756	$341,101
Cash Flow Year 35	$262,157	$43,723	$157,820	$469,213	$201,883	$343,191
Cash Flow Year 36	$267,618	$45,938	$144,499	$436,491	$204,512	$354,357
Cash Flow Year 37	$269,230	$46,376	$169,397	$453,122	$204,161	$355,791
Cash Flow Year 38	$267,102	$45,229	$167,725	$492,411	$204,155	$351,828
Cash Flow Year 39	$265,740	$44,789	$173,614	$448,964	$205,339	$352,733
Cash Flow Year 40	$265,872	$45,086	$149,948	$502,024	$207,923	$349,502
40 Year NPV	$2,621,606	$170,027	$2,123,899	$3,142,600	$2,345,791	$2,900,953
Perpetuity NPV	$2,668,590	$170,301	$2,166,960	$3,198,964	$2,387,768	$2,946,487

Table J.15 – Summary statistics for farm representative of Brown soil zone, dryland production, field pea rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$133,382	$118,298	-$169,202	$644,283	-$16,379	$355,747
Cash Flow Year 2	$111,101	$116,603	-$123,783	$621,109	-$39,792	$342,248
Cash Flow Year 3	$111,364	$114,425	-$150,189	$674,538	-$42,106	$328,969
Cash Flow Year 4	$127,337	$103,316	-$123,869	$549,650	$141	$330,447
Cash Flow Year 5	$138,234	$111,990	-$129,124	$656,344	$4,791	$351,483
Cash Flow Year 6	$136,352	$110,212	-$117,423	$702,303	-$347	$354,301
Cash Flow Year 7	$135,907	$108,297	-$120,702	$627,569	$822	$342,725
Cash Flow Year 8	$133,348	$105,221	-$122,522	$607,696	-$1,734	$337,716
Cash Flow Year 9	$140,222	$111,195	-$118,762	$644,473	$6,697	$360,927
Cash Flow Year 10	$136,605	$103,589	-$130,154	$773,819	$7,452	$324,886
Cash Flow Year 11	$135,661	$106,985	-$175,425	$694,112	-$242	$335,278
Cash Flow Year 12	$133,506	$107,455	-$150,303	$611,061	-$9,072	$342,454
Cash Flow Year 13	$135,396	$105,757	-$130,438	$631,955	$3,585	$336,233
Cash Flow Year 14	$136,783	$107,799	-$127,634	$676,624	$511	$344,814
Cash Flow Year 15	$132,217	$107,200	-$120,886	$546,811	-$842	$340,289
Cash Flow Year 16	$129,808	$104,561	-$127,310	$610,834	-$5,454	$330,385
Cash Flow Year 17	$134,786	$109,752	-$122,616	$623,207	-$1,588	$347,113
Cash Flow Year 18	$136,424	$110,182	-$125,890	$636,550	-$235	$346,554
Cash Flow Year 19	$136,086	$108,203	-$126,492	$727,304	-$5,753	$340,023
Cash Flow Year 20	$132,162	$108,351	-$117,802	$658,860	-$7,882	$328,681

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 21	$133,587	$106,962	-$140,079	$524,219	$2,597	$346,176
Cash Flow Year 22	$136,421	$106,849	-$131,778	$663,677	$3,426	$331,456
Cash Flow Year 23	$136,033	$105,187	-$125,889	$553,993	$4,809	$334,507
Cash Flow Year 24	$134,215	$109,680	-$157,035	$637,133	-$1,050	$334,210
Cash Flow Year 25	$131,495	$106,022	-$128,687	$557,284	$3,862	$340,790
Cash Flow Year 26	$137,890	$105,400	-$123,414	$582,026	$4,071	$331,810
Cash Flow Year 27	$136,564	$104,750	-$123,036	$626,116	$6,284	$331,896
Cash Flow Year 28	$136,604	$106,598	-$133,059	$666,776	$1,649	$329,769
Cash Flow Year 29	$131,659	$105,356	-$120,616	$630,175	-$4,320	$332,122
Cash Flow Year 30	$134,533	$105,843	-$158,283	$561,648	$7,044	$340,876
Cash Flow Year 31	$135,909	$108,701	-$119,372	$720,184	$673	$330,841
Cash Flow Year 32	$132,593	$106,538	-$125,253	$659,019	-$3,637	$330,274
Cash Flow Year 33	$134,844	$110,807	-$117,368	$784,705	-$6,251	$334,641
Cash Flow Year 34	$139,927	$113,651	-$116,860	$649,673	$1,315	$355,402
Cash Flow Year 35	$132,406	$110,100	-$137,056	$584,630	-$6,590	$342,977
Cash Flow Year 36	$133,545	$105,931	-$129,694	$606,609	-$2,333	$331,138
Cash Flow Year 37	$133,430	$108,699	-$120,805	$670,291	-$667	$337,681
Cash Flow Year 38	$137,064	$113,453	-$123,439	$677,042	-$8,578	$352,218
Cash Flow Year 39	$140,400	$108,827	-$123,682	$615,271	$9,498	$348,557
Cash Flow Year 40	$137,782	$109,025	-$124,836	$703,686	$4,346	$343,925
40 Year NPV	$1,364,216	$343,856	$332,060	$2,388,372	$801,244	$1,921,252
Perpetuity NPV	$1,394,374	$344,382	$342,836	$2,446,130	$839,234	$1,950,569

Table J.16 – Summary statistics for farm representative of Dark Brown soil zone, field pea rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$134,570	$96,955	-$116,955	$477,359	$10,482	$305,485
Cash Flow Year 2	$114,694	$93,298	-$126,530	$550,378	-$4,130	$286,687
Cash Flow Year 3	$117,914	$91,256	-$119,870	$497,570	-$2,791	$279,586
Cash Flow Year 4	$138,315	$94,109	-$119,626	$512,264	$22,621	$316,027
Cash Flow Year 5	$145,012	$89,189	-$121,582	$529,736	$29,828	$318,135
Cash Flow Year 6	$140,525	$89,432	-$126,794	$552,278	$29,386	$310,091
Cash Flow Year 7	$138,540	$92,325	-$129,141	$533,406	$23,674	$310,518
Cash Flow Year 8	$135,580	$89,907	-$126,077	$649,003	$21,421	$303,452
Cash Flow Year 9	$140,224	$87,490	-$120,009	$529,843	$31,160	$304,438
Cash Flow Year 10	$143,892	$89,834	-$129,318	$480,492	$33,717	$319,385
Cash Flow Year 11	$142,868	$91,837	-$124,926	$553,328	$28,831	$311,811
Cash Flow Year 12	$140,728	$89,685	-$122,059	$535,967	$30,705	$310,677
Cash Flow Year 13	$142,199	$91,525	-$133,286	$561,755	$29,950	$324,157
Cash Flow Year 14	$141,477	$89,204	-$122,136	$496,096	$27,379	$310,749
Cash Flow Year 15	$140,808	$89,281	-$129,767	$584,310	$27,383	$313,666
Cash Flow Year 16	$141,851	$93,553	-$125,011	$542,856	$22,988	$315,350

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 17	$138,535	$83,598	-$114,026	$491,820	$27,413	$297,160
Cash Flow Year 18	$139,708	$86,346	-$123,511	$424,639	$24,523	$304,058
Cash Flow Year 19	$137,617	$82,995	-$118,582	$484,611	$29,000	$294,238
Cash Flow Year 20	$139,672	$95,675	-$128,061	$554,802	$26,210	$322,277
Cash Flow Year 21	$137,098	$90,077	-$122,019	$493,462	$21,738	$314,513
Cash Flow Year 22	$141,850	$92,714	-$130,620	$584,535	$25,119	$320,686
Cash Flow Year 23	$140,964	$88,053	-$117,862	$619,343	$28,784	$302,026
Cash Flow Year 24	$142,157	$90,351	-$118,506	$519,817	$30,356	$312,268
Cash Flow Year 25	$140,955	$87,825	-$124,801	$511,966	$28,817	$307,507
Cash Flow Year 26	$139,581	$88,860	-$119,940	$496,388	$26,142	$309,530
Cash Flow Year 27	$140,708	$87,849	-$113,098	$600,011	$27,987	$302,940
Cash Flow Year 28	$142,614	$90,665	-$118,266	$533,532	$27,385	$313,857
Cash Flow Year 29	$138,306	$86,124	-$131,508	$501,540	$29,017	$303,763
Cash Flow Year 30	$141,692	$87,827	-$126,188	$486,192	$35,130	$316,959
Cash Flow Year 31	$140,010	$85,994	-$120,109	$529,306	$29,066	$300,844
Cash Flow Year 32	$139,250	$85,589	-$121,344	$535,857	$30,470	$300,823
Cash Flow Year 33	$139,012	$89,510	-$118,931	$510,391	$29,889	$308,087
Cash Flow Year 34	$143,455	$89,187	-$117,317	$526,415	$28,803	$308,938
Cash Flow Year 35	$140,256	$93,678	-$122,025	$518,393	$27,069	$318,597
Cash Flow Year 36	$143,915	$91,740	-$120,705	$490,367	$26,804	$324,693
Cash Flow Year 37	$136,836	$87,536	-$126,882	$493,156	$22,350	$311,675
Cash Flow Year 38	$140,274	$89,586	-$128,065	$556,901	$28,492	$311,659
Cash Flow Year 39	$140,320	$90,835	-$127,540	$526,452	$26,144	$317,860
Cash Flow Year 40	$142,018	$92,294	-$123,917	$575,555	$30,818	$317,274
40 Year NPV	$1,427,755	$276,325	$598,446	$2,245,551	$967,380	$1,888,978
Perpetuity NPV	$1,459,713	$276,665	$626,064	$2,261,044	$1,002,928	$1,913,937

Table J.17 – Summary statistics for farm representative of Black soil zone, field pea rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$249,718	$88,195	$37,643	$659,656	$128,491	$414,891
Cash Flow Year 2	$246,008	$96,629	$32,805	$582,567	$113,565	$426,176
Cash Flow Year 3	$246,947	$93,624	$46,351	$698,682	$119,025	$423,756
Cash Flow Year 4	$264,498	$94,093	$42,706	$675,726	$138,638	$437,685
Cash Flow Year 5	$265,076	$92,030	$14,385	$642,350	$147,434	$446,070
Cash Flow Year 6	$254,902	$91,772	$49,393	$660,501	$132,350	$432,502
Cash Flow Year 7	$254,580	$89,517	-$122,650	$732,355	$135,713	$416,110
Cash Flow Year 8	$255,867	$88,462	-$114,754	$648,389	$135,438	$411,595
Cash Flow Year 9	$266,752	$94,908	$58,007	$631,184	$137,329	$438,332
Cash Flow Year 10	$267,638	$97,704	$64,854	$728,345	$138,365	$454,329
Cash Flow Year 11	$260,067	$90,529	$35,625	$558,962	$136,697	$441,528
Cash Flow Year 12	$256,361	$91,276	-$126,558	$682,586	$139,382	$426,688

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 13	$260,307	$94,057	-$111,324	$631,330	$133,563	$442,128
Cash Flow Year 14	$260,745	$91,270	$29,928	$681,014	$135,116	$439,726
Cash Flow Year 15	$259,766	$92,676	$63,887	$674,910	$132,429	$441,544
Cash Flow Year 16	$263,716	$93,821	$70,938	$697,695	$145,792	$439,898
Cash Flow Year 17	$259,848	$92,180	$82,848	$613,897	$136,835	$439,248
Cash Flow Year 18	$257,485	$87,898	$37,823	$707,219	$140,640	$415,395
Cash Flow Year 19	$263,380	$95,360	$43,525	$750,961	$140,833	$441,621
Cash Flow Year 20	$261,201	$91,695	-$121,813	$670,584	$137,698	$439,238
Cash Flow Year 21	$261,611	$93,855	-$119,243	$663,279	$137,014	$445,315
Cash Flow Year 22	$257,566	$92,042	-$126,655	$617,707	$131,347	$428,190
Cash Flow Year 23	$254,569	$90,854	$34,379	$588,750	$135,970	$431,810
Cash Flow Year 24	$261,986	$95,552	$57,006	$608,533	$133,258	$455,164
Cash Flow Year 25	$260,445	$93,276	$62,690	$603,767	$133,226	$442,996
Cash Flow Year 26	$259,658	$91,365	$62,674	$618,677	$134,689	$433,517
Cash Flow Year 27	$257,774	$93,821	-$116,634	$701,089	$129,915	$429,131
Cash Flow Year 28	$257,867	$94,086	-$114,518	$692,561	$136,777	$437,603
Cash Flow Year 29	$259,899	$93,307	$19,250	$656,107	$136,243	$429,541
Cash Flow Year 30	$261,653	$96,015	$46,765	$698,162	$132,336	$450,884
Cash Flow Year 31	$258,932	$92,998	-$114,615	$617,463	$135,837	$437,313
Cash Flow Year 32	$262,410	$92,540	$56,487	$840,292	$143,795	$438,412
Cash Flow Year 33	$264,747	$94,663	-$126,981	$727,597	$144,865	$443,048
Cash Flow Year 34	$257,024	$88,435	-$107,369	$601,711	$134,809	$428,190
Cash Flow Year 35	$255,230	$92,556	-$114,634	$694,236	$132,783	$438,615
Cash Flow Year 36	$262,801	$96,523	$54,811	$686,689	$139,152	$447,698
Cash Flow Year 37	$263,151	$92,176	-$122,432	$682,582	$136,932	$434,755
Cash Flow Year 38	$263,537	$95,850	$40,840	$660,223	$136,835	$448,720
Cash Flow Year 39	$257,500	$93,176	-$111,375	$690,634	$131,804	$428,171
Cash Flow Year 40	$259,996	$93,814	-$114,991	$614,852	$133,606	$449,645
40 Year NPV	$2,765,354	$298,096	$1,854,964	$3,841,045	$2,297,432	$3,298,306
Perpetuity NPV	$2,823,872	$299,176	$1,908,847	$3,930,231	$2,358,739	$3,353,506

Table J.18 – Summary statistics for farm representative of Dark Grey soil zone, field pea rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$218,119	$64,699	$79,360	$546,809	$125,910	$343,353
Cash Flow Year 2	$215,666	$69,670	$41,381	$485,129	$120,120	$343,192
Cash Flow Year 3	$215,894	$69,261	$64,884	$622,858	$122,158	$350,211
Cash Flow Year 4	$230,087	$65,672	$67,757	$492,245	$139,358	$357,030
Cash Flow Year 5	$228,721	$61,363	$46,394	$486,034	$147,046	$341,985
Cash Flow Year 6	$224,372	$63,106	$72,257	$523,400	$142,949	$347,906
Cash Flow Year 7	$222,475	$61,397	$77,490	$442,984	$138,924	$345,136
Cash Flow Year 8	$227,084	$62,705	$96,327	$467,653	$139,969	$347,984

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 9	$230,449	$63,786	$83,317	$473,598	$144,975	$348,509
Cash Flow Year 10	$230,028	$64,865	$90,020	$537,513	$142,393	$350,756
Cash Flow Year 11	$227,055	$61,919	$77,935	$512,286	$142,968	$340,872
Cash Flow Year 12	$223,253	$61,664	$82,916	$520,378	$141,650	$336,624
Cash Flow Year 13	$226,723	$63,487	$57,995	$522,856	$141,660	$346,058
Cash Flow Year 14	$226,232	$62,361	$72,979	$533,553	$138,327	$344,435
Cash Flow Year 15	$225,020	$61,836	$45,737	$465,613	$142,415	$343,096
Cash Flow Year 16	$228,659	$59,662	$73,469	$502,257	$147,457	$339,399
Cash Flow Year 17	$229,419	$65,713	$93,991	$495,653	$141,617	$355,043
Cash Flow Year 18	$228,531	$64,673	$52,494	$493,178	$143,259	$354,482
Cash Flow Year 19	$228,064	$64,105	$93,995	$516,992	$144,596	$347,487
Cash Flow Year 20	$226,516	$63,498	$80,121	$501,898	$144,915	$348,769
Cash Flow Year 21	$226,444	$59,808	$88,584	$472,698	$143,449	$341,276
Cash Flow Year 22	$226,574	$62,247	$88,430	$443,038	$143,890	$343,536
Cash Flow Year 23	$225,112	$63,000	$41,482	$511,528	$138,324	$352,004
Cash Flow Year 24	$228,219	$65,490	$87,772	$587,427	$138,603	$352,149
Cash Flow Year 25	$229,620	$65,655	$87,484	$515,221	$141,902	$358,331
Cash Flow Year 26	$227,799	$63,510	$87,811	$482,525	$140,678	$352,449
Cash Flow Year 27	$227,134	$61,519	$76,256	$473,880	$139,408	$343,744
Cash Flow Year 28	$228,370	$64,888	$85,909	$507,856	$142,092	$353,880
Cash Flow Year 29	$228,957	$63,250	$72,339	$489,580	$140,878	$351,800
Cash Flow Year 30	$228,076	$62,471	$90,963	$583,980	$144,903	$356,114
Cash Flow Year 31	$225,732	$62,403	$90,210	$519,691	$139,754	$342,059
Cash Flow Year 32	$228,324	$64,491	$70,226	$553,676	$144,699	$353,756
Cash Flow Year 33	$230,456	$66,821	$86,874	$501,065	$137,506	$360,770
Cash Flow Year 34	$223,277	$59,272	$93,121	$487,648	$144,878	$342,723
Cash Flow Year 35	$223,690	$64,060	$76,569	$478,714	$141,413	$350,311
Cash Flow Year 36	$227,740	$65,250	$77,024	$493,384	$137,430	$347,975
Cash Flow Year 37	$228,793	$64,847	$69,290	$483,200	$140,262	$354,413
Cash Flow Year 38	$226,712	$64,948	$97,776	$495,876	$138,508	$349,855
Cash Flow Year 39	$226,452	$64,583	$93,780	$480,474	$141,161	$346,776
Cash Flow Year 40	$226,135	$65,148	$72,655	$591,029	$140,983	$350,609
40 Year NPV	$2,415,366	$215,473	$1,799,550	$3,127,954	$2,055,672	$2,765,104
Perpetuity NPV	$2,457,592	$216,222	$1,818,436	$3,167,858	$2,098,885	$2,803,870

Table J.19 – Summary statistics for farm representative of Brown soil zone, dryland production, legume green manure rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$90,073	$106,395	-$197,340	$539,733	-$99,397	$289,385
Cash Flow Year 2	$60,883	$104,391	-$145,216	$548,927	-$108,794	$263,807
Cash Flow Year 3	$55,753	$105,461	-$173,819	$594,834	-$110,500	$249,872
Cash Flow Year 4	$68,484	$98,636	-$182,825	$479,583	-$105,383	$248,528

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 5	$75,931	$107,253	-$167,394	$544,986	-$105,702	$272,601
Cash Flow Year 6	$69,278	$107,024	-$153,753	$553,875	-$108,610	$271,717
Cash Flow Year 7	$68,276	$104,419	-$192,517	$580,782	-$107,864	$259,735
Cash Flow Year 8	$65,462	$102,020	-$165,760	$522,251	-$108,340	$259,059
Cash Flow Year 9	$72,686	$107,450	-$175,847	$516,756	-$105,785	$274,551
Cash Flow Year 10	$69,264	$102,220	-$186,445	$657,529	-$106,910	$256,301
Cash Flow Year 11	$68,278	$103,203	-$196,118	$512,166	-$108,241	$251,403
Cash Flow Year 12	$67,678	$101,392	-$184,707	$484,286	-$109,209	$251,593
Cash Flow Year 13	$69,869	$102,386	-$201,978	$513,213	-$108,054	$262,282
Cash Flow Year 14	$71,077	$102,520	-$182,871	$553,969	-$106,839	$254,810
Cash Flow Year 15	$66,370	$102,303	-$179,391	$438,864	-$106,822	$270,220
Cash Flow Year 16	$63,812	$101,315	-$185,192	$496,595	-$106,983	$249,992
Cash Flow Year 17	$68,441	$106,511	-$170,519	$548,645	-$108,791	$264,088
Cash Flow Year 18	$69,576	$103,483	-$150,155	$552,662	-$107,994	$264,372
Cash Flow Year 19	$70,319	$103,209	-$173,683	$590,643	-$107,944	$256,178
Cash Flow Year 20	$65,643	$104,651	-$210,004	$525,564	-$108,551	$256,007
Cash Flow Year 21	$67,684	$103,889	-$205,159	$438,533	-$105,584	$273,174
Cash Flow Year 22	$70,932	$101,511	-$187,002	$562,156	-$104,744	$257,916
Cash Flow Year 23	$69,889	$103,677	-$165,426	$462,736	-$105,906	$265,977
Cash Flow Year 24	$66,328	$106,525	-$186,668	$576,313	-$109,250	$248,238
Cash Flow Year 25	$65,106	$103,054	-$192,927	$504,863	-$109,424	$262,291
Cash Flow Year 26	$69,200	$103,110	-$174,514	$450,205	-$106,938	$247,429
Cash Flow Year 27	$69,633	$101,759	-$145,919	$549,905	-$103,886	$255,051
Cash Flow Year 28	$68,413	$104,562	-$140,267	$590,855	-$106,580	$260,780
Cash Flow Year 29	$68,344	$101,355	-$161,651	$513,483	-$105,149	$246,916
Cash Flow Year 30	$67,986	$101,665	-$174,825	$480,992	-$107,243	$257,628
Cash Flow Year 31	$69,714	$105,934	-$178,226	$562,290	-$109,072	$255,430
Cash Flow Year 32	$66,963	$101,509	-$191,237	$545,569	-$106,020	$252,042
Cash Flow Year 33	$67,431	$105,985	-$186,510	$666,399	-$106,806	$258,609
Cash Flow Year 34	$72,435	$109,592	-$157,016	$537,101	-$106,694	$272,125
Cash Flow Year 35	$66,743	$106,851	-$173,611	$500,725	-$109,036	$262,774
Cash Flow Year 36	$67,263	$101,552	-$162,399	$484,168	-$108,350	$252,225
Cash Flow Year 37	$66,022	$105,322	-$168,967	$522,728	-$107,955	$255,975
Cash Flow Year 38	$68,814	$108,524	-$163,289	$587,957	-$108,289	$280,463
Cash Flow Year 39	$73,220	$106,149	-$149,549	$470,032	-$104,332	$266,423
Cash Flow Year 40	$72,471	$104,214	-$189,029	$607,552	-$108,163	$264,466
40 Year NPV	$762,823	$344,734	-$391,137	$1,810,048	$210,476	$1,333,755
Perpetuity NPV	$778,252	$345,417	-$383,889	$1,863,967	$226,559	$1,334,414

Table J.20 – Summary statistics for farm representative of Dark Brown soil zone, legume green manure rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$103,939	$88,915	-$124,650	$447,213	-$13,909	$260,652
Cash Flow Year 2	$77,974	$84,265	-$148,209	$452,232	-$34,738	$230,551
Cash Flow Year 3	$74,946	$85,105	-$128,636	$402,562	-$105,225	$216,229
Cash Flow Year 4	$90,105	$87,197	-$131,469	$418,371	-$28,544	$250,290
Cash Flow Year 5	$92,446	$83,369	-$136,374	$473,662	-$25,448	$233,128
Cash Flow Year 6	$84,956	$87,009	-$136,524	$379,987	-$101,945	$242,895
Cash Flow Year 7	$83,169	$90,067	-$159,833	$418,705	-$103,525	$250,350
Cash Flow Year 8	$80,082	$89,590	-$140,395	$492,520	-$102,609	$243,710
Cash Flow Year 9	$84,459	$85,255	-$138,814	$457,342	-$41,950	$232,326
Cash Flow Year 10	$89,464	$85,269	-$144,715	$404,562	-$25,276	$249,752
Cash Flow Year 11	$86,968	$89,143	-$132,087	$404,874	-$39,729	$244,316
Cash Flow Year 12	$87,899	$87,806	-$149,240	$402,210	-$40,351	$255,580
Cash Flow Year 13	$87,187	$86,003	-$182,838	$460,752	-$22,508	$248,519
Cash Flow Year 14	$85,741	$85,629	-$136,601	$389,647	-$46,337	$238,119
Cash Flow Year 15	$84,468	$84,159	-$133,559	$420,283	-$33,502	$242,645
Cash Flow Year 16	$87,156	$89,900	-$132,960	$445,879	-$42,404	$248,284
Cash Flow Year 17	$84,776	$83,468	-$131,074	$447,229	-$28,012	$243,847
Cash Flow Year 18	$84,406	$83,070	-$129,694	$385,077	-$43,606	$227,286
Cash Flow Year 19	$83,477	$81,750	-$126,414	$387,437	-$46,424	$227,699
Cash Flow Year 20	$83,829	$92,745	-$151,906	$425,828	-$106,032	$256,200
Cash Flow Year 21	$83,744	$89,706	-$132,496	$476,274	-$106,786	$246,084
Cash Flow Year 22	$89,151	$86,553	-$138,010	$393,970	-$27,227	$248,891
Cash Flow Year 23	$87,771	$83,877	-$137,425	$511,068	-$30,565	$238,292
Cash Flow Year 24	$88,337	$87,540	-$136,228	$396,344	-$31,386	$247,120
Cash Flow Year 25	$85,866	$86,433	-$133,794	$468,454	-$57,002	$239,187
Cash Flow Year 26	$85,696	$84,021	-$133,752	$387,262	-$29,834	$235,040
Cash Flow Year 27	$85,010	$85,865	-$120,434	$436,637	-$39,488	$232,117
Cash Flow Year 28	$86,826	$89,702	-$151,753	$401,822	-$66,308	$251,637
Cash Flow Year 29	$84,676	$87,289	-$169,302	$402,807	-$41,602	$246,313
Cash Flow Year 30	$85,731	$85,953	-$170,073	$371,798	-$38,298	$244,239
Cash Flow Year 31	$85,782	$83,688	-$130,632	$464,633	-$29,990	$234,828
Cash Flow Year 32	$83,918	$84,582	-$135,245	$530,846	-$34,886	$232,493
Cash Flow Year 33	$84,330	$85,178	-$150,642	$457,081	-$35,661	$232,173
Cash Flow Year 34	$89,011	$86,229	-$130,595	$438,549	-$30,021	$243,016
Cash Flow Year 35	$86,590	$90,636	-$151,362	$431,351	-$43,830	$249,399
Cash Flow Year 36	$88,704	$89,039	-$129,438	$403,909	-$33,619	$255,978
Cash Flow Year 37	$84,029	$85,650	-$136,038	$382,974	-$48,716	$243,739
Cash Flow Year 38	$85,542	$88,658	-$142,384	$444,561	-$34,006	$243,148
Cash Flow Year 39	$85,738	$85,146	-$152,687	$417,390	-$31,118	$239,993
Cash Flow Year 40	$88,400	$88,994	-$140,287	$484,980	-$48,243	$251,171

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
40 Year NPV	$942,690	$295,834	$21,826	$1,788,416	$458,861	$1,450,610
Perpetuity NPV	$962,575	$296,480	$38,653	$1,834,808	$471,723	$1,464,342

Table J.21 – Summary statistics for farm representative of Black soil zone, oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$245,914	$85,696	$40,144	$681,689	$127,545	$414,674
Cash Flow Year 2	$221,990	$84,709	-$114,443	$532,915	$103,121	$380,312
Cash Flow Year 3	$224,997	$85,560	-$106,319	$619,255	$108,330	$383,948
Cash Flow Year 4	$238,711	$87,524	-$109,948	$636,707	$123,939	$397,223
Cash Flow Year 5	$237,669	$85,778	-$113,785	$614,332	$129,404	$407,919
Cash Flow Year 6	$225,008	$86,073	-$105,424	$576,170	$107,389	$386,486
Cash Flow Year 7	$221,240	$86,022	-$115,216	$647,299	$105,926	$384,803
Cash Flow Year 8	$224,329	$84,918	-$117,011	$571,710	$106,428	$375,959
Cash Flow Year 9	$233,109	$90,257	-$112,792	$589,825	$111,617	$402,123
Cash Flow Year 10	$235,147	$94,414	-$108,739	$690,758	$110,294	$423,320
Cash Flow Year 11	$229,469	$87,734	$27,184	$530,282	$107,868	$391,760
Cash Flow Year 12	$223,822	$86,731	-$127,051	$589,156	$111,490	$384,650
Cash Flow Year 13	$227,510	$90,028	-$114,461	$613,954	$107,465	$401,061
Cash Flow Year 14	$228,541	$88,046	-$111,185	$622,973	$107,926	$404,349
Cash Flow Year 15	$227,084	$87,420	$26,121	$604,405	$102,750	$387,744
Cash Flow Year 16	$230,424	$89,586	$23,518	$600,343	$110,806	$407,060
Cash Flow Year 17	$228,731	$88,765	$59,085	$589,141	$114,669	$404,146
Cash Flow Year 18	$227,023	$85,487	-$115,083	$629,444	$110,905	$382,893
Cash Flow Year 19	$230,348	$91,822	-$108,693	$672,131	$109,977	$402,058
Cash Flow Year 20	$228,630	$88,593	-$117,975	$669,562	$110,534	$400,577
Cash Flow Year 21	$228,613	$87,465	-$124,191	$505,356	$110,588	$399,163
Cash Flow Year 22	$225,922	$88,519	-$127,288	$586,321	$105,943	$392,023
Cash Flow Year 23	$223,288	$87,650	-$115,116	$575,756	$105,438	$390,389
Cash Flow Year 24	$229,637	$92,004	-$114,648	$539,214	$103,567	$403,561
Cash Flow Year 25	$229,511	$88,448	$13,819	$546,780	$106,003	$396,645
Cash Flow Year 26	$228,441	$86,197	$41,426	$566,638	$109,871	$388,279
Cash Flow Year 27	$226,587	$90,587	-$117,795	$669,966	$105,459	$391,179
Cash Flow Year 28	$225,467	$90,475	-$119,620	$634,360	$107,636	$392,999
Cash Flow Year 29	$227,815	$89,283	-$116,482	$607,393	$109,286	$398,287
Cash Flow Year 30	$228,596	$91,501	-$113,973	$696,682	$107,294	$407,229
Cash Flow Year 31	$226,115	$88,793	-$121,179	$556,930	$109,926	$396,826
Cash Flow Year 32	$230,677	$87,662	$37,137	$723,885	$112,584	$392,488
Cash Flow Year 33	$232,200	$90,693	-$128,247	$603,115	$113,256	$394,261
Cash Flow Year 34	$224,364	$84,799	-$120,792	$541,345	$109,517	$385,356
Cash Flow Year 35	$224,820	$89,103	-$118,542	$584,871	$106,507	$392,575
Cash Flow Year 36	$231,230	$92,125	$15,186	$630,500	$110,343	$399,389

