University of Alberta

Farm Level Economics of Winter Wheat Production in the Canadian Prairies

by

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Abstract

This research project estimated economic costs and benefits of winter wheat production in the Canadian Prairies at a farm level. A combination of Net Present Value analysis and Monte Carlo simulation was used to build cash flow farm models by province and soil zone. The objective of this study was to examine the economic feasibility of winter wheat production on the Prairies. Results show that Prairie farmers will benefit from growing winter wheat if crop research further improves cold tolerance, yield, or quality of winter wheat. Incorporating winter wheat into crop rotations has potential to increase farmers' wealth in the Canadian Prairies.

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Chapter 1 Introduction

1.1 Background

The Prairies are referred to as one of the two ecozones with the most extensive agriculture being practised in Canada[1] (McRae et al., 2000). Ecozone is defined as the “broadest ecological class in the classification system, based on continental-scale physical geography and climate” (McRae et al., 2000, p. 14). Due to its location and geography, the Prairies have several pronounced characteristics, such as flat topography, semi-arid climate, harsh winters, and warm summers (Environment Canada, 2005). Canada’s productive agricultural land, including cropland, rangeland, and pasture, are mainly concentrated in this region (Environment Canada, 2005). As the Breadbasket of Canada, the Prairies have 94% of the land base in farm land and grow many different types of crops (Environment Canada, 2005). Winter wheat is grown on a small proportion of the total acres of crops seeded in the Canadian Prairies. This study examines the economics of incorporating winter wheat into crop rotations by soil zone and province.

The Canadian Prairies include three provinces, Alberta, Saskatchewan, and Manitoba. When farms are divided into industry groups, farms engaged in crop farming [2] represented 39.1%, 64.3%, and 47.7% of all the farms in Alberta, Saskatchewan, and Manitoba, respectively, in 2006 (Statistics Canada, 2007). A cropping system involves a group of plants managed by a farm to achieve goals in several aspects, such as food, fiber, and farm wealth (Pearson et al., 2009). When making decisions related to cropping systems, potential gross revenues, production costs, risk levels, and environmental influences all need to be considered (Campbell et al., 1990). Prairie farmers face constraints in making decisions regarding cropping systems because of the climate in the Canadian

[1] The other ecozone is the Mixedwood Plain (McRae et al., 2000).
[2] Crop farming includes oilseed and grain farming, vegetable and melon farming, fruit and tree-nut farming, greenhouse, nursery and floriculture production, and other crop farming (Statistics Canada, 2007).

Prairies. More specifically, the constraints come from the low temperatures and lack of water in this region (IISD, 1994).

Regarding which types of crops to grow, Prairie farmers' choices are limited due to climatic constraints. A large proportion of farm land in this region is devoted to growing wheat, barley, and other cereal crops (Bradshaw, 2004). Oilseed and pulse crops are also grown and their seeded area is expanding (Campbell et al., 2002). Meanwhile, new crops and crop varieties emerge every year with the advancement of crop breeding programs (IISD, 1994).

Dr. Fowler and his colleagues at the University of Saskatchewan, collaborating with other research groups, are working on a project named Use of Genomics Tools for Crop Improvement in Temperate Climates. The primary goals of this project are "identifying the biological mechanisms governing low temperature adaptation and then applying the acquired knowledge and our genomic resources in crop improvement programs" (Crop Adaptation Genomics website, 2006). Low temperatures are a significant problem in crop production. Crop damage resulting from low temperatures can lead to annual economic losses of millions of dollars which can be greatly reduced if even 1 or 2 ºC increase in tolerance to low temperatures is achieved (Unterschultz, 2008). Winter wheat, one target in cold tolerance research, has some adaptive mechanisms to develop tolerance to low temperatures to survive harsh winters (Fowler, 2002). Traditionally grown in Southern Alberta, winter wheat has slowly expanded its growing area to other parts of the Canadian Prairies with the introduction of the stubbled-in management system (Fowler, 2002). In the stubbled-in management system, crops are no-till seeded into standing crop stubble from previous year (Fowler, 2002). Stubbled-in winter wheat has a number of advantages in agronomic, environmental, and economic aspects, such as stronger cold tolerance, reduced soil erosion, decreased tillage, higher yield potential, and better protection of wildlife (Fowler, 2002; Salmon and McLelland, 1999; Rourke, 1983). Regarding all these advantages, stubbled-in winter wheat has the potential to become both economically feasible and more environmentally friendly than spring seeded wheat (Salmon and McLelland, 1999).

Winter wheat has a much smaller seeded area relative to other main field crops in the Canadian Prairies, especially when compared to spring wheat (CANSIM II, 2009). The low acreage of winter wheat is due to a number of problems related to winter hardiness, historical weather, crop diseases, farm management, world wheat markets, and quality issues (Salmon and McLelland, 1999; Fowler, 2002). The detailed statistics of winter wheat production and related concerns are discussed in Chapter 2.

1.2 Economic Problems

The GE3LS (Genomics, Ethics, Environment, Economics, Law, and Society) research is the socio-economic component of the above mentioned project led by Dr Fowler. One of the objectives of the GE3LS research is to evaluate farm-level costs and benefits of crops which are tolerant to low temperatures in the Canadian Prairies (Crop Adaptation Genomics website, 2006). This study chooses winter wheat as the research target. Winter wheat has cold tolerance and usually out-yields spring wheat, but winter wheat price is generally lower than spring wheat due to its lower protein concentrations. Cold tolerance, yield, and quality of winter wheat are examined for their influences on farmers' wealth respectively. Economic problems include which one of the three traits has the greatest impact on Prairie farmers' economic choice of growing winter wheat versus spring wheat. Additionally on which trait should future winter wheat research focus in order to have the greatest economic impact at the farm level?

Several research questions are addressed: is it economically feasible to grow winter wheat in a specific province/soil zone in the Canadian Prairies? Is there any difference in the economic feasibility across provinces or soil zones? If so, why is the economic feasibility different? How will the improvement of the three traits influence the economic feasibility and which one has the largest effect?

How can we improve the economic feasibility of growing winter wheat? Overall, this study intends to shed some light on the prospects of winter wheat production in the Canadian Prairies. The objective of this study is to analyze the farm level economic costs and benefits of growing winter wheat by province and soil zone in the Canadian Prairies.

There are nine province-soil combinations included in this study: Alberta Black Soil Zone, Alberta Brown Soil Zone, Alberta Dark Brown Soil Zone, Alberta Grey Soil Zone, Alberta Peace Region, Saskatchewan Black Soil Zone, Saskatchewan Brown Soil Zone, Saskatchewan Dark Brown Soil Zone, and Manitoba. No soil zone is specified for Manitoba due to lack of data. For each province-soil combination, there is a representative crop farm and a corresponding farm model. Net Present Value (NPV), combined with stochastic simulation, is used to develop cash flow farm models. Scenario analyses, sensitivity analyses, and elasticity analyses are conducted to analyze the results of simulation models.

1.3 Thesis Outline

The following chapter, Chapter 2, introduces climate and soils of the Canadian Prairies, followed by a description of crop production with historical acreage statistics. Inputs used in crop production and recent changes in farm management practices are discussed. Then different aspects of winter wheat are introduced, including agronomic characteristics, current production, related concerns, new changes, and economic, environmental, and agronomic benefits.

Chapter 3 presents the research methodology. Capital budgeting techniques, such as net present value, payback period, accounting rate of return, and internal rate of return, are discussed and compared based upon the objective of the firm. The techniques of modeling a farm, including optimization and simulation, are reviewed and compared. The methodology for this study is determined accompanied with an illustration of the simulation model structure.

The characteristics of representative farms, such as farm size, machinery complements, and crop rotations, are discussed in Chapter 4. Economic relationships involved in cropping activities are described, followed by an introduction to the stochastic implementation. This chapter concludes with an overview of scenario analysis, sensitivity analysis, and elasticity analysis performed in the study.

Chapter 5 presents results for all the scenarios, sensitivity analyses, and elasticity analyses. Comparison of the results between province–soil combinations is made.

Chapter 6 summarizes the conclusions about the economic feasibility of winter wheat production. Policy implications are briefly mentioned. Model limitations and further research directions are also discussed.

Chapter 2 Crop Industry in the Canadian Prairies and Winter Wheat

This chapter provides background information for the target of this study, winter wheat. The background information answers questions about the climate and soil conditions in the Canadian Prairies, the crop industry (crop types, crop acreage, and production inputs), and the changes in farm management practices. To further understand winter wheat, different aspects of winter wheat are presented, such as the agronomic characteristics, the biological process of winter survival, people's concerns about this crop, changes, and various advantages.

2.1 Climate and Soil in the Canadian Prairies

From the Rocky Mountains to the Red River Valley and along the border between Canada and the United States, the Prairies are located in the inner land of North America (Environment Canada, 2005). The neighboring Rocky Mountains are a natural barrier to moisture-bearing winds from the Pacific (Environment Canada, 2005). The location and geography of the Prairies jointly determine the subhumid to semi-arid climate (Environment Canada, 2005). The climate in most of the Prairies is continental or extreme continental with temperatures averaging -10ºC in winter and 15ºC in summer (IISD, 1994; Canadian Biodiversity Web Site, 2008). The mean annual temperature is lower than most other important agricultural regions of the world (IISD, 1994). Annual precipitation is relatively low: 400 - 600 mm in Manitoba, and 300 - 500 mm in both Saskatchewan and Alberta (IISD et al., 1997). Most of the precipitation on the Prairies is received during the growing season from May to August (IISD et al., 1997). The climate places a significant constraint on crop production in the Canadian Prairies, especially on what to grow and how to grow crops. In the following context of this chapter, how stubbled-in winter wheat fits the Prairie climate is discussed. As mentioned in Chapter 1, different soil zones will be considered in this study. Table 2.1 compares four types of soils in depth of surface layer, soil organic matter (SOC), texture, topography, and constraints for crop production. Generally, black soils are more productive agricultural lands than other soils.

2.2 Crop Production in the Canadian Prairies

2.2.1 Statistics of Main Field Crops

There are many different field crops grown in the Canadian Prairies. Figure 2.1 shows an overall increasing trend from 1908 to 2008 in the total acres of main field crops in the Canadian Prairies. Wheat is the leading field crop in terms of acreage in this region. Wheat acreage increases overall with large year to year variations, starting at 5.63 million acres in 1908 and ending at 23.52 million acres in 2008. Oats also vary in seeded acres, from 2.77 million acres in 1908 to 3.91 million acres in 2008. Barley has a relatively steady increase in acreage, from 0.87 million acres in 1908 to 8.76 million acres in 2008. An increasing trend is found in the seeded area of flax, going from 0.14 million acres in 1908 to 1.56 million acres in 2008. Currently, canola is the second largest crop in terms of acreage, with an increase from 3,212 acres in 1943 to 16 million acres in 2008. Rye contributes to only a small part to the total acres of field crops.