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 37	$230,619	$86,142	-$122,513	$551,781	$110,046	$392,649
Cash Flow Year 38	$231,899	$92,056	$13,422	$626,683	$110,423	$404,386
Cash Flow Year 39	$225,645	$90,210	-$117,018	$714,818	$102,022	$385,666
Cash Flow Year 40	$228,135	$89,348	-$122,006	$588,014	$104,689	$401,316
40 Year NPV	$2,498,997	$308,469	$1,588,577	$3,601,266	$2,020,469	$3,028,726
Perpetuity NPV	$2,545,356	$309,612	$1,630,455	$3,677,967	$2,065,423	$3,076,733

Table J.22 – Summary statistics for farm representative of Dark Grey soil zone, oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$223,926	$67,554	$77,858	$540,104	$127,620	$351,833
Cash Flow Year 2	$206,656	$65,691	$50,741	$449,530	$117,402	$329,392
Cash Flow Year 3	$209,545	$66,453	$77,203	$590,476	$122,816	$337,756
Cash Flow Year 4	$222,986	$63,294	$53,571	$474,634	$139,827	$341,131
Cash Flow Year 5	$221,401	$59,253	$38,610	$448,484	$141,415	$336,557
Cash Flow Year 6	$215,311	$60,970	$73,294	$535,618	$135,661	$324,776
Cash Flow Year 7	$212,389	$58,965	$58,222	$463,725	$130,284	$328,758
Cash Flow Year 8	$215,939	$61,007	$75,649	$448,373	$130,670	$337,986
Cash Flow Year 9	$218,908	$63,472	$81,842	$505,560	$131,925	$333,874
Cash Flow Year 10	$219,281	$64,360	$76,859	$529,517	$130,080	$340,606
Cash Flow Year 11	$217,003	$61,311	$74,927	$512,182	$133,029	$330,102
Cash Flow Year 12	$212,351	$61,428	$67,608	$515,658	$129,536	$327,754
Cash Flow Year 13	$215,202	$62,436	$52,543	$515,205	$131,296	$330,336
Cash Flow Year 14	$215,805	$61,431	$62,636	$483,164	$129,508	$329,748
Cash Flow Year 15	$215,106	$61,418	$39,942	$448,951	$132,457	$331,188
Cash Flow Year 16	$217,733	$59,106	$51,206	$475,644	$134,286	$324,470
Cash Flow Year 17	$218,188	$64,396	$89,023	$460,601	$132,267	$342,286
Cash Flow Year 18	$217,745	$64,146	$57,313	$486,312	$133,769	$343,875
Cash Flow Year 19	$216,941	$62,562	$74,518	$561,968	$135,529	$339,853
Cash Flow Year 20	$215,546	$62,992	$66,889	$511,488	$133,657	$334,552
Cash Flow Year 21	$215,873	$59,869	$78,574	$466,219	$130,992	$326,110
Cash Flow Year 22	$216,500	$61,472	$57,458	$425,755	$136,060	$332,497
Cash Flow Year 23	$214,121	$60,758	$30,922	$483,266	$130,621	$331,407
Cash Flow Year 24	$217,084	$63,498	$67,034	$534,142	$131,588	$333,598
Cash Flow Year 25	$218,395	$64,656	$74,434	$485,489	$130,371	$344,492
Cash Flow Year 26	$217,162	$61,792	$91,324	$465,064	$133,787	$334,534
Cash Flow Year 27	$216,216	$60,572	$75,860	$440,218	$132,826	$330,213
Cash Flow Year 28	$217,907	$63,769	$80,233	$483,400	$132,132	$341,908
Cash Flow Year 29	$218,013	$62,544	$69,122	$482,030	$134,532	$334,898
Cash Flow Year 30	$216,868	$60,639	$88,205	$581,097	$137,190	$333,439
Cash Flow Year 31	$214,292	$61,401	$91,432	$496,989	$130,534	$330,850
Cash Flow Year 32	$217,294	$63,827	$66,717	$520,437	$130,135	$336,286

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 33	$218,658	$64,991	$57,230	$485,890	$130,193	$351,270
Cash Flow Year 34	$212,941	$59,065	$77,703	$488,580	$133,563	$329,207
Cash Flow Year 35	$212,909	$63,353	$79,635	$481,878	$127,154	$338,425
Cash Flow Year 36	$217,264	$63,916	$57,847	$515,115	$127,903	$336,315
Cash Flow Year 37	$217,391	$63,657	$68,567	$484,762	$130,421	$334,654
Cash Flow Year 38	$216,868	$64,962	$83,419	$485,363	$128,950	$343,686
Cash Flow Year 39	$215,565	$63,650	$61,226	$481,719	$131,971	$341,492
Cash Flow Year 40	$216,027	$63,604	$72,302	$560,049	$131,688	$329,720
40 Year NPV	$2,335,381	$216,274	$1,724,083	$3,052,431	$1,978,390	$2,682,534
Perpetuity NPV	$2,372,483	$217,208	$1,750,305	$3,090,587	$2,009,409	$2,728,897

Table J.23 – Summary statistics for farm representative of Dark Brown soil zone, alfalfa hay and field pea rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$149,050	$86,987	-$68,527	$452,365	$30,844	$303,040
Cash Flow Year 2	$146,943	$90,577	-$110,476	$524,539	$22,957	$311,164
Cash Flow Year 3	$228,453	$96,861	-$1,936	$546,777	$78,776	$389,758
Cash Flow Year 4	$256,525	$100,453	$20,436	$586,380	$107,229	$431,231
Cash Flow Year 5	$261,485	$91,553	$57,050	$617,702	$127,679	$426,991
Cash Flow Year 6	$261,418	$82,686	$74,771	$566,664	$144,588	$415,346
Cash Flow Year 7	$266,913	$78,917	$62,051	$588,699	$156,105	$413,073
Cash Flow Year 8	$272,644	$74,710	$98,410	$624,410	$172,415	$424,334
Cash Flow Year 9	$275,934	$72,966	$101,566	$528,313	$176,220	$421,237
Cash Flow Year 10	$279,433	$73,827	$115,319	$551,270	$178,915	$416,684
Cash Flow Year 11	$278,651	$77,755	$80,993	$608,353	$178,023	$427,352
Cash Flow Year 12	$274,627	$73,391	$108,324	$562,008	$171,798	$414,194
Cash Flow Year 13	$276,277	$77,864	$81,714	$577,729	$172,245	$439,043
Cash Flow Year 14	$278,094	$74,544	$103,842	$578,863	$175,741	$422,417
Cash Flow Year 15	$277,729	$77,287	$122,554	$596,105	$174,913	$427,055
Cash Flow Year 16	$278,741	$77,301	$109,749	$622,402	$173,381	$430,316
Cash Flow Year 17	$273,103	$69,545	$108,266	$534,264	$169,660	$404,546
Cash Flow Year 18	$275,707	$71,977	$120,376	$524,863	$172,097	$415,553
Cash Flow Year 19	$273,838	$70,888	$109,444	$567,785	$170,600	$406,465
Cash Flow Year 20	$275,515	$76,808	$65,067	$645,390	$172,410	$421,441
Cash Flow Year 21	$276,429	$74,786	$107,407	$601,473	$172,830	$420,314
Cash Flow Year 22	$278,445	$77,648	$90,794	$596,708	$175,220	$431,993
Cash Flow Year 23	$278,461	$77,694	$124,746	$630,446	$171,754	$425,136
Cash Flow Year 24	$278,710	$76,931	$122,557	$592,572	$171,069	$427,013
Cash Flow Year 25	$278,814	$75,550	$102,037	$548,775	$175,195	$417,177
Cash Flow Year 26	$277,577	$73,732	$119,052	$592,049	$177,052	$421,465
Cash Flow Year 27	$277,071	$75,070	$87,264	$642,385	$173,946	$414,216
Cash Flow Year 28	$277,441	$74,867	$71,573	$606,690	$173,712	$415,569

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 29	$274,024	$71,114	$117,365	$581,914	$174,220	$411,479
Cash Flow Year 30	$277,770	$74,694	$98,058	$578,899	$173,728	$420,616
Cash Flow Year 31	$276,056	$72,240	$87,455	$532,919	$176,221	$406,398
Cash Flow Year 32	$275,461	$72,562	$91,063	$615,666	$174,163	$409,779
Cash Flow Year 33	$277,022	$74,259	$111,370	$581,285	$173,125	$422,600
Cash Flow Year 34	$282,458	$75,907	$88,633	$611,246	$176,012	$425,766
Cash Flow Year 35	$278,207	$75,586	$101,087	$631,008	$174,875	$424,422
Cash Flow Year 36	$280,055	$77,488	$107,667	$564,754	$178,546	$435,950
Cash Flow Year 37	$275,538	$72,882	$119,211	$589,634	$176,120	$415,780
Cash Flow Year 38	$276,761	$73,152	$93,304	$602,231	$177,564	$417,393
Cash Flow Year 39	$276,222	$74,274	$107,512	$540,428	$175,329	$424,480
Cash Flow Year 40	$281,344	$75,339	$101,425	$592,862	$183,268	$418,636
40 Year NPV	$2,506,315	$250,594	$1,673,556	$3,267,081	$2,081,714	$2,902,069
Perpetuity NPV	$2,568,349	$250,880	$1,703,371	$3,324,176	$2,146,444	$2,964,616

Table J.24 – Summary statistics for farm representative of Black soil zone, alfalfa hay and field pea rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$215,641	$59,063	$39,270	$465,454	$123,189	$311,131
Cash Flow Year 2	$213,596	$67,812	$48,188	$450,532	$115,722	$340,090
Cash Flow Year 3	$273,806	$76,569	$86,786	$557,093	$157,057	$404,992
Cash Flow Year 4	$302,173	$78,924	$93,006	$589,534	$184,797	$439,508
Cash Flow Year 5	$302,438	$74,711	$101,450	$549,485	$193,670	$439,175
Cash Flow Year 6	$296,392	$71,018	$146,308	$582,304	$197,159	$427,651
Cash Flow Year 7	$303,345	$63,977	$170,154	$597,735	$215,239	$419,546
Cash Flow Year 8	$310,851	$58,711	$153,148	$554,956	$228,415	$420,614
Cash Flow Year 9	$319,854	$63,894	$162,599	$539,986	$229,261	$444,660
Cash Flow Year 10	$320,402	$61,418	$172,304	$546,901	$237,281	$434,233
Cash Flow Year 11	$313,875	$59,544	$159,822	$572,470	$227,811	$421,373
Cash Flow Year 12	$311,629	$58,702	$142,601	$538,651	$230,504	$420,104
Cash Flow Year 13	$313,295	$60,432	$177,995	$558,956	$222,857	$427,767
Cash Flow Year 14	$314,745	$60,692	$151,327	$522,712	$230,016	$428,776
Cash Flow Year 15	$316,678	$63,364	$132,080	$596,119	$225,212	$435,570
Cash Flow Year 16	$317,347	$61,895	$179,265	$581,252	$233,291	$439,717
Cash Flow Year 17	$315,608	$60,670	$184,601	$520,447	$231,611	$432,684
Cash Flow Year 18	$313,341	$58,038	$176,951	$568,389	$229,085	$419,966
Cash Flow Year 19	$317,017	$60,725	$168,831	$582,564	$232,174	$424,419
Cash Flow Year 20	$316,408	$59,263	$176,981	$591,630	$233,813	$430,204
Cash Flow Year 21	$315,086	$61,864	$152,884	$594,450	$232,280	$434,252
Cash Flow Year 22	$313,659	$59,898	$158,718	$570,103	$232,065	$422,258
Cash Flow Year 23	$311,483	$59,350	$147,533	$510,162	$230,241	$426,940
Cash Flow Year 24	$316,029	$63,040	$148,775	$562,585	$228,821	$437,894

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 25	$314,313	$60,735	$152,727	$570,529	$225,513	$430,694
Cash Flow Year 26	$315,289	$60,920	$171,189	$528,933	$232,745	$434,902
Cash Flow Year 27	$314,303	$61,427	$173,671	$566,249	$226,031	$427,018
Cash Flow Year 28	$314,274	$60,396	$128,460	$532,828	$226,235	$430,620
Cash Flow Year 29	$316,374	$61,069	$142,876	$518,537	$232,685	$428,802
Cash Flow Year 30	$316,337	$62,665	$172,525	$563,350	$230,595	$432,121
Cash Flow Year 31	$315,858	$61,644	$177,555	$575,426	$233,686	$434,590
Cash Flow Year 32	$318,062	$61,977	$174,882	$706,852	$233,251	$434,095
Cash Flow Year 33	$318,438	$61,149	$187,161	$587,600	$235,403	$433,191
Cash Flow Year 34	$312,678	$55,037	$173,701	$522,281	$234,877	$411,474
Cash Flow Year 35	$310,575	$58,413	$169,767	$582,569	$229,964	$420,274
Cash Flow Year 36	$316,379	$64,020	$178,017	$583,262	$231,194	$440,526
Cash Flow Year 37	$319,349	$64,327	$167,236	$577,365	$230,471	$438,005
Cash Flow Year 38	$317,255	$63,012	$150,504	$618,715	$233,038	$435,920
Cash Flow Year 39	$315,402	$62,719	$141,092	$559,045	$225,879	$434,660
Cash Flow Year 40	$315,345	$61,264	$133,703	$578,537	$226,194	$428,198
40 Year NPV	$3,093,074	$226,964	$2,469,062	$4,117,228	$2,724,929	$3,480,273
Perpetuity NPV	$3,155,688	$227,461	$2,534,101	$4,188,496	$2,782,145	$3,541,586

Table J.25 – Summary statistics for farm representative of Dark Grey soil zone, alfalfa hay and field pea rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$183,095	$40,388	$66,319	$417,148	$116,555	$251,263
Cash Flow Year 2	$178,557	$45,442	$47,856	$377,583	$111,064	$261,406
Cash Flow Year 3	$223,251	$56,544	$98,356	$460,833	$137,661	$321,434
Cash Flow Year 4	$244,224	$55,499	$112,584	$438,261	$162,228	$342,297
Cash Flow Year 5	$243,196	$52,520	$128,173	$407,695	$165,396	$342,208
Cash Flow Year 6	$239,231	$50,100	$115,108	$411,754	$167,397	$331,729
Cash Flow Year 7	$244,386	$45,834	$130,025	$433,436	$180,664	$326,965
Cash Flow Year 8	$252,029	$44,115	$135,344	$418,296	$190,071	$337,234
Cash Flow Year 9	$256,477	$43,643	$143,083	$402,448	$195,488	$334,280
Cash Flow Year 10	$255,327	$43,987	$143,895	$458,010	$194,271	$336,748
Cash Flow Year 11	$252,732	$42,566	$135,400	$407,978	$191,593	$331,563
Cash Flow Year 12	$250,269	$41,668	$127,022	$439,302	$189,522	$325,156
Cash Flow Year 13	$252,260	$42,189	$119,041	$409,419	$192,771	$329,668
Cash Flow Year 14	$252,590	$43,572	$142,401	$412,862	$191,401	$329,817
Cash Flow Year 15	$253,272	$44,836	$128,541	$450,052	$189,737	$336,649
Cash Flow Year 16	$254,451	$43,284	$154,435	$470,443	$192,173	$335,844
Cash Flow Year 17	$254,944	$45,415	$142,386	$430,194	$190,550	$340,708
Cash Flow Year 18	$254,087	$43,942	$118,744	$446,387	$192,522	$334,827
Cash Flow Year 19	$254,306	$43,120	$156,181	$442,824	$194,078	$336,116
Cash Flow Year 20	$253,975	$43,271	$152,775	$424,583	$192,290	$331,480

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 21	$253,431	$41,550	$155,253	$410,833	$190,520	$330,958
Cash Flow Year 22	$253,699	$43,466	$138,345	$423,557	$192,897	$334,227
Cash Flow Year 23	$251,327	$41,599	$101,793	$401,673	$192,446	$328,955
Cash Flow Year 24	$254,564	$43,840	$139,359	$427,127	$192,639	$335,467
Cash Flow Year 25	$255,794	$43,936	$157,246	$443,716	$194,104	$340,730
Cash Flow Year 26	$254,264	$42,583	$148,487	$439,592	$193,024	$332,891
Cash Flow Year 27	$253,492	$42,172	$149,854	$451,213	$193,917	$330,865
Cash Flow Year 28	$253,922	$42,144	$147,967	$404,958	$192,758	$330,800
Cash Flow Year 29	$255,200	$42,623	$133,251	$424,703	$193,165	$331,501
Cash Flow Year 30	$254,333	$43,207	$168,540	$413,870	$194,106	$337,820
Cash Flow Year 31	$253,279	$43,472	$154,793	$418,497	$190,585	$338,870
Cash Flow Year 32	$255,313	$43,443	$137,842	$488,025	$190,657	$337,044
Cash Flow Year 33	$256,389	$45,142	$138,899	$440,417	$193,435	$343,693
Cash Flow Year 34	$251,185	$40,194	$128,435	$409,035	$193,413	$324,476
Cash Flow Year 35	$249,694	$42,429	$141,291	$446,947	$189,986	$328,003
Cash Flow Year 36	$254,581	$45,145	$138,833	$430,698	$190,948	$338,285
Cash Flow Year 37	$256,596	$45,928	$143,928	$424,368	$194,348	$341,693
Cash Flow Year 38	$253,882	$44,437	$151,069	$462,605	$190,465	$339,874
Cash Flow Year 39	$253,388	$43,281	$150,738	$431,366	$195,832	$335,988
Cash Flow Year 40	$253,149	$43,751	$148,209	$477,003	$194,516	$332,267
40 Year NPV	$2,525,101	$167,485	$2,007,257	$3,026,277	$2,249,800	$2,797,018
Perpetuity NPV	$2,570,017	$167,861	$2,062,197	$3,078,691	$2,292,730	$2,846,304

Table J.26 – Summary statistics for farm representative of Dark Brown soil zone, alfalfa hay and legume green manure rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$122,763	$76,544	-$74,219	$411,090	$19,986	$265,413
Cash Flow Year 2	$127,352	$83,054	-$110,593	$463,004	$12,871	$279,181
Cash Flow Year 3	$229,514	$92,011	-$9,050	$499,143	$79,179	$380,563
Cash Flow Year 4	$258,646	$96,417	$11,583	$563,692	$105,836	$417,555
Cash Flow Year 5	$262,157	$88,749	$53,867	$571,244	$126,848	$418,165
Cash Flow Year 6	$262,706	$79,135	$63,675	$538,673	$138,987	$400,574
Cash Flow Year 7	$269,626	$74,234	$46,729	$532,210	$163,776	$405,706
Cash Flow Year 8	$277,835	$69,556	$110,306	$557,433	$182,046	$414,285
Cash Flow Year 9	$280,732	$67,017	$97,631	$524,983	$185,546	$404,998
Cash Flow Year 10	$284,352	$67,367	$128,131	$542,109	$189,633	$401,787
Cash Flow Year 11	$283,452	$70,609	$101,167	$553,390	$187,321	$410,254
Cash Flow Year 12	$280,863	$67,307	$108,284	$534,434	$183,970	$404,023
Cash Flow Year 13	$282,334	$70,281	$96,612	$540,970	$188,981	$419,135
Cash Flow Year 14	$283,577	$66,904	$112,666	$548,680	$186,383	$407,333
Cash Flow Year 15	$282,906	$70,057	$124,753	$542,109	$186,437	$414,793
Cash Flow Year 16	$284,294	$70,663	$111,474	$574,480	$184,997	$421,241

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 17	$279,016	$63,734	$119,618	$500,009	$184,907	$396,632
Cash Flow Year 18	$281,636	$65,032	$121,235	$507,617	$183,865	$399,316
Cash Flow Year 19	$280,072	$64,455	$116,486	$549,442	$187,173	$399,883
Cash Flow Year 20	$280,799	$69,567	$73,786	$596,403	$184,390	$407,271
Cash Flow Year 21	$283,134	$69,556	$119,722	$599,016	$183,412	$417,463
Cash Flow Year 22	$284,716	$70,689	$105,262	$535,705	$188,410	$416,833
Cash Flow Year 23	$285,400	$71,174	$125,717	$571,765	$184,430	$421,654
Cash Flow Year 24	$285,182	$70,504	$135,854	$558,323	$182,589	$411,380
Cash Flow Year 25	$285,348	$69,213	$90,647	$519,982	$185,166	$409,456
Cash Flow Year 26	$283,878	$66,783	$132,767	$558,790	$189,838	$412,627
Cash Flow Year 27	$282,794	$68,727	$107,629	$593,395	$185,410	$408,063
Cash Flow Year 28	$282,539	$68,509	$66,604	$556,288	$182,168	$408,854
Cash Flow Year 29	$280,796	$65,244	$109,530	$526,122	$182,220	$401,280
Cash Flow Year 30	$282,866	$68,663	$107,398	$541,470	$180,071	$411,981
Cash Flow Year 31	$282,332	$65,930	$89,447	$515,899	$183,672	$397,203
Cash Flow Year 32	$281,754	$66,846	$101,248	$604,815	$187,552	$402,857
Cash Flow Year 33	$282,566	$67,441	$107,173	$518,524	$186,145	$405,064
Cash Flow Year 34	$289,174	$69,025	$86,072	$581,327	$187,311	$417,565
Cash Flow Year 35	$284,880	$69,132	$100,595	$583,518	$190,892	$412,208
Cash Flow Year 36	$285,579	$70,226	$112,181	$545,467	$186,402	$420,870
Cash Flow Year 37	$282,271	$67,902	$118,280	$570,793	$185,709	$411,613
Cash Flow Year 38	$283,522	$66,668	$117,476	$612,369	$189,007	$403,819
Cash Flow Year 39	$282,324	$66,272	$114,144	$505,854	$188,870	$406,077
Cash Flow Year 40	$287,804	$69,253	$107,537	$554,734	$189,611	$415,735
40 Year NPV	$2,498,681	$249,299	$1,681,491	$3,310,153	$2,092,638	$2,888,332
Perpetuity NPV	$2,562,013	$249,690	$1,718,383	$3,372,986	$2,152,537	$2,947,562

Table J.27 – Summary statistics for farm representative of Black soil zone, alfalfa hay and oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$213,624	$58,183	$40,938	$478,050	$120,305	$307,919
Cash Flow Year 2	$203,338	$64,828	$41,784	$439,698	$106,535	$320,918
Cash Flow Year 3	$263,855	$74,030	$79,716	$524,830	$152,373	$398,274
Cash Flow Year 4	$291,269	$76,819	$88,386	$587,091	$176,293	$420,674
Cash Flow Year 5	$290,720	$72,809	$83,103	$539,558	$183,838	$422,674
Cash Flow Year 6	$284,984	$69,122	$108,338	$544,791	$189,324	$411,400
Cash Flow Year 7	$291,151	$61,941	$156,359	$560,647	$204,057	$406,003
Cash Flow Year 8	$298,481	$57,563	$150,189	$539,456	$216,963	$411,208
Cash Flow Year 9	$306,602	$61,441	$147,677	$519,803	$218,946	$424,539
Cash Flow Year 10	$307,891	$61,519	$163,030	$545,559	$223,009	$423,435
Cash Flow Year 11	$303,066	$58,554	$139,472	$538,119	$220,610	$412,203
Cash Flow Year 12	$299,192	$57,577	$128,067	$529,314	$218,594	$403,791

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 13	$300,609	$59,317	$171,829	$518,651	$215,607	$413,313
Cash Flow Year 14	$301,929	$59,027	$154,405	$546,063	$218,430	$407,591
Cash Flow Year 15	$303,894	$60,970	$133,456	$540,559	$214,353	$421,046
Cash Flow Year 16	$304,530	$60,434	$158,896	$535,639	$221,559	$420,752
Cash Flow Year 17	$303,358	$60,429	$160,434	$525,958	$220,175	$418,904
Cash Flow Year 18	$301,174	$57,963	$159,523	$547,016	$219,434	$406,517
Cash Flow Year 19	$303,878	$59,768	$142,539	$578,084	$218,597	$415,288
Cash Flow Year 20	$303,616	$58,511	$168,302	$621,584	$222,239	$414,918
Cash Flow Year 21	$302,786	$59,313	$146,757	$508,037	$219,681	$413,686
Cash Flow Year 22	$300,569	$58,488	$118,245	$535,993	$215,820	$408,012
Cash Flow Year 23	$299,786	$58,313	$146,684	$519,346	$215,218	$410,052
Cash Flow Year 24	$303,956	$61,593	$137,181	$498,556	$213,804	$423,600
Cash Flow Year 25	$302,633	$59,187	$132,186	$570,407	$215,862	$412,922
Cash Flow Year 26	$303,408	$59,519	$141,841	$525,943	$219,865	$414,379
Cash Flow Year 27	$302,852	$60,164	$161,183	$579,951	$217,107	$410,617
Cash Flow Year 28	$301,818	$59,100	$113,788	$530,184	$215,898	$414,703
Cash Flow Year 29	$304,523	$60,181	$113,712	$518,125	$219,720	$420,004
Cash Flow Year 30	$304,013	$60,806	$150,379	$548,296	$217,400	$416,143
Cash Flow Year 31	$303,124	$59,217	$160,102	$534,755	$223,232	$417,029
Cash Flow Year 32	$305,484	$60,174	$161,597	$662,531	$219,725	$419,885
Cash Flow Year 33	$305,920	$59,291	$172,690	$525,801	$225,502	$417,694
Cash Flow Year 34	$299,653	$54,005	$164,230	$527,550	$219,941	$398,541
Cash Flow Year 35	$298,877	$57,575	$157,012	$546,455	$218,378	$406,550
Cash Flow Year 36	$304,230	$62,720	$160,892	$558,508	$219,764	$423,297
Cash Flow Year 37	$306,747	$62,465	$161,537	$532,228	$216,996	$426,430
Cash Flow Year 38	$305,198	$61,863	$127,836	$604,224	$220,630	$417,299
Cash Flow Year 39	$302,867	$61,688	$122,925	$621,694	$213,037	$415,364
Cash Flow Year 40	$302,276	$59,902	$115,934	$591,999	$214,222	$407,181
40 Year NPV	$2,986,868	$236,953	$2,321,072	$4,046,918	$2,606,900	$3,389,593
Perpetuity NPV	$3,044,274	$237,405	$2,381,269	$4,109,849	$2,667,696	$3,451,003

Table J.28 – Summary statistics for farm representative of Dark Grey soil zone, alfalfa hay and oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$185,961	$41,011	$66,872	$412,678	$120,968	$253,491
Cash Flow Year 2	$177,550	$45,909	$50,858	$374,696	$112,177	$261,428
Cash Flow Year 3	$222,385	$57,099	$94,759	$456,693	$136,966	$323,764
Cash Flow Year 4	$244,161	$56,667	$109,944	$459,313	$162,339	$348,064
Cash Flow Year 5	$242,597	$52,883	$125,794	$422,569	$163,299	$338,491
Cash Flow Year 6	$238,361	$51,104	$116,034	$415,318	$164,253	$329,792
Cash Flow Year 7	$243,418	$46,230	$119,245	$420,565	$177,715	$329,637
Cash Flow Year 8	$250,600	$44,355	$146,699	$419,594	$189,723	$335,600

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 9	$255,481	$44,537	$147,208	$399,742	$191,843	$337,831
Cash Flow Year 10	$254,468	$44,891	$150,186	$456,549	$192,317	$339,539
Cash Flow Year 11	$252,133	$43,523	$137,075	$418,889	$189,021	$333,656
Cash Flow Year 12	$249,256	$43,203	$119,377	$435,626	$185,110	$324,824
Cash Flow Year 13	$250,680	$43,018	$117,420	$425,211	$190,740	$329,458
Cash Flow Year 14	$250,759	$43,622	$124,672	$427,290	$189,673	$331,359
Cash Flow Year 15	$252,353	$45,730	$119,547	$465,589	$188,520	$338,757
Cash Flow Year 16	$253,207	$43,913	$141,096	$472,942	$192,436	$335,105
Cash Flow Year 17	$254,001	$46,240	$138,321	$426,455	$189,816	$345,397
Cash Flow Year 18	$253,167	$45,376	$129,121	$445,700	$190,701	$341,607
Cash Flow Year 19	$252,642	$43,945	$147,421	$419,963	$190,279	$336,734
Cash Flow Year 20	$252,477	$44,322	$144,599	$413,950	$190,157	$335,452
Cash Flow Year 21	$252,085	$42,485	$146,541	$396,519	$189,037	$326,462
Cash Flow Year 22	$252,156	$43,870	$132,403	$417,286	$193,703	$335,512
Cash Flow Year 23	$249,755	$41,961	$95,929	$392,221	$191,383	$325,694
Cash Flow Year 24	$252,418	$44,110	$138,308	$414,382	$189,972	$334,670
Cash Flow Year 25	$254,214	$44,277	$150,219	$439,959	$192,385	$339,965
Cash Flow Year 26	$253,472	$43,235	$142,772	$417,494	$192,834	$335,055
Cash Flow Year 27	$252,538	$43,058	$146,658	$449,808	$191,366	$328,264
Cash Flow Year 28	$253,297	$43,083	$157,630	$424,993	$191,278	$330,080
Cash Flow Year 29	$254,201	$43,646	$148,159	$445,973	$193,302	$334,731
Cash Flow Year 30	$253,530	$43,790	$163,924	$417,639	$191,861	$335,501
Cash Flow Year 31	$251,492	$43,996	$145,854	$425,547	$187,275	$331,830
Cash Flow Year 32	$253,141	$44,642	$136,653	$468,032	$191,081	$338,075
Cash Flow Year 33	$254,506	$45,280	$135,594	$429,834	$188,589	$336,768
Cash Flow Year 34	$250,235	$41,345	$147,570	$403,106	$190,680	$327,467
Cash Flow Year 35	$248,463	$43,138	$154,484	$434,229	$187,467	$330,940
Cash Flow Year 36	$253,507	$46,312	$137,135	$414,284	$186,397	$340,904
Cash Flow Year 37	$255,101	$46,451	$133,180	$428,732	$192,562	$339,050
Cash Flow Year 38	$253,864	$45,815	$154,720	$472,652	$190,511	$340,283
Cash Flow Year 39	$251,864	$44,733	$154,175	$413,211	$191,056	$334,654
Cash Flow Year 40	$251,831	$44,553	$133,063	$483,861	$191,636	$334,274
40 Year NPV	$2,518,884	$169,321	$2,034,010	$3,014,567	$2,239,998	$2,786,594
Perpetuity NPV	$2,562,102	$169,710	$2,089,488	$3,068,425	$2,277,318	$2,829,031

Table J.29 – Summary statistics for farm representative of Dark Brown soil zone, alfalfa hay, field pea and legume green manure rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$146,500	$86,478	-$71,644	$449,248	$29,178	$299,923
Cash Flow Year 2	$142,952	$89,457	-$111,696	$521,528	$21,272	$301,089
Cash Flow Year 3	$223,877	$96,128	-$4,364	$543,757	$76,745	$386,318
Cash Flow Year 4	$251,584	$99,602	$19,045	$583,370	$103,634	$424,260

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 5	$256,560	$91,098	$54,348	$613,736	$124,444	$417,524
Cash Flow Year 6	$256,626	$82,390	$70,175	$563,706	$139,661	$408,076
Cash Flow Year 7	$262,120	$78,765	$58,365	$585,700	$153,017	$406,384
Cash Flow Year 8	$267,575	$74,512	$95,805	$610,497	$167,245	$421,418
Cash Flow Year 9	$271,037	$72,720	$96,628	$525,356	$171,500	$417,275
Cash Flow Year 10	$274,389	$73,412	$110,544	$544,622	$174,381	$410,721
Cash Flow Year 11	$273,798	$77,251	$76,085	$603,260	$172,606	$422,603
Cash Flow Year 12	$269,857	$73,177	$103,869	$563,295	$169,078	$407,429
Cash Flow Year 13	$271,599	$77,702	$75,648	$574,975	$168,150	$432,333
Cash Flow Year 14	$273,309	$74,008	$98,946	$562,035	$172,246	$412,608
Cash Flow Year 15	$273,073	$77,114	$116,970	$593,373	$170,950	$424,059
Cash Flow Year 16	$273,913	$76,877	$106,950	$618,591	$168,181	$423,959
Cash Flow Year 17	$268,535	$69,456	$104,163	$531,516	$165,899	$397,881
Cash Flow Year 18	$271,107	$71,412	$117,588	$520,360	$168,529	$408,633
Cash Flow Year 19	$269,372	$70,259	$104,888	$565,350	$167,715	$400,868
Cash Flow Year 20	$270,880	$76,360	$61,233	$634,445	$169,677	$412,888
Cash Flow Year 21	$271,981	$74,649	$104,486	$595,234	$169,488	$415,177
Cash Flow Year 22	$273,947	$77,082	$86,916	$589,094	$172,068	$423,987
Cash Flow Year 23	$274,240	$77,318	$119,999	$628,001	$168,596	$422,655
Cash Flow Year 24	$274,193	$76,388	$118,514	$588,776	$168,057	$420,867
Cash Flow Year 25	$274,551	$75,082	$96,726	$546,345	$171,888	$409,319
Cash Flow Year 26	$273,038	$73,030	$116,702	$588,730	$172,547	$414,099
Cash Flow Year 27	$272,503	$74,808	$83,411	$639,954	$169,966	$408,209
Cash Flow Year 28	$273,027	$74,663	$66,928	$600,649	$170,287	$412,282
Cash Flow Year 29	$269,555	$70,674	$114,666	$579,492	$170,474	$407,164
Cash Flow Year 30	$273,265	$74,285	$93,574	$576,473	$170,733	$413,177
Cash Flow Year 31	$271,605	$71,857	$83,285	$518,262	$170,343	$403,036
Cash Flow Year 32	$271,079	$72,269	$88,828	$618,549	$171,570	$406,153
Cash Flow Year 33	$272,449	$73,914	$110,021	$572,640	$170,634	$416,617
Cash Flow Year 34	$278,115	$75,360	$82,422	$606,020	$172,659	$422,235
Cash Flow Year 35	$273,854	$75,366	$96,865	$628,567	$171,680	$419,961
Cash Flow Year 36	$275,519	$77,115	$102,698	$554,253	$173,232	$431,189
Cash Flow Year 37	$270,937	$72,717	$114,287	$592,726	$172,262	$411,889
Cash Flow Year 38	$272,423	$72,864	$89,859	$607,824	$173,463	$410,698
Cash Flow Year 39	$271,656	$73,610	$103,697	$538,035	$171,719	$418,717
Cash Flow Year 40	$276,902	$75,186	$98,569	$590,430	$179,885	$410,385
40 Year NPV	$2,462,505	$249,567	$1,634,823	$3,233,981	$2,041,758	$2,857,539
Perpetuity NPV	$2,523,564	$249,851	$1,664,149	$3,289,981	$2,102,907	$2,914,028

Table J.30 – Summary statistics for farm representative of Black soil zone, alfalfa hay, field pea and oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$210,915	$57,222	$37,372	$444,151	$118,816	$305,826
Cash Flow Year 2	$202,318	$63,360	$45,393	$436,941	$105,985	$322,805
Cash Flow Year 3	$253,573	$71,240	$79,973	$510,466	$144,204	$378,587
Cash Flow Year 4	$279,481	$73,086	$82,158	$549,791	$170,806	$406,308
Cash Flow Year 5	$279,962	$70,102	$87,962	$505,464	$176,983	$408,071
Cash Flow Year 6	$273,407	$66,646	$123,198	$523,924	$177,206	$393,931
Cash Flow Year 7	$280,443	$60,898	$149,598	$546,871	$195,846	$392,724
Cash Flow Year 8	$286,252	$55,625	$139,685	$527,199	$207,208	$386,828
Cash Flow Year 9	$294,675	$60,178	$145,712	$494,195	$207,576	$407,352
Cash Flow Year 10	$295,235	$59,490	$159,079	$515,197	$214,862	$409,549
Cash Flow Year 11	$289,774	$56,385	$136,779	$520,212	$209,925	$393,236
Cash Flow Year 12	$287,652	$55,690	$125,453	$504,707	$212,311	$389,644
Cash Flow Year 13	$288,314	$57,512	$153,304	$538,136	$202,513	$399,789
Cash Flow Year 14	$289,699	$57,608	$149,657	$502,177	$207,687	$393,384
Cash Flow Year 15	$291,509	$60,261	$121,582	$553,037	$204,065	$407,256
Cash Flow Year 16	$292,274	$59,777	$163,101	$544,857	$211,128	$404,507
Cash Flow Year 17	$290,419	$58,217	$154,856	$487,307	$211,612	$403,462
Cash Flow Year 18	$288,868	$55,721	$153,915	$545,674	$209,340	$391,287
Cash Flow Year 19	$291,749	$58,033	$133,932	$549,093	$210,002	$399,227
Cash Flow Year 20	$291,188	$56,683	$155,189	$570,892	$212,973	$398,634
Cash Flow Year 21	$290,436	$58,611	$138,411	$546,323	$208,667	$400,065
Cash Flow Year 22	$288,386	$57,509	$118,439	$510,914	$207,622	$393,833
Cash Flow Year 23	$287,041	$56,536	$145,643	$476,356	$209,409	$392,052
Cash Flow Year 24	$291,940	$59,773	$131,836	$532,542	$208,767	$405,990
Cash Flow Year 25	$289,798	$57,269	$127,604	$530,527	$204,372	$400,896
Cash Flow Year 26	$290,963	$57,915	$149,263	$503,323	$209,748	$403,109
Cash Flow Year 27	$290,234	$58,536	$157,663	$539,201	$208,063	$395,742
Cash Flow Year 28	$289,825	$57,775	$105,870	$499,874	$207,276	$402,706
Cash Flow Year 29	$291,858	$58,454	$111,115	$489,922	$211,569	$397,765
Cash Flow Year 30	$291,677	$59,931	$143,003	$537,282	$210,194	$402,494
Cash Flow Year 31	$291,099	$58,233	$153,544	$524,515	$212,916	$405,869
Cash Flow Year 32	$293,064	$58,808	$153,113	$672,746	$210,950	$406,015
Cash Flow Year 33	$293,286	$57,884	$168,132	$544,899	$215,813	$406,557
Cash Flow Year 34	$287,970	$52,931	$156,191	$489,503	$211,988	$386,181
Cash Flow Year 35	$285,930	$55,522	$148,010	$534,712	$208,173	$387,299
Cash Flow Year 36	$291,680	$61,228	$154,974	$548,861	$212,093	$410,398
Cash Flow Year 37	$294,242	$60,650	$152,312	$525,397	$207,932	$409,015
Cash Flow Year 38	$293,069	$60,913	$126,262	$573,715	$210,279	$406,501
Cash Flow Year 39	$290,988	$59,939	$119,143	$563,502	$205,857	$402,793
Cash Flow Year 40	$290,598	$58,151	$108,872	$544,705	$206,030	$397,914

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
40 Year NPV	$2,888,422	$225,066	$2,255,523	$3,896,928	$2,525,550	$3,259,104
Perpetuity NPV	$2,944,221	$225,512	$2,314,030	$3,962,168	$2,577,631	$3,320,536

Table J.31 – Summary statistics for farm representative of Dark Grey soil zone, alfalfa hay, field pea and oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$184,343	$40,019	$76,030	$406,141	$119,852	$249,689
Cash Flow Year 2	$178,428	$43,857	$44,071	$377,615	$114,006	$256,103
Cash Flow Year 3	$219,148	$53,977	$99,889	$439,253	$136,088	$313,871
Cash Flow Year 4	$238,872	$52,841	$113,058	$423,082	$162,093	$332,669
Cash Flow Year 5	$238,438	$49,943	$126,409	$407,301	$162,249	$330,375
Cash Flow Year 6	$234,233	$47,950	$122,178	$392,329	$165,549	$324,840
Cash Flow Year 7	$239,337	$43,873	$123,803	$404,032	$177,634	$318,938
Cash Flow Year 8	$245,707	$41,984	$144,873	$397,708	$186,640	$326,425
Cash Flow Year 9	$250,086	$42,231	$147,929	$392,823	$190,613	$328,801
Cash Flow Year 10	$249,439	$42,239	$154,540	$453,880	$189,349	$326,377
Cash Flow Year 11	$246,747	$40,449	$131,856	$397,370	$188,011	$322,307
Cash Flow Year 12	$244,409	$40,471	$122,200	$422,123	$183,953	$317,121
Cash Flow Year 13	$245,700	$40,528	$130,375	$407,597	$188,457	$321,164
Cash Flow Year 14	$246,025	$41,794	$140,121	$408,389	$186,297	$322,963
Cash Flow Year 15	$247,113	$43,146	$122,710	$444,631	$186,776	$329,055
Cash Flow Year 16	$248,180	$41,954	$138,298	$459,640	$188,610	$326,481
Cash Flow Year 17	$248,689	$43,721	$140,166	$412,425	$187,247	$331,295
Cash Flow Year 18	$247,876	$42,261	$120,449	$424,965	$189,430	$325,252
Cash Flow Year 19	$247,843	$41,228	$136,805	$416,207	$188,021	$324,587
Cash Flow Year 20	$247,127	$41,894	$146,871	$400,565	$188,815	$322,843
Cash Flow Year 21	$246,777	$40,108	$154,812	$396,237	$187,407	$318,424
Cash Flow Year 22	$247,335	$41,837	$133,428	$394,027	$190,128	$323,868
Cash Flow Year 23	$244,699	$39,519	$102,211	$374,952	$187,549	$314,648
Cash Flow Year 24	$247,485	$41,889	$142,220	$407,090	$186,367	$324,423
Cash Flow Year 25	$248,902	$42,099	$151,787	$417,739	$190,431	$330,991
Cash Flow Year 26	$248,122	$40,876	$144,061	$406,847	$188,106	$324,312
Cash Flow Year 27	$247,129	$40,630	$142,349	$438,756	$190,237	$322,112
Cash Flow Year 28	$247,934	$40,583	$149,913	$398,936	$188,305	$319,688
Cash Flow Year 29	$248,837	$41,008	$155,466	$416,317	$191,278	$324,999
Cash Flow Year 30	$248,035	$41,237	$165,832	$397,407	$191,696	$326,728
Cash Flow Year 31	$246,715	$41,617	$150,931	$402,390	$185,678	$326,624
Cash Flow Year 32	$248,276	$41,964	$134,491	$478,523	$188,214	$326,533
Cash Flow Year 33	$249,308	$42,688	$133,607	$414,322	$187,931	$325,593
Cash Flow Year 34	$244,868	$38,997	$150,001	$396,705	$187,913	$318,958
Cash Flow Year 35	$243,218	$40,527	$153,272	$424,034	$184,079	$319,718
Cash Flow Year 36	$248,301	$43,604	$135,569	$402,057	$186,055	$329,226

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 37	$249,645	$44,008	$143,611	$430,679	$188,823	$327,902
Cash Flow Year 38	$248,418	$43,402	$153,398	$450,743	$188,649	$330,793
Cash Flow Year 39	$246,795	$41,987	$153,887	$409,579	$189,001	$327,803
Cash Flow Year 40	$246,495	$41,724	$145,454	$462,877	$190,852	$318,811
40 Year NPV	$2,479,958	$163,507	$1,984,114	$2,966,797	$2,212,558	$2,743,470
Perpetuity NPV	$2,522,781	$163,807	$2,040,012	$3,018,294	$2,253,501	$2,781,514

Table J.32 – Summary statistics for farm representative of Brown soil zone, dryland production, field pea and legume green manure rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$109,874	$104,520	-$161,850	$556,157	-$23,623	$305,057
Cash Flow Year 2	$82,536	$101,758	-$127,461	$531,841	-$76,127	$276,525
Cash Flow Year 3	$80,934	$99,955	-$153,145	$611,466	-$98,892	$267,217
Cash Flow Year 4	$96,011	$92,409	-$151,237	$459,668	-$23,240	$277,382
Cash Flow Year 5	$105,854	$101,228	-$124,317	$613,398	-$19,739	$297,376
Cash Flow Year 6	$101,387	$99,977	-$124,788	$607,267	-$24,516	$307,774
Cash Flow Year 7	$100,619	$97,468	-$137,137	$560,713	-$26,146	$289,699
Cash Flow Year 8	$98,016	$94,959	-$120,403	$510,860	-$27,479	$280,075
Cash Flow Year 9	$104,427	$100,588	-$119,285	$542,852	-$14,901	$304,071
Cash Flow Year 10	$100,071	$92,889	-$122,921	$644,422	-$21,309	$262,096
Cash Flow Year 11	$101,034	$96,909	-$164,945	$646,684	-$26,428	$281,982
Cash Flow Year 12	$97,884	$96,575	-$142,647	$554,015	-$45,005	$287,619
Cash Flow Year 13	$100,629	$95,958	-$126,686	$584,205	-$21,251	$289,018
Cash Flow Year 14	$101,453	$97,147	-$125,121	$590,099	-$20,324	$284,163
Cash Flow Year 15	$98,966	$96,444	-$118,719	$456,344	-$24,243	$286,097
Cash Flow Year 16	$96,084	$94,146	-$126,311	$552,280	-$29,572	$277,948
Cash Flow Year 17	$99,449	$99,344	-$121,144	$597,215	-$25,444	$295,957
Cash Flow Year 18	$101,786	$97,499	-$122,544	$549,736	-$23,948	$284,061
Cash Flow Year 19	$101,328	$97,814	-$122,776	$622,695	-$23,857	$285,201
Cash Flow Year 20	$97,952	$97,030	-$136,770	$541,251	-$32,959	$281,991
Cash Flow Year 21	$98,473	$95,875	-$129,082	$461,419	-$23,322	$282,336
Cash Flow Year 22	$101,526	$96,610	-$128,345	$549,778	-$15,537	$284,905
Cash Flow Year 23	$102,345	$95,720	-$122,662	$477,079	-$15,023	$278,790
Cash Flow Year 24	$99,601	$99,289	-$159,033	$607,092	-$39,265	$278,541
Cash Flow Year 25	$97,531	$95,944	-$125,121	$501,063	-$30,619	$284,377
Cash Flow Year 26	$103,139	$96,247	-$118,266	$494,994	-$24,885	$281,143
Cash Flow Year 27	$102,353	$94,406	-$119,778	$566,276	-$14,604	$282,763
Cash Flow Year 28	$101,630	$95,680	-$126,920	$610,139	-$21,945	$274,245
Cash Flow Year 29	$98,672	$93,934	-$122,471	$493,342	-$25,935	$272,559
Cash Flow Year 30	$100,604	$95,446	-$147,923	$491,294	-$22,467	$284,674
Cash Flow Year 31	$101,551	$98,254	-$115,410	$605,140	-$21,899	$282,182
Cash Flow Year 32	$98,362	$96,173	-$124,449	$559,331	-$26,758	$284,938

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 33	$101,399	$99,287	-$143,612	$687,658	-$20,173	$285,412
Cash Flow Year 34	$105,358	$103,053	-$113,913	$573,025	-$21,900	$303,089
Cash Flow Year 35	$97,206	$100,188	-$133,892	$532,756	-$97,399	$280,145
Cash Flow Year 36	$99,448	$94,599	-$126,882	$491,489	-$23,375	$277,898
Cash Flow Year 37	$99,812	$98,301	-$119,034	$594,342	-$23,745	$286,491
Cash Flow Year 38	$102,530	$101,905	-$122,462	$571,399	-$30,738	$302,657
Cash Flow Year 39	$105,647	$98,765	-$122,574	$530,206	-$13,756	$297,081
Cash Flow Year 40	$102,220	$100,262	-$155,953	$604,684	-$24,331	$295,940
40 Year NPV	$1,045,612	$307,113	$126,492	$2,052,170	$547,088	$1,545,720
Perpetuity NPV	$1,068,009	$307,636	$133,617	$2,113,093	$568,460	$1,568,912

Table J.33 – Summary statistics for farm representative of Dark Brown soil zone, field pea and legume green manure rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$145,191	$109,635	-$123,107	$546,190	$8,474	$343,801
Cash Flow Year 2	$122,390	$102,624	-$131,174	$611,553	-$8,473	$314,744
Cash Flow Year 3	$126,883	$102,567	-$124,145	$549,149	-$11,753	$306,544
Cash Flow Year 4	$148,868	$105,059	-$127,134	$540,331	$21,866	$349,934
Cash Flow Year 5	$156,102	$98,171	-$129,565	$579,477	$30,521	$343,312
Cash Flow Year 6	$150,929	$98,970	-$131,913	$576,800	$24,426	$336,913
Cash Flow Year 7	$148,758	$101,630	-$138,347	$551,055	$20,796	$344,109
Cash Flow Year 8	$145,338	$101,057	-$135,178	$669,514	$15,036	$339,218
Cash Flow Year 9	$151,288	$97,802	-$127,095	$542,826	$27,552	$332,967
Cash Flow Year 10	$155,876	$99,005	-$135,706	$531,797	$29,089	$345,055
Cash Flow Year 11	$153,184	$102,298	-$131,328	$597,997	$22,165	$343,966
Cash Flow Year 12	$151,207	$99,443	-$127,917	$613,591	$23,746	$339,624
Cash Flow Year 13	$153,001	$102,329	-$149,948	$594,434	$29,470	$350,409
Cash Flow Year 14	$152,466	$98,764	-$129,131	$515,221	$23,592	$339,614
Cash Flow Year 15	$151,851	$97,887	-$132,389	$648,786	$24,745	$340,698
Cash Flow Year 16	$151,942	$104,695	-$130,475	$598,400	$22,762	$342,259
Cash Flow Year 17	$149,182	$94,298	-$118,363	$549,939	$26,244	$325,339
Cash Flow Year 18	$150,162	$95,806	-$126,715	$472,348	$20,750	$326,112
Cash Flow Year 19	$148,978	$92,481	-$125,879	$534,488	$26,304	$319,322
Cash Flow Year 20	$149,989	$105,956	-$137,618	$608,565	$20,133	$341,167
Cash Flow Year 21	$147,486	$103,078	-$128,066	$559,208	$8,708	$336,397
Cash Flow Year 22	$153,411	$102,629	-$137,940	$655,830	$24,011	$352,180
Cash Flow Year 23	$152,434	$98,534	-$122,778	$673,989	$23,339	$332,429
Cash Flow Year 24	$153,924	$100,215	-$126,523	$554,515	$29,371	$336,902
Cash Flow Year 25	$151,564	$98,533	-$126,064	$543,571	$22,218	$329,222
Cash Flow Year 26	$150,568	$98,386	-$127,789	$531,324	$27,185	$333,642
Cash Flow Year 27	$151,660	$98,000	-$119,159	$623,595	$23,797	$327,400
Cash Flow Year 28	$152,841	$101,613	-$125,848	$571,197	$26,328	$338,749

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 29	$148,317	$97,479	-$145,140	$520,244	$25,846	$332,961
Cash Flow Year 30	$152,563	$96,702	-$144,876	$531,216	$32,218	$341,124
Cash Flow Year 31	$151,294	$95,744	-$138,977	$577,960	$25,476	$335,839
Cash Flow Year 32	$149,255	$94,029	-$129,106	$614,909	$27,596	$321,438
Cash Flow Year 33	$149,669	$97,546	-$123,293	$582,553	$26,835	$335,963
Cash Flow Year 34	$156,020	$98,943	-$125,781	$547,954	$27,447	$338,909
Cash Flow Year 35	$152,489	$104,614	-$128,590	$579,073	$23,253	$348,887
Cash Flow Year 36	$155,900	$102,632	-$130,318	$562,615	$26,922	$356,536
Cash Flow Year 37	$147,184	$98,247	-$134,825	$559,835	$18,812	$335,860
Cash Flow Year 38	$150,285	$100,611	-$135,137	$620,186	$22,934	$337,784
Cash Flow Year 39	$152,346	$98,831	-$132,125	$548,173	$26,786	$336,603
Cash Flow Year 40	$154,130	$101,782	-$132,485	$608,523	$30,804	$334,492
40 Year NPV	$1,528,746	$309,606	$592,703	$2,391,475	$1,019,609	$2,042,864
Perpetuity NPV	$1,563,429	$310,093	$623,307	$2,419,941	$1,056,827	$2,075,343

Table J.34 – Summary statistics for farm representative of Black soil zone, field pea and oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$234,531	$78,041	$35,164	$604,187	$125,735	$380,675
Cash Flow Year 2	$225,050	$85,906	-$108,327	$559,225	$104,165	$385,215
Cash Flow Year 3	$225,945	$84,325	$26,070	$619,713	$108,124	$385,865
Cash Flow Year 4	$240,362	$84,452	$24,444	$613,065	$126,172	$401,550
Cash Flow Year 5	$240,194	$84,722	-$2,931	$575,519	$128,708	$405,599
Cash Flow Year 6	$228,277	$83,971	$34,671	$606,395	$115,024	$387,072
Cash Flow Year 7	$228,316	$83,546	-$116,342	$667,286	$118,606	$387,727
Cash Flow Year 8	$229,479	$82,118	-$111,218	$550,015	$116,302	$378,086
Cash Flow Year 9	$238,524	$87,036	$40,473	$566,284	$120,495	$397,125
Cash Flow Year 10	$240,739	$91,011	$51,797	$659,911	$121,446	$420,123
Cash Flow Year 11	$233,441	$83,937	$31,789	$502,707	$117,680	$394,009
Cash Flow Year 12	$230,099	$84,077	-$122,053	$626,934	$120,564	$385,622
Cash Flow Year 13	$232,768	$87,413	-$110,843	$591,270	$117,299	$402,080
Cash Flow Year 14	$232,951	$85,255	-$107,814	$621,939	$118,800	$401,340
Cash Flow Year 15	$232,673	$86,011	$39,120	$630,881	$115,303	$399,343
Cash Flow Year 16	$235,937	$88,043	$46,693	$624,325	$120,411	$404,594
Cash Flow Year 17	$232,733	$85,582	$67,635	$554,465	$122,367	$394,971
Cash Flow Year 18	$231,157	$82,446	-$115,163	$655,346	$117,493	$375,803
Cash Flow Year 19	$235,787	$88,490	$33,012	$655,917	$118,130	$400,587
Cash Flow Year 20	$234,004	$85,788	-$120,579	$629,669	$117,156	$406,571
Cash Flow Year 21	$234,009	$86,140	-$118,896	$564,915	$120,648	$402,135
Cash Flow Year 22	$230,848	$85,501	-$124,034	$561,017	$115,176	$386,129
Cash Flow Year 23	$228,417	$84,283	$19,454	$535,429	$117,187	$390,966
Cash Flow Year 24	$235,063	$88,691	$37,904	$560,546	$115,923	$404,033

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 25	$233,490	$85,672	$41,247	$537,211	$115,933	$401,054
Cash Flow Year 26	$233,340	$84,433	$46,197	$577,068	$119,384	$389,158
Cash Flow Year 27	$231,110	$87,822	-$116,662	$643,691	$112,296	$393,133
Cash Flow Year 28	$231,018	$87,584	-$115,724	$618,209	$116,805	$399,938
Cash Flow Year 29	$232,838	$87,347	-$108,198	$573,914	$116,971	$401,448
Cash Flow Year 30	$234,372	$89,524	-$108,994	$677,551	$116,222	$411,389
Cash Flow Year 31	$231,744	$86,591	-$114,828	$550,089	$117,737	$397,122
Cash Flow Year 32	$235,412	$85,909	$51,463	$768,853	$120,484	$399,348
Cash Flow Year 33	$236,865	$87,252	-$124,223	$651,306	$123,850	$399,753
Cash Flow Year 34	$230,102	$82,368	-$109,032	$534,144	$117,987	$388,326
Cash Flow Year 35	$228,404	$85,334	-$116,440	$604,329	$116,621	$388,495
Cash Flow Year 36	$235,680	$89,371	$40,391	$601,931	$119,338	$401,421
Cash Flow Year 37	$235,871	$84,596	-$119,395	$584,345	$120,473	$396,533
Cash Flow Year 38	$237,143	$90,247	$24,068	$622,702	$118,751	$408,746
Cash Flow Year 39	$231,216	$87,211	-$111,900	$676,753	$115,780	$392,138
Cash Flow Year 40	$233,161	$87,349	-$115,879	$563,095	$114,699	$413,287
40 Year NPV	$2,525,124	$283,948	$1,685,887	$3,576,442	$2,073,001	$3,026,039
Perpetuity NPV	$2,573,881	$284,952	$1,726,444	$3,654,453	$2,118,467	$3,065,275

Table J.35 – Summary statistics for farm representative of Dark Grey soil zone, field pea and oat rotation