In the world wheat market, Canada usually ranks seventh in wheat production and second in wheat exports (AAFC, 2004). The Prairies are the major production area of wheat in Canada (AAFC, 2004). In 2008, 93.4% of Canadian wheat was grown on the Prairies; 54.4% of Canadian winter wheat was grown on the Prairies (CANSIM II, 2009). However, winter wheat acreage in Canada is low relative to other parts of the world. For example, the seeded area of winter wheat in Canada in 2008 was 2.79 million acres which was about 6.0% of the 46.28 million acres of winter wheat grown in the United States in the same year (CANSIM II, 2009; USDA, 2009). In the Canadian Prairies, the seeded area of winter wheat does not exceed 5.0% of spring wheat in any given year from 1981 to 2006 (CANSIM II, 2009). In 2007, winter wheat increased to 1.17 million acres which was 7.9% of the total spring wheat area; in 2008, it increased to 1.52 million acres which was 9.5% of the total spring wheat area (CANSIM II, 2009). The reasons behind the relatively low acreage and recent acreage increase are discussed in section 2.3.2 and 2.3.3. The comparison between winter wheat and spring wheat in seeded area by province is displayed in Figures 2.2 – 2.5.

Figure 2.6 shows the variation in seeded area of winter wheat for each Prairie Province from 1976 to 2008. In Alberta, winter wheat starts with about 0.3 million acres in 1976, and then experiences a peak of 0.48 million acres in 1987, followed by an overall decreasing trend to about 60,000 acres in 2002. It increases back to 0.3 million acres in 2008. Winter wheat seeded area in Saskatchewan increases from about 50,000 acres in 1981 to 0.88 million acres in 1986, and then has a steady falling trend to about 35,000 acres in 1994. After that, winter wheat has an overall increasing trend to 0.6 million acres in 2008. In Manitoba, winter wheat increases from about 17,000 acres in 1981 to 0.62 million acres in 2008. Manitoba has the highest winter wheat seeded area among the three Prairie Provinces in 2008. The reasons for the variations over time in winter wheat acreage are discussed in section 2.3.2.

2.2.2 Inputs of Crop Production

Inputs involved in crop production are seed, fertilizer, chemicals, fuel, machinery, and labor, and these have direct influences on farm costs. When making decisions on these inputs, several factors need to be taken into account, such as seed bed type and preparation, seed variety and quality, seed treatment, seeding method, seeding date, fertilizing, pest control, weed control, and harvesting (MAFRI, 2008). Climatic and weather conditions should also be considered. Meanwhile, economics, such as relative input prices, has an impact on crop input decisions.

2.2.3 Recent Changes in Farm Management

The Canadian Prairies have been well-known for the production of monoculture cereal crops, frequent use of summerfallow, and extensive application of conventional tillage (Zentner et al., 2001; Zentner et al., 2002). Changes in farm management practices are changing the Prairie crop industry: first, there is a trend to increase crop diversification (Campbell et al., 2002; Carlyle, 2002). Second, summerfallow acreage is declining year to year (Campbell et al., 2002). Third, conservation tillage has been adopted for its potential to increase crop yields, reduce labor and fuel use, and control soil erosion (Gebhardt et al, 1985; Zentner et al, 2002). Fourth, there is continuous progress made in crop breeding and crop adaptation programs and successful examples include the development of canola from rapeseed and the adaptation of durum wheat to the Brown Soil Zones in Saskatchewan and Alberta (Carlyle, 2002). Winter wheat relates to all these changes in farm management, which is discussed in section 2.3.3 and 2.3.4.

There are discrepancies and continuous changes in the definitions and classification of tillage systems (Fowler, 2002; AAFC, 2008). AAFC (2008) describes no-till (zero tillage) as a tillage system which avoids all tillage operations and minimizes soil disturbance when seeding and applying fertilizer. According to the Soil Management Guide (MAFRI, 2006), no-till is a tillage system which allows some other low disturbance tillage besides tillage for planting, such as fall fertilizer banding with low disturbance openers. The latter definition is used in this study. Appendix A provides definitions and classification of tillage systems.

2.3 Winter Wheat

Winter wheat, one type of winter cereal, differs from spring wheat. The difference between the two types of wheat does not only lie in the seeding time and harvesting time. Winter wheat develops tolerance to low temperatures to survive harsh winters. The biological process through which it obtains cold tolerance is called cold acclimation or hardening-off. By contrast, spring wheat does not have such tolerance to low temperatures. Additionally, winter wheat usually has higher yield and lower protein concentration than spring wheat. Table 2.2 provides a summary of points of comparison between winter wheat and spring wheat.

2.3.1 Winter Survival

The whole biological process of winter survival of winter wheat is temperature regulated. Figure 2.7 summarizes the stages involved in this process, adapted from Fowler (2002). Since the crown of plants contains tissues which are vital to winter survival, the soil temperature at the crown depth (i.e., five centimeters below the soil surface; called CT in the following context) is the key point in the whole biological process. After seeding, winter wheat enters an active growth stage of four to five weeks if the CT is maintained above 9˚C. It is most desirable for winter wheat to have well developed crowns before freezeup, but two or three leaves are also enough for plants to enter the next stage. Once the CT drops below 9˚C, winter wheat experiences the process of cold acclimation (hardening-off) which usually takes four to eight weeks. In this stage, if the CT rises above 9˚C, the cold acclimation process will be reversed and winter wheat will lose cold hardiness rapidly. Fully acclimated winter wheat needs to maintain its cold hardiness to survive winters by satisfying several conditions: the CT is above minimum survival temperature (MST) of plants; the CT is below freezing point; no prolonged periods of cold weather; plants have adequate energy supply. The first condition is also the most important one and depends upon air temperature and snow cover in winter (Fowler, 2002). Figure 2.7 provides a simplified illustration of winter wheat survival. The mechanisms involved in the biological process are beyond the scope of this economic study.

2.3.2 Concerns about Winter Wheat

Winter wheat has been one of the crop choices available to Prairie farmers for many years. However, several constraints limit the acreage of winter wheat grown in this region. Winterkill, one of the most important constraints, can result from failure in any stage of the temperature regulated process mentioned in section 2.3.1 as well as from crop diseases. Fowler (2002) regards low temperature damage to the plant crown in winter as the main cause of winterkill in the Canadian Prairies. For example, in Saskatchewan, the mild winters in the early 1980's resulted in an increase in the seeded area of winter wheat until 1986. Colder winters after 1986, combined with stem rust epidemics, drought, and wheat price crashes, reduced the seeded area until the early 1990's (Fowler, 2002).

When extreme low temperatures occur in winter, winter wheat may not be able to overwinter unless special management practices are applied (Fowler, 2002). Using special farm management practices is an issue in winter wheat production because winter wheat needs different management practices from commonly grown spring wheat (Salmon and McLelland, 1999; Fowler, 2002). Among the special management practices, the choice of tillage system is crucial for winter wheat survival (Fowler, 2002). Early winter wheat growers used conventional tillage systems. These systems were risky on the Prairies because field crops have direct exposure to cold temperatures, resulting in a high frequency of winterkill if the winter is extremely cold (Fowler, 2002). In recent years, producers have changed the tillage systems used with growing winter wheat.

Another concern with winter wheat relates to protein levels. Winter wheat generally has lower protein levels than spring wheat (Table 2.2). Additionally, some older cultivars of winter wheat are not comparable to spring wheat in milling and baking quality (Salmon and McLelland, 1999; Fowler, 2002). These low quality concerns may be considered by farmers when facing the choices of growing winter wheat versus spring wheat. In summary, cold winters, potential winterkills, lack of special farm management practices, and lower quality contribute to the relatively small acreage of winter wheat grown in the Canadian Prairies.

2.3.3 Changes to Winter Wheat

Several changes occurred to winter wheat in recent years, and the most important one is the change from conventional tillage systems to stubbled-in systems. The high risk of winterkill during the Prairie winters makes the choice of tillage system especially important for winter wheat survival. In the stubbled-in system, the snow cover trapped by the standing stubble of previous crops helps to insulate winter wheat from extreme temperatures in winters (Fowler, 2002). For example, in Saskatchewan, field studies have shown that the soil temperature on stubble fields with two inches of snow cover can be 10°C higher than neighboring bare summerfallow fields (Fowler, 2002). The stubbled-in system reduces the risk of winterkill and makes winter wheat more adaptive to the Canadian Prairies. A research project initiated in 1976 by the University of Manitoba found substantial improvements in overwinter survival of winter wheat under a no-till system relative to a conventional tillage system (Rourke, 1983). Furthermore, standing stubble from previous crops reduces the loss of spring soil moisture, and the snow trapped enhances moisture conservation (Fowler, 2002; SAF, 2005). Thus, using a stubbled-in system can relieve the two major problems, low temperatures and lack of water, in crop production on the Prairies. The most desirable snow pack for winter wheat survival is loosely packed and uniformly distributed over the fields before temperatures reach critical levels (Fowler, 2002). Deeper snow cover usually relates to better winter survival of crops, but also increases the chance of crop diseases, such as snow mold (Fowler, 2002).

Besides tillage systems, much experience has been accumulated in other farm management practices for winter wheat production (AARD, 2007; MAFRI 2008). A combination of effective management practices, including recommended seeding date, shallow seeding, stubbled-in system, proper fertilization, and moist and weed-free field, can minimize the risk of winterkill (Fowler, 2002). Thus, it is more technically feasible to grow winter wheat in the Canadian Prairies now than in the past.

The qualities of winter wheat, such as protein concentration, milling quality, and baking quality, have improved with the development of new cultivars (Fowler, 2002; Salmon and McLelland, 1999). This creates opportunities for winter wheat exports. Fowler (2001) identified other market opportunities for winter wheat, such as domestic feed and commercial alcohol production.

2.3.4 Advantages of Winter Wheat

Winter wheat, combined with the stubbled-in system and diversified crop rotations, has a number of agronomic, environmental, and economic advantages. These advantages are discussed as follows:

2.3.4.1 Higher Yields

Winter wheat usually has higher yields than spring wheat (Salmon and McLelland, 1999; Heaney, 2000; Fowler, 2002; McKenzie, 2007). Salmon and McLelland (1999) and Heaney (2000) estimated a 10 – 15% yield advantage of winter wheat compared to spring wheat, while McKenzie (2007) suggested a 20% yield advantage. Another example is a 17-year field trial which proved that stubble seeded Norstar winter wheat can have a yield advantage of 36% compared to stubble seeded hard red spring wheat (Fowler, 2002).

Based upon annual data from CANSIM II, Yang et al. (2007) compared winter wheat yield to spring wheat yield at a provincial level. Descriptive statistics for provincial average wheat yields are provided in Table 2.3. Winter wheat out-yields spring wheat on average, but its variability in yield is also higher than spring wheat (Yang et al., 2007). For example, from 1981 to 2006 in Saskatchewan, the average yield of winter wheat is 30.26bu/ac which is 6.3% higher than spring wheat; the standard deviation of winter wheat is 7.66bu/ac which is 53.8% higher than spring wheat (Yang et al., 2007). Appendix B provides historical trends of wheat yields in each Prairie Province.

To examine the yield difference between winter yield and spring wheat, Yang et al. (2007) estimated the following model using the provincial level yield data:

$$Log(Yield) = \beta_0 + \beta_1 T + \beta_2 AB + \beta_3 MB + \beta_4 winter + \beta_5 (T \cdot winter) + e \tag{2.1}$$

where:

Variable	Definition
Yield	Wheat yield in bu/ac, which is converted to a natural log value for use as the dependent variable
T	A time trend variable (T=year-1980)
AB	A binary variable (=1 for Alberta, and 0 otherwise)
MB	A binary variable (=1 for Manitoba, and 0 otherwise)
winter	A binary variable (=1 for winter wheat, and 0 for spring wheat)
T·winter	An interaction variable which is the product of the time variable and the dummy variable representing winter
e	Error term

The period of study is from 1981 to 2006. As the base case, Saskatchewan is dropped from the regression. Table 2.4 presents the regression results. Winter wheat yield is 11.3% lower than spring wheat in 1981. During the first eight years, spring wheat out-yields winter wheat. However, winter wheat yield becomes higher from the ninth year due to the extra annual increase of 1.3% relative to spring wheat. At the end of the time period, winter wheat is predicted to have 22.0% higher yield than spring wheat in each province. From the regression results, winter wheat is found to increase yield faster than spring wheat.