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$215,103	$59,860	$88,058	$512,572	$128,778	$328,887
Cash Flow Year 2	$210,234	$64,550	$60,663	$445,304	$122,945	$330,798
Cash Flow Year 3	$212,434	$64,333	$70,434	$568,875	$126,718	$337,227
Cash Flow Year 4	$225,531	$61,157	$66,472	$466,508	$143,942	$338,840
Cash Flow Year 5	$225,158	$57,393	$50,907	$462,894	$147,201	$334,241
Cash Flow Year 6	$219,958	$58,581	$86,439	$493,183	$143,935	$333,194
Cash Flow Year 7	$219,185	$56,757	$78,482	$450,815	$142,308	$335,458
Cash Flow Year 8	$221,935	$58,223	$92,637	$426,798	$140,964	$337,012
Cash Flow Year 9	$224,705	$59,984	$92,725	$466,998	$143,848	$337,565
Cash Flow Year 10	$224,783	$60,859	$94,536	$524,652	$140,561	$336,484
Cash Flow Year 11	$222,526	$57,381	$85,557	$498,453	$143,890	$326,758
Cash Flow Year 12	$218,552	$57,649	$83,630	$484,018	$142,099	$329,682
Cash Flow Year 13	$221,161	$58,420	$86,791	$499,043	$140,666	$329,150
Cash Flow Year 14	$221,713	$58,167	$78,460	$471,579	$140,294	$326,146
Cash Flow Year 15	$220,486	$58,212	$56,228	$450,394	$142,802	$329,319
Cash Flow Year 16	$223,784	$56,222	$62,069	$473,657	$145,336	$326,621
Cash Flow Year 17	$224,217	$60,994	$95,013	$461,751	$144,214	$344,895
Cash Flow Year 18	$223,410	$60,082	$65,321	$481,291	$144,547	$342,957
Cash Flow Year 19	$222,756	$58,923	$96,547	$529,476	$147,356	$336,314
Cash Flow Year 20	$221,299	$59,342	$84,236	$499,120	$141,935	$335,846

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 21	$221,711	$56,071	$82,904	$457,754	$141,737	$327,371
Cash Flow Year 22	$222,013	$58,168	$82,541	$427,544	$146,803	$333,062
Cash Flow Year 23	$219,898	$57,413	$50,729	$479,516	$143,000	$333,597
Cash Flow Year 24	$222,701	$60,451	$83,261	$541,548	$141,901	$336,378
Cash Flow Year 25	$224,185	$60,940	$84,624	$484,384	$141,963	$343,043
Cash Flow Year 26	$222,805	$58,394	$100,522	$428,944	$142,123	$334,205
Cash Flow Year 27	$222,129	$57,940	$88,081	$445,782	$141,880	$332,162
Cash Flow Year 28	$223,680	$60,429	$99,948	$482,958	$144,684	$337,712
Cash Flow Year 29	$224,032	$59,102	$94,247	$471,551	$144,392	$336,401
Cash Flow Year 30	$223,003	$57,552	$101,702	$544,495	$146,568	$338,264
Cash Flow Year 31	$220,391	$58,446	$99,721	$496,040	$141,702	$333,093
Cash Flow Year 32	$223,175	$60,512	$72,996	$528,135	$144,552	$336,764
Cash Flow Year 33	$224,678	$61,504	$78,123	$488,426	$138,490	$347,601
Cash Flow Year 34	$218,896	$55,597	$92,059	$459,005	$144,743	$325,764
Cash Flow Year 35	$218,492	$59,659	$94,453	$442,271	$137,977	$338,520
Cash Flow Year 36	$223,184	$60,545	$79,647	$478,223	$139,869	$332,874
Cash Flow Year 37	$223,216	$60,747	$79,738	$480,502	$138,662	$336,994
Cash Flow Year 38	$222,912	$61,373	$97,163	$480,819	$140,526	$338,332
Cash Flow Year 39	$221,454	$60,692	$82,733	$459,987	$140,942	$339,953
Cash Flow Year 40	$221,790	$60,102	$88,250	$556,104	$141,009	$332,609
40 Year NPV	$2,371,215	$204,959	$1,804,347	$3,009,628	$2,034,906	$2,697,819
Perpetuity NPV	$2,410,627	$205,674	$1,828,416	$3,048,542	$2,070,814	$2,745,500

Table J.36 – Summary statistics for farm representative of Brown soil zone, irrigated production, with shelterbelt adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$264,380	$161,269	-$311,680	$860,645	$37,337	$566,073
Cash Flow Year 2	$174,760	$144,720	-$315,692	$800,044	-$13,687	$429,582
Cash Flow Year 3	$158,348	$137,584	-$332,490	$698,685	-$10,893	$414,411
Cash Flow Year 4	$199,695	$141,096	-$323,650	$937,891	$40,125	$466,601
Cash Flow Year 5	$213,065	$132,688	-$309,019	$746,020	$47,001	$446,234
Cash Flow Year 6	$203,921	$142,218	-$303,349	$749,223	$33,462	$458,810
Cash Flow Year 7	$184,557	$147,374	-$307,482	$733,690	$1,437	$459,768
Cash Flow Year 8	$178,692	$138,876	-$300,786	$792,975	$3,045	$424,620
Cash Flow Year 9	$188,875	$144,064	-$322,743	$784,747	$10,468	$452,659
Cash Flow Year 10	$199,238	$136,516	-$316,028	$887,668	$25,299	$450,275
Cash Flow Year 11	$194,219	$129,511	-$302,997	$706,493	$23,013	$425,409
Cash Flow Year 12	$192,291	$135,116	-$298,793	$805,756	$19,205	$452,236
Cash Flow Year 13	$192,545	$139,508	-$316,666	$701,607	$21,767	$467,810
Cash Flow Year 14	$197,990	$129,603	-$298,676	$680,014	$22,938	$427,826
Cash Flow Year 15	$196,960	$131,631	-$305,761	$805,480	$25,392	$461,103
Cash Flow Year 16	$197,815	$138,981	-$302,244	$864,575	$26,655	$466,631

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 17	$196,015	$133,735	-$291,392	$754,769	$14,328	$458,315
Cash Flow Year 18	$198,061	$131,875	-$316,030	$780,010	$32,139	$441,102
Cash Flow Year 19	$204,258	$134,366	-$284,594	$740,325	$32,691	$461,523
Cash Flow Year 20	$198,607	$138,811	-$304,482	$952,014	$30,196	$452,141
Cash Flow Year 21	$196,438	$134,891	-$317,375	$928,741	$26,726	$449,376
Cash Flow Year 22	$195,271	$138,466	-$297,717	$843,931	$22,255	$449,390
Cash Flow Year 23	$201,250	$135,623	-$316,032	$776,982	$29,926	$458,357
Cash Flow Year 24	$208,252	$145,381	-$316,058	$790,791	$25,815	$470,196
Cash Flow Year 25	$204,875	$135,590	-$311,505	$748,218	$28,096	$449,248
Cash Flow Year 26	$206,774	$135,101	-$322,731	$800,690	$34,909	$456,170
Cash Flow Year 27	$203,653	$129,925	-$311,413	$752,318	$36,559	$441,518
Cash Flow Year 28	$202,020	$130,162	-$320,602	$818,514	$35,753	$440,388
Cash Flow Year 29	$203,056	$135,585	-$298,806	$935,621	$36,033	$457,277
Cash Flow Year 30	$199,119	$128,649	-$289,581	$745,200	$29,718	$436,072
Cash Flow Year 31	$198,686	$137,340	-$312,910	$830,755	$25,742	$442,633
Cash Flow Year 32	$207,270	$133,021	-$305,282	$777,976	$31,355	$437,585
Cash Flow Year 33	$211,426	$141,364	-$321,597	$841,652	$38,255	$491,439
Cash Flow Year 34	$208,692	$138,094	-$291,152	$739,463	$27,766	$466,934
Cash Flow Year 35	$206,403	$142,168	-$300,665	$849,693	$23,866	$460,375
Cash Flow Year 36	$208,214	$131,840	-$314,330	$844,486	$40,300	$464,070
Cash Flow Year 37	$208,524	$142,828	-$304,300	$772,842	$31,464	$478,567
Cash Flow Year 38	$200,659	$128,199	-$313,472	$815,489	$27,632	$434,429
Cash Flow Year 39	$207,224	$134,001	-$306,771	$970,544	$34,318	$445,485
Cash Flow Year 40	$205,940	$132,924	-$305,893	$736,368	$36,659	$460,808
40 Year NPV	$2,206,433	$412,797	$982,116	$3,944,646	$1,532,520	$2,873,168
Perpetuity NPV	$2,248,072	$414,808	$1,051,940	$4,026,676	$1,567,825	$2,915,473

Table J.37 – Summary statistics for farm representative of Brown soil zone, dryland production, with shelterbelt adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$82,840	$105,669	-$203,230	$526,877	-$102,368	$278,933
Cash Flow Year 2	$52,944	$102,988	-$152,625	$527,613	-$111,692	$249,015
Cash Flow Year 3	$43,404	$104,051	-$182,733	$563,975	-$113,690	$231,427
Cash Flow Year 4	$52,965	$97,040	-$192,389	$452,990	-$110,335	$228,001
Cash Flow Year 5	$55,452	$104,390	-$179,287	$518,449	-$110,129	$241,285
Cash Flow Year 6	$44,459	$103,563	-$167,345	$516,376	-$113,501	$235,131
Cash Flow Year 7	$42,006	$100,208	-$202,561	$518,601	-$112,150	$222,115
Cash Flow Year 8	$37,973	$96,839	-$185,031	$470,826	-$113,138	$217,459
Cash Flow Year 9	$53,350	$101,668	-$162,683	$475,388	-$105,863	$242,337
Cash Flow Year 10	$52,618	$95,786	-$172,842	$617,942	-$104,166	$226,258
Cash Flow Year 11	$53,832	$97,753	-$188,077	$475,061	-$105,110	$224,678
Cash Flow Year 12	$56,768	$95,208	-$175,082	$442,174	-$104,743	$232,550

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 13	$61,775	$95,629	-$188,996	$473,449	-$102,916	$244,753
Cash Flow Year 14	$66,956	$95,190	-$168,148	$518,842	-$100,894	$242,759
Cash Flow Year 15	$62,842	$95,633	-$165,620	$418,484	-$100,522	$252,053
Cash Flow Year 16	$61,675	$93,185	-$170,190	$477,767	-$100,506	$234,119
Cash Flow Year 17	$66,374	$98,448	-$157,022	$510,361	-$101,729	$248,149
Cash Flow Year 18	$67,510	$95,368	-$137,328	$510,053	-$101,714	$245,886
Cash Flow Year 19	$68,202	$95,101	-$124,339	$552,124	-$101,334	$239,639
Cash Flow Year 20	$63,359	$97,071	-$194,036	$500,275	-$102,415	$242,025
Cash Flow Year 21	$65,640	$95,574	-$188,830	$404,696	-$99,457	$255,420
Cash Flow Year 22	$68,309	$94,236	-$172,669	$524,369	-$98,735	$244,690
Cash Flow Year 23	$67,877	$95,026	-$127,043	$440,540	-$99,070	$246,382
Cash Flow Year 24	$64,007	$98,506	-$171,993	$530,127	-$102,400	$230,585
Cash Flow Year 25	$63,493	$94,789	-$176,676	$464,805	-$102,888	$243,384
Cash Flow Year 26	$67,271	$95,096	-$161,001	$416,980	-$100,632	$236,985
Cash Flow Year 27	$67,633	$93,910	-$123,723	$510,435	-$97,445	$240,252
Cash Flow Year 28	$66,915	$95,855	-$131,792	$544,198	-$100,089	$243,248
Cash Flow Year 29	$66,344	$93,337	-$149,236	$481,790	-$99,157	$231,016
Cash Flow Year 30	$65,853	$94,178	-$161,676	$446,532	-$100,651	$243,964
Cash Flow Year 31	$67,496	$97,941	-$163,736	$538,755	-$102,494	$237,703
Cash Flow Year 32	$64,907	$94,012	-$159,691	$527,760	-$100,251	$236,114
Cash Flow Year 33	$65,625	$97,990	-$171,775	$615,310	-$101,195	$239,087
Cash Flow Year 34	$70,262	$101,261	-$141,980	$517,770	-$100,235	$252,764
Cash Flow Year 35	$65,529	$98,062	-$159,412	$484,804	-$102,360	$247,760
Cash Flow Year 36	$65,393	$93,438	-$137,537	$452,006	-$101,933	$236,436
Cash Flow Year 37	$64,583	$96,880	-$133,141	$491,464	-$101,635	$245,076
Cash Flow Year 38	$66,853	$100,066	-$149,540	$542,934	-$102,079	$263,563
Cash Flow Year 39	$70,929	$97,630	-$137,308	$435,715	-$98,337	$246,478
Cash Flow Year 40	$70,347	$95,865	-$173,709	$560,162	-$101,898	$244,358
40 Year NPV	$644,864	$338,553	-$496,310	$1,663,569	$95,482	$1,210,921
Perpetuity NPV	$659,880	$339,125	-$488,499	$1,713,118	$103,544	$1,218,140

Table J.38 – Summary statistics for farm representative of Dark Brown soil zone, with shelterbelt adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$102,760	$87,946	-$124,378	$442,718	-$14,643	$257,592
Cash Flow Year 2	$78,033	$83,721	-$148,468	$441,506	-$35,332	$228,941
Cash Flow Year 3	$73,022	$83,795	-$128,824	$410,092	-$106,060	$213,599
Cash Flow Year 4	$86,104	$84,829	-$131,063	$421,729	-$31,507	$239,690
Cash Flow Year 5	$85,877	$81,223	-$136,058	$447,090	-$37,312	$224,902
Cash Flow Year 6	$75,426	$85,374	-$136,652	$349,882	-$104,418	$223,867
Cash Flow Year 7	$72,492	$86,895	-$142,663	$383,080	-$104,669	$227,786
Cash Flow Year 8	$67,445	$86,838	-$139,483	$476,407	-$104,602	$221,475

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 9	$78,988	$81,031	-$133,433	$426,193	-$34,837	$221,853
Cash Flow Year 10	$85,341	$82,121	-$138,804	$385,409	-$22,878	$241,802
Cash Flow Year 11	$85,254	$85,079	-$126,262	$390,585	-$29,901	$237,037
Cash Flow Year 12	$87,639	$83,732	-$136,715	$398,991	-$26,284	$251,061
Cash Flow Year 13	$89,534	$82,853	-$167,626	$438,930	-$15,242	$247,679
Cash Flow Year 14	$92,156	$80,640	-$125,516	$393,044	-$19,020	$240,483
Cash Flow Year 15	$91,210	$79,686	-$124,600	$423,015	-$9,169	$244,324
Cash Flow Year 16	$94,608	$84,418	-$123,683	$428,099	-$14,509	$247,235
Cash Flow Year 17	$92,080	$78,296	-$121,006	$428,128	-$11,779	$241,523
Cash Flow Year 18	$92,831	$77,173	-$122,277	$377,286	-$15,754	$227,322
Cash Flow Year 19	$91,467	$76,498	-$118,918	$371,945	-$18,597	$232,552
Cash Flow Year 20	$92,053	$87,224	-$142,620	$436,898	-$23,413	$252,272
Cash Flow Year 21	$91,229	$83,836	-$124,419	$457,141	-$30,579	$242,659
Cash Flow Year 22	$96,562	$82,511	-$129,162	$420,275	-$10,477	$251,406
Cash Flow Year 23	$95,188	$79,403	-$124,332	$495,025	-$14,094	$241,987
Cash Flow Year 24	$96,557	$82,431	-$126,230	$396,199	-$10,734	$248,784
Cash Flow Year 25	$94,501	$80,462	-$124,200	$443,390	-$10,572	$239,497
Cash Flow Year 26	$94,514	$79,677	-$124,731	$391,508	-$14,307	$242,103
Cash Flow Year 27	$94,880	$78,989	-$112,632	$450,221	-$9,614	$232,246
Cash Flow Year 28	$96,554	$83,119	-$133,810	$392,024	-$10,070	$251,830
Cash Flow Year 29	$94,398	$80,752	-$152,456	$389,882	-$12,312	$246,527
Cash Flow Year 30	$95,497	$80,029	-$129,858	$368,494	-$8,859	$247,829
Cash Flow Year 31	$94,820	$79,029	-$119,105	$447,836	-$10,961	$236,712
Cash Flow Year 32	$93,611	$79,361	-$125,266	$505,604	-$10,885	$237,016
Cash Flow Year 33	$94,238	$80,008	-$121,651	$443,033	-$10,205	$241,016
Cash Flow Year 34	$98,627	$81,377	-$122,207	$422,658	-$9,257	$247,487
Cash Flow Year 35	$96,594	$84,621	-$131,362	$417,252	-$12,428	$252,289
Cash Flow Year 36	$98,048	$83,947	-$120,774	$386,267	-$13,107	$258,643
Cash Flow Year 37	$93,223	$80,236	-$125,753	$377,811	-$16,668	$246,246
Cash Flow Year 38	$95,974	$82,484	-$128,427	$452,369	-$9,762	$249,932
Cash Flow Year 39	$96,171	$79,375	-$126,177	$406,295	-$7,892	$245,357
Cash Flow Year 40	$98,608	$83,554	-$126,084	$466,528	-$10,965	$251,436
40 Year NPV	$934,297	$292,146	$21,258	$1,778,388	$452,464	$1,427,796
Perpetuity NPV	$956,363	$292,528	$40,422	$1,788,212	$468,231	$1,446,164

Table J.39 – Summary statistics for farm representative of Black soil zone, with shelterbelt adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$263,362	$98,296	$41,786	$753,446	$128,669	$446,380
Cash Flow Year 2	$237,960	$94,491	-$113,370	$595,702	$106,031	$411,395
Cash Flow Year 3	$239,668	$92,519	$38,508	$694,512	$113,429	$413,196
Cash Flow Year 4	$254,221	$94,038	-$116,275	$663,904	$130,262	$424,580

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 5	$251,094	$89,461	-$113,181	$663,359	$137,752	$419,225
Cash Flow Year 6	$238,177	$88,902	$7,802	$625,222	$116,946	$410,923
Cash Flow Year 7	$229,542	$86,864	-$125,230	$680,134	$109,485	$376,036
Cash Flow Year 8	$229,802	$87,973	-$122,305	$643,402	$107,788	$381,835
Cash Flow Year 9	$241,949	$94,998	-$113,988	$609,621	$113,556	$414,956
Cash Flow Year 10	$242,697	$97,365	$33,528	$728,475	$112,153	$434,292
Cash Flow Year 11	$236,986	$91,137	$12,422	$543,831	$111,806	$414,914
Cash Flow Year 12	$231,471	$90,499	-$131,166	$605,212	$113,136	$393,650
Cash Flow Year 13	$237,166	$93,822	-$108,968	$629,789	$109,423	$417,978
Cash Flow Year 14	$240,054	$90,109	$23,940	$644,185	$116,067	$423,623
Cash Flow Year 15	$237,373	$90,287	$37,614	$609,982	$112,617	$410,900
Cash Flow Year 16	$241,057	$91,085	$37,405	$615,326	$121,321	$412,813
Cash Flow Year 17	$238,839	$90,890	$67,298	$608,562	$119,201	$412,588
Cash Flow Year 18	$236,288	$86,657	$22,941	$635,852	$119,716	$389,779
Cash Flow Year 19	$240,239	$95,244	-$111,277	$737,758	$118,546	$413,105
Cash Flow Year 20	$237,932	$90,444	-$117,005	$675,775	$117,122	$401,117
Cash Flow Year 21	$237,935	$90,653	-$127,962	$557,730	$119,403	$412,448
Cash Flow Year 22	$234,278	$90,326	-$128,543	$607,522	$109,473	$397,939
Cash Flow Year 23	$230,126	$90,077	-$111,200	$592,449	$111,558	$405,920
Cash Flow Year 24	$237,397	$94,040	-$117,877	$533,224	$107,612	$423,445
Cash Flow Year 25	$236,531	$91,222	$23,808	$574,362	$109,545	$412,300
Cash Flow Year 26	$234,522	$88,251	$49,347	$592,852	$112,872	$395,305
Cash Flow Year 27	$232,617	$93,077	-$116,716	$688,661	$107,452	$398,933
Cash Flow Year 28	$232,039	$91,050	-$117,331	$672,782	$110,848	$408,681
Cash Flow Year 29	$233,334	$90,935	-$117,649	$638,541	$111,747	$400,877
Cash Flow Year 30	$234,326	$93,018	-$112,222	$655,103	$111,783	$410,722
Cash Flow Year 31	$231,392	$90,366	-$120,390	$573,954	$114,042	$403,949
Cash Flow Year 32	$235,781	$89,391	$33,026	$733,992	$116,078	$402,557
Cash Flow Year 33	$239,086	$91,565	-$130,803	$640,222	$117,070	$407,256
Cash Flow Year 34	$229,212	$86,493	-$119,279	$564,334	$113,331	$391,144
Cash Flow Year 35	$229,800	$92,201	-$115,286	$640,547	$106,924	$414,490
Cash Flow Year 36	$235,731	$94,243	$29,296	$669,664	$113,993	$410,249
Cash Flow Year 37	$235,737	$88,682	-$125,193	$617,555	$113,507	$407,130
Cash Flow Year 38	$235,592	$92,888	-$112,375	$629,513	$113,779	$416,056
Cash Flow Year 39	$230,099	$91,411	-$116,082	$678,089	$108,716	$395,025
Cash Flow Year 40	$232,366	$91,506	-$120,376	$605,123	$107,356	$418,188
40 Year NPV	$2,609,624	$323,151	$1,693,840	$3,749,833	$2,110,515	$3,180,086
Perpetuity NPV	$2,660,446	$324,231	$1,743,570	$3,830,350	$2,169,901	$3,235,652

Table J.40 – Summary statistics for farm representative of Dark Grey soil zone, with shelterbelt adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$226,957	$73,575	$73,261	$581,459	$124,436	$373,551
Cash Flow Year 2	$208,170	$70,330	$55,535	$475,208	$114,796	$340,901
Cash Flow Year 3	$207,700	$70,479	$57,140	$647,307	$113,879	$343,181
Cash Flow Year 4	$220,522	$66,768	$43,773	$485,606	$132,028	$347,112
Cash Flow Year 5	$216,628	$61,487	$22,346	$483,502	$132,516	$336,003
Cash Flow Year 6	$209,691	$63,729	$44,273	$559,012	$126,187	$327,151
Cash Flow Year 7	$203,424	$61,507	$45,460	$457,349	$117,864	$329,600
Cash Flow Year 8	$206,895	$63,755	$65,646	$452,020	$120,732	$334,131
Cash Flow Year 9	$211,809	$65,954	$60,140	$498,400	$123,178	$336,988
Cash Flow Year 10	$211,502	$67,484	$61,537	$528,314	$121,157	$339,569
Cash Flow Year 11	$208,559	$64,562	$52,463	$496,535	$121,412	$326,525
Cash Flow Year 12	$204,537	$64,219	$56,581	$518,240	$119,375	$324,258
Cash Flow Year 13	$208,637	$66,526	$22,459	$539,452	$118,473	$332,866
Cash Flow Year 14	$208,926	$64,340	$48,406	$529,838	$118,695	$328,662
Cash Flow Year 15	$207,651	$64,035	$24,379	$448,811	$121,975	$324,991
Cash Flow Year 16	$210,707	$61,211	$56,435	$460,946	$125,312	$322,205
Cash Flow Year 17	$211,597	$67,784	$70,757	$474,222	$121,983	$344,917
Cash Flow Year 18	$211,474	$66,895	$45,583	$497,865	$122,126	$343,087
Cash Flow Year 19	$210,404	$66,086	$56,852	$523,714	$125,948	$343,136
Cash Flow Year 20	$208,834	$65,312	$56,686	$486,917	$121,705	$337,569
Cash Flow Year 21	$208,970	$61,859	$70,623	$477,063	$120,440	$326,355
Cash Flow Year 22	$208,351	$63,768	$53,229	$434,846	$125,475	$330,893
Cash Flow Year 23	$207,035	$64,639	$10,833	$507,057	$120,956	$335,576
Cash Flow Year 24	$210,344	$66,865	$59,467	$568,434	$121,852	$341,316
Cash Flow Year 25	$211,264	$67,200	$62,354	$488,144	$120,624	$345,338
Cash Flow Year 26	$209,084	$65,098	$77,037	$450,827	$122,630	$334,275
Cash Flow Year 27	$208,070	$62,618	$67,665	$464,530	$122,521	$327,548
Cash Flow Year 28	$209,445	$66,342	$59,643	$487,616	$120,479	$342,619
Cash Flow Year 29	$209,819	$64,956	$49,836	$477,694	$123,892	$336,609
Cash Flow Year 30	$208,661	$63,720	$65,029	$606,247	$122,671	$337,731
Cash Flow Year 31	$205,836	$63,520	$64,468	$496,270	$117,856	$324,946
Cash Flow Year 32	$208,760	$65,626	$54,960	$519,509	$122,215	$336,588
Cash Flow Year 33	$210,533	$68,724	$58,438	$485,432	$114,739	$347,532
Cash Flow Year 34	$203,659	$60,645	$72,371	$452,182	$122,712	$324,679
Cash Flow Year 35	$203,828	$66,678	-$85,232	$489,760	$120,147	$337,062
Cash Flow Year 36	$208,089	$66,490	$59,635	$513,670	$118,514	$330,577
Cash Flow Year 37	$209,040	$66,262	$46,111	$468,377	$117,535	$334,448
Cash Flow Year 38	$206,959	$66,464	$79,188	$488,927	$118,286	$332,177
Cash Flow Year 39	$206,810	$66,134	$59,936	$472,913	$120,447	$335,852
Cash Flow Year 40	$206,733	$66,864	$64,421	$575,447	$117,401	$335,223

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
40 Year NPV	$2,288,331	$226,345	$1,642,925	$3,062,509	$1,919,793	$2,642,621
Perpetuity NPV	$2,325,182	$227,062	$1,654,256	$3,099,467	$1,953,051	$2,684,638

Table J.41 – Summary statistics for farm representative of Brown soil zone, irrigated production, with buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$270,229	$162,675	-$308,810	$868,644	$44,630	$573,875
Cash Flow Year 2	$183,738	$146,124	-$313,344	$816,974	-$6,614	$443,447
Cash Flow Year 3	$170,253	$139,383	-$330,929	$723,123	-$1,278	$434,276
Cash Flow Year 4	$215,721	$144,886	-$322,630	$976,227	$49,814	$493,613
Cash Flow Year 5	$232,861	$138,950	-$308,167	$788,210	$58,433	$479,430
Cash Flow Year 6	$228,247	$149,784	-$303,009	$799,950	$46,564	$498,616
Cash Flow Year 7	$213,372	$152,537	-$308,509	$790,507	$24,277	$504,008
Cash Flow Year 8	$208,280	$147,547	-$302,631	$861,043	$23,591	$471,576
Cash Flow Year 9	$216,064	$149,635	-$329,161	$841,453	$30,941	$493,804
Cash Flow Year 10	$224,804	$143,105	-$322,696	$950,240	$43,731	$487,395
Cash Flow Year 11	$218,364	$135,126	-$309,945	$755,876	$41,421	$457,207
Cash Flow Year 12	$214,659	$141,029	-$306,144	$861,806	$33,459	$486,007
Cash Flow Year 13	$212,375	$145,790	-$325,615	$746,733	$31,280	$500,225
Cash Flow Year 14	$215,614	$135,633	-$307,823	$722,950	$32,837	$456,995
Cash Flow Year 15	$213,736	$137,947	-$315,016	$854,555	$34,819	$490,655
Cash Flow Year 16	$213,362	$147,518	-$311,453	$917,758	$32,972	$495,339
Cash Flow Year 17	$210,789	$141,483	-$300,256	$799,646	$20,820	$489,107
Cash Flow Year 18	$212,891	$138,907	-$325,395	$827,976	$38,742	$471,615
Cash Flow Year 19	$218,213	$142,314	-$292,581	$784,188	$35,719	$489,560
Cash Flow Year 20	$211,524	$148,320	-$314,143	$1,005,843	$33,272	$478,494
Cash Flow Year 21	$209,685	$142,578	-$327,131	$984,272	$30,239	$477,615
Cash Flow Year 22	$208,184	$145,812	-$307,173	$898,332	$25,275	$475,684
Cash Flow Year 23	$214,072	$143,407	-$325,892	$822,175	$33,887	$485,569
Cash Flow Year 24	$221,097	$153,804	-$325,510	$834,192	$30,115	$496,788
Cash Flow Year 25	$217,303	$143,331	-$321,342	$786,233	$32,153	$474,859
Cash Flow Year 26	$218,447	$143,818	-$333,301	$843,509	$37,206	$477,603
Cash Flow Year 27	$214,948	$138,989	-$321,061	$794,932	$37,348	$465,688
Cash Flow Year 28	$213,456	$137,171	-$330,341	$864,053	$38,277	$466,533
Cash Flow Year 29	$214,302	$143,133	-$308,478	$985,458	$40,241	$482,947
Cash Flow Year 30	$209,304	$137,178	-$297,944	$786,114	$29,491	$461,198
Cash Flow Year 31	$209,434	$144,694	-$322,928	$875,622	$25,657	$466,238
Cash Flow Year 32	$218,183	$140,219	-$315,365	$819,195	$34,027	$462,396
Cash Flow Year 33	$221,748	$149,821	-$331,692	$885,219	$36,320	$519,574
Cash Flow Year 34	$218,784	$147,101	-$301,312	$778,562	$28,135	$496,105
Cash Flow Year 35	$216,054	$151,918	-$310,607	$898,090	$23,892	$483,449
Cash Flow Year 36	$218,070	$140,662	-$324,619	$883,708	$41,175	$488,456