2.3.4.2 Lower Production Costs

The growing cycle of winter wheat can largely avoid the hazardous effects of fall frosts, summer droughts, insects, diseases (Rourke, 1983), and spring emerging weeds (Salmon and McLelland, 1999). Consequently, input costs of winter wheat are usually lower than spring wheat since less pesticide and herbicide is needed (Fowler, 2002). For example, based upon the provincial budget data (AARD, 2000 - 2003; AARD, 2004 - 2008), in the Alberta Dark Brown Soil Zone, the average annual variable expense of stubble seeded winter wheat from 2000 to 2008 is $106.00/ac which is 12.6% less than stubble seeded spring wheat at $121.32/ac. The main difference between the costs of winter wheat and spring wheat is chemical costs.

2.3.4.3 Environmental and Agronomic Benefits

Reduced use of pesticide and herbicide protects the environment besides lowering production costs (Fowler, 2002). Stubbled-in winter wheat results in less disturbance to soil and wildlife since the standing stubble of previous crops provides crop residue cover on the soil surface during fall and winter, which reduces soil erosion by water and wind, and provides nesting habitats and protection for wildlife (Salmon and McLelland, 1999; Fowler, 2001; Fowler, 2002). Winter wheat has a longer growing period, which is helpful to reduce summerfallow area (Fowler 2001; Fowler 2002). Moreover, winter wheat uses early spring moisture more efficiently than spring wheat by rooting to depth earlier (Fowler, 2002; SAF, 2005).

2.3.4.4 Redistribution of Farm Workload

Winter wheat redistributes workload of farmers (Rourke, 1983). The seeding time of winter wheat is late August or early September which may conflict with the harvesting time of spring wheat (Fowler, 2002). However, incorporating winter wheat into crop rotations can help farmers spread out harvest if proper farm management practices are combined with good time management (Salmon and McLelland, 1999; McKenzie, 2007).

Stubbled-in winter wheat, with winter hardiness to survive the Prairie winters, has economic, agronomic, and environmental advantages as discussed in this chapter. With the accumulation of farm management experience, especially in tillage system, winter wheat production becomes more technically feasible. Improved quality is another change to winter wheat. However, according to the crop acreage statistics, winter wheat is still far behind other major field crops in terms of seeded area in the Canadian Prairies. This study is intended to shed some light on farmers' choices of growing winter wheat versus spring wheat from an economic view. In the following chapters, winter wheat is further investigated by comparing its economic costs and benefits.

Table 2.1 - Soil Characteristics in the Canadian Prairies

Soil Zone	Average Depth of Surface Layer (cm)	SOC of the Surface 30cm of soil (%)	Texture	Topography	Constraints for Crop Production
Brown Soil	12.5	2	Mostly medium	Nearly level to very hilly	Moisture deficit, wind erosion, salinity
Dark Brown Soil	17.5	4	Mostly medium	Nearly level	Moisture deficit, salinity
Black Soil	20 - 25	7	Mostly medium	Level to gently rolling	N/A
Grey Luvisols	5	1 - 10	Sandy	n/a	Early fall frost, water erosion

Note: SOC represents soil organic matter; n/a represents not available.
Source: adapted from Campbell et al. (1990)

Table 2.2 - Comparison between Winter Wheat and Spring Wheat in Western Canada

	Winter Wheat versus Spring Wheat
Seeding Time	Winter wheat is seeded in late August or early September, whereas spring wheat is seeded in spring.
Harvesting Time	Winter wheat is harvested late July or early August which is earlier than spring wheat.
Winter hardiness	Fully acclimated winter wheat has winter hardiness, whereas spring wheat does not have winter hardiness.
Yield	Winter wheat usually outperforms spring wheat in yield when it is successfully overwintered.
Protein concentration	Winter wheat has lower protein concentration than spring wheat because higher yield often relates to lower protein concentration at similar soil nitrogen levels.

Source: adapted from Fowler (2002)

Table 2.3 - Comparison of Provincial Average Wheat Yields (1981-2006)

Province	Wheat	Mean (bu/ac)	Standard Deviation (bu/ac)
Alberta	Winter	38.0	9.0
	Spring	35.5	6.0
Saskatchewan	Winter	30.3	7.7
	Spring	28.5	5.0
Manitoba	Winter	38.9	13.8
	Spring	34.1	5.8

Source: Yang et al. (2007)

Table 2.4 - Regression Results of Winter Wheat Yields versus Spring Wheat Yields in Alberta, Saskatchewan and Manitoba

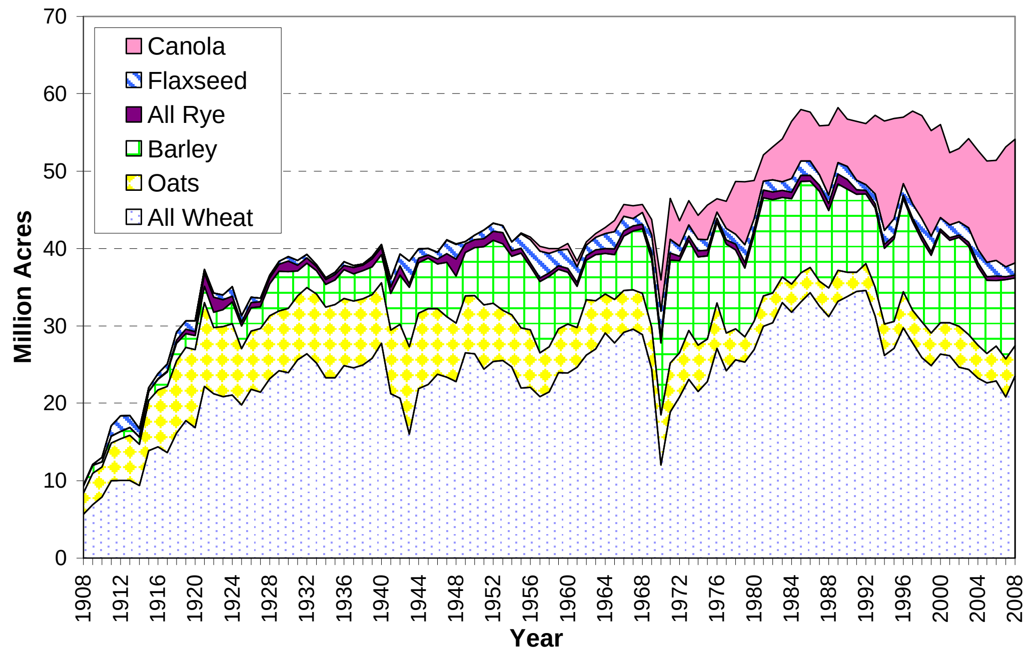
Variable	Estimated Coefficient	P-value
Time trend	0.0112	0.001
AB	0.2303	0.000
MB	0.2049	0.000
Winter	-0.1131	0.111
T·winter	0.0128	0.006
Constant	7.3792	0.000

Note: The dependent variable is $Log(yield)$.

R-squared = 0.4151; Number of observations = 156

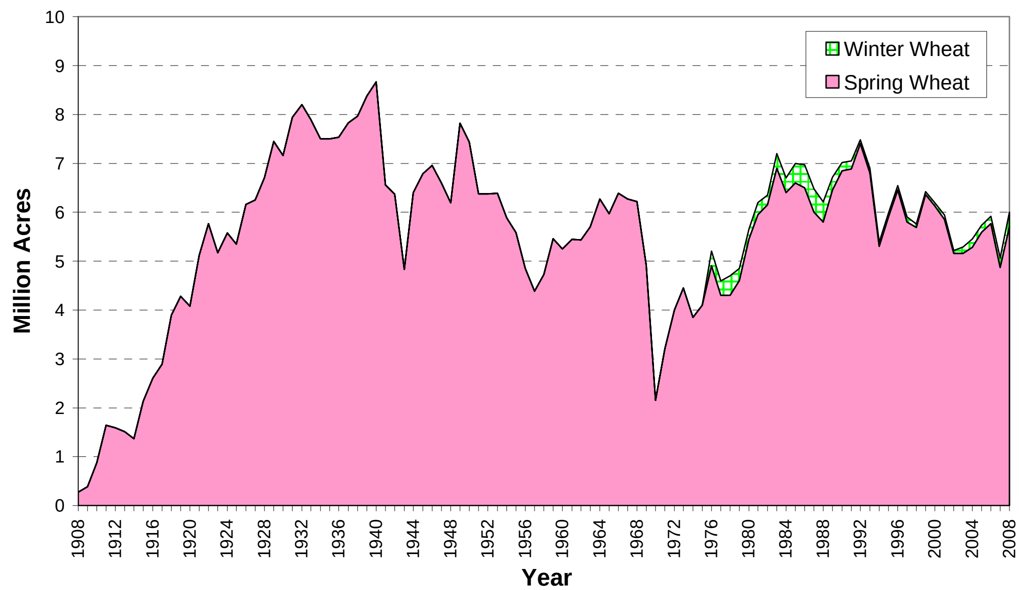
Source: Yang et al. (2007)

Figure 2.1 – Seeded Area of Field Crops in the Canadian Prairies (1908-2008)



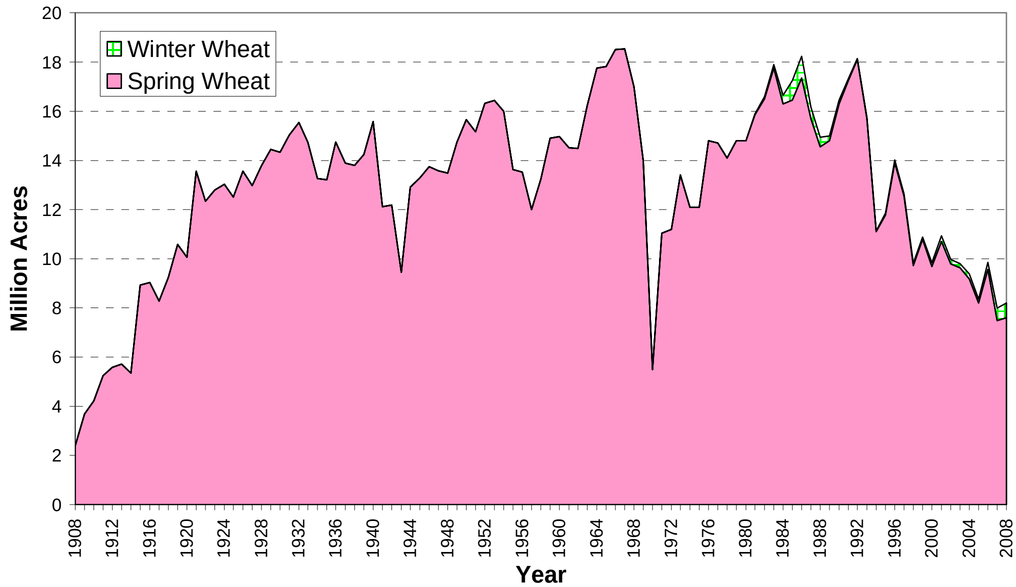
(Source: CANSIM II, 2009)