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 37	$219,070	$150,505	-$314,741	$817,927	$30,430	$504,864
Cash Flow Year 38	$210,333	$136,643	-$323,443	$861,483	$30,327	$456,058
Cash Flow Year 39	$217,387	$142,883	-$316,432	$1,023,448	$35,969	$470,920
Cash Flow Year 40	$216,064	$140,814	-$315,807	$775,915	$38,733	$485,441
40 Year NPV	$2,373,032	$419,471	$1,113,412	$4,134,171	$1,676,851	$3,061,150
Perpetuity NPV	$2,417,557	$421,760	$1,188,121	$4,222,540	$1,720,393	$3,097,519

Table J.42 – Summary statistics for farm representative of Brown soil zone, dryland production, with buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$92,464	$105,546	-$191,623	$538,243	-$67,533	$290,321
Cash Flow Year 2	$65,512	$104,061	-$139,399	$547,233	-$106,322	$265,920
Cash Flow Year 3	$60,918	$104,982	-$168,435	$592,688	-$108,095	$253,630
Cash Flow Year 4	$74,107	$97,789	-$177,001	$487,317	-$102,792	$255,613
Cash Flow Year 5	$81,869	$106,161	-$158,350	$563,545	-$103,448	$276,247
Cash Flow Year 6	$75,802	$105,757	-$148,129	$570,005	-$105,591	$275,913
Cash Flow Year 7	$74,042	$103,863	-$186,430	$578,698	-$105,068	$264,057
Cash Flow Year 8	$72,441	$100,413	-$160,303	$534,068	-$105,778	$262,223
Cash Flow Year 9	$79,492	$106,044	-$169,658	$526,626	-$102,668	$279,785
Cash Flow Year 10	$75,558	$101,650	-$180,460	$676,983	-$103,537	$257,547
Cash Flow Year 11	$74,610	$102,326	-$190,194	$521,370	-$105,922	$253,067
Cash Flow Year 12	$74,104	$100,606	-$156,066	$482,897	-$106,791	$262,828
Cash Flow Year 13	$75,926	$100,929	-$170,750	$514,769	-$105,183	$267,952
Cash Flow Year 14	$77,961	$100,891	-$176,759	$560,326	-$104,557	$263,224
Cash Flow Year 15	$72,551	$101,990	-$174,317	$451,756	-$103,914	$273,838
Cash Flow Year 16	$70,276	$99,882	-$179,168	$516,756	-$104,223	$254,445
Cash Flow Year 17	$74,896	$105,548	-$164,952	$552,110	-$105,514	$269,707
Cash Flow Year 18	$75,683	$102,359	-$144,067	$550,296	-$105,099	$267,049
Cash Flow Year 19	$76,127	$102,360	-$129,747	$596,500	-$105,075	$260,406
Cash Flow Year 20	$71,196	$104,043	-$204,643	$539,568	-$106,159	$262,055
Cash Flow Year 21	$73,303	$102,773	-$199,076	$437,243	-$103,233	$276,685
Cash Flow Year 22	$76,396	$101,094	-$181,990	$567,443	-$102,453	$266,240
Cash Flow Year 23	$75,888	$102,033	-$132,675	$475,598	-$102,909	$267,629
Cash Flow Year 24	$71,788	$105,618	-$181,303	$573,675	-$106,329	$251,091
Cash Flow Year 25	$71,186	$101,645	-$185,882	$502,918	-$106,685	$264,893
Cash Flow Year 26	$75,271	$101,958	-$169,815	$450,301	-$104,475	$257,194
Cash Flow Year 27	$75,571	$100,693	-$129,518	$551,020	-$100,961	$260,462
Cash Flow Year 28	$74,164	$103,457	-$137,724	$588,085	-$103,973	$264,172
Cash Flow Year 29	$73,960	$100,308	-$156,610	$518,628	-$102,925	$251,582
Cash Flow Year 30	$73,475	$101,160	-$169,835	$483,232	-$104,565	$265,744
Cash Flow Year 31	$75,315	$105,122	-$172,415	$580,407	-$106,469	$257,640
Cash Flow Year 32	$72,373	$101,006	-$168,053	$569,395	-$104,157	$256,476

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 33	$72,870	$105,501	-$181,025	$662,933	-$104,957	$259,162
Cash Flow Year 34	$78,336	$108,637	-$149,097	$559,744	-$104,215	$274,569
Cash Flow Year 35	$73,106	$105,313	-$168,009	$525,202	-$106,403	$268,689
Cash Flow Year 36	$72,991	$100,271	-$144,097	$485,674	-$106,099	$256,802
Cash Flow Year 37	$72,210	$103,963	-$160,893	$530,164	-$105,482	$265,277
Cash Flow Year 38	$74,582	$107,344	-$157,118	$585,221	-$106,044	$284,755
Cash Flow Year 39	$79,027	$104,776	-$143,716	$470,819	-$101,902	$268,125
Cash Flow Year 40	$78,244	$103,018	-$183,126	$604,620	-$105,920	$265,047
40 Year NPV	$817,587	$343,574	-$356,136	$1,839,374	$257,774	$1,388,753
Perpetuity NPV	$834,301	$344,328	-$346,911	$1,893,429	$277,020	$1,399,604

Table J.43 – Summary statistics for farm representative of Dark Brown soil zone, with buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$109,679	$87,701	-$120,536	$450,825	-$6,846	$266,074
Cash Flow Year 2	$87,448	$84,502	-$137,675	$455,514	-$22,377	$241,733
Cash Flow Year 3	$86,172	$84,339	-$124,479	$429,669	-$39,341	$230,490
Cash Flow Year 4	$101,824	$85,851	-$126,500	$447,211	-$7,716	$261,179
Cash Flow Year 5	$104,444	$82,865	-$131,413	$478,885	-$10,547	$250,273
Cash Flow Year 6	$98,699	$86,040	-$131,851	$383,934	-$17,514	$253,383
Cash Flow Year 7	$96,886	$88,689	-$138,790	$422,056	-$20,584	$259,697
Cash Flow Year 8	$93,725	$88,428	-$136,131	$523,297	-$27,930	$254,925
Cash Flow Year 9	$98,364	$82,998	-$133,782	$460,537	-$8,580	$245,688
Cash Flow Year 10	$103,007	$84,331	-$140,261	$414,921	-$6,986	$263,796
Cash Flow Year 11	$100,641	$87,395	-$127,968	$418,312	-$17,450	$256,462
Cash Flow Year 12	$101,060	$85,796	-$130,691	$424,704	-$14,258	$268,629
Cash Flow Year 13	$100,264	$85,538	-$172,494	$463,259	-$6,476	$262,906
Cash Flow Year 14	$99,662	$83,782	-$129,730	$413,471	-$14,150	$253,915
Cash Flow Year 15	$98,179	$83,043	-$128,864	$445,531	-$9,444	$257,072
Cash Flow Year 16	$100,434	$88,483	-$127,857	$452,518	-$13,548	$260,183
Cash Flow Year 17	$97,549	$81,949	-$125,149	$449,843	-$10,634	$253,241
Cash Flow Year 18	$97,686	$80,963	-$126,391	$394,598	-$16,347	$238,497
Cash Flow Year 19	$95,949	$80,204	-$123,051	$389,764	-$25,395	$244,229
Cash Flow Year 20	$96,489	$91,339	-$147,729	$461,376	-$25,931	$264,016
Cash Flow Year 21	$94,904	$88,650	-$128,676	$477,779	-$42,222	$253,633
Cash Flow Year 22	$100,944	$86,136	-$133,704	$440,054	-$10,972	$262,580
Cash Flow Year 23	$99,090	$83,328	-$129,863	$517,923	-$15,834	$253,555
Cash Flow Year 24	$100,409	$86,214	-$130,758	$413,861	-$11,632	$259,059
Cash Flow Year 25	$97,804	$84,766	-$128,588	$469,916	-$22,334	$248,626
Cash Flow Year 26	$97,559	$84,031	-$129,149	$407,335	-$17,088	$252,519
Cash Flow Year 27	$97,757	$83,319	-$116,557	$470,300	-$13,506	$242,238
Cash Flow Year 28	$99,339	$87,662	-$138,608	$410,482	-$16,675	$262,197

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 29	$97,184	$84,686	-$159,720	$405,019	-$14,161	$255,817
Cash Flow Year 30	$98,198	$83,841	-$136,595	$382,721	-$10,064	$258,303
Cash Flow Year 31	$97,740	$82,460	-$123,410	$466,118	-$12,283	$245,571
Cash Flow Year 32	$96,086	$83,165	-$129,891	$531,701	-$15,115	$245,980
Cash Flow Year 33	$96,347	$84,314	-$125,975	$458,800	-$15,095	$249,241
Cash Flow Year 34	$101,257	$85,120	-$126,749	$440,419	-$12,970	$256,092
Cash Flow Year 35	$98,652	$89,253	-$136,270	$433,346	-$20,000	$261,857
Cash Flow Year 36	$100,162	$88,553	-$125,359	$406,165	-$19,196	$268,817
Cash Flow Year 37	$95,365	$84,215	-$130,286	$390,995	-$22,790	$255,418
Cash Flow Year 38	$97,758	$87,326	-$134,788	$470,341	-$16,618	$258,830
Cash Flow Year 39	$98,840	$82,880	-$130,878	$422,514	-$9,138	$254,295
Cash Flow Year 40	$101,396	$87,172	-$132,723	$486,418	-$13,409	$260,819
40 Year NPV	$1,058,502	$294,756	$106,568	$1,894,578	$557,733	$1,561,497
Perpetuity NPV	$1,081,114	$295,249	$126,255	$1,933,309	$574,037	$1,583,227

Table J.44 – Summary statistics for farm representative of Black soil zone, with buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$265,650	$98,511	$29,022	$753,907	$131,633	$448,732
Cash Flow Year 2	$242,619	$95,716	-$110,659	$602,198	$108,686	$417,935
Cash Flow Year 3	$246,960	$94,377	$44,125	$706,681	$117,599	$423,760
Cash Flow Year 4	$264,261	$96,056	-$113,239	$682,093	$137,683	$439,791
Cash Flow Year 5	$263,631	$92,820	-$109,973	$687,943	$145,057	$439,067
Cash Flow Year 6	$253,281	$93,052	$18,929	$655,450	$127,073	$435,425
Cash Flow Year 7	$248,525	$89,350	-$122,373	$717,348	$123,014	$403,230
Cash Flow Year 8	$251,553	$91,172	-$119,819	$685,143	$123,727	$412,832
Cash Flow Year 9	$261,882	$98,501	-$113,417	$645,000	$128,151	$442,206
Cash Flow Year 10	$262,648	$101,077	$46,493	$769,093	$126,739	$462,166
Cash Flow Year 11	$256,809	$94,563	$24,244	$576,008	$127,310	$441,344
Cash Flow Year 12	$250,543	$93,992	-$132,473	$639,995	$127,689	$418,855
Cash Flow Year 13	$255,756	$96,970	-$109,746	$665,546	$123,074	$443,214
Cash Flow Year 14	$257,581	$93,801	$30,443	$679,497	$129,473	$448,616
Cash Flow Year 15	$254,694	$94,241	$45,528	$643,455	$124,132	$435,838
Cash Flow Year 16	$258,755	$95,331	$45,201	$650,626	$133,629	$438,845
Cash Flow Year 17	$256,334	$95,383	$76,602	$644,196	$131,157	$438,848
Cash Flow Year 18	$253,782	$91,200	$30,096	$673,561	$129,476	$415,091
Cash Flow Year 19	$258,686	$99,365	-$112,277	$779,353	$130,410	$440,634
Cash Flow Year 20	$256,488	$95,144	-$118,143	$717,253	$129,744	$428,284
Cash Flow Year 21	$256,812	$95,507	-$129,602	$594,085	$132,050	$440,639
Cash Flow Year 22	$253,311	$95,229	-$130,254	$646,130	$121,106	$426,490
Cash Flow Year 23	$249,609	$94,052	-$111,917	$631,442	$123,246	$435,079
Cash Flow Year 24	$257,464	$99,205	-$118,890	$569,936	$121,802	$454,192

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 25	$256,966	$96,365	$33,274	$613,912	$122,961	$443,307
Cash Flow Year 26	$255,128	$93,377	$59,945	$634,225	$126,844	$424,716
Cash Flow Year 27	$253,514	$98,390	-$117,498	$735,207	$121,435	$429,386
Cash Flow Year 28	$253,268	$96,270	-$118,194	$718,617	$125,011	$440,398
Cash Flow Year 29	$255,109	$96,252	-$118,245	$683,799	$126,562	$433,083
Cash Flow Year 30	$256,430	$97,970	-$112,546	$698,773	$127,070	$443,542
Cash Flow Year 31	$253,812	$94,461	-$121,244	$616,883	$130,207	$436,478
Cash Flow Year 32	$258,274	$94,579	$43,977	$785,315	$131,755	$434,931
Cash Flow Year 33	$261,987	$96,887	-$132,164	$686,818	$134,875	$440,616
Cash Flow Year 34	$251,876	$90,843	-$119,961	$604,116	$129,479	$422,614
Cash Flow Year 35	$252,551	$97,035	-$115,833	$688,244	$122,892	$447,665
Cash Flow Year 36	$258,569	$99,596	$40,952	$703,431	$130,544	$442,670
Cash Flow Year 37	$258,704	$93,834	-$126,268	$663,070	$129,159	$439,250
Cash Flow Year 38	$258,519	$98,140	-$112,740	$676,188	$129,857	$449,946
Cash Flow Year 39	$252,792	$96,179	-$116,627	$727,580	$124,034	$426,458
Cash Flow Year 40	$255,138	$96,759	-$121,095	$649,066	$123,502	$452,083
40 Year NPV	$2,750,060	$326,543	$1,792,651	$3,874,803	$2,246,666	$3,329,264
Perpetuity NPV	$2,806,884	$327,738	$1,848,739	$3,962,966	$2,305,974	$3,391,854

Table J.45 – Summary statistics for farm representative of Dark Grey soil zone, with buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$227,150	$73,181	$74,986	$579,058	$125,662	$372,837
Cash Flow Year 2	$209,774	$70,456	$57,094	$476,324	$115,954	$342,579
Cash Flow Year 3	$210,531	$71,003	$59,485	$651,048	$115,933	$347,000
Cash Flow Year 4	$224,464	$68,023	$46,863	$492,337	$134,744	$353,306
Cash Flow Year 5	$221,943	$62,978	$25,885	$493,316	$137,005	$344,495
Cash Flow Year 6	$216,592	$65,545	$49,092	$572,848	$132,557	$337,430
Cash Flow Year 7	$212,102	$63,516	$51,923	$472,322	$124,878	$342,310
Cash Flow Year 8	$216,972	$65,957	$71,364	$469,382	$127,812	$348,834
Cash Flow Year 9	$221,089	$67,467	$66,561	$514,351	$130,166	$349,324
Cash Flow Year 10	$220,840	$68,927	$67,952	$544,838	$128,525	$351,714
Cash Flow Year 11	$217,766	$65,824	$59,659	$512,459	$128,367	$338,276
Cash Flow Year 12	$213,538	$65,541	$61,825	$534,466	$126,649	$335,430
Cash Flow Year 13	$217,189	$67,803	$20,968	$555,954	$125,520	$344,053
Cash Flow Year 14	$216,858	$65,701	$52,492	$545,201	$123,321	$339,159
Cash Flow Year 15	$215,610	$65,498	$27,682	$462,586	$127,765	$335,833
Cash Flow Year 16	$218,678	$62,798	$60,331	$475,173	$131,258	$332,864
Cash Flow Year 17	$219,651	$69,597	$75,168	$488,999	$127,710	$356,456
Cash Flow Year 18	$219,599	$68,741	$49,349	$514,187	$127,767	$354,505
Cash Flow Year 19	$218,555	$68,045	$61,191	$540,810	$131,754	$355,538
Cash Flow Year 20	$217,227	$67,183	$60,855	$502,787	$127,615	$349,870

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 21	$217,495	$63,627	$75,328	$493,647	$126,223	$338,576
Cash Flow Year 22	$217,023	$65,688	$57,592	$450,503	$131,711	$343,123
Cash Flow Year 23	$215,741	$66,617	$14,044	$524,486	$127,200	$348,030
Cash Flow Year 24	$219,406	$68,891	$63,956	$587,879	$128,263	$354,432
Cash Flow Year 25	$220,481	$69,285	$67,244	$505,954	$126,804	$358,683
Cash Flow Year 26	$218,373	$67,165	$82,606	$468,073	$129,542	$347,862
Cash Flow Year 27	$217,579	$64,566	$73,104	$482,310	$129,289	$340,682
Cash Flow Year 28	$219,005	$68,455	$64,537	$505,727	$127,262	$356,291
Cash Flow Year 29	$219,529	$67,068	$54,648	$496,780	$130,910	$350,711
Cash Flow Year 30	$218,471	$65,763	$70,589	$627,631	$130,197	$351,616
Cash Flow Year 31	$215,796	$65,545	$70,141	$515,587	$125,331	$339,033
Cash Flow Year 32	$218,816	$67,748	$60,394	$539,126	$129,588	$351,032
Cash Flow Year 33	$220,691	$70,927	$63,893	$504,387	$122,022	$361,924
Cash Flow Year 34	$213,703	$62,558	$78,338	$470,144	$130,316	$338,768
Cash Flow Year 35	$213,980	$68,335	$47,419	$505,250	$127,098	$350,563
Cash Flow Year 36	$218,344	$68,569	$65,331	$533,577	$125,716	$344,192
Cash Flow Year 37	$219,312	$68,344	$51,320	$486,517	$124,694	$348,435
Cash Flow Year 38	$217,111	$68,568	$85,189	$508,195	$125,850	$346,571
Cash Flow Year 39	$216,913	$68,244	$65,584	$490,268	$127,862	$350,899
Cash Flow Year 40	$216,849	$68,965	$70,393	$597,105	$124,702	$349,605
40 Year NPV	$2,350,338	$227,017	$1,706,571	$3,125,587	$1,981,066	$2,708,580
Perpetuity NPV	$2,389,698	$227,806	$1,719,623	$3,165,471	$2,015,334	$2,752,734

Table J.46 – Summary statistics for farm representative of Brown soil zone, irrigated production, with buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$270,466	$162,702	-$308,727	$868,885	$44,953	$574,044
Cash Flow Year 2	$184,073	$146,192	-$313,118	$817,570	-$6,057	$444,009
Cash Flow Year 3	$170,619	$139,437	-$330,631	$723,518	-$962	$434,520
Cash Flow Year 4	$216,120	$144,927	-$322,534	$976,536	$50,220	$493,848
Cash Flow Year 5	$233,296	$138,981	-$307,972	$788,629	$58,880	$479,926
Cash Flow Year 6	$229,045	$149,042	-$302,915	$800,307	$47,711	$499,098
Cash Flow Year 7	$214,182	$151,831	-$308,446	$791,111	$25,745	$504,670
Cash Flow Year 8	$208,752	$147,544	-$302,402	$861,175	$24,118	$472,109
Cash Flow Year 9	$216,561	$149,629	-$328,969	$841,488	$31,445	$494,245
Cash Flow Year 10	$225,277	$143,106	-$322,477	$950,651	$43,970	$487,980
Cash Flow Year 11	$218,835	$135,122	-$309,735	$756,213	$41,794	$457,581
Cash Flow Year 12	$215,134	$141,026	-$305,986	$862,237	$34,122	$486,464
Cash Flow Year 13	$212,848	$145,792	-$325,391	$747,094	$31,731	$500,912
Cash Flow Year 14	$216,079	$135,626	-$307,716	$723,555	$33,220	$457,272
Cash Flow Year 15	$214,235	$137,966	-$314,807	$854,758	$35,296	$491,053
Cash Flow Year 16	$213,823	$147,516	-$311,363	$918,156	$33,487	$495,983

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 17	$211,228	$141,494	-$300,050	$800,083	$21,286	$489,563
Cash Flow Year 18	$213,360	$138,901	-$325,275	$828,369	$39,232	$471,759
Cash Flow Year 19	$218,691	$142,319	-$292,373	$784,795	$36,081	$489,938
Cash Flow Year 20	$211,997	$148,331	-$313,887	$1,006,305	$33,825	$479,054
Cash Flow Year 21	$210,158	$142,579	-$326,899	$984,896	$30,762	$477,990
Cash Flow Year 22	$208,659	$145,818	-$307,031	$898,801	$25,772	$476,201
Cash Flow Year 23	$214,534	$143,416	-$325,738	$822,718	$34,433	$486,049
Cash Flow Year 24	$221,566	$153,815	-$325,387	$834,626	$30,601	$497,464
Cash Flow Year 25	$217,727	$143,354	-$321,213	$786,364	$32,710	$475,306
Cash Flow Year 26	$218,952	$143,808	-$333,211	$843,816	$37,916	$478,314
Cash Flow Year 27	$215,451	$138,992	-$320,989	$795,473	$37,758	$466,156
Cash Flow Year 28	$213,931	$137,187	-$330,188	$864,763	$38,736	$466,884
Cash Flow Year 29	$214,780	$143,128	-$308,261	$985,921	$40,700	$483,363
Cash Flow Year 30	$210,064	$136,440	-$297,789	$786,643	$31,687	$461,793
Cash Flow Year 31	$209,911	$144,690	-$322,826	$876,438	$26,137	$466,859
Cash Flow Year 32	$218,617	$140,245	-$315,265	$819,778	$34,422	$463,005
Cash Flow Year 33	$222,226	$149,826	-$331,523	$886,054	$36,972	$519,941
Cash Flow Year 34	$219,256	$147,099	-$301,047	$779,213	$28,640	$496,332
Cash Flow Year 35	$216,513	$151,914	-$310,404	$898,265	$24,397	$483,966
Cash Flow Year 36	$218,498	$140,659	-$324,448	$883,900	$41,615	$488,994
Cash Flow Year 37	$219,574	$150,507	-$314,602	$818,425	$30,853	$505,350
Cash Flow Year 38	$210,852	$136,623	-$323,395	$861,930	$30,811	$456,632
Cash Flow Year 39	$217,859	$142,889	-$316,289	$1,023,861	$36,514	$471,208
Cash Flow Year 40	$216,478	$140,831	-$315,689	$776,504	$39,164	$485,901
40 Year NPV	$2,377,550	$419,555	$1,117,192	$4,138,139	$1,681,148	$3,065,133
Perpetuity NPV	$2,422,233	$421,843	$1,192,537	$4,226,724	$1,724,864	$3,101,925

Table J.47 – Summary statistics for farm representative of Brown soil zone, dryland production, with buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$93,023	$105,700	-$190,690	$539,909	-$67,125	$291,037
Cash Flow Year 2	$66,126	$104,146	-$138,649	$548,060	-$105,970	$267,117
Cash Flow Year 3	$61,713	$105,026	-$167,837	$593,864	-$107,926	$254,911
Cash Flow Year 4	$75,026	$97,671	-$176,199	$487,838	-$102,553	$256,290
Cash Flow Year 5	$82,786	$106,123	-$157,724	$565,271	-$103,160	$277,204
Cash Flow Year 6	$76,735	$105,739	-$147,360	$570,565	-$105,252	$277,300
Cash Flow Year 7	$75,140	$103,630	-$185,508	$578,928	-$104,836	$265,269
Cash Flow Year 8	$73,299	$100,445	-$159,258	$535,366	-$105,544	$263,433
Cash Flow Year 9	$80,534	$105,871	-$168,634	$527,872	-$102,501	$280,557
Cash Flow Year 10	$76,571	$101,601	-$179,848	$677,753	-$103,323	$258,612
Cash Flow Year 11	$75,829	$102,042	-$188,900	$522,444	-$105,644	$253,746
Cash Flow Year 12	$75,128	$100,512	-$155,478	$484,561	-$106,566	$263,503

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 13	$76,737	$101,039	-$169,657	$515,664	-$104,888	$269,305
Cash Flow Year 14	$78,789	$100,984	-$176,351	$561,559	-$104,226	$263,693
Cash Flow Year 15	$73,349	$102,047	-$173,817	$452,942	-$103,591	$274,787
Cash Flow Year 16	$71,531	$99,488	-$178,328	$517,135	-$103,981	$254,959
Cash Flow Year 17	$75,797	$105,543	-$164,057	$553,195	-$105,257	$270,168
Cash Flow Year 18	$76,741	$102,252	-$143,220	$552,106	-$104,636	$268,248
Cash Flow Year 19	$77,167	$102,225	-$129,472	$596,850	-$104,698	$260,789
Cash Flow Year 20	$72,096	$104,058	-$203,658	$540,547	-$105,931	$262,572
Cash Flow Year 21	$74,200	$102,758	-$198,532	$438,931	-$102,991	$277,620
Cash Flow Year 22	$77,373	$100,909	-$155,209	$567,982	-$102,232	$267,983
Cash Flow Year 23	$76,811	$102,020	-$132,573	$476,404	-$102,427	$268,084
Cash Flow Year 24	$72,654	$105,747	-$180,805	$574,579	-$106,153	$251,771
Cash Flow Year 25	$72,032	$101,722	-$184,989	$503,544	-$106,360	$265,657
Cash Flow Year 26	$76,221	$101,938	-$168,803	$452,184	-$104,177	$257,693
Cash Flow Year 27	$76,600	$100,621	-$128,270	$551,603	-$100,757	$261,207
Cash Flow Year 28	$75,484	$102,994	-$137,579	$588,874	-$103,677	$264,999
Cash Flow Year 29	$75,163	$99,996	-$155,760	$519,083	-$102,579	$252,026
Cash Flow Year 30	$74,608	$100,934	-$169,430	$484,440	-$104,130	$266,171
Cash Flow Year 31	$76,444	$104,824	-$171,816	$582,403	-$106,184	$258,478
Cash Flow Year 32	$73,512	$100,794	-$167,591	$570,762	-$103,638	$256,961
Cash Flow Year 33	$74,209	$105,135	-$180,201	$664,159	-$104,679	$259,631
Cash Flow Year 34	$79,164	$108,710	-$148,137	$560,432	-$103,639	$275,036
Cash Flow Year 35	$73,982	$105,321	-$166,912	$526,149	-$105,873	$269,149
Cash Flow Year 36	$73,966	$100,259	-$143,412	$487,413	-$105,805	$257,246
Cash Flow Year 37	$73,186	$103,832	-$138,951	$531,338	-$105,305	$266,404
Cash Flow Year 38	$75,669	$107,244	-$156,478	$586,077	-$105,748	$285,487
Cash Flow Year 39	$80,036	$104,717	-$142,510	$472,620	-$101,542	$269,455
Cash Flow Year 40	$79,242	$102,945	-$182,056	$604,831	-$105,442	$265,976
40 Year NPV	$826,334	$343,416	-$349,206	$1,846,481	$265,859	$1,395,616
Perpetuity NPV	$843,273	$344,247	-$339,612	$1,900,736	$285,616	$1,408,535

Table J.48 – Summary statistics for farm representative of Dark Brown soil zone, with buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$110,441	$87,696	-$120,344	$451,855	-$5,430	$266,530
Cash Flow Year 2	$88,166	$84,678	-$136,512	$456,628	-$21,857	$242,444
Cash Flow Year 3	$86,974	$84,477	-$124,102	$430,419	-$38,654	$231,153
Cash Flow Year 4	$102,746	$85,981	-$125,928	$448,848	-$6,307	$261,959
Cash Flow Year 5	$105,372	$83,011	-$130,988	$480,561	-$9,339	$251,392
Cash Flow Year 6	$99,914	$85,900	-$131,564	$385,140	-$15,205	$254,349
Cash Flow Year 7	$98,119	$88,478	-$138,324	$422,391	-$17,429	$261,049
Cash Flow Year 8	$94,716	$88,532	-$135,981	$524,546	-$26,531	$256,450

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 9	$99,565	$82,846	-$133,444	$462,157	-$6,966	$246,475
Cash Flow Year 10	$104,356	$83,938	-$139,787	$415,937	-$3,928	$264,340
Cash Flow Year 11	$101,825	$87,278	-$127,668	$419,866	-$15,929	$257,526
Cash Flow Year 12	$102,104	$85,897	-$130,410	$425,787	-$13,182	$269,172
Cash Flow Year 13	$101,448	$85,433	-$171,135	$464,047	-$5,432	$264,335
Cash Flow Year 14	$100,907	$83,514	-$129,346	$414,595	-$12,917	$254,384
Cash Flow Year 15	$99,329	$82,880	-$128,524	$446,829	-$6,699	$258,831
Cash Flow Year 16	$101,816	$88,112	-$127,244	$454,024	-$10,407	$261,438
Cash Flow Year 17	$98,609	$82,013	-$124,851	$450,531	-$9,578	$254,869
Cash Flow Year 18	$98,762	$80,998	-$126,003	$395,080	-$15,375	$239,310
Cash Flow Year 19	$97,185	$80,000	-$122,491	$390,521	-$18,068	$244,987
Cash Flow Year 20	$97,536	$91,395	-$147,207	$462,378	-$25,000	$265,347
Cash Flow Year 21	$96,375	$88,036	-$128,281	$478,384	-$36,142	$255,712
Cash Flow Year 22	$102,010	$86,244	-$133,390	$441,524	-$9,644	$263,668
Cash Flow Year 23	$100,128	$83,389	-$129,026	$518,886	-$14,718	$255,347
Cash Flow Year 24	$101,672	$86,078	-$130,545	$415,162	-$10,224	$260,006
Cash Flow Year 25	$99,191	$84,258	-$128,173	$471,448	-$11,997	$249,692
Cash Flow Year 26	$98,699	$83,949	-$128,795	$407,857	-$16,131	$253,558
Cash Flow Year 27	$98,850	$83,231	-$116,291	$472,108	-$12,425	$243,228
Cash Flow Year 28	$100,496	$87,549	-$138,050	$411,920	-$15,502	$263,136
Cash Flow Year 29	$98,301	$84,590	-$159,087	$406,212	-$12,937	$256,469
Cash Flow Year 30	$99,213	$83,931	-$135,937	$383,760	-$9,990	$259,609
Cash Flow Year 31	$98,896	$82,349	-$122,688	$467,010	-$11,026	$247,249
Cash Flow Year 32	$97,196	$83,101	-$129,625	$533,025	-$13,989	$246,834
Cash Flow Year 33	$97,409	$84,394	-$125,597	$459,969	-$13,857	$250,580
Cash Flow Year 34	$102,322	$85,210	-$126,404	$440,962	-$12,177	$256,898
Cash Flow Year 35	$100,060	$88,757	-$135,768	$434,402	-$13,937	$263,686
Cash Flow Year 36	$101,393	$88,421	-$125,102	$407,156	-$16,699	$269,293
Cash Flow Year 37	$96,867	$83,558	-$129,863	$392,515	-$17,738	$255,894
Cash Flow Year 38	$99,086	$86,999	-$133,346	$471,716	-$12,689	$259,645
Cash Flow Year 39	$99,850	$82,965	-$130,429	$423,823	-$7,472	$255,235
Cash Flow Year 40	$102,475	$87,247	-$132,085	$487,623	-$12,089	$262,768
40 Year NPV	$1,068,670	$294,803	$114,753	$1,905,144	$569,350	$1,571,119
Perpetuity NPV	$1,091,522	$295,291	$134,670	$1,942,920	$587,281	$1,593,721

Table J.49 – Summary statistics for farm representative of Black soil zone, with buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$266,169	$98,695	$29,069	$754,822	$131,977	$449,415
Cash Flow Year 2	$243,312	$95,877	-$110,325	$603,085	$108,933	$419,353
Cash Flow Year 3	$247,635	$94,537	$44,856	$707,792	$118,144	$424,454
Cash Flow Year 4	$265,102	$96,185	-$112,852	$683,724	$138,273	$440,257

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 5	$264,554	$92,876	-$109,755	$688,724	$145,882	$439,705
Cash Flow Year 6	$254,256	$93,093	$20,124	$656,522	$127,719	$436,576
Cash Flow Year 7	$249,532	$89,401	-$122,179	$718,712	$123,902	$404,255
Cash Flow Year 8	$252,490	$91,231	-$119,549	$686,266	$124,698	$413,696
Cash Flow Year 9	$262,868	$98,514	-$112,992	$646,075	$129,273	$443,036
Cash Flow Year 10	$263,618	$101,091	$47,932	$770,084	$128,151	$462,847
Cash Flow Year 11	$257,755	$94,599	$24,919	$577,609	$128,165	$442,427
Cash Flow Year 12	$251,405	$94,013	-$132,095	$641,053	$128,561	$419,929
Cash Flow Year 13	$256,774	$96,960	-$109,507	$667,073	$124,073	$444,363
Cash Flow Year 14	$258,514	$93,823	$31,624	$680,756	$130,235	$449,798
Cash Flow Year 15	$255,700	$94,268	$46,100	$644,663	$125,458	$437,176
Cash Flow Year 16	$259,742	$95,377	$46,261	$651,974	$134,157	$440,113
Cash Flow Year 17	$257,292	$95,421	$77,546	$645,283	$132,560	$440,135
Cash Flow Year 18	$254,741	$91,201	$31,161	$673,844	$130,327	$416,674
Cash Flow Year 19	$259,861	$98,888	$28,021	$779,844	$131,329	$441,670
Cash Flow Year 20	$257,677	$94,503	-$117,735	$718,644	$131,052	$429,321
Cash Flow Year 21	$257,828	$95,545	-$129,304	$595,395	$133,064	$441,990
Cash Flow Year 22	$254,275	$95,234	-$129,873	$646,477	$122,003	$427,511
Cash Flow Year 23	$250,504	$94,082	-$111,752	$632,671	$124,737	$435,748
Cash Flow Year 24	$258,420	$99,253	-$118,549	$571,213	$122,712	$455,909
Cash Flow Year 25	$257,913	$96,403	$34,288	$615,495	$123,969	$444,179
Cash Flow Year 26	$256,111	$93,425	$60,897	$635,062	$127,805	$426,321
Cash Flow Year 27	$254,448	$98,458	-$117,387	$736,167	$122,599	$430,459
Cash Flow Year 28	$254,243	$96,318	-$117,983	$719,291	$126,895	$441,965
Cash Flow Year 29	$256,058	$96,290	-$117,891	$684,431	$127,600	$433,765
Cash Flow Year 30	$257,432	$98,041	-$112,368	$699,977	$127,462	$444,113
Cash Flow Year 31	$254,821	$94,488	-$120,903	$617,954	$131,199	$437,629
Cash Flow Year 32	$259,264	$94,604	$44,982	$787,423	$132,510	$435,645
Cash Flow Year 33	$262,927	$96,968	-$131,822	$687,757	$135,442	$442,339
Cash Flow Year 34	$252,838	$90,842	-$119,561	$604,451	$130,567	$424,057
Cash Flow Year 35	$253,567	$97,028	-$115,510	$689,485	$123,975	$448,857
Cash Flow Year 36	$259,555	$99,616	$42,132	$704,584	$131,728	$443,298
Cash Flow Year 37	$259,665	$93,894	-$125,829	$664,421	$129,927	$439,881
Cash Flow Year 38	$259,504	$98,175	-$112,341	$677,237	$131,049	$450,909
Cash Flow Year 39	$253,757	$96,215	-$116,395	$728,511	$124,820	$427,933
Cash Flow Year 40	$256,124	$96,785	-$120,664	$650,293	$124,311	$452,826
40 Year NPV	$2,758,615	$326,658	$1,803,151	$3,884,848	$2,254,596	$3,333,241
Perpetuity NPV	$2,815,807	$327,866	$1,859,611	$3,973,721	$2,318,840	$3,400,835

Table J.50 – Summary statistics for farm representative of Dark Grey soil zone, with buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$227,397	$73,307	$75,418	$580,367	$125,944	$373,019
Cash Flow Year 2	$210,131	$70,638	$48,182	$476,578	$115,985	$343,327
Cash Flow Year 3	$211,036	$71,063	$59,799	$651,526	$116,305	$347,399
Cash Flow Year 4	$224,955	$68,120	$47,210	$493,180	$135,145	$353,697
Cash Flow Year 5	$222,480	$63,054	$26,483	$493,769	$136,400	$344,981
Cash Flow Year 6	$217,205	$65,548	$49,797	$573,445	$132,493	$338,564
Cash Flow Year 7	$212,704	$63,555	$52,635	$472,730	$125,275	$343,226
Cash Flow Year 8	$217,556	$65,975	$71,942	$470,060	$128,569	$349,388
Cash Flow Year 9	$221,715	$67,460	$67,025	$515,053	$130,816	$349,994
Cash Flow Year 10	$221,462	$68,918	$68,740	$545,541	$129,249	$352,253
Cash Flow Year 11	$218,372	$65,814	$60,254	$513,135	$128,708	$338,353
Cash Flow Year 12	$214,034	$65,535	$62,283	$534,711	$127,353	$336,498
Cash Flow Year 13	$217,789	$67,815	$21,508	$556,109	$126,024	$344,595
Cash Flow Year 14	$217,478	$65,695	$53,100	$545,963	$123,959	$339,896
Cash Flow Year 15	$216,198	$65,536	$28,208	$462,973	$128,194	$336,443
Cash Flow Year 16	$219,297	$62,835	$61,059	$475,846	$131,949	$333,418
Cash Flow Year 17	$220,269	$69,618	$76,056	$489,887	$128,163	$357,032
Cash Flow Year 18	$220,230	$68,746	$50,149	$514,677	$128,397	$355,060
Cash Flow Year 19	$219,164	$68,044	$61,703	$541,321	$132,251	$356,195
Cash Flow Year 20	$217,821	$67,193	$61,251	$503,347	$128,364	$350,322
Cash Flow Year 21	$218,141	$63,641	$75,840	$493,976	$126,844	$339,315
Cash Flow Year 22	$217,661	$65,681	$58,161	$451,006	$132,239	$343,776
Cash Flow Year 23	$216,363	$66,605	$14,325	$525,073	$127,562	$348,458
Cash Flow Year 24	$219,973	$68,952	$64,273	$588,634	$128,655	$355,200
Cash Flow Year 25	$221,042	$69,328	$67,519	$506,544	$127,213	$359,425
Cash Flow Year 26	$219,020	$67,140	$82,809	$468,853	$130,257	$348,391
Cash Flow Year 27	$218,195	$64,619	$73,664	$482,691	$129,915	$341,267
Cash Flow Year 28	$219,643	$68,429	$65,201	$506,189	$127,708	$357,059
Cash Flow Year 29	$220,135	$67,055	$55,313	$497,594	$131,521	$351,092
Cash Flow Year 30	$219,082	$65,800	$71,391	$628,040	$130,943	$351,876
Cash Flow Year 31	$216,379	$65,568	$70,806	$516,076	$125,946	$339,949
Cash Flow Year 32	$219,440	$67,752	$61,085	$540,243	$130,121	$351,912
Cash Flow Year 33	$221,322	$70,947	$64,324	$505,616	$122,592	$362,625
Cash Flow Year 34	$214,333	$62,562	$79,125	$470,936	$130,936	$339,307
Cash Flow Year 35	$214,569	$68,341	$47,949	$505,663	$128,303	$350,768
Cash Flow Year 36	$218,991	$68,599	$66,278	$534,008	$126,335	$344,913
Cash Flow Year 37	$219,889	$68,355	$51,865	$487,282	$125,628	$349,142
Cash Flow Year 38	$217,714	$68,598	$85,846	$509,109	$126,414	$347,392
Cash Flow Year 39	$217,548	$68,247	$66,174	$490,988	$128,452	$351,368
Cash Flow Year 40	$217,455	$68,983	$70,984	$597,993	$125,449	$350,433

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
40 Year NPV	$2,355,522	$227,019	$1,710,835	$3,131,601	$1,987,205	$2,714,549
Perpetuity NPV	$2,395,069	$227,822	$1,724,167	$3,171,836	$2,018,598	$2,758,431

Table J.51 – Summary statistics for farm representative of Brown soil zone, irrigated production, with residue management adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$286,600	$166,409	-$303,829	$892,879	$55,462	$598,072
Cash Flow Year 2	$195,222	$149,651	-$307,706	$853,105	$5,406	$465,392
Cash Flow Year 3	$184,961	$139,448	-$333,571	$746,058	$8,938	$455,435
Cash Flow Year 4	$231,248	$144,962	-$315,024	$1,005,907	$61,918	$513,722
Cash Flow Year 5	$250,591	$138,491	-$303,054	$812,567	$71,132	$500,016
Cash Flow Year 6	$244,903	$148,689	-$303,270	$821,443	$61,546	$516,749
Cash Flow Year 7	$232,105	$152,124	-$302,956	$816,697	$37,389	$524,092
Cash Flow Year 8	$224,317	$146,553	-$297,812	$894,428	$40,415	$489,435
Cash Flow Year 9	$234,087	$150,745	-$325,112	$866,937	$47,238	$515,972
Cash Flow Year 10	$241,016	$144,183	-$315,812	$974,464	$56,812	$507,978
Cash Flow Year 11	$235,734	$136,796	-$304,179	$769,785	$57,941	$476,726
Cash Flow Year 12	$230,420	$139,935	-$300,187	$886,720	$50,304	$498,135
Cash Flow Year 13	$230,703	$146,048	-$319,923	$771,458	$49,588	$522,969
Cash Flow Year 14	$232,507	$134,524	-$303,881	$711,350	$50,002	$474,506
Cash Flow Year 15	$231,504	$139,493	-$309,520	$880,834	$51,345	$509,940
Cash Flow Year 16	$230,300	$146,411	-$307,453	$940,137	$52,985	$515,833
Cash Flow Year 17	$228,780	$141,991	-$295,679	$824,303	$36,437	$509,803
Cash Flow Year 18	$229,800	$137,241	-$318,066	$860,306	$56,102	$489,048
Cash Flow Year 19	$236,809	$141,523	-$286,383	$808,373	$51,006	$510,518
Cash Flow Year 20	$227,810	$147,117	-$309,851	$1,044,565	$51,336	$497,609
Cash Flow Year 21	$227,116	$144,137	-$321,874	$1,010,678	$47,163	$497,659
Cash Flow Year 22	$224,454	$146,351	-$301,394	$952,703	$41,871	$494,034
Cash Flow Year 23	$232,717	$143,151	-$320,430	$847,607	$51,331	$503,942
Cash Flow Year 24	$237,911	$153,350	-$319,729	$857,455	$46,480	$518,168
Cash Flow Year 25	$235,382	$143,628	-$316,115	$811,349	$49,037	$497,109
Cash Flow Year 26	$235,488	$142,389	-$327,360	$870,757	$54,384	$496,687
Cash Flow Year 27	$233,516	$137,716	-$315,474	$819,459	$54,042	$488,028
Cash Flow Year 28	$229,696	$136,890	-$326,377	$887,052	$58,124	$481,234
Cash Flow Year 29	$231,886	$144,920	-$303,309	$1,011,406	$56,255	$504,537
Cash Flow Year 30	$226,312	$136,028	-$293,561	$808,801	$49,454	$481,929
Cash Flow Year 31	$227,382	$145,697	-$318,091	$901,576	$41,925	$487,295
Cash Flow Year 32	$234,565	$139,765	-$318,831	$849,833	$48,223	$482,612
Cash Flow Year 33	$240,582	$149,304	-$326,383	$910,260	$50,914	$542,474
Cash Flow Year 34	$235,420	$145,868	-$297,243	$811,358	$43,475	$514,885
Cash Flow Year 35	$234,504	$151,787	-$306,614	$923,392	$39,662	$506,213
Cash Flow Year 36	$234,615	$139,629	-$320,041	$908,870	$57,953	$497,879

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 37	$237,095	$151,466	-$309,435	$837,101	$48,933	$519,593
Cash Flow Year 38	$226,186	$136,190	-$317,401	$885,706	$44,055	$474,784
Cash Flow Year 39	$235,327	$142,945	-$310,367	$1,050,248	$55,966	$494,037
Cash Flow Year 40	$232,361	$141,775	-$310,585	$796,747	$52,718	$500,299
40 Year NPV	$2,533,312	$421,754	$1,255,068	$4,278,813	$1,843,146	$3,233,464
Perpetuity NPV	$2,582,058	$424,000	$1,375,758	$4,371,513	$1,874,316	$3,273,206

Table J.52 – Summary statistics for farm representative of Brown soil zone, dryland production, with residue management adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$93,526	$106,716	-$192,989	$544,018	-$67,939	$293,670
Cash Flow Year 2	$65,477	$104,363	-$140,255	$534,108	-$106,415	$265,060
Cash Flow Year 3	$67,470	$107,097	-$168,187	$615,055	-$107,677	$267,944
Cash Flow Year 4	$78,048	$98,862	-$176,400	$498,686	-$101,701	$263,837
Cash Flow Year 5	$85,245	$107,189	-$158,241	$577,560	-$103,533	$282,638
Cash Flow Year 6	$76,797	$106,412	-$149,090	$580,105	-$106,134	$279,077
Cash Flow Year 7	$75,181	$104,145	-$187,362	$573,201	-$105,660	$268,206
Cash Flow Year 8	$79,483	$102,338	-$157,412	$552,514	-$104,454	$275,558
Cash Flow Year 9	$83,800	$107,699	-$169,578	$540,114	-$102,298	$288,848
Cash Flow Year 10	$78,885	$102,715	-$180,401	$688,666	-$103,068	$263,342
Cash Flow Year 11	$75,354	$103,052	-$191,637	$528,706	-$106,873	$256,035
Cash Flow Year 12	$75,046	$100,997	-$157,059	$488,945	-$107,225	$258,650
Cash Flow Year 13	$82,650	$103,314	-$169,472	$537,999	-$104,521	$277,608
Cash Flow Year 14	$81,976	$102,605	-$176,992	$580,879	-$104,558	$270,798
Cash Flow Year 15	$75,667	$103,047	-$174,698	$461,247	-$103,937	$279,044
Cash Flow Year 16	$71,346	$100,169	-$149,601	$525,853	-$104,813	$257,464
Cash Flow Year 17	$75,626	$106,277	-$164,676	$558,088	-$106,111	$269,294
Cash Flow Year 18	$82,495	$104,700	-$139,281	$570,746	-$104,456	$280,364
Cash Flow Year 19	$80,210	$103,752	-$130,435	$611,344	-$105,293	$266,706
Cash Flow Year 20	$74,555	$105,195	-$205,440	$551,968	-$106,469	$264,112
Cash Flow Year 21	$74,411	$103,004	-$201,027	$442,015	-$103,700	$279,942
Cash Flow Year 22	$77,139	$101,738	-$157,350	$574,720	-$102,807	$268,649
Cash Flow Year 23	$82,710	$104,520	-$131,898	$494,250	-$102,106	$281,276
Cash Flow Year 24	$75,725	$106,791	-$180,460	$587,500	-$106,232	$256,790
Cash Flow Year 25	$74,237	$102,902	-$185,442	$507,141	-$106,591	$269,067
Cash Flow Year 26	$76,490	$102,344	-$170,970	$455,206	-$104,968	$253,772
Cash Flow Year 27	$76,781	$100,928	-$129,837	$556,902	-$101,512	$261,677
Cash Flow Year 28	$81,886	$105,257	-$138,254	$605,553	-$102,953	$279,199
Cash Flow Year 29	$77,996	$101,728	-$156,438	$537,905	-$102,705	$256,759
Cash Flow Year 30	$76,934	$102,309	-$169,464	$492,370	-$104,100	$272,245
Cash Flow Year 31	$76,418	$105,384	-$172,470	$586,602	-$107,282	$260,752
Cash Flow Year 32	$73,492	$101,479	-$169,041	$571,516	-$104,686	$255,517

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 33	$80,301	$107,609	-$179,597	$683,405	-$103,852	$274,423
Cash Flow Year 34	$82,145	$110,336	-$147,021	$573,940	-$103,728	$282,780
Cash Flow Year 35	$75,960	$106,452	-$167,088	$536,807	-$106,516	$272,856
Cash Flow Year 36	$74,072	$100,813	-$145,044	$492,556	-$106,399	$257,544
Cash Flow Year 37	$72,988	$104,726	-$164,474	$535,898	-$106,467	$268,654
Cash Flow Year 38	$81,441	$109,558	-$156,127	$606,228	-$105,061	$294,229
Cash Flow Year 39	$83,377	$106,290	-$143,332	$486,483	-$101,807	$277,038
Cash Flow Year 40	$81,590	$104,013	-$183,408	$615,866	-$105,745	$271,982
40 Year NPV	$846,826	$342,877	-$331,711	$1,858,247	$280,400	$1,418,450
Perpetuity NPV	$864,268	$343,732	-$321,627	$1,913,617	$301,775	$1,434,410

Table J.53 – Summary statistics for farm representative of Dark Brown soil zone, with residue management adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$110,723	$88,814	-$121,170	$455,784	-$6,370	$269,222
Cash Flow Year 2	$95,975	$87,557	-$131,397	$475,800	-$15,386	$256,560
Cash Flow Year 3	$87,204	$84,760	-$125,194	$434,413	-$39,702	$233,276
Cash Flow Year 4	$108,779	$88,089	-$126,362	$468,347	-$2,715	$273,306
Cash Flow Year 5	$106,746	$83,302	-$132,067	$484,104	-$8,729	$254,723
Cash Flow Year 6	$109,303	$87,549	-$131,940	$405,579	-$5,834	$267,991
Cash Flow Year 7	$99,612	$88,692	-$139,582	$426,666	-$15,965	$261,784
Cash Flow Year 8	$100,807	$90,923	-$136,022	$546,750	-$23,543	$265,486
Cash Flow Year 9	$101,433	$83,237	-$133,871	$465,844	-$6,544	$248,876
Cash Flow Year 10	$113,401	$85,682	-$139,768	$432,663	$1,840	$276,626
Cash Flow Year 11	$103,319	$87,236	-$128,423	$422,909	-$14,554	$258,703
Cash Flow Year 12	$108,639	$87,948	-$131,093	$438,196	-$8,903	$277,871
Cash Flow Year 13	$103,327	$85,767	-$173,518	$472,625	-$3,183	$265,974
Cash Flow Year 14	$109,948	$85,831	-$127,136	$434,002	-$4,441	$271,474
Cash Flow Year 15	$101,261	$83,173	-$130,035	$448,218	-$6,459	$260,175
Cash Flow Year 16	$108,422	$90,540	-$127,663	$469,490	-$9,228	$270,398
Cash Flow Year 17	$100,657	$81,873	-$125,753	$454,764	-$7,646	$256,215
Cash Flow Year 18	$107,299	$83,679	-$124,617	$413,422	-$7,238	$253,169
Cash Flow Year 19	$98,602	$80,035	-$123,769	$394,113	-$20,143	$243,656
Cash Flow Year 20	$104,513	$92,618	-$147,846	$477,885	-$14,530	$276,871
Cash Flow Year 21	$97,885	$88,564	-$129,352	$482,967	-$38,138	$258,519
Cash Flow Year 22	$110,778	$88,975	-$133,104	$468,081	-$3,908	$280,536
Cash Flow Year 23	$101,678	$83,256	-$130,395	$523,499	-$12,740	$252,660
Cash Flow Year 24	$108,384	$88,176	-$130,341	$428,048	-$4,911	$264,917
Cash Flow Year 25	$100,929	$84,875	-$129,085	$474,992	-$18,925	$252,403
Cash Flow Year 26	$108,302	$85,467	-$128,573	$424,984	-$7,420	$268,508
Cash Flow Year 27	$100,394	$83,332	-$117,121	$475,385	-$11,707	$244,084
Cash Flow Year 28	$107,567	$89,024	-$138,592	$427,641	-$7,293	$275,228

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 29	$99,907	$84,566	-$160,200	$404,304	-$12,064	$258,848
Cash Flow Year 30	$108,912	$85,884	-$131,920	$403,565	-$1,555	$272,601
Cash Flow Year 31	$100,291	$82,585	-$124,169	$471,155	-$9,801	$248,408
Cash Flow Year 32	$103,950	$84,672	-$129,145	$549,111	-$7,972	$255,874
Cash Flow Year 33	$99,238	$84,270	-$126,656	$463,834	-$12,699	$253,487
Cash Flow Year 34	$110,860	$87,984	-$125,297	$462,120	-$4,197	$271,673
Cash Flow Year 35	$101,496	$89,257	-$137,039	$438,096	-$16,708	$264,733
Cash Flow Year 36	$108,188	$89,895	-$124,199	$421,712	-$7,675	$279,071
Cash Flow Year 37	$98,274	$84,426	-$131,241	$397,384	-$20,265	$258,943
Cash Flow Year 38	$108,444	$88,707	-$130,836	$489,784	-$4,726	$275,382
Cash Flow Year 39	$101,577	$82,733	-$131,477	$427,185	-$5,328	$257,305
Cash Flow Year 40	$108,993	$89,757	-$130,752	$505,508	-$7,444	$271,687
40 Year NPV	$1,110,275	$295,928	$141,908	$1,945,717	$609,996	$1,615,207
Perpetuity NPV	$1,133,498	$296,407	$162,077	$1,993,569	$627,258	$1,643,832

Table J.54 – Summary statistics for farm representative of Black soil zone, with residue management adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$272,617	$102,450	$30,203	$772,765	$134,847	$461,863
Cash Flow Year 2	$255,483	$99,844	$37,349	$630,183	$113,189	$439,180
Cash Flow Year 3	$246,321	$92,756	$47,820	$716,041	$119,551	$425,734
Cash Flow Year 4	$268,847	$96,897	-$112,711	$700,344	$141,214	$444,386
Cash Flow Year 5	$277,136	$96,441	$18,337	$714,491	$154,785	$460,549
Cash Flow Year 6	$254,474	$90,511	$27,648	$664,059	$132,129	$431,686
Cash Flow Year 7	$253,024	$90,129	-$123,587	$761,687	$132,498	$416,292
Cash Flow Year 8	$264,069	$95,532	-$116,585	$719,952	$135,748	$434,826
Cash Flow Year 9	$262,230	$96,301	-$113,981	$653,507	$133,949	$440,963
Cash Flow Year 10	$268,233	$100,879	$50,535	$738,395	$132,782	$471,473
Cash Flow Year 11	$269,238	$98,490	$31,846	$596,207	$135,514	$465,910
Cash Flow Year 12	$251,242	$91,725	-$134,403	$659,301	$135,636	$418,057
Cash Flow Year 13	$260,633	$97,358	-$110,829	$678,225	$130,655	$445,551
Cash Flow Year 14	$270,142	$98,989	$47,009	$720,946	$136,445	$470,755
Cash Flow Year 15	$255,724	$92,529	$50,635	$656,269	$130,576	$434,786
Cash Flow Year 16	$264,405	$96,536	$51,789	$678,448	$135,897	$451,205
Cash Flow Year 17	$268,486	$100,302	$79,209	$669,227	$139,674	$456,980
Cash Flow Year 18	$254,753	$89,073	$37,089	$680,835	$133,596	$417,169
Cash Flow Year 19	$264,636	$100,224	-$117,503	$799,780	$138,123	$449,202
Cash Flow Year 20	$269,062	$97,981	$49,030	$721,417	$137,560	$454,513
Cash Flow Year 21	$257,252	$93,284	-$130,096	$608,816	$135,389	$441,110
Cash Flow Year 22	$257,257	$94,101	-$130,489	$635,978	$129,566	$428,766
Cash Flow Year 23	$262,181	$98,106	$22,794	$666,899	$128,999	$448,596
Cash Flow Year 24	$257,866	$96,604	-$120,139	$589,960	$128,197	$446,050

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 25	$262,545	$96,487	$27,726	$617,766	$129,301	$451,235
Cash Flow Year 26	$267,684	$97,501	$71,604	$648,649	$134,873	$446,489
Cash Flow Year 27	$253,872	$96,221	-$118,324	$734,435	$125,400	$425,530
Cash Flow Year 28	$258,965	$97,790	-$117,995	$737,434	$127,460	$452,056
Cash Flow Year 29	$267,639	$100,321	-$114,647	$703,313	$136,115	$459,034
Cash Flow Year 30	$257,359	$96,552	-$113,277	$709,068	$126,967	$445,202
Cash Flow Year 31	$258,563	$93,972	-$121,214	$633,585	$134,379	$432,486
Cash Flow Year 32	$270,806	$98,732	$52,828	$826,374	$138,859	$459,125
Cash Flow Year 33	$262,538	$95,824	-$135,212	$710,800	$141,924	$442,349
Cash Flow Year 34	$257,257	$92,752	-$120,009	$611,669	$133,285	$436,596
Cash Flow Year 35	$265,771	$101,120	-$113,111	$720,709	$136,609	$474,284
Cash Flow Year 36	$259,473	$96,996	$53,984	$712,542	$133,441	$434,418
Cash Flow Year 37	$263,935	$95,145	-$125,842	$699,352	$133,491	$448,021
Cash Flow Year 38	$271,978	$102,051	$36,749	$709,986	$141,220	$472,355
Cash Flow Year 39	$253,200	$93,233	-$118,391	$690,234	$127,614	$420,812
Cash Flow Year 40	$259,867	$97,914	-$120,280	$663,789	$128,297	$452,328
40 Year NPV	$2,812,407	$317,359	$1,880,456	$3,972,657	$2,326,190	$3,382,526
Perpetuity NPV	$2,872,261	$318,774	$1,941,824	$4,070,242	$2,392,323	$3,438,136

Table J.55 – Summary statistics for farm representative of Dark Grey soil zone, with residue management adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$233,156	$76,315	$81,127	$593,626	$127,206	$384,802
Cash Flow Year 2	$217,608	$73,270	$50,434	$492,351	$118,981	$356,707
Cash Flow Year 3	$208,619	$68,656	$64,677	$640,150	$116,141	$345,462
Cash Flow Year 4	$228,418	$68,869	$53,010	$505,664	$136,657	$363,196
Cash Flow Year 5	$229,634	$65,459	$34,609	$509,629	$139,579	$355,943
Cash Flow Year 6	$215,399	$62,162	$55,271	$521,573	$135,374	$333,475
Cash Flow Year 7	$216,092	$65,029	$56,250	$486,257	$129,640	$344,993
Cash Flow Year 8	$224,759	$68,383	$89,276	$481,813	$133,085	$365,238
Cash Flow Year 9	$218,919	$65,171	$72,625	$489,603	$132,347	$343,369
Cash Flow Year 10	$224,157	$69,260	$74,230	$569,136	$133,754	$358,018
Cash Flow Year 11	$225,640	$68,868	$66,780	$531,451	$134,329	$350,950
Cash Flow Year 12	$212,016	$63,425	$65,273	$517,733	$128,846	$327,458
Cash Flow Year 13	$220,493	$67,560	$35,067	$570,394	$129,680	$347,313
Cash Flow Year 14	$224,183	$68,131	$61,459	$556,363	$130,930	$352,608
Cash Flow Year 15	$214,521	$63,204	$27,470	$463,988	$130,383	$330,551
Cash Flow Year 16	$223,494	$64,918	$67,295	$492,538	$137,490	$345,027
Cash Flow Year 17	$227,600	$72,258	$78,197	$506,491	$130,296	$369,796
Cash Flow Year 18	$217,962	$66,253	$51,331	$491,793	$130,147	$349,847
Cash Flow Year 19	$222,537	$69,447	$73,545	$517,663	$134,029	$361,288
Cash Flow Year 20	$224,589	$69,558	$67,869	$506,342	$132,120	$360,104