Figure 2.2 - Seeded Area of Spring Wheat versus Winter Wheat in Alberta (1908-2008)



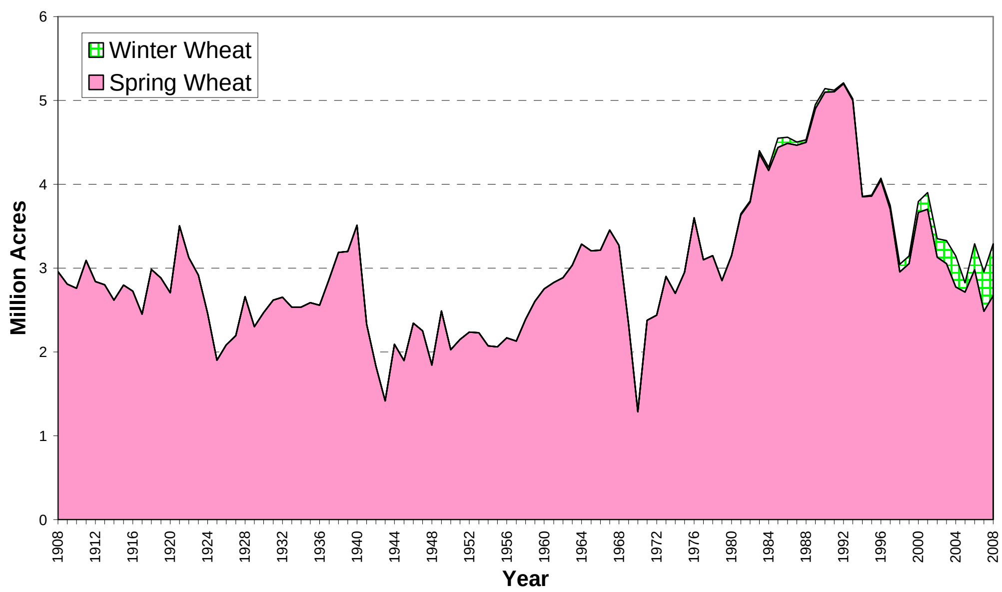
(Source: CANSIM II, 2009)

Figure 2.3 - Seeded Area of Spring Wheat versus Winter Wheat in Saskatchewan (1908-2008)



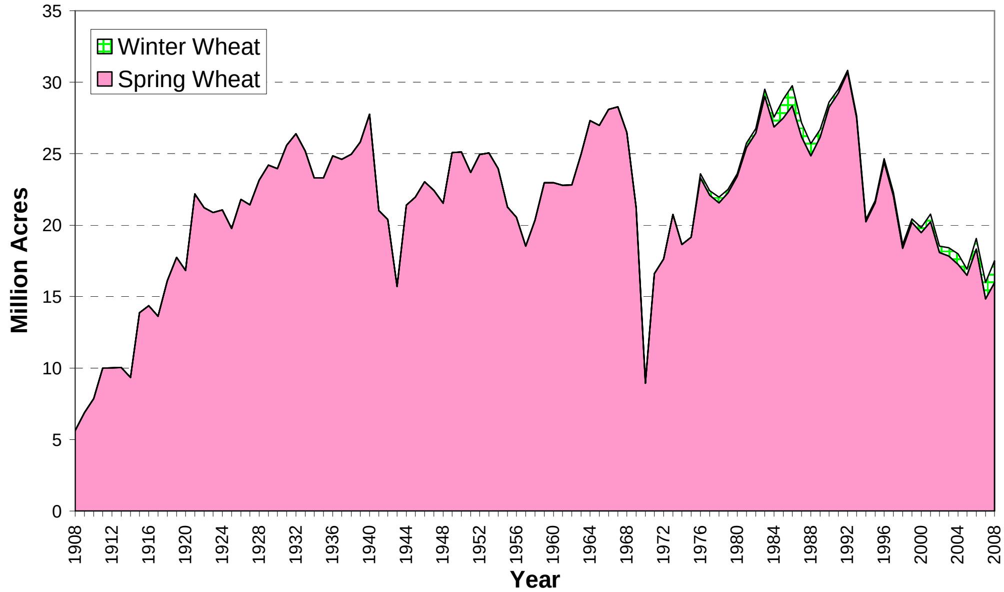
(Source: CANSIM II, 2009)

Figure 2.4- Seeded Area of Spring Wheat versus Winter Wheat in Manitoba (1908-2008)



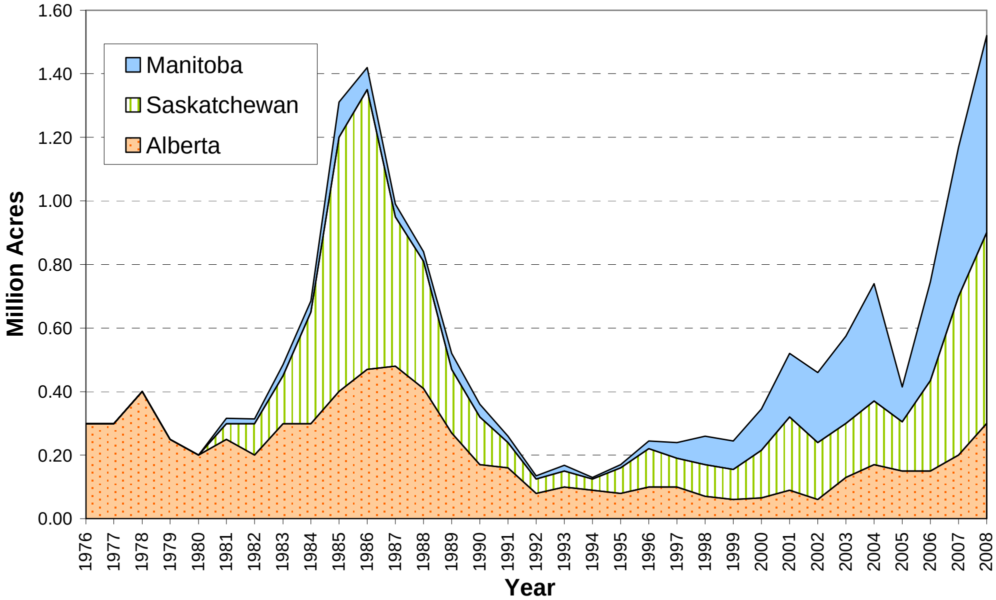
(Source: CANSIM II, 2009)

Figure 2.5 - Seeded Area of Spring Wheat versus Winter Wheat in the three Prairie Provinces (1908-2008)



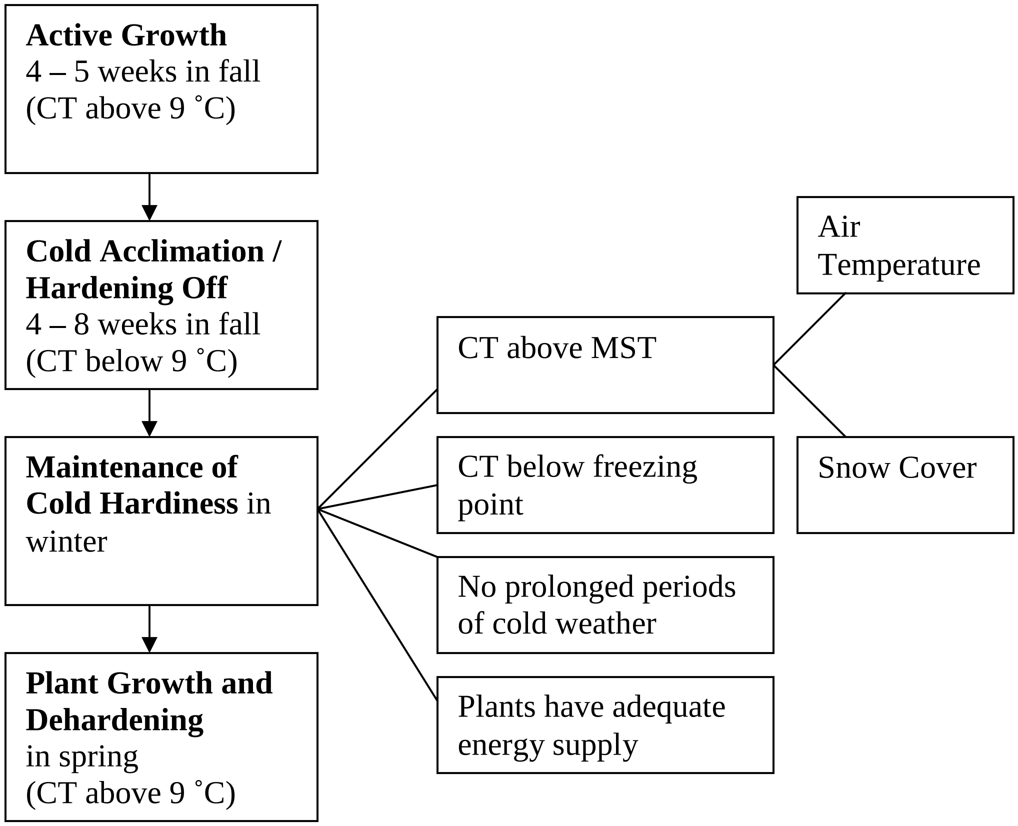
(Source: CANSIM II, 2009)

Figure 2.6 - Seeded Area of Winter Wheat in the Prairie Provinces (1976-2008)



(Source: CANSIM II, 2009)

Figure 2.7 - Winter Survival of Winter Wheat



Note: CT represents the soil temperature at the crown depth; MST represents minimum survival temperature.
Source: adapted from Fowler (2002)

Chapter 3 Methodology

This chapter discusses and compares different capital budgeting techniques, and chooses one of them to evaluate winter wheat production. Options with respect to farm modeling approaches are also discussed. Two types of widely used farm modeling techniques, optimization and simulation, are reviewed and compared. A choice of methodology for the purpose of this study is made based upon these discussions, followed by an illustration of the simulation model structure.

3.1 Capital Budgeting

Copeland and Weston (1988) pointed out the fundamental criterion of decision making, otherwise known as the objective of the firm, is to maximize shareholders' wealth. The criterion is based upon the assumption of perfect certainty. More specifically, the time value of money (interest rate) and all future payoffs from the investment decisions are assumed to be known with certainty. Additionally, there are no imperfections, such as transaction costs, existing in capital markets.

Maximization of shareholders' wealth is equivalent to maximization of the discounted cash flows from investments (Copeland and Weston, 1988). In this study, growing winter wheat is the investment under consideration, and all expected cash flow from this investment can be estimated. The only question left is how to evaluate the investment, which requires investment decision rules, otherwise known as capital budgeting techniques. The selected capital budgeting technique should be consistent with the objective of maximization of shareholders' wealth. For this purpose, Copeland and Weston (1988) suggested four criteria to choose a capital budgeting technique to evaluate a project:

- Consider all cash flows;
- Discount the cash flows with the market-determined opportunity cost of capital;

- Be able to choose one project to maximize shareholders' wealth from mutually exclusive projects[3];
- Be able to consider projects separately, which means that each project is considered on its own[4].

There are four commonly used capital budgeting techniques; net present value, payback period, accounting rate of return, and internal rate of return. They are discussed and compared based upon the four criteria.

3.1.1 Net Present Value

The Net Present Value (NPV) is defined as the present value of expected cash inflows minus the present value of expected cash outflows (Seitz and Ellison, 2005). To calculate the present values, a discount rate which represents the opportunity cost of capital is chosen to discount all future cash flows. NPV, based upon cash inflows and cash outflows of all periods, is expressed by Seitz and Ellison (2005) as follows:

$$NPV = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + ... + \frac{CF_n}{(1+r)^n} - I_0$$

$$= \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0 \qquad (3.1)$$

where CF_t is the net cash flow (i.e., cash inflow – cash outflow) at the end of period t ($t = 1,2,...,n$); I_0 is the initial outlay; r is the discount rate.

Brealey et al. (2007) suggested four steps to use NPV to make an investment decision:

Step 1: Estimate cash flows of a project in all time periods.

Step 2: Choose a discount rate for the project.

3 Mutually exclusive investments are investments that compete with each other and only one of them can be chosen (Brealey et al., 2007).

4 The fourth criterion is known as the value-additivity principle, which implies that the value of a firm is the sum of the values of separate projects accepted by the firm (Copeland and Weston, 1988).

Step 3: Discount future cash flows with the discount rate.
Step 4: Add all the discounted cash flows altogether, and subtract the initial outlay.

Whether an investment is acceptable or not depends upon the sign on its NPV. If the NPV is positive, the investment is acceptable; otherwise, it is not (Copeland and Weston, 1988; Ross et al., 2007). When facing a group of mutually exclusive projects, the project with the highest NPV is selected. Thus, the technique of NPV meets all the four criteria mentioned above: it takes into account cash flows in all time periods of a project; it takes the time value of money into consideration by discounting the cash flows with the opportunity cost of capital; it is able to compare mutually exclusive investments; it considers one project independently from others (Copeland and Weston, 1988; Ross et al., 2007; Brealey et al., 2007).

3.1.2 Other Capital Budgeting Techniques

The payback period of a project is an estimate of the time required to recover the initial investment (Copeland and Weston, 1988; Ross et al., 2007). Whether a project is acceptable is determined by comparing the payback period to some specified time period. Using this technique, the project with the shortest payback period is selected from a group of mutually exclusive projects. One limitation of this technique is that it does not consider all cash flows of a project so that it may ignore large negative cash flows in the last years of the project. Another limitation is that it does not discount cash flows, so it ignores the time value of money.

The accounting rate of return (ARR) is the average profit after tax divided by the initial cash outlay (Copeland and Weston, 1988; Ross et al., 2007). The ARR is compared to a target value to decide whether to accept a project. The project with the largest ARR is chosen from a group of mutually exclusive investments based upon this investment decision rule. This technique is not preferred because it does not take into account the time value of money. Another problem with this technique is that it considers accounting profits, not cash flows when making decisions.

The internal rate of return (IRR) of a project is the discount rate that leads to a zero NPV for the project (Copeland and Weston, 1988; Ross et al., 2007). The IRR is compared to the required rate of return to determine whether a project is desirable. Among a group of mutually exclusive projects, the project with the largest IRR is preferred using this technique. IRR, like NPV, takes into account all cash flows and discounts the cash flows. However, the discount rate in this technique is not the market-determined opportunity cost of capital, but the IRR itself. This leads to an incorrect reinvestment rate assumption which assumes that shareholders can reinvest funds in projects with the same risk using different discount rates. Another problem of using IRR to choose one project from a group of projects is that different choices may occur when considering each project in isolation and in combination with other projects. Moreover, multiple rates of return may occur if the signs on cash flows change more than once.

From the above discussion, payback period, ARR and IRR all violate some of the investment criteria. None of them can guarantee successfully choosing projects which fulfill the wealth objective of the firm. NPV is the only capital budgeting technique consistent with maximization of shareholders' wealth, so it is used to build farm models in this study.

3.1.3 Determining a Discount Rate for NPV

Since NPV is the chosen capital budgeting technique, a discount rate is required. The riskiness of cash flows is reflected by the discount rate (Sharpe et al., 2000). To calculate how much money needs to be invested now to obtain a certain amount of return in the future. an expected rate of return needs to be known. Ross et al. (2003) suggested that a risky security will only be held "if its expected return is high enough to compensate for its risk" (p. 244). Consequently, the expected rate of return of comparable investment alternatives (i.e., investments with a similar level of risk) is often used as a discount rate for a project (Brealey et al., 2007).

This study uses the theory of Capital Market Line (CML) to calculate the expected rate of return of crop farms. Figure 3.1, adapted from Ross et al. (2003), illustrates the theory of CML. The feasible set of securities, also called opportunity set of securities, includes all the possible portfolios. Every point on and within the feasible set represents a possible security portfolio defined in terms of its expected return and standard deviation of returns. The line which starts from risk-free rate r_f and is tangent to the feasible set is the CML which is regarded as the efficient set of all risky and riskless assets. Since the CML is tangent to the feasible set, it provides the highest expected return that can be achieved among all the possible lines which start from r_f and have the same standard deviation. The tangent point B represents the optimal portfolio of risky assets with riskless borrowing and lending. If investors are more risk averse, they will probably choose point C (i.e., lend money to decrease risky assets); if investors are more risk seeking, they will probably choose point A (i.e., borrow money to increase risky assets) (Ross et al., 2003).

The CML theory was used by Miller (2002), Cortus (2005), and Koeckhoven (2008) in their farm-level studies to calculate expected rates of returns and then the discount rates in NPV analysis. Sharpe et al. (2000) suggested a formula based upon the CML theory to calculate the expected rate of return of a project:

$$r_p = r_f + \left[\frac{\bar{r}_m - r_f}{\sigma_m} \right] \sigma_p \tag{3.2}$$

where r_p is the expected farm return; r_f is the market risk-free rate; $\bar{r}_m$ is the expected market return; σ_m is the standard deviation of market portfolio; σ_p is the standard deviation of the farm's return. The vertical intercept of CML is r_f , the market risk-free rate. The slope of CML is $\left[\frac{\bar{r}_m - r_f}{\sigma_m}\right]$, the difference in expected return between the market portfolio and the risk-free asset (i.e., $\bar{r}_m - r_f$) divided by the difference in their risks (i.e., $\sigma_m - 0 = \sigma_m$). The difference in expected return between the market portfolio and the risk-free asset is called the market risk premium (Ross et al., 2003).

The rate of return of treasure bills issued by government is often regarded as the risk-free rate (Ross et al., 2003). A broad-based index, such as Toronto Stock Exchange 300 Index, can be used to estimate the expected return and standard deviation of market portfolio since it is "a good proxy for the highly diversified portfolios of many investors" (Ross et al., 2003, p. 290). The volatility of farm return determined by Cortus (2005) is used as the volatility of farm return in this study.

3.2 Farm Modeling Techniques

Budgets can be classified into four basic types: whole-farm budget, enterprise budget, partial budget, and cash flow budget (Olson, 2004). Whole-farm budgets deal with the entire farm business; enterprise budgets focus on a specific crop or livestock type; partial budgets study changes in some part(s) of a business; a cash flow budget involves a cash analysis of a business (Dalsted and Gutierrez, 2007). This study mainly uses cash flow budgets, combined with other types of budgets, to address the investment problem. Cash flow budget, summarizing all projected cash inflows and cash outflows during the period of study, involves many important aspects in a farm business, such as the evaluation of financial feasibility of a new project, estimation of borrowing needs, ability to repay loans, and timing of financial activities (Kay et al., 2008). Crop enterprise budgets are examined and combined together to form the whole-farm budget. Partial budget is also considered since the study deals with the change from growing spring wheat to winter wheat. As with all the other farming activities, winter wheat production has risk involved. A single budget generates a single result which provides too little information and may be misleading (Vlahos, 1997). An extension to single budgets is discussed later in this chapter to deal with risk in agriculture.

Whole-farm decision making deal with large amounts of information, including farmer's knowledge, machinery, economic relationship, policy, weather, and environmental concerns (Pannell, 1996). In the decision making process, integrating and analyzing all the information is more difficult than collecting the information (Pannell, 1996). Farm models are built to evaluate information and assist in making decisions. The increasing complexity and significance of farm planning in agricultural production requires more formal planning techniques (Glen, 1987). Development of farm-level models has a long history in North America and a lot of modeling experience has been accumulated since the first computerized farm-level models were developed in the early 1950's (Klein and Narayanan, 1992). Optimization and simulation are two major types of techniques to build farm models.

3.2.1 Optimization

Optimization, also called mathematical programming, maximizes or minimizes an objective function, subject to a set of constraints. The objective function usually takes the form of profits to be maximized or costs to be minimized. Optimization is widely used to build farm models and includes different programming techniques.

Linear programming (LP) optimizes a linear objective function subject to a set of linear constraints. It has extensive and flexible applications in farm planning, such as finding optimal crop mix to maximize farm revenue subject to a group of constraints on farm resources. Boehlje and White (1969) modeled production and investment decisions by developing a multi-period LP model to formulate the growth process of a hypothetical corn-hog farm in central Indiana. Barry (1972) established a multi-period LP model to examine the influences of asset indivisibility on various measures of farm growth for a cash grain farm.

Mixed integer programming (MIP) is LP with some of the unknown variables being constrained to take on integer values. It is often used to model crop and machinery choice problems (Danok et al., 1980). For example, a MIP model was developed to incorporate weather variability and choose optimal crop and machinery plans for a 600-acre cash grain farm in central Indiana (Danok et al., 1980). Reid and Bradford (1987) also developed a multi-period MIP model to decide optimal machinery investment for a beef-forage farm.

Goal programming (GP) is an extension to LP. It deals with a number of goals, and each goal is given a target value and a weight. The objective function of GP is to minimize the deviations between the target values and the actually achieved values of all goals based upon predetermined weights. Wheeler and Russell (1977) applied GP to address the planning problems for a mixed 600-acre farm, taking into account several goals. However, there is difficulty in finding values of goal targets and goal weights when applying GP (Barnett et al., 1982). GP models may also contain nonlinear functions (Ignizio, 1978).

Hardaker et al. (2004) suggested some limitations of LP: LP assumes linearity which is usually not the case in reality; the linear objective function is a problem of LP to cope with risk; coefficients in LP model are regarded as known constants, which makes LP hard to deal with risk (this problem also applies to most optimization techniques). Many efforts have been made to tackle risk problems within LP framework. Rae (1971) established a discrete stochastic programming (DSP) model for farm management to incorporate stochastic variables in a LP model. DSP is suitable for decisions problems which have sequential nature and can model risk in both constraints and input-output coefficients (Hardaker et al., 2004). However, computational difficulty cannot be avoided in large multi-stage DSP models (Hardaker et al., 2004).

Quadratic programming (QP), a nonlinear optimization technique, calculates efficient E-V pairs by optimizing a quadratic objective function subject to a set of linear constraints. E is expected income; V is associated income variance. QP seeks optimal farm plans with minimum associated income variances at the given levels of expected income. Scott and Baker (1972) adopted a QP model to select an optimum plan for a Midwest corn-soybean farm. Wiens (1976) used QP technique to evaluate the influence of yield uncertainty on resource allocation of a Chinese village. QP incorporates risk in modeling, but users of this technique need to know the values of some parameters first, such as the mean gross margins of each farm plan and corresponding variances and covariances, all of which are need to be obtained through estimation (Hazell, 1971).