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 21	$216,186	$60,794	$72,169	$495,944	$128,196	$332,728
Cash Flow Year 22	$221,202	$66,958	$65,514	$463,386	$136,260	$352,300
Cash Flow Year 23	$223,137	$69,421	$14,041	$555,420	$130,841	$364,308
Cash Flow Year 24	$217,633	$66,521	$67,536	$598,792	$127,376	$348,385
Cash Flow Year 25	$223,774	$70,167	$71,367	$519,030	$130,069	$358,775
Cash Flow Year 26	$226,022	$69,983	$85,453	$480,947	$131,591	$360,618
Cash Flow Year 27	$216,303	$62,320	$68,410	$449,513	$129,489	$334,848
Cash Flow Year 28	$222,329	$69,421	$71,930	$527,916	$130,000	$356,726
Cash Flow Year 29	$226,570	$69,599	$70,113	$488,394	$134,911	$363,830
Cash Flow Year 30	$216,777	$63,744	$76,504	$621,761	$131,070	$342,939
Cash Flow Year 31	$219,104	$66,675	$78,622	$494,573	$129,460	$346,025
Cash Flow Year 32	$226,499	$70,762	$66,429	$556,591	$133,461	$363,040
Cash Flow Year 33	$219,119	$68,644	$67,294	$511,715	$125,107	$355,349
Cash Flow Year 34	$217,958	$63,567	$81,508	$483,522	$133,417	$342,525
Cash Flow Year 35	$221,406	$71,432	$54,671	$530,947	$130,534	$362,241
Cash Flow Year 36	$216,720	$66,036	$69,720	$530,138	$126,948	$343,157
Cash Flow Year 37	$223,091	$69,514	$57,354	$506,213	$131,310	$355,159
Cash Flow Year 38	$224,447	$71,118	$87,352	$524,798	$129,972	$358,332
Cash Flow Year 39	$215,303	$65,785	$68,064	$484,058	$130,009	$343,690
Cash Flow Year 40	$220,748	$70,804	$71,456	$618,388	$127,303	$360,176
40 Year NPV	$2,386,257	$223,732	$1,756,073	$3,107,583	$2,029,381	$2,750,557
Perpetuity NPV	$2,427,078	$224,770	$1,770,596	$3,147,285	$2,069,084	$2,795,625

Table J.56 – Summary statistics for farm representative of Brown soil zone, irrigated production, with shelterbelt and buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$261,768	$160,303	-$310,670	$853,533	$39,364	$560,992
Cash Flow Year 2	$173,159	$143,333	-$314,646	$793,293	-$13,853	$425,402
Cash Flow Year 3	$156,817	$136,347	-$331,325	$692,575	-$11,349	$410,297
Cash Flow Year 4	$197,580	$139,833	-$322,534	$930,039	$38,616	$462,080
Cash Flow Year 5	$210,632	$131,670	-$308,004	$739,474	$45,479	$441,824
Cash Flow Year 6	$201,265	$141,143	-$302,365	$742,596	$32,219	$454,263
Cash Flow Year 7	$181,989	$146,294	-$306,461	$727,129	$203	$455,183
Cash Flow Year 8	$175,825	$138,524	-$299,806	$785,927	$994	$420,259
Cash Flow Year 9	$186,284	$143,017	-$321,579	$777,834	$9,158	$448,145
Cash Flow Year 10	$196,578	$135,528	-$314,909	$880,004	$23,885	$445,800
Cash Flow Year 11	$191,607	$128,578	-$301,966	$700,170	$21,641	$421,136
Cash Flow Year 12	$189,704	$134,143	-$297,788	$798,702	$17,851	$447,772
Cash Flow Year 13	$189,972	$138,501	-$315,527	$695,347	$20,410	$463,254
Cash Flow Year 14	$195,394	$128,667	-$297,659	$673,919	$21,603	$423,565
Cash Flow Year 15	$194,349	$130,720	-$304,695	$798,477	$24,035	$456,621
Cash Flow Year 16	$195,233	$137,973	-$301,203	$857,136	$25,339	$462,083

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 17	$193,451	$132,764	-$290,428	$748,144	$13,093	$453,833
Cash Flow Year 18	$195,438	$130,919	-$314,892	$773,190	$30,758	$436,719
Cash Flow Year 19	$201,882	$132,742	-$283,682	$733,806	$31,331	$457,037
Cash Flow Year 20	$196,034	$137,802	-$303,422	$943,967	$28,848	$447,708
Cash Flow Year 21	$193,884	$133,911	-$316,225	$920,843	$25,394	$444,974
Cash Flow Year 22	$192,727	$137,460	-$296,705	$836,625	$20,973	$444,994
Cash Flow Year 23	$198,664	$134,638	-$314,891	$770,202	$28,580	$453,931
Cash Flow Year 24	$205,617	$144,325	-$314,919	$783,928	$24,493	$465,649
Cash Flow Year 25	$202,268	$134,605	-$310,396	$741,686	$26,765	$444,886
Cash Flow Year 26	$204,155	$134,119	-$321,539	$793,762	$33,524	$451,786
Cash Flow Year 27	$201,032	$128,993	-$310,306	$745,726	$35,164	$437,198
Cash Flow Year 28	$199,439	$129,216	-$319,430	$811,445	$34,382	$436,057
Cash Flow Year 29	$200,470	$134,597	-$297,785	$927,714	$34,671	$452,855
Cash Flow Year 30	$196,563	$127,713	-$288,633	$738,668	$28,386	$431,816
Cash Flow Year 31	$196,135	$136,342	-$311,789	$823,606	$24,460	$438,284
Cash Flow Year 32	$204,658	$132,053	-$304,214	$771,216	$30,013	$433,287
Cash Flow Year 33	$208,784	$140,336	-$320,416	$834,437	$36,882	$486,747
Cash Flow Year 34	$206,072	$137,089	-$290,181	$732,983	$26,447	$462,396
Cash Flow Year 35	$203,800	$141,135	-$299,630	$842,389	$22,565	$455,943
Cash Flow Year 36	$205,598	$130,880	-$313,197	$837,281	$38,891	$459,554
Cash Flow Year 37	$205,906	$141,789	-$303,236	$766,092	$30,146	$473,961
Cash Flow Year 38	$198,097	$127,265	-$312,347	$808,437	$26,335	$430,181
Cash Flow Year 39	$204,615	$133,024	-$305,695	$962,375	$32,978	$441,128
Cash Flow Year 40	$203,341	$131,957	-$304,822	$729,907	$35,297	$456,351
40 Year NPV	$2,182,966	$410,290	$967,588	$3,913,888	$1,513,407	$2,845,083
Perpetuity NPV	$2,223,964	$412,282	$1,033,187	$3,994,905	$1,549,818	$2,887,611

Table J.57 – Summary statistics for farm representative of Brown soil zone, dryland production, with shelterbelt and buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$81,944	$104,471	-$201,864	$521,102	-$101,924	$275,584
Cash Flow Year 2	$52,039	$102,003	-$151,769	$521,751	-$111,161	$245,905
Cash Flow Year 3	$42,651	$103,009	-$181,594	$557,673	-$113,140	$228,436
Cash Flow Year 4	$52,022	$96,062	-$191,167	$447,718	-$109,824	$224,994
Cash Flow Year 5	$54,291	$103,302	-$178,208	$512,429	-$109,658	$238,090
Cash Flow Year 6	$43,276	$102,470	-$166,402	$510,296	-$112,965	$231,939
Cash Flow Year 7	$40,818	$99,142	-$201,245	$512,436	-$111,621	$219,027
Cash Flow Year 8	$36,821	$95,794	-$183,883	$465,098	-$112,594	$214,389
Cash Flow Year 9	$52,108	$100,598	-$161,646	$469,733	-$105,347	$239,126
Cash Flow Year 10	$51,416	$94,801	-$171,675	$610,816	-$103,656	$223,242
Cash Flow Year 11	$52,624	$96,730	-$186,723	$469,457	-$104,580	$221,705
Cash Flow Year 12	$55,558	$94,211	-$173,839	$436,946	-$104,204	$229,521

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 13	$60,535	$94,634	-$187,582	$467,910	-$102,387	$241,627
Cash Flow Year 14	$65,693	$94,199	-$166,925	$512,857	-$100,377	$239,680
Cash Flow Year 15	$61,628	$94,635	-$164,422	$413,561	-$100,009	$248,870
Cash Flow Year 16	$60,481	$92,211	-$168,944	$472,209	-$99,992	$231,121
Cash Flow Year 17	$65,135	$97,417	-$155,915	$504,457	-$101,204	$245,006
Cash Flow Year 18	$66,262	$94,369	-$136,425	$504,167	-$101,188	$242,769
Cash Flow Year 19	$66,949	$94,103	-$123,576	$545,786	-$100,813	$236,581
Cash Flow Year 20	$62,233	$95,959	-$192,541	$494,493	-$101,881	$238,957
Cash Flow Year 21	$64,415	$94,572	-$187,389	$399,915	-$98,953	$252,214
Cash Flow Year 22	$67,056	$93,247	-$171,395	$518,315	-$98,238	$241,581
Cash Flow Year 23	$66,629	$94,030	-$126,251	$435,384	-$98,569	$243,259
Cash Flow Year 24	$62,799	$97,473	-$170,726	$524,012	-$101,866	$227,619
Cash Flow Year 25	$62,291	$93,795	-$175,364	$459,381	-$102,350	$240,288
Cash Flow Year 26	$66,030	$94,099	-$159,846	$412,071	-$100,117	$233,965
Cash Flow Year 27	$66,389	$92,926	-$122,962	$504,541	-$96,963	$237,203
Cash Flow Year 28	$65,673	$94,849	-$130,951	$537,948	-$99,579	$240,154
Cash Flow Year 29	$65,108	$92,357	-$148,212	$476,194	-$98,658	$228,050
Cash Flow Year 30	$64,622	$93,189	-$160,523	$441,306	-$100,138	$240,862
Cash Flow Year 31	$66,246	$96,914	-$162,562	$532,562	-$101,962	$234,668
Cash Flow Year 32	$63,685	$93,025	-$158,558	$521,682	-$99,742	$233,095
Cash Flow Year 33	$64,395	$96,962	-$170,516	$608,314	-$100,676	$236,036
Cash Flow Year 34	$68,982	$100,199	-$141,033	$511,797	-$99,726	$249,570
Cash Flow Year 35	$64,299	$97,034	-$158,283	$479,177	-$101,829	$244,619
Cash Flow Year 36	$64,164	$92,458	-$136,637	$446,723	-$101,407	$233,414
Cash Flow Year 37	$63,364	$95,864	-$132,287	$485,767	-$101,112	$241,963
Cash Flow Year 38	$65,609	$99,016	-$148,515	$536,698	-$101,551	$260,256
Cash Flow Year 39	$69,642	$96,606	-$136,410	$430,603	-$97,848	$243,351
Cash Flow Year 40	$69,067	$94,859	-$172,430	$553,745	-$101,372	$241,253
40 Year NPV	$634,108	$336,124	-$498,066	$1,641,670	$88,308	$1,193,416
Perpetuity NPV	$648,847	$336,682	-$490,456	$1,690,580	$95,296	$1,204,338

Table J.58 – Summary statistics for farm representative of Dark Brown soil zone, with shelterbelt and buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$101,716	$87,101	-$123,744	$437,760	-$14,379	$254,444
Cash Flow Year 2	$77,105	$82,782	-$147,666	$436,508	-$35,207	$226,031
Cash Flow Year 3	$71,958	$82,893	-$128,148	$405,348	-$105,610	$210,802
Cash Flow Year 4	$84,827	$83,903	-$130,372	$416,813	-$31,689	$236,591
Cash Flow Year 5	$84,300	$80,571	-$135,315	$441,865	-$39,108	$221,915
Cash Flow Year 6	$73,932	$84,478	-$135,902	$345,588	-$103,995	$220,849
Cash Flow Year 7	$71,015	$85,993	-$141,846	$378,413	-$104,240	$224,707
Cash Flow Year 8	$66,018	$85,927	-$138,692	$470,751	-$104,170	$218,443

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 9	$77,496	$80,203	-$132,665	$421,150	-$35,204	$218,911
Cash Flow Year 10	$83,800	$81,289	-$137,973	$380,812	-$23,321	$238,680
Cash Flow Year 11	$83,735	$84,219	-$125,551	$385,954	-$30,259	$233,989
Cash Flow Year 12	$86,130	$82,886	-$135,907	$394,299	-$26,699	$247,890
Cash Flow Year 13	$88,016	$82,016	-$166,479	$433,860	-$15,716	$244,568
Cash Flow Year 14	$90,640	$79,822	-$124,788	$388,461	-$19,422	$237,472
Cash Flow Year 15	$89,711	$78,876	-$123,880	$418,125	-$9,654	$241,270
Cash Flow Year 16	$93,083	$83,557	-$122,973	$423,134	-$14,934	$244,159
Cash Flow Year 17	$90,586	$77,497	-$120,323	$423,190	-$12,212	$238,507
Cash Flow Year 18	$91,334	$76,385	-$121,581	$372,888	-$16,148	$224,456
Cash Flow Year 19	$89,987	$75,716	-$118,255	$367,594	-$18,951	$229,622
Cash Flow Year 20	$90,569	$86,333	-$141,716	$431,847	-$23,715	$249,146
Cash Flow Year 21	$89,755	$82,980	-$123,700	$451,929	-$30,811	$239,640
Cash Flow Year 22	$95,036	$81,668	-$128,395	$415,432	-$10,909	$248,298
Cash Flow Year 23	$93,677	$78,592	-$123,602	$489,421	-$14,490	$238,968
Cash Flow Year 24	$95,033	$81,589	-$125,491	$391,613	-$11,160	$245,714
Cash Flow Year 25	$93,001	$79,641	-$123,483	$438,249	-$10,999	$236,526
Cash Flow Year 26	$93,015	$78,864	-$124,008	$386,985	-$14,696	$239,094
Cash Flow Year 27	$93,379	$78,184	-$112,032	$445,058	-$10,048	$229,337
Cash Flow Year 28	$95,037	$82,271	-$132,995	$387,452	-$10,496	$248,729
Cash Flow Year 29	$92,916	$79,927	-$151,435	$385,381	-$12,714	$243,486
Cash Flow Year 30	$93,994	$79,214	-$129,062	$364,212	-$9,301	$244,763
Cash Flow Year 31	$93,324	$78,224	-$118,438	$442,738	-$11,383	$233,767
Cash Flow Year 32	$92,129	$78,553	-$124,535	$499,866	-$11,301	$234,071
Cash Flow Year 33	$92,756	$79,186	-$120,959	$438,007	-$10,637	$238,024
Cash Flow Year 34	$97,095	$80,549	-$121,507	$417,811	-$9,689	$244,443
Cash Flow Year 35	$95,083	$83,759	-$130,570	$412,475	-$12,823	$249,189
Cash Flow Year 36	$96,507	$83,102	-$120,089	$381,756	-$13,503	$255,475
Cash Flow Year 37	$91,747	$79,419	-$125,019	$373,448	-$17,029	$243,204
Cash Flow Year 38	$94,469	$81,644	-$127,649	$447,231	-$10,190	$246,862
Cash Flow Year 39	$94,665	$78,566	-$125,438	$401,624	-$8,336	$242,331
Cash Flow Year 40	$97,076	$82,702	-$125,326	$461,232	-$11,373	$248,346
40 Year NPV	$920,964	$289,996	$13,547	$1,758,581	$441,784	$1,409,088
Perpetuity NPV	$942,688	$290,370	$32,399	$1,765,782	$458,351	$1,429,083

Table J.59 – Summary statistics for farm representative of Black soil zone, with shelterbelt and buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$260,960	$96,315	$41,861	$743,601	$127,970	$440,244
Cash Flow Year 2	$235,322	$92,814	-$112,705	$587,708	$105,444	$405,634
Cash Flow Year 3	$236,839	$90,867	$37,266	$685,258	$112,249	$407,373
Cash Flow Year 4	$250,925	$92,594	-$115,579	$654,946	$129,326	$418,566

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 5	$247,571	$88,214	-$112,520	$654,330	$135,573	$413,219
Cash Flow Year 6	$234,428	$87,755	$6,903	$616,593	$114,726	$404,967
Cash Flow Year 7	$225,863	$85,758	-$124,414	$670,755	$107,349	$370,470
Cash Flow Year 8	$226,085	$86,844	-$121,521	$634,413	$105,650	$376,153
Cash Flow Year 9	$238,100	$93,796	-$113,281	$601,119	$111,336	$408,917
Cash Flow Year 10	$238,837	$96,137	$32,293	$718,467	$109,932	$428,009
Cash Flow Year 11	$233,198	$89,989	$11,458	$536,169	$109,592	$408,885
Cash Flow Year 12	$227,759	$89,358	-$130,227	$596,771	$110,897	$387,895
Cash Flow Year 13	$233,393	$92,637	-$108,305	$621,038	$107,250	$411,922
Cash Flow Year 14	$236,257	$88,970	$22,901	$635,265	$113,838	$417,506
Cash Flow Year 15	$233,611	$89,143	$36,392	$601,499	$110,437	$404,939
Cash Flow Year 16	$237,275	$89,904	$36,185	$606,756	$119,036	$406,814
Cash Flow Year 17	$235,055	$89,732	$65,698	$600,071	$116,938	$406,582
Cash Flow Year 18	$232,563	$85,529	$21,906	$627,004	$117,446	$384,076
Cash Flow Year 19	$236,430	$94,027	-$110,584	$727,626	$116,292	$407,086
Cash Flow Year 20	$234,149	$89,288	-$116,241	$666,397	$114,876	$395,248
Cash Flow Year 21	$234,179	$89,480	-$127,058	$549,847	$117,131	$406,428
Cash Flow Year 22	$230,532	$89,171	-$127,631	$599,010	$107,327	$392,091
Cash Flow Year 23	$226,428	$88,924	-$110,511	$584,113	$109,375	$399,978
Cash Flow Year 24	$233,601	$92,836	-$117,103	$525,634	$105,472	$417,260
Cash Flow Year 25	$232,741	$90,053	$22,734	$566,238	$107,378	$406,247
Cash Flow Year 26	$230,753	$87,119	$47,949	$584,482	$110,662	$389,479
Cash Flow Year 27	$228,868	$91,882	-$115,959	$679,065	$105,313	$393,043
Cash Flow Year 28	$228,293	$89,881	-$116,566	$663,387	$108,650	$402,671
Cash Flow Year 29	$229,567	$89,767	-$116,883	$629,569	$109,540	$394,948
Cash Flow Year 30	$230,543	$91,823	-$111,526	$645,949	$109,570	$404,655
Cash Flow Year 31	$227,677	$89,199	-$119,588	$565,794	$111,802	$397,979
Cash Flow Year 32	$231,974	$88,243	$31,822	$723,787	$113,809	$396,607
Cash Flow Year 33	$235,234	$90,389	-$129,868	$631,213	$114,784	$401,238
Cash Flow Year 34	$225,487	$85,383	-$118,493	$556,330	$111,089	$385,335
Cash Flow Year 35	$226,066	$91,016	-$114,549	$631,521	$104,762	$408,385
Cash Flow Year 36	$231,920	$93,034	$28,129	$660,453	$111,738	$404,204
Cash Flow Year 37	$231,925	$87,544	-$124,330	$608,834	$111,268	$401,127
Cash Flow Year 38	$231,783	$91,696	-$111,676	$620,633	$111,532	$409,923
Cash Flow Year 39	$226,360	$90,238	-$115,336	$668,585	$106,539	$389,183
Cash Flow Year 40	$228,599	$90,332	-$119,576	$596,573	$105,187	$412,029
40 Year NPV	$2,576,145	$319,970	$1,669,388	$3,715,404	$2,077,718	$3,140,735
Perpetuity NPV	$2,625,799	$321,009	$1,717,828	$3,794,237	$2,138,502	$3,195,104

Table J.60 – Summary statistics for farm representative of Dark Grey soil zone, with shelterbelt and buffer strip adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$224,781	$71,950	$71,752	$573,823	$124,707	$368,420
Cash Flow Year 2	$205,896	$68,981	$55,010	$468,827	$114,577	$336,140
Cash Flow Year 3	$205,331	$69,300	$56,256	$638,807	$113,377	$338,363
Cash Flow Year 4	$217,705	$65,727	$42,881	$479,034	$130,759	$342,224
Cash Flow Year 5	$213,616	$60,615	$21,743	$476,917	$130,843	$331,225
Cash Flow Year 6	$206,494	$62,935	$43,087	$551,467	$123,964	$322,456
Cash Flow Year 7	$200,261	$60,737	$44,239	$451,024	$115,761	$324,853
Cash Flow Year 8	$203,671	$62,954	$64,190	$445,730	$118,586	$329,305
Cash Flow Year 9	$208,534	$65,135	$58,741	$491,565	$121,002	$332,156
Cash Flow Year 10	$208,230	$66,648	$60,121	$521,109	$119,012	$334,708
Cash Flow Year 11	$205,324	$63,763	$51,149	$489,722	$119,258	$321,828
Cash Flow Year 12	$201,369	$63,408	$55,240	$511,160	$117,531	$319,595
Cash Flow Year 13	$205,410	$65,702	$21,527	$532,112	$116,359	$328,099
Cash Flow Year 14	$205,702	$63,542	$47,179	$522,628	$116,591	$323,954
Cash Flow Year 15	$204,444	$63,239	$23,452	$442,604	$119,832	$320,323
Cash Flow Year 16	$207,461	$60,449	$55,113	$454,586	$123,128	$317,572
Cash Flow Year 17	$208,340	$66,939	$69,254	$467,695	$119,842	$339,999
Cash Flow Year 18	$208,217	$66,060	$44,394	$491,032	$119,984	$338,193
Cash Flow Year 19	$207,160	$65,260	$55,519	$516,557	$123,758	$338,229
Cash Flow Year 20	$205,607	$64,496	$55,357	$480,222	$119,565	$332,730
Cash Flow Year 21	$205,739	$61,086	$69,118	$470,479	$118,317	$321,654
Cash Flow Year 22	$205,126	$62,971	$51,940	$428,786	$123,286	$326,135
Cash Flow Year 23	$203,825	$63,831	$10,072	$500,099	$118,821	$330,760
Cash Flow Year 24	$207,074	$66,039	$58,100	$560,706	$119,703	$336,420
Cash Flow Year 25	$207,996	$66,359	$60,948	$481,411	$118,491	$340,392
Cash Flow Year 26	$205,842	$64,283	$75,444	$444,554	$120,468	$329,461
Cash Flow Year 27	$204,839	$61,834	$66,188	$458,084	$120,358	$322,822
Cash Flow Year 28	$206,194	$65,511	$58,269	$480,885	$118,344	$337,704
Cash Flow Year 29	$206,563	$64,142	$48,582	$471,072	$121,713	$331,760
Cash Flow Year 30	$205,417	$62,922	$63,582	$598,036	$120,500	$332,872
Cash Flow Year 31	$202,613	$62,740	$63,026	$489,419	$115,744	$320,240
Cash Flow Year 32	$205,512	$64,804	$53,637	$512,373	$120,049	$331,738
Cash Flow Year 33	$207,262	$67,862	$57,072	$478,717	$112,667	$342,549
Cash Flow Year 34	$200,475	$59,885	$70,830	$445,884	$120,539	$319,976
Cash Flow Year 35	$200,641	$65,843	-$84,786	$482,992	$118,006	$332,215
Cash Flow Year 36	$204,879	$65,657	$58,251	$506,602	$116,398	$325,812
Cash Flow Year 37	$205,787	$65,432	$44,898	$461,891	$115,426	$329,628
Cash Flow Year 38	$203,733	$65,632	$77,563	$482,167	$116,168	$327,379
Cash Flow Year 39	$203,585	$65,306	$58,550	$466,382	$118,307	$330,998
Cash Flow Year 40	$203,509	$66,027	$62,976	$567,607	$115,295	$330,398

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
40 Year NPV	$2,259,579	$224,123	$1,620,037	$3,022,407	$1,892,489	$2,610,770
Perpetuity NPV	$2,295,542	$224,880	$1,630,845	$3,058,289	$1,930,393	$2,652,361

Table J.61 – Summary statistics for farm representative of Brown soil zone, irrigated production, with shelterbelt and buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$262,232	$159,735	-$310,587	$853,774	$39,814	$561,164
Cash Flow Year 2	$173,440	$143,436	-$314,420	$793,890	-$13,648	$425,965
Cash Flow Year 3	$157,127	$136,425	-$331,027	$692,970	-$11,065	$410,541
Cash Flow Year 4	$197,982	$139,873	-$322,438	$930,349	$38,928	$462,315
Cash Flow Year 5	$211,065	$131,702	-$307,808	$739,893	$45,799	$442,359
Cash Flow Year 6	$201,672	$141,175	-$302,271	$742,953	$32,479	$454,853
Cash Flow Year 7	$182,470	$146,303	-$306,397	$727,732	$862	$455,846
Cash Flow Year 8	$176,622	$137,851	-$299,577	$786,059	$2,332	$420,792
Cash Flow Year 9	$186,777	$143,014	-$321,387	$777,869	$9,714	$448,768
Cash Flow Year 10	$197,050	$135,529	-$314,690	$880,416	$24,384	$446,416
Cash Flow Year 11	$192,080	$128,579	-$301,756	$700,507	$22,196	$421,990
Cash Flow Year 12	$190,198	$134,119	-$297,631	$799,133	$18,322	$448,104
Cash Flow Year 13	$190,773	$137,696	-$315,303	$695,707	$21,283	$463,812
Cash Flow Year 14	$195,859	$128,661	-$297,552	$674,524	$22,073	$423,842
Cash Flow Year 15	$194,811	$130,716	-$304,486	$798,680	$24,501	$457,207
Cash Flow Year 16	$195,720	$137,957	-$301,112	$857,534	$25,816	$462,573
Cash Flow Year 17	$193,911	$132,750	-$290,222	$748,581	$13,534	$454,289
Cash Flow Year 18	$195,907	$130,913	-$314,772	$773,583	$30,750	$437,424
Cash Flow Year 19	$202,390	$132,736	-$283,474	$734,413	$31,823	$457,270
Cash Flow Year 20	$196,507	$137,811	-$303,166	$944,428	$29,488	$448,080
Cash Flow Year 21	$194,357	$133,911	-$315,993	$921,467	$25,769	$445,349
Cash Flow Year 22	$193,202	$137,466	-$296,563	$837,094	$21,470	$445,275
Cash Flow Year 23	$199,155	$134,642	-$314,737	$770,745	$29,013	$454,461
Cash Flow Year 24	$206,727	$142,921	-$314,796	$784,361	$25,988	$466,434
Cash Flow Year 25	$202,734	$134,603	-$310,266	$741,818	$27,521	$445,321
Cash Flow Year 26	$204,663	$134,118	-$321,449	$794,069	$34,020	$452,546
Cash Flow Year 27	$201,830	$128,211	-$310,233	$746,266	$35,568	$437,566
Cash Flow Year 28	$199,909	$129,214	-$319,277	$812,155	$34,840	$436,476
Cash Flow Year 29	$200,922	$134,606	-$297,569	$928,177	$35,242	$453,296
Cash Flow Year 30	$197,041	$127,712	-$288,478	$739,198	$28,852	$432,478
Cash Flow Year 31	$196,611	$136,338	-$311,688	$824,422	$25,145	$438,573
Cash Flow Year 32	$205,131	$132,049	-$304,114	$771,798	$30,409	$433,896
Cash Flow Year 33	$209,220	$140,361	-$320,248	$835,271	$37,191	$487,114
Cash Flow Year 34	$206,566	$137,063	-$289,916	$733,635	$26,935	$462,914
Cash Flow Year 35	$204,225	$141,160	-$299,427	$842,564	$23,120	$456,337
Cash Flow Year 36	$206,028	$130,875	-$313,026	$837,473	$39,191	$460,236

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 37	$206,333	$141,806	-$303,097	$766,589	$30,569	$474,398
Cash Flow Year 38	$198,559	$127,252	-$312,299	$808,885	$26,848	$430,370
Cash Flow Year 39	$205,095	$133,039	-$305,552	$962,788	$33,768	$441,417
Cash Flow Year 40	$204,073	$131,198	-$304,703	$730,496	$37,616	$456,811
40 Year NPV	$2,187,552	$410,576	$971,735	$3,917,857	$1,517,826	$2,849,455
Perpetuity NPV	$2,228,703	$412,602	$1,037,507	$3,999,089	$1,553,646	$2,887,790