Optimization has been widely used in farm-level modeling as earlier discussed. However, some limitations of optimizations can be summarized based upon Hardaker et al. (2004): first, some optimization models, such as LP models, are regarded as not realistic; second, some optimization techniques fail to incorporate complex relationships, such as risk and uncertainty; third, although efforts have been made to incorporate risk into optimization models, challenges still exist in identifying the source and impact of risk, modeling risk, and finding appropriate solutions; and fourth, incorporating risk into optimization models may result in more difficulty in computation.

3.2.2 Simulation models

Simulation, unlike optimization, does not involve maximization of profit or minimization of cost. Hardaker et al. (2004) defined simulation as “the use of an analogue in order to study the properties of the real system” (p.158). A set of parameters and equations are used to represent the real system (Hardaker et al., 2004). It uses computer technology to numerically exercise a model to observe how the inputs of interest influence output performance (Law, 2007). Simulation is often used to address “what-if” questions since it is an imitation of reality. It explores a system without actually changing it and evaluates a decision without actually implementing it (Evans and Olson, 2002).

Stochastic simulation, one type of simulation, deals with uncertainty and risk. It incorporates random or stochastic components into selected variables and relations in the form of probability distributions (Hardaker et al., 2004). A stochastic simulation model provides probability distributions of both parameters in interest and possible outcomes, resulting in a better understanding of risk (Vlahos, 1997).

Simulation is used to study a wide range of problems in agriculture, such as analyzing harvest machinery capacity with regard to weather risk (Donaldson, 1968), determining the effects of alternative pest control strategies on the Mexican bean beetle control (Reichelderfer and Bender, 1979), evaluating irrigation system investments in the coastal plains regions (Amerling, 1983), analyzing barley leaf rust epidemic to predict related yield reduction (Teng et al., 1977), and examining sheep grazing system of a hypothetical farm (Cacho et al., 1995). More recent applications of simulation include determining impacts of environment programs on dairy farms (Huylenbroeck et al., 2000), studying integrated crop-livestock farming systems (Thornton and Herrero, 2001), evaluating riparian management strategies (Miller, 2002), examining the economic feasibility of wetland drainage (Cortus, 2005), investigating nutrient conservation technologies and strategies on dairy farms (Rotz et al., 2006), examining warm-season grass production in warm temperate regions (Corson et al., 2007), and analyzing costs and benefits of best management practices in a watershed area (Koeckhoven, 2008).

Some researchers used simulation techniques to address problems related to farm production plans in Western Canada, which is of particular interest to this study. Zentner et al. (1978) developed a farm planning simulation model for grain farms in the Brown Soil Zone in Western Canada to test new crop alternatives. The model inputs included available resource, production and management alternatives, prices and technical coefficients, personal financial data, and additional constraints (Zentner et al., 1978). Klein and Sonntag (1982) established a bioeconomic firm-level simulation model for beef, forage, and grain farms in Western Canada to evaluate various management strategies. Gary et al. (1996) used the technique of simulation to compare a zero-tillage system to a conventional direct-seeding system in a central Saskatchewan farm.

Debertin and Pagoulatos (1992) mentioned that “the distinctions between computer simulation and mathematical programming are becoming increasingly blurred” (p. 14). In fact, many efforts have been made to combine the two methods together. For example, an integrated optimization-simulation model was developed by Mishra et al. (2005) to evaluate major irrigation projects in India. Another example is stochastic optimization models developed by Wilson et al. (2005, 2006, and 2007) to explore costs and risks of a marketing system which contains both genetically modified (GM) wheat and non-GM wheat.

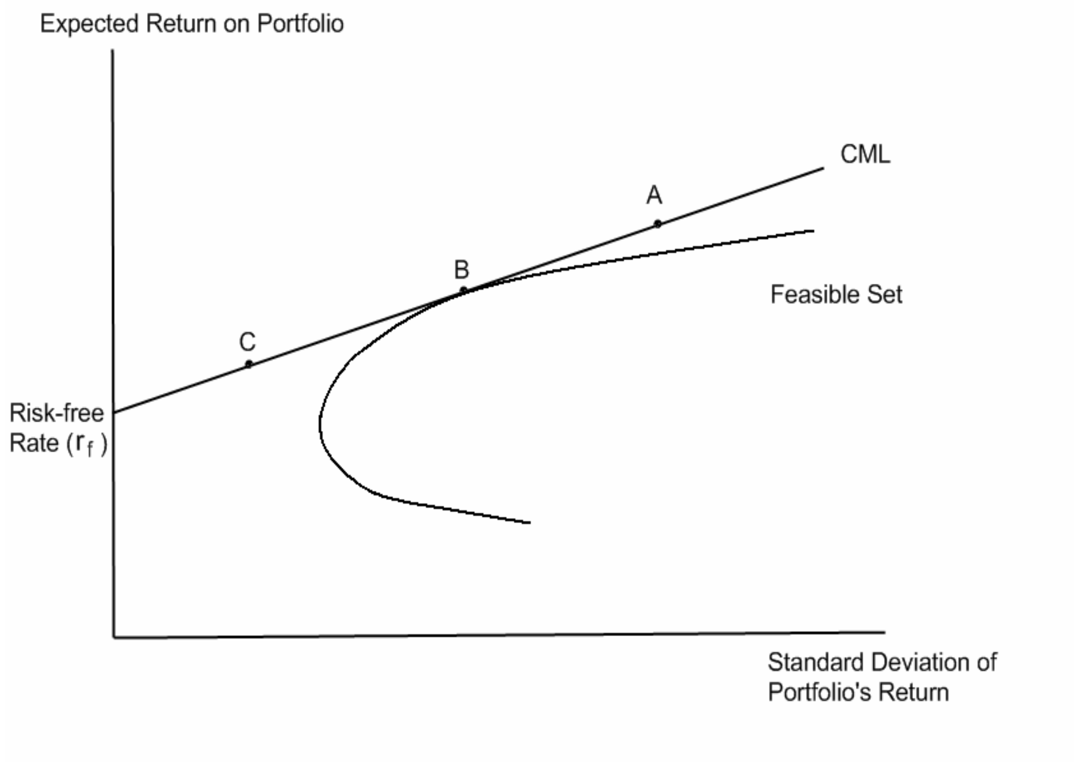
Simulation is preferred in this study based upon two features of the study itself. First, a whole-farm budget is established to examine the effects of growing winter wheat on the entire farm in this study. Simulation model is often used to develop whole-farm budgets (Pannell, 1996). Second, the data of this study are stored and managed in spreadsheets. The integration of simulation model and database is helpful to analyze model inputs, outputs, and their relationship (Bechini and Stockle, 2007). Additionally, simulation has a flexible structure to incorporate complex relationships (Hardaker et al., 2004).

Hardaker et al. (2004) suggests using stochastic budgeting to account for risk in agriculture. Stochastic budgeting is a sub-category of stochastic simulation. Combining cash flow and stochastic simulation to build farm models, otherwise known as stochastic budgeting, can be found in the research work of Miller (2002), Cortus (2005), and Koeckhoven (2008). This study also combines cash flow and stochastic simulation to establish farm-level models. Monte Carlo sampling is used to generate input values. Using this sampling technique, a set of random draws of inputs from specified probability distributions leads to an evaluation of the model, which is called an iteration (Hardaker et al., 2004). A predetermined number of iterations generate probability distributions of outputs if the number of iterations is large enough. In the following chapters, NPV stochastic simulation models are built for representative farms to evaluate the economic feasibility of winter wheat production in the Canadian Prairies.

3.3 Simulation Model Structure

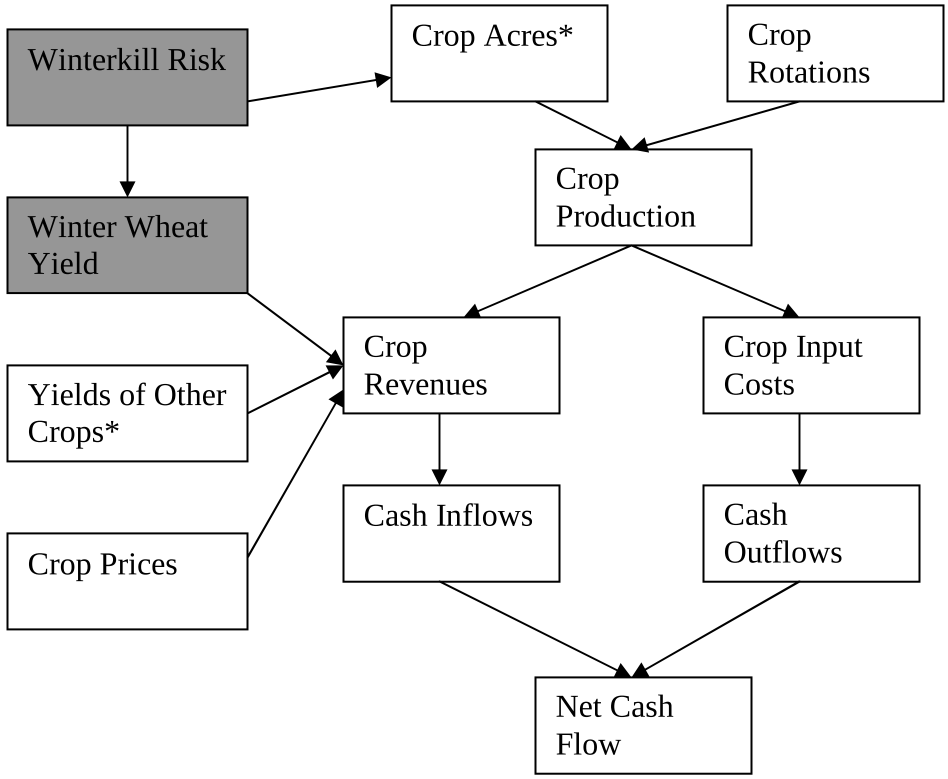
Figure 3.2 displays simulation model structure which includes all components and the relationships between them. Winterkill risk is stochastic, and it influences winter wheat yield throughout the simulation. Most crop yields except winter wheat are constant, but barley yield may have some changes in certain circumstances (refer to section 4.3). All the crop prices are constant. Crop rotations, including rotations before and after incorporating winter wheat, are predetermined. Crop acres are also predetermined except for barley, which is explained in section 4.3. Crop production generates crop revenues and input costs. Crops yields and crop prices jointly determine crop revenues, which consist of cash inflows in the model. On the other side, crop input costs determine cash outflows. Cash inflows and cash outflows are combined to generate net cash flow. Detailed economic relationships and how to model stochastic winter wheat yields are discussed in Chapter 4.

Figure 3.1 - Capital Market Line



Source: adapted from Ross et al. (2003)

Figure 3.2 - Simulation Model Structure



Note: Objects in shaded boxes are stochastic.

* Crop acres are predetermined except for barley (see section 4.3). Yields of other crops are predetermined except for barely in certain circumstances (see section 4.3).

Chapter 4 Representative Farms and Empirical Model

Details of representative farms, such as farm size, machinery complement, and crop rotations are presented in this chapter. Economic relationships on revenues, input costs, and discount rate are discussed and incorporated into simulation models. Stochastic implementation is presented with an introduction of a random variable which is related to cold tolerance. Winter wheat yield models are described. An overview of analyses performed on the economic viability of winter wheat is presented, including scenario analysis, sensitivity analysis, and elasticity analysis.

Default data used in simulation models are averages of 2007 and 2008 provincial budget estimates: Production Costs and Returns (AARD, 2007 and 2008), Crop Planning Guide (SAF, 2007 and 2008), and Guidelines for Estimating Crop Production Costs (MAFRI, 2007 and 2008). The only exception is that crop yields in Manitoba are average yields for 2006 and 2007 from Yield Manitoba (MASC, 2007 and 2008). All of these data are presented in Appendix E. The data use permission from Statistics Canada is in Appendix F.

Some data are missing and these must be dealt with for the purpose of the study. For example, to handle missing data for winter wheat yields, prices, and input costs in some province-soil combinations, the ratio of spring wheat data to winter wheat data is assumed to be the same between any two soil zones in the same province. Consequently, the missing winter wheat data for the target soil zone are calculated by adjusting the spring wheat data for the same soil zone using the ratio of spring wheat to winter wheat data for another soil zone in the same province in that year. Data for yields and costs of fallow seeded crops are missing in some years. For a particular crop, the same ratio is assumed to exist between stubble seeding data and fallow seeding data within a province-soil combination between any two years. The missing fallow seeding data in any specific year are calculated using the stubble seeding data for that year and the ratio of stubble to fallow seeded crop in another year. There are some other missing data, such as building replacement cost and labor related costs, in the budget tables of one or two provinces. The values of these categories are assumed to be the same across the Prairie Provinces, so the values of one province are used for other provinces.

4.1 Representative Farms

The representative farms used in this study are crop farms and other agricultural activities beyond crop production are not considered. No livestock or other type of farm enterprise is discussed or modeled in the analysis.

4.1.1 Farm Size

As earlier discussed, this study includes nine province-soil combinations: Alberta Black Soil Zone, Alberta Brown Soil Zone, Alberta Dark Brown Soil Zone, Alberta Grey Soil Zone, Alberta Peace Region, Saskatchewan Black Soil Zone, Saskatchewan Brown Soil Zone, Saskatchewan Dark Brown Soil Zone, and Manitoba.. Farm sizes vary across the Prairies. Census of Agriculture 2006 (Statistics Canada, 2007) provides data on the numbers of farms and total area of farm land by census division (CD) in each province. The maps of CDs for each Prairie Province are displayed in Appendix C. Tables 4.1 – 4.3 list the maximum and minimum of average farm sizes of every CD, which provides a range of farm sizes in each province.

Average farm size widely varies between CDs within a province: Saskatchewan varies from 973 to 3,273 acres; Alberta varies from 473 to 3,927 acres; Manitoba varies from 347 to 2,432 acres (Tables 4.1 – 4.3). In the present study, a farm size of 2,000 acres is used as a general assumption for all province-soil combinations. This size is chosen for three reasons: first, this size lies in the ranges of the average farm sizes in Tables 4.1 – 4.3. Second, the objective of the present study is to examine the economic effects of incorporating winter wheat into a four-year or five-year crop rotation, so a farm size which can support production of four or five types of crops is appropriate. Finally, the 2000-acre size assumption makes the comparison of economic influences of growing winter wheat between soil zones and provinces more straightforward.

4.1.2 Machinery Complement

The 2000-acre representative crop farm needs a machinery complement which can complete all cropping activities within the farm. Cortus (2005) discussed two methods to determine a machinery complement for a representative farm. One method is to use a machinery selection algorithm. Danok et al. (1980) applied the technique of mixed integer programming to choose optimal machinery sets and crop plans with regard to stochastic weather conditions. Rotz et al. (1983) developed a computer algorithm to select machinery complements for both conventional and conservation tillage systems, taking into account different soil types and weather probability levels. However, the optimal machinery complement selected by an algorithm is usually smaller than real farms due to farmers' risk consideration (Rotz et al., 1983). Farmers tend to choose a larger machinery complement to reduce time and weather related risks in farming activities.

Given the gap between an optimal choice and real situation, Cortus (2005) chose another selection method to determine a machinery complement. A machinery complement for a Saskatchewan crop farm was determined by Cortus (2005) based upon field operations necessary for the farm, time available for field operations, and weather conditions. Koeckhoven (2008) also used this method to choose a machinery complement for a livestock and crop mixed farm in southern Alberta. This study uses the method developed by Cortus (2005) and Koeckhoven (2008) to build a machinery complement for a crop farm in the Alberta Brown Soil Zone (Table 4.4). It is established by choosing power equipment based upon horsepower to operate different types and sizes of drawn equipment for a 2000-acre crop farm. Due to data and time limitations, this study does not establish machinery complements for other province-soil combinations.

4.1.3 Crop Rotation

As a vital part of a cropping system, a crop rotation is a “recurring sequence of crops on a particular field” (SAF, 2004). A proper crop rotation can maximize farm economic returns and improve agronomic conditions, such as optimize nutrient and water use, minimize disease problems, and control weeds (SAF, 2005). How to determine a crop rotation depends upon conditions of an individual field at a specific time period, including nutrients, moisture, diseases, weeds, herbicides, etc. (SAF, 2005). Additionally, farmers’ equipment, individual preferences, and market conditions affect the choice of crop rotation (SAF, 2005).

There are nine province-soil combinations in this study and each combination has a 2000-acre representative farm. For every representative farm, a crop rotation and number of acres for each crop in the rotation is determined. There are two factors considered in the decision-making process. One of them is crop area data by census division (CD) from the 2006 Census of Agriculture (Statistics Canada, 2007). In each province, one soil zone usually covers more than one CD, but only one CD is chosen to represent each province-soil combination based upon two criteria: first, the CD must be completely or mostly located in the target province-soil combination; second, the CD has complete data on major field crops. If more than one CD meets the two criteria, the CD with the largest geographical area is chosen. For Alberta, the CDs which are located or mostly located in the irrigated region are avoided because of the different farming practices adopted in that region. After the representative CD is decided for a province-soil combination, crops are ranked by seeded area within the CD (Appendix D). Basically, four or five crops with the highest acres are included in the crop rotation. The sequence of the crops depends upon the other factor, crop agronomy. Some agronomic factors, such as not growing continuous wheat or continuous barley (MAFRI, 2008) and alternating cereal and broadleaf crops (MAFRI, 2008), are taken into account when making the crop rotation decisions.

4.1.3.1 Determine Which Crop to Provide Winter Wheat with Standing Stubble

Within the crop rotation, the crop proceeding winter wheat is of particular importance since it provides winter wheat with standing stubble. The effectiveness of standing stubble in trapping snow is very important for winter wheat to survive the harsh winters in Western Canada. The snow trapping potential of stubble depends upon its height and density (Fowler, 2002). Different types of crops have different types of stubble, resulting in different snow trapping potential. Besides snow trapping potential, the selected stubble should provide some crop rotation advantages, such as reduced weed, insect, and disease problems (Mckenzie, 2007; SAF, 2008). Table 4.5 gives a list of recommendations on stubble choices for winter wheat from agricultural organizations and crop specialists. Because of superior snow trapping potential and crop rotation advantages, canola stubble is generally recommended for winter wheat seeding, and barley stubble is also one of the choices. This study uses canola as the first stubble choice, and in areas where canola seeded area is insignificant, feed barley is chosen to provide winter wheat with standing stubble for fall seeding.

4.1.3.2 Crop Rotation Choices for this Study

Based upon the above discussion, crop rotations and number of acres for each crop are determined for each province-soil combination. These are presented in Table 4.6. According to Thoroughgood (2008), farmers usually switch from spring wheat to winter wheat, and a combination of spring wheat and winter wheat helps to manage weather risk. In this study, to incorporate winter wheat, half the acreage of spring wheat is replaced with winter wheat, which represents the difference between the rotations before and after incorporating winter wheat. As the stubble source, canola or barley is followed by winter wheat. All other crops besides winter wheat in this study adopt stubble seeding, unless otherwise specified. Stubble seeding and fallow seeding incur different yields and costs for the same type of crop.

The crop rotations determined for this study are not necessarily the crop rotations adopted by Prairie farmers. From observing the farming activities in the Prairie region, differences between the crop rotations used in this study and the reality are expected. However, such differences do not harm the purpose of this study. This study assumes that winter wheat replaces half spring wheat acreage if winter wheat is incorporated into a crop rotation. Consequently, changes in other crop types and acres can only shift the farm NPVs up and down, but not affect the NPV difference (NPV with winter wheat – NPV without winter wheat). This is a result from the model structure which is explained in section 4.3.

4.2 Economic Relationships

4.2.1 Revenues

The only source of farm revenues considered in this study is crop sales since the representative farms are crop farms. Every representative farm grows four to five crops each year and every crop generates crop revenue. Crop revenue for each crop is calculated by multiplying its price ($/bu), yield (bu/ac), and number of seeded area (acre). Default crop acres in the simulation models are listed in Table 4.6. Default crop prices and yields, provided in Appendix E, are averages of 2007 and 2008 provincial budget estimates (AARD, 2007 and 2008; SAF, 2007 and 2008; MAFRI, 2007 and 2008) with an exception of the Manitoba yields which are averages of 2006 and 2007 data (MASC, 2007 and 2008). There is no adjustment for inflation. Because of the existence of winterkill and possible reseeding, winter wheat and barley may experience some changes in revenue year to year. Total annual crop revenue is calculated by adding up all crop revenues in the same year.

4.2.2 Input Costs

This study only considers input costs related to cash flows (Appendix E). For example, there are costs of seed, fertilizer, chemicals, trucking and marketing, fuel, oil and lube, machinery repairs, building repairs, custom work and hired labor, and utilities and miscellaneous listed as variable costs, while there are machinery replacement cost, building replacement cost, license and insurance, and property tax listed as fixed costs. Machinery repairs include minor machinery repairs and replacement of machinery parts. Custom work and hired labor, often listed separately in a budget table, are treated as one category since there is no need to separate them in the context of this study.

There are some explanations about the category of machinery replacement. Since the period of study is 30 years, there is a problem about machinery depreciation and replacement. This study uses cash flow models, so only considers machinery replacement. Machinery replacement is affected by many factors, such as replacement cycle and salvage value. To simplify the model, a constant amount of money is assumed being spent on the equipment each year to maintain and replace the machinery complement. An annual economic depreciation rate of 8% is chosen based upon the study of Untershultz and Mumey (1996).

For Alberta, a machinery complement for the 2000-acre crop farm in the Alberta Brown Soil Zone is built with the help of Koeckhoven (2008). Current market values of the machinery are provided by Koeckhoven (2008) using data from *Ironsearch.com*, a website to trade new and used equipment in North America. The quantity of each type of equipment is multiplied by its price and then the amounts spent on different equipment are summed up to form a machinery asset base for the representative farm (Table 4.4). The machinery asset base is multiplied by the chosen depreciation rate to generate the annual machinery replacement cost which is further divided by 2000 acres to obtain the annual machinery replacement cost, $30/acre/year. However, the value of this category from the provincial budget estimates (AARD, 2007 and 2008) is $25/acre/year. This study chooses the latter value since it matches provincial budgets. Other soil zones in Alberta also use the provincial budget estimates (AARD, 2007 and 2008) as a source of annual machinery replacement cost.

For Saskatchewan, Cortus (2005) calculated the annual machinery replacement cost for a crop farm in the Saskatchewan Black Soil Zone. The result of $19/acre/year is compared to the estimated $19.8/acre/year in the same soil zone from provincial budget estimates (SAF, 2007 and 2008). There is no obvious difference between the two values. This study chooses the provincial budget estimates (SAF, 2007 and 2008) as the source of annual machinery replacement cost for each soil zone in Saskatchewan.

For Manitoba, there is no previous study found about annual machinery replacement cost. The estimated $25/acre/year from provincial budget estimates (MAFRI, 2007 and 2008) is used in this study.

For building replacement, a constant amount of money is assumed being spent each year to maintain and replace the building. Each province uses provincial budget estimates as the source for the category of annual building replacement cost. Default input costs are averages of 2007 and 2008 provincial budget estimates provided on a per acre basis (AFRD, 2007 and 2008; SAF, 2007 and 2008; MAFRI, 2007 and 2008) (Appendix E). There is no adjustment for inflation. For each crop, variable costs and fixed costs are added together and then multiplied by the seeded crop acres to generate a total input cost. The input costs of all crops in the same year are summed up to obtain the total annual costs of the representative farm.

4.2.3 Determining the Discount Rate

Section 3.1.2 introduced the CML theory to determine expected rate of return and therefore discount rate of a project. According to Equation (3.2), the market risk-free rate (r_f), expected market return ($\bar{r}_m$), standard deviation of market return (σ_m), and standard deviation of farm return (σ_p) are needed to calculate the expected farm return ($\bar{r}_p$).

The yield on a one-year Government of Canada Treasury Bill on January 12, 2009 was 0.78%. This is used as the market risk-free rate. Ross et al. (2005) estimated the expected market return, standard deviation of market return, and risk premium to be 10.64%, 16.41%, and 3.84% respectively for Canadian common stocks from 1957 to 2003 and these values are used in the calculation of the expected farm return in this study. The volatility of farm return for a crop farm in the Saskatchewan Black Soil Zone from Cortus (2005), 33.07%, is used. Using Equation (3.2), the expected rate of return of a farm is calculated as:

$$\bar{r}_p = 0.78\% + \left[\frac{3.84\%}{16.41\%}\right] \times 33.07\% = 8.52\% \tag{4.1}$$

The choices of crop types are limited by agronomic conditions of an individual field at a specific time period as earlier discussed. Besides, weather has a great influence on crop production, and weather risk is especially important in this study because the whole winter survival process of winter wheat is temperature-regulated as described in Figure 2.7. Consequently, this study adjusts the discount rate calculated from Equation (3.2) up to 10% based upon risk consideration and a review of previous studies in the same Prairie region (i.e., Cortus, 2005; Koeckhoven, 2008). A possible reason for the lower pre-adjusted discount rate is the low risk-free market rate which reflects the economic situation from the end of 2008 up to now. Sensitivity analysis is conducted on the discount rate in the simulations.

4.3 Stochastic Implementation

Cash flow models are built using a 30 year time horizon to allow the flexibility to capture the winterkill risk in winter wheat production in the long run. Each cash flow model includes a group of crops and each crop generates its own cash inflow and cash outflow annually. In each year, all crop cash inflows are combined to form the total cash inflow, and all crop cash outflows are combined to form the total cash outflow. The difference between the total cash inflow and total cash outflow in the same year is net cash flow which is further discounted. All discounted net cash flows over 30 years are added up to generate the NPV.

Appendix G provides an example of cash flows without winter wheat production in the Alberta Black Soil Zone. Since everything in the base model is deterministic, net cash flows are constant over 30 years. When incorporating winter wheat, net cash flows may change year to year for winterkill and reseeding. @RISK 5.0, a simulation package added in Microsoft Excel, is used to run the simulation models and do the analysis. Monte Carlo simulation is performed on cash flow models to calculate NPVs. Each iteration of the Monte Carlo simulation involves running a cash flow model one time, generating one NPV calculated over the 30 year period. 5000 iterations are performed in each Monte Carlo simulation. One reason to use 5000 iterations instead of fewer times of iterations is that the computing time of 5000 iterations is minimal for this study, and the other reason is that 5000 iterations make output distributions more stable and accurate than fewer times of iterations.

This study considers only winter wheat yield as stochastic in the simulation models, where uncertainty of winter wheat yield arises from the possibility of winterkill. There are two types of winterkill: complete winterkill and partial winterkill. Complete winterkill is regarded as a complete loss of winter wheat and the field is reseeded to barley in the spring, so winter wheat yield becomes zero. Partial winterkill is regarded as a partial loss of winter wheat and the field does not need reseeding. In this case, there is a positive winter wheat yield but it is below the default yield. Another two yield outcomes are considered: a default year in which winterkill is not severe enough to affect winter wheat production so that winter wheat yield keeps the default value, and above default in which winterkill is at a minimum level so that winter wheat yield is above the default yield. Complete winterkill, partial winterkill, default year, and above default represents the four yield outcomes for winter wheat production and each of these relates to a different response of winter wheat yield. Simulation is used to mimic the winterkill risk: a stochastic variable is established to determine which one of the above mentioned outcomes occurs and to calculate corresponding winter wheat yield. Winter wheat price, as well as yields and prices for other crops, are not stochastic in this study.

This study does not directly simulate winterkill for two reasons. One is that the biological processes involved in winter survival are complicated (Figure 2.7). How to scientifically define the above mentioned four yield outcomes is beyond the scope of this economic study. The other reason is that there is no need to directly simulate winterkill for the purpose of this study (i.e., examining the economic feasibility of winter wheat production). Among all the questions related to the four yield outcomes in winter wheat production and winter wheat yields, only two are of interest to this study: what is the probability of each outcome and how does winter wheat yield respond to each outcome? The stochastic variable mentioned above is used to evaluate the two questions.

4.3.1 Stochastic Variable Related to Cold Tolerance

There are no historical or trial data on the probabilities of complete winterkill, partial winterkill, default year, and above default. This study determines the probability of each outcome based upon calculations done using expert opinion as a guide.

According to expert opinion (Thoroughgood, 2008), the probability of complete winterkill is approximately 5% and the probability of partial winterkill is approximately 20%. The probability of the yield being above default is the frequency with which winter wheat yield is above a default yield. This depends upon which group of yield data is observed and how a default yield is defined. The annual provincial estimated yields in the Alberta Dark Brown Soil Zone from 2000 to 2008 (AARD, 2000-2003; AARD, 2004-2008) are chosen to estimate the above default yield and probability. The mean and standard deviation of the mean for the yields from 2000 to 2008 are calculated[5]. The default yield is calculated by adding the mean and one standard deviation of the mean together. The yield of the soil zone in each year during the time period is compared to the default yield of 38.08bu/ac. Only one in nine years has a yield higher than the default yield, which suggests a probability of 11.1%. Any yield above the default yield relates to the scenario of interest, so the probability of above default is 11.1%. Since the simulation models use the budget averages of crop data for 2007 and 2008 when crop yields are higher than previous years, 15% is chosen to be the probability of above default. Subsequently, the probability of default year is calculated to be 60%. Thus, the probabilities of the four yield outcomes are determined: 5% complete winterkill, 20% partial winterkill, 60% default year, and 15% above default. These probabilities are varied in the scenario analysis.

A cold tolerance related stochastic variable x which has a uniform distribution ($x \in [0,1]$) is built using the function "Define Distributions" in @RISK 5.0. A uniform distribution defines equal probability over a given range. The cumulative distribution function (CDF) of the random variable x is defined as $F_x(a) = P\{x \le a\}$ for every real number x, where $P\{x \le a\}$ is the probability that x takes a value equal to or less than a (Papoulis and Pillai, 2002). The probability that x lies in an interval $[b, c]$ is

$$P_x(b \le x \le c) = P\{x \le c\} - P\{x \le b\} \tag{4.2}$$

The uniform distribution used in this study ranges from 0 to 1, so it is in a standard form. The CDF of a standard uniform distribution is

$$F_x(x) = x \; (0 \le x \le 1) \tag{4.3}$$

Based upon the above discussion, the probability of each scenario in winter wheat production is represented as follows:

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[5] The yields in the Alberta Dark Brown Soil Zone from 2000 to 2008 are 40bu/ac, 36bu/ac, 36bu/ac, 36bu/ac, 36bu/ac, 38bu/ac, 36bu/ac, 36bu/ac, and 36bu/ac respectively. The mean is 36.67bu/ac, and the standard deviation of the mean is 1.41bu/ac.

Complete winterkill

$$P_x(0.95 \le x \le 1) = P\{x \le 1\} - P\{x \le 0.95\} = 1 - 0.95 = 0.05 \qquad (4.4)$$

Partial winterkill

$$P_x(0.75 \le x < 0.95) = P\{x < 0.95\} - P\{x \le 0.75\} = 0.95 - 0.75 = 0.2 \qquad (4.5)$$

Default year

$$P_x(0.15 \le x < 0.75) = P\{x < 0.75\} - P\{x \le 0.15\} = 0.75 - 0.15 = 0.6 \qquad (4.6)$$

Above default

$$P_x(0 \le x < 0.15) = P\{x < 0.15\} = 0.15 \qquad (4.7)$$

These probabilities are in accordance with the predetermined probabilities of the four yield outcomes. In a single iteration of a simulation, a different random variable x is drawn from this uniform distribution for each year from year 1 to year 30. Based upon the range in which it lies, a yield outcome is decided for each year. There is independence assumed between years within each iteration. The probabilities of the four yield outcomes can be varied, which is examined in scenario analysis.

4.3.2 Winter Wheat Yield Model

Winterkill risk is very crucial for winter wheat production, but the default data do not incorporate any winterkill risk. A set of mathematical models are built to capture the influences of winterkill risk on winter wheat yield. The numerical relationship between the yield outcomes and winter wheat yield was not found in literature, but should be developed for the purpose of this study. This study estimates winter wheat yield as a function of the random variable x . Expert opinion (Thoroughgood, 2008 and Irvine, 2008) is used as a reference when building the functional forms.

Winter wheat yield responds to each yield outcome in winter wheat production differently. The responsiveness of winter wheat yield to complete winterkill, partial winterkill, default year, and above default is presented in functional forms in Table 4.7. Complete winterkill relates to zero yield; partial winterkill relates to in a yield loss of 5 – 25% below the default yield; default year keeps winter wheat yield equal to the default yield; above default relates to a yield increase of 0 – 15% above the default yield. Both the yield loss factor A and yield increase factor B (Table 4.7) allow for flexibility in yield responsiveness and are examined in sensitivity analysis. The limitations of the winter wheat yield models are discussed after introducing scenarios in section 4.4.2.

4.3.3 Graphical Interpretation of Stochastic Implementation

The stochastic process is presented graphically in Figure 4.1. Each random draw of x determines a yield outcome which corresponds to unique yield responsiveness as described in Table 4.7. For example, $x \in [0.95,1]$ determines complete winterkill which relates to zero winter wheat yield. Complete winterkill also relates to a lower variable cost of winter wheat because no costs for this enterprise are incurred after winter wheat is winterkilled. In general, farming activities for winter wheat before winter include seeding and application of phosphorus and herbicides, so there are four kinds of variable costs incurred; seed cost, phosphorus cost, herbicide cost, and labor cost. Phosphorus is assumed to be only applied in fall; herbicides are assumed to be applied in fall and spring equally; labor is assumed to be distributed to fall and spring equally. Using the Saskatchewan Black Soil Zone as an example, the variable costs incurred before winter are summed up to be approximately 30% of the total default variable cost when there is complete winterkill.

Complete winterkill also relates to reseeding to feed barley in spring. Estimating low temperature