Table J.62 – Summary statistics for farm representative of Brown soil zone, dryland production, with shelterbelt and buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$82,568	$104,480	-$200,930	$522,768	-$101,758	$276,300
Cash Flow Year 2	$52,837	$101,952	-$151,019	$522,578	-$110,876	$247,102
Cash Flow Year 3	$43,390	$103,034	-$180,996	$558,849	-$112,931	$229,717
Cash Flow Year 4	$52,856	$96,063	-$190,365	$448,239	-$109,454	$225,670
Cash Flow Year 5	$55,116	$103,360	-$177,378	$514,155	-$109,380	$239,271
Cash Flow Year 6	$44,285	$102,441	-$165,633	$510,856	-$112,511	$233,433
Cash Flow Year 7	$41,670	$99,212	-$200,321	$512,666	-$111,317	$220,239
Cash Flow Year 8	$37,784	$95,793	-$183,837	$466,396	-$112,184	$215,599
Cash Flow Year 9	$53,007	$100,627	-$171,707	$470,979	-$105,169	$239,396
Cash Flow Year 10	$52,253	$94,864	-$170,822	$611,586	-$103,218	$223,602
Cash Flow Year 11	$53,814	$96,539	-$185,428	$470,531	-$104,276	$222,679
Cash Flow Year 12	$56,446	$94,234	-$173,181	$438,611	-$103,984	$230,093
Cash Flow Year 13	$61,435	$94,655	-$187,052	$468,804	-$102,186	$242,981
Cash Flow Year 14	$66,620	$94,175	-$166,518	$514,091	-$99,985	$240,149
Cash Flow Year 15	$62,700	$94,435	-$163,918	$414,747	-$99,584	$249,819
Cash Flow Year 16	$61,440	$92,172	-$168,104	$472,587	-$99,689	$231,859
Cash Flow Year 17	$66,039	$97,439	-$155,021	$505,541	-$100,973	$245,467
Cash Flow Year 18	$67,231	$94,353	-$135,577	$505,976	-$100,242	$244,175
Cash Flow Year 19	$67,798	$94,204	-$123,301	$546,136	-$100,436	$236,924
Cash Flow Year 20	$63,256	$95,833	-$191,556	$495,473	-$101,616	$239,474
Cash Flow Year 21	$65,242	$94,651	-$186,845	$401,602	-$98,711	$253,068
Cash Flow Year 22	$68,061	$93,058	-$146,610	$518,854	-$98,157	$243,325
Cash Flow Year 23	$67,537	$94,039	-$126,149	$436,190	-$98,262	$243,588
Cash Flow Year 24	$64,013	$97,282	-$170,229	$524,916	-$101,748	$229,376
Cash Flow Year 25	$63,471	$93,602	-$174,471	$460,007	-$102,024	$241,052
Cash Flow Year 26	$67,309	$93,678	-$158,835	$413,955	-$99,871	$234,464
Cash Flow Year 27	$67,680	$92,704	-$121,715	$505,125	-$96,760	$238,307
Cash Flow Year 28	$66,560	$94,854	-$130,806	$538,738	-$99,309	$240,981
Cash Flow Year 29	$66,222	$92,172	-$147,361	$476,649	-$98,364	$228,776
Cash Flow Year 30	$65,707	$93,002	-$160,117	$442,514	-$99,806	$241,896
Cash Flow Year 31	$67,336	$96,633	-$161,962	$534,558	-$101,420	$235,669
Cash Flow Year 32	$64,833	$92,724	-$158,096	$523,050	-$99,159	$233,836

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 33	$65,319	$96,936	-$169,691	$609,540	-$100,398	$236,489
Cash Flow Year 34	$69,938	$100,095	-$140,073	$512,485	-$99,422	$250,038
Cash Flow Year 35	$65,111	$97,107	-$157,185	$480,124	-$101,309	$244,919
Cash Flow Year 36	$65,122	$92,521	-$135,952	$448,462	-$100,963	$233,858
Cash Flow Year 37	$64,454	$95,629	-$131,560	$486,941	-$100,257	$243,139
Cash Flow Year 38	$66,892	$98,626	-$147,874	$537,553	-$101,295	$260,988
Cash Flow Year 39	$70,731	$96,466	-$135,204	$432,404	-$97,488	$244,849
Cash Flow Year 40	$69,986	$94,814	-$171,360	$553,955	-$100,900	$242,182
40 Year NPV	$642,776	$336,006	-$491,480	$1,648,734	$96,795	$1,202,749
Perpetuity NPV	$657,725	$336,535	-$483,501	$1,697,845	$103,161	$1,211,625

Table J.63 – Summary statistics for farm representative of Dark Brown soil zone, with shelterbelt and buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$102,387	$87,087	-$123,552	$438,790	-$14,035	$254,899
Cash Flow Year 2	$77,826	$82,963	-$146,503	$437,622	-$34,552	$226,743
Cash Flow Year 3	$72,912	$82,876	-$127,778	$406,098	-$105,374	$211,465
Cash Flow Year 4	$85,737	$84,046	-$129,800	$418,450	-$30,193	$237,366
Cash Flow Year 5	$85,391	$80,476	-$134,890	$443,541	-$36,543	$223,034
Cash Flow Year 6	$75,289	$84,165	-$135,615	$346,795	-$103,685	$221,751
Cash Flow Year 7	$72,096	$86,036	-$141,381	$378,749	-$103,882	$226,059
Cash Flow Year 8	$67,270	$85,762	-$138,542	$472,000	-$103,957	$219,968
Cash Flow Year 9	$78,525	$80,288	-$132,327	$422,770	-$34,214	$219,699
Cash Flow Year 10	$85,011	$81,153	-$137,499	$381,828	-$21,304	$238,899
Cash Flow Year 11	$84,797	$84,309	-$125,251	$387,508	-$29,536	$235,175
Cash Flow Year 12	$87,257	$82,798	-$134,953	$395,382	-$25,279	$248,661
Cash Flow Year 13	$89,012	$82,135	-$165,121	$434,649	-$14,728	$245,999
Cash Flow Year 14	$91,665	$79,886	-$124,404	$389,585	-$18,189	$238,783
Cash Flow Year 15	$90,997	$78,609	-$123,540	$419,359	-$8,528	$243,029
Cash Flow Year 16	$94,153	$83,635	-$122,361	$424,640	-$13,617	$245,664
Cash Flow Year 17	$91,676	$77,562	-$120,024	$423,878	-$10,875	$240,135
Cash Flow Year 18	$92,355	$76,422	-$121,192	$373,370	-$15,143	$225,312
Cash Flow Year 19	$91,186	$75,571	-$117,695	$368,350	-$17,637	$230,405
Cash Flow Year 20	$91,670	$86,293	-$141,193	$432,849	-$22,507	$250,023
Cash Flow Year 21	$90,848	$83,061	-$123,306	$452,534	-$29,415	$241,425
Cash Flow Year 22	$96,315	$81,363	-$128,081	$416,902	-$8,301	$249,387
Cash Flow Year 23	$94,851	$78,465	-$122,766	$490,383	-$12,240	$240,760
Cash Flow Year 24	$96,165	$81,527	-$125,278	$392,914	-$9,752	$246,986
Cash Flow Year 25	$94,092	$79,721	-$123,068	$439,781	-$10,372	$237,592
Cash Flow Year 26	$94,401	$78,351	-$123,654	$387,508	-$11,618	$240,682
Cash Flow Year 27	$94,606	$77,905	-$111,766	$446,865	-$7,165	$230,885
Cash Flow Year 28	$96,368	$81,926	-$132,437	$388,891	-$8,939	$249,936

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 29	$93,953	$80,005	-$150,802	$386,575	-$11,559	$244,137
Cash Flow Year 30	$95,225	$78,973	-$128,405	$365,251	-$6,760	$246,298
Cash Flow Year 31	$94,400	$78,264	-$117,717	$443,631	-$8,691	$235,246
Cash Flow Year 32	$93,304	$78,399	-$124,269	$501,190	-$10,178	$234,924
Cash Flow Year 33	$93,984	$79,022	-$120,581	$439,176	-$8,801	$239,093
Cash Flow Year 34	$98,159	$80,629	-$121,162	$418,354	-$8,629	$245,249
Cash Flow Year 35	$96,323	$83,632	-$130,068	$413,530	-$9,679	$250,984
Cash Flow Year 36	$97,666	$83,047	-$119,824	$382,747	-$13,359	$255,950
Cash Flow Year 37	$92,911	$79,326	-$124,597	$374,969	-$15,638	$244,486
Cash Flow Year 38	$95,588	$81,587	-$126,207	$448,605	-$9,162	$247,677
Cash Flow Year 39	$95,995	$78,203	-$124,988	$402,933	-$7,213	$243,083
Cash Flow Year 40	$98,293	$82,581	-$124,800	$462,436	-$10,031	$249,947
40 Year NPV	$931,083	$289,906	$22,105	$1,769,083	$455,430	$1,417,177
Perpetuity NPV	$953,085	$290,277	$41,186	$1,778,905	$469,204	$1,440,678

Table J.64 – Summary statistics for farm representative of Black soil zone, with shelterbelt and buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$261,419	$96,543	$41,912	$744,517	$128,296	$440,927
Cash Flow Year 2	$236,027	$92,996	-$112,372	$588,594	$105,650	$407,052
Cash Flow Year 3	$237,449	$91,195	$38,040	$686,370	$112,324	$408,067
Cash Flow Year 4	$251,757	$92,725	-$115,191	$656,577	$129,916	$419,032
Cash Flow Year 5	$248,447	$88,275	-$112,302	$655,111	$136,382	$413,858
Cash Flow Year 6	$235,355	$87,823	$8,098	$617,666	$115,534	$406,118
Cash Flow Year 7	$226,871	$85,801	-$124,220	$672,119	$108,115	$371,495
Cash Flow Year 8	$226,984	$86,884	-$121,251	$635,537	$106,497	$377,017
Cash Flow Year 9	$239,098	$93,794	-$112,856	$602,194	$112,366	$409,747
Cash Flow Year 10	$239,830	$96,119	$33,732	$719,458	$111,248	$429,135
Cash Flow Year 11	$234,106	$90,077	$12,133	$537,884	$110,585	$409,631
Cash Flow Year 12	$228,714	$89,366	-$129,850	$597,829	$111,948	$388,969
Cash Flow Year 13	$234,357	$92,660	-$108,066	$622,564	$108,317	$413,267
Cash Flow Year 14	$237,246	$88,965	$24,082	$636,524	$114,998	$418,688
Cash Flow Year 15	$234,595	$89,171	$36,964	$602,707	$111,577	$406,340
Cash Flow Year 16	$238,282	$89,948	$37,435	$608,104	$120,185	$408,082
Cash Flow Year 17	$236,044	$89,749	$66,643	$601,158	$118,341	$408,002
Cash Flow Year 18	$233,424	$85,615	$22,971	$627,286	$118,319	$385,022
Cash Flow Year 19	$237,484	$93,727	-$110,343	$728,117	$116,995	$408,232
Cash Flow Year 20	$235,106	$89,267	-$115,833	$667,788	$115,912	$395,879
Cash Flow Year 21	$235,086	$89,581	-$126,760	$551,157	$118,169	$407,348
Cash Flow Year 22	$231,456	$89,217	-$127,250	$599,588	$108,054	$393,112
Cash Flow Year 23	$227,412	$88,896	-$110,346	$585,342	$110,499	$401,440
Cash Flow Year 24	$234,560	$92,911	-$116,762	$526,911	$106,697	$418,977

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 25	$233,721	$90,105	$23,748	$567,822	$108,436	$407,119
Cash Flow Year 26	$231,683	$87,175	$48,902	$585,318	$111,625	$391,084
Cash Flow Year 27	$229,830	$91,886	-$115,848	$680,024	$106,196	$393,644
Cash Flow Year 28	$229,286	$89,932	-$116,355	$664,060	$109,423	$404,036
Cash Flow Year 29	$230,532	$89,845	-$116,528	$630,201	$109,993	$395,630
Cash Flow Year 30	$231,497	$91,890	-$111,348	$647,154	$110,379	$405,741
Cash Flow Year 31	$228,685	$89,231	-$119,246	$566,865	$112,648	$399,131
Cash Flow Year 32	$232,966	$88,256	$32,828	$725,894	$114,564	$397,320
Cash Flow Year 33	$236,231	$90,400	-$129,526	$632,151	$116,837	$402,770
Cash Flow Year 34	$226,692	$84,838	-$118,093	$556,664	$112,176	$386,802
Cash Flow Year 35	$226,996	$91,038	-$114,226	$632,762	$106,093	$409,577
Cash Flow Year 36	$232,924	$93,042	$29,308	$661,607	$112,956	$404,832
Cash Flow Year 37	$232,908	$87,592	-$123,890	$610,185	$112,036	$401,758
Cash Flow Year 38	$232,786	$91,717	-$111,277	$621,682	$112,912	$410,973
Cash Flow Year 39	$227,372	$90,239	-$115,104	$669,517	$107,206	$390,185
Cash Flow Year 40	$229,588	$90,379	-$119,146	$597,799	$106,080	$413,100
40 Year NPV	$2,584,490	$320,039	$1,679,943	$3,722,024	$2,086,129	$3,145,928
Perpetuity NPV	$2,634,503	$321,087	$1,728,756	$3,801,568	$2,143,370	$3,201,680

Table J.65 – Summary statistics for farm representative of Dark Grey soil zone, with shelterbelt and buffer strip with hay adoption

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 1	$225,088	$72,075	$72,184	$575,132	$124,200	$368,602
Cash Flow Year 2	$206,289	$69,105	$55,298	$469,080	$114,762	$336,888
Cash Flow Year 3	$205,801	$69,362	$56,571	$639,286	$113,650	$338,762
Cash Flow Year 4	$218,250	$65,784	$43,228	$479,876	$131,145	$342,616
Cash Flow Year 5	$214,159	$60,685	$22,340	$477,370	$131,243	$331,710
Cash Flow Year 6	$207,043	$62,942	$43,792	$552,064	$124,907	$323,269
Cash Flow Year 7	$200,879	$60,780	$44,952	$451,432	$116,495	$325,769
Cash Flow Year 8	$204,301	$62,946	$64,692	$446,408	$119,198	$329,859
Cash Flow Year 9	$209,170	$65,132	$59,205	$492,267	$121,608	$332,825
Cash Flow Year 10	$208,835	$66,647	$60,909	$521,813	$119,660	$335,247
Cash Flow Year 11	$205,908	$63,721	$51,743	$490,399	$119,791	$321,906
Cash Flow Year 12	$201,933	$63,419	$55,698	$511,405	$117,875	$320,663
Cash Flow Year 13	$206,017	$65,699	$22,067	$532,267	$116,874	$328,675
Cash Flow Year 14	$206,325	$63,547	$47,787	$523,391	$117,418	$324,692
Cash Flow Year 15	$205,056	$63,252	$23,977	$442,991	$120,176	$320,933
Cash Flow Year 16	$208,075	$60,521	$55,841	$455,259	$123,806	$318,172
Cash Flow Year 17	$208,958	$66,959	$70,143	$468,583	$120,161	$340,575
Cash Flow Year 18	$208,879	$66,038	$45,194	$491,522	$120,545	$338,748
Cash Flow Year 19	$207,771	$65,264	$56,031	$517,068	$124,256	$338,886
Cash Flow Year 20	$206,235	$64,492	$55,753	$480,782	$120,433	$333,182

	Mean	Standard Deviation	Minimum	Maximum	5%	95%
Cash Flow Year 21	$206,349	$61,079	$69,630	$470,809	$118,938	$322,393
Cash Flow Year 22	$205,731	$62,989	$52,509	$429,289	$123,813	$326,790
Cash Flow Year 23	$204,441	$63,821	$10,353	$500,686	$119,217	$331,189
Cash Flow Year 24	$207,688	$66,045	$58,417	$561,461	$120,211	$337,149
Cash Flow Year 25	$208,574	$66,350	$61,223	$482,001	$118,934	$341,133
Cash Flow Year 26	$206,508	$64,271	$75,646	$445,334	$120,921	$329,921
Cash Flow Year 27	$205,510	$61,820	$66,748	$458,465	$120,962	$323,635
Cash Flow Year 28	$206,833	$65,486	$58,933	$481,347	$118,891	$338,147
Cash Flow Year 29	$207,168	$64,164	$49,247	$471,885	$122,324	$332,054
Cash Flow Year 30	$205,986	$62,924	$64,384	$598,446	$121,246	$333,133
Cash Flow Year 31	$203,233	$62,758	$63,691	$489,909	$116,359	$321,156
Cash Flow Year 32	$206,114	$64,836	$54,328	$513,490	$120,693	$332,574
Cash Flow Year 33	$207,905	$67,853	$57,503	$479,946	$113,237	$343,306
Cash Flow Year 34	$201,130	$59,874	$71,524	$446,676	$121,241	$320,515
Cash Flow Year 35	$201,269	$65,821	-$84,577	$483,405	$118,541	$332,420
Cash Flow Year 36	$205,570	$65,655	$59,199	$507,032	$117,016	$326,911
Cash Flow Year 37	$206,408	$65,445	$45,442	$462,911	$115,939	$330,334
Cash Flow Year 38	$204,363	$65,641	$78,220	$483,080	$116,821	$328,200
Cash Flow Year 39	$204,201	$65,331	$59,140	$467,227	$118,930	$331,773
Cash Flow Year 40	$204,133	$66,038	$63,568	$568,495	$115,971	$331,030
40 Year NPV	$2,264,896	$224,112	$1,624,301	$3,028,303	$1,897,811	$2,616,739
Perpetuity NPV	$2,301,048	$224,873	$1,635,389	$3,064,536	$1,932,212	$2,657,636

Appendix K: Summary Results for Rotational and Non-Rotational BMP Combinations

Table K.1 – Summary statistics for BMP combinations on representative farm in the Brown soil zone, irrigated production

BMP Combination	Mean	Standard Deviation
Alfalfa hay and shelterbelts	$2,590,724	$351,477
Alfalfa hay and buffer strips	$2,788,352	$357,682
Alfalfa hay and buffer strips with hay	$2,792,691	$357,922
Alfalfa hay and residue management	$2,927,895	$359,730
Alfalfa hay, shelterbelts and buffer strips	$2,564,369	$350,223
Alfalfa hay, shelterbelts and buffer strips with hay	$2,568,824	$350,446

Table K.2 – Summary statistics for BMP combinations on representative farm in the Brown soil zone, dryland production

BMP Combination	Mean	Standard Deviation
Field pea and shelterbelts	$1,180,275	$337,588
Field pea and buffer strips	$1,377,563	$341,713
Field pea and buffer strips with hay	$1,386,493	$340,998
Field pea and residue management	$1,409,126	$338,838
Field pea, shelterbelts and buffer strips	$1,163,422	$335,064
Field pea, shelterbelts and buffer strips with hay	$1,172,611	$334,655
Legume green manure and shelterbelts	$589,939	$337,591
Legume green manure and buffer strips	$767,586	$342,851
Legume green manure and buffer strips with hay	$777,147	$342,956
Legume green manure and residue management	$796,478	$342,765
Legume green manure, shelterbelts and buffer strips	$579,472	$335,065
Legume green manure, shelterbelts and buffer strips with hay	$588,409	$334,955
Field pea, legume green manure and shelterbelts	$866,957	$300,491
Field pea, legume green manure and buffer strips	$1,054,532	$305,489
Field pea, legume green manure and buffer strips with hay	$1,063,603	$305,611
Field pea, legume green manure and residue management	$1,087,509	$305,014
Field pea, legume green manure, shelterbelts and buffer strips	$853,626	$298,400
Field pea, legume green manure, shelterbelts and buffer strips with hay	$862,496	$298,115

Table K.3 – Summary statistics for BMP combinations on representative farm in the Dark Brown soil zone

BMP Combination	Mean	Standard Deviation
Alfalfa hay and shelterbelts	$1,677,836	$217,700
Alfalfa hay and buffer strips	$1,895,259	$220,017
Alfalfa hay and buffer strips with hay	$1,905,463	$220,548
Alfalfa hay and residue management	$1,901,423	$225,250
Alfalfa hay, shelterbelts and buffer strips	$1,655,972	$216,332
Alfalfa hay, shelterbelts and buffer strips with hay	$1,666,075	$216,795
Field pea and shelterbelts	$1,299,366	$272,366
Field pea and buffer strips	$1,442,372	$274,548
Field pea and buffer strips with hay	$1,452,740	$274,599
Field pea and residue management	$1,501,731	$275,800
Field pea, shelterbelts and buffer strips	$1,282,067	$270,936
Field pea, shelterbelts and buffer strips with hay	$1,292,563	$270,729
Legume green manure and shelterbelts	$834,166	$290,287
Legume green manure and buffer strips	$950,224	$294,311
Legume green manure and buffer strips with hay	$960,872	$293,615
Legume green manure and residue management	$999,545	$295,331
Legume green manure, shelterbelts and buffer strips	$821,851	$288,520
Legume green manure, shelterbelts and buffer strips with hay	$832,686	$288,438
Alfalfa hay, field pea and shelterbelts	$2,317,211	$245,047
Alfalfa hay, field pea and buffer strips	$2,539,719	$248,978
Alfalfa hay, field pea and buffer strips with hay	$2,549,921	$249,287
Alfalfa hay, field pea and residue management	$2,598,471	$252,221
Alfalfa hay, field pea, shelterbelts and buffer strips	$2,288,792	$243,272
Alfalfa hay, field pea, shelterbelts and buffer strips with hay	$2,298,842	$243,519
Alfalfa hay, legume green manure and shelterbelts	$2,307,791	$244,064
Alfalfa hay, legume green manure and buffer strips	$2,533,681	$247,887
Alfalfa hay, legume green manure and buffer strips with hay	$2,543,772	$248,164
Alfalfa hay, legume green manure and residue management	$2,588,268	$252,038
Alfalfa hay, legume green manure, shelterbelts and buffer strips	$2,279,527	$242,260
Alfalfa hay, legume green manure, shelterbelts and buffer strips with hay	$2,289,614	$242,553
Field pea, legume green manure and shelterbelts	$1,403,176	$305,359
Field pea, legume green manure and buffer strips	$1,545,043	$307,663
Field pea, legume green manure and buffer strips with hay	$1,555,457	$307,418
Field pea, legume green manure and residue management	$1,607,337	$308,821
Field pea, legume green manure, shelterbelts and buffer strips	$1,384,615	$302,627

BMP Combination	Mean	Standard Deviation
Field pea, legume green manure, shelterbelts and buffer strips with hay	$1,395,476	$302,548
Alfalfa hay, field pea, legume green manure and shelterbelts	$2,276,722	$244,387
Alfalfa hay, field pea, legume green manure and buffer strips	$2,495,598	$247,979
Alfalfa hay, field pea, legume green manure and buffer strips with hay	$2,505,642	$248,357
Alfalfa hay, field pea, legume green manure and residue management	$2,553,530	$251,438
Alfalfa hay, field pea, legume green manure, shelterbelts and buffer strips	$2,248,803	$242,559
Alfalfa hay, field pea, legume green manure, shelterbelts and buffer strips with hay	$2,258,757	$242,834

Table K.4 – Summary statistics for BMP combinations on representative farm in the Black soil zone

BMP Combination	Mean	Standard Deviation
Alfalfa hay and shelterbelts	$3,118,277	$235,208
Alfalfa hay and buffer strips	$3,295,395	$234,805
Alfalfa hay and buffer strips with hay	$3,304,364	$234,870
Alfalfa hay and residue management	$3,401,524	$237,245
Alfalfa hay, shelterbelts and buffer strips	$3,007,974	$233,839
Alfalfa hay, shelterbelts and buffer strips with hay	$3,086,771	$234,035
Field pea and shelterbelts	$2,623,707	$293,205
Field pea and buffer strips	$2,789,352	$296,714
Field pea and buffer strips with hay	$2,798,229	$296,654
Field pea and residue management	$2,890,548	$295,078
Field pea, shelterbelts and buffer strips	$2,589,374	$290,625
Field pea, shelterbelts and buffer strips with hay	$2,598,093	$290,673
Oat and shelterbelts	$2,372,189	$304,457
Oat and buffer strips	$2,514,322	$306,916
Oat and buffer strips with hay	$2,523,046	$306,796
Oat and residue management	$2,623,741	$306,676
Oat, shelterbelts and buffer strips	$2,341,556	$301,766
Oat, shelterbelts and buffer strips with hay	$2,350,349	$301,745
Alfalfa hay, field pea and shelterbelts	$2,947,908	$227,020
Alfalfa hay, field pea and buffer strips	$3,117,090	$226,445
Alfalfa hay, field pea and buffer strips with hay	$3,126,056	$226,652
Alfalfa hay, field pea and residue management	$3,208,113	$228,269
Alfalfa hay, field pea, shelterbelts and buffer strips	$2,909,586	$226,029
Alfalfa hay, field pea, shelterbelts and buffer strips with hay	$2,918,630	$226,287

BMP Combination	Mean	Standard Deviation
Alfalfa hay, oat and shelterbelts	$2,834,892	$235,988
Alfalfa hay, oat and buffer strips	$3,007,515	$236,485
Alfalfa hay, oat and buffer strips with hay	$3,016,405	$236,456
Alfalfa hay, oat and residue management	$3,049,730	$239,694
Alfalfa hay, oat, shelterbelts and buffer strips	$2,798,327	$234,581
Alfalfa hay, oat, shelterbelts and buffer strips with hay	$2,807,198	$234,876
Field pea, oat and shelterbelts	$2,382,464	$280,981
Field pea, oat and buffer strips	$2,542,618	$282,753
Field pea, oat and buffer strips with hay	$2,551,275	$282,768
Field pea, oat and residue management	$2,610,545	$281,113
Field pea, oat, shelterbelts and buffer strips	$2,351,250	$278,826
Field pea, oat, shelterbelts and buffer strips with hay	$2,360,348	$278,793
Alfalfa hay, field pea, oat and shelterbelts	$2,744,417	$224,737
Alfalfa hay, field pea, oat and buffer strips	$2,908,410	$224,352
Alfalfa hay, field pea, oat and buffer strips with hay	$2,917,320	$224,569
Alfalfa hay, field pea, oat and residue management	$3,001,713	$225,658
Alfalfa hay, field pea, oat, shelterbelts and buffer strips	$2,708,599	$223,614
Alfalfa hay, field pea, oat, shelterbelts and buffer strips with hay	$2,717,396	$223,619

Table K.5 – Summary statistics for BMP combinations on representative farm in the Dark Grey soil zone

BMP Combination	Mean	Standard Deviation
Alfalfa hay and shelterbelts	$2,557,896	$169,051
Alfalfa hay and buffer strips	$2,636,143	$169,184
Alfalfa hay and buffer strips with hay	$2,641,677	$169,307
Alfalfa hay and residue management	$2,715,551	$170,745
Alfalfa hay, shelterbelts and buffer strips	$2,525,557	$168,129
Alfalfa hay, shelterbelts and buffer strips with hay	$2,531,155	$168,178
Field pea and shelterbelts	$2,351,895	$213,321
Field pea and buffer strips	$2,427,365	$214,296
Field pea and buffer strips with hay	$2,432,737	$214,395
Field pea and residue management	$2,507,455	$214,896
Field pea, shelterbelts and buffer strips	$2,321,643	$211,259
Field pea, shelterbelts and buffer strips with hay	$2,327,122	$211,372
Oat and shelterbelts	$2,276,024	$214,642
Oat and buffer strips	$2,343,261	$215,198
Oat and buffer strips with hay	$2,348,715	$215,161
Oat and residue management	$2,437,933	$215,567
Oat, shelterbelts and buffer strips	$2,247,182	$212,972
Oat, shelterbelts and buffer strips with hay	$2,252,589	$213,031

BMP Combination	Mean	Standard Deviation
Alfalfa hay, field pea and shelterbelts	$2,461,723	$166,944
Alfalfa hay, field pea and buffer strips	$2,538,868	$166,956
Alfalfa hay, field pea and buffer strips with hay	$2,544,457	$167,079
Alfalfa hay, field pea and residue management	$2,603,684	$168,364
Alfalfa hay, field pea, shelterbelts and buffer strips	$2,430,861	$166,054
Alfalfa hay, field pea, shelterbelts and buffer strips with hay	$2,436,367	$166,149
Alfalfa hay, oat and shelterbelts	$2,450,331	$168,522
Alfalfa hay, oat and buffer strips	$2,531,026	$168,764
Alfalfa hay, oat and buffer strips with hay	$2,536,576	$168,845
Alfalfa hay, oat and residue management	$2,566,785	$171,201
Alfalfa hay, oat, shelterbelts and buffer strips	$2,419,350	$167,536
Alfalfa hay, oat, shelterbelts and buffer strips with hay	$2,424,805	$167,745
Field pea, oat and shelterbelts	$2,304,894	$203,307
Field pea, oat and buffer strips	$2,381,139	$203,892
Field pea, oat and buffer strips with hay	$2,386,564	$203,941
Field pea, oat and residue management	$2,443,065	$202,504
Field pea, oat, shelterbelts and buffer strips	$2,275,324	$201,764
Field pea, oat, shelterbelts and buffer strips with hay	$2,280,747	$201,730
Alfalfa hay, field pea, oat and shelterbelts	$2,414,885	$162,814
Alfalfa hay, field pea, oat and buffer strips	$2,492,223	$163,070
Alfalfa hay, field pea, oat and buffer strips with hay	$2,497,627	$163,133
Alfalfa hay, field pea, oat and residue management	$2,565,093	$164,534
Alfalfa hay, field pea, oat, shelterbelts and buffer strips	$2,384,282	$162,112
Alfalfa hay, field pea, oat, shelterbelts and buffer strips with hay	$2,389,875	$162,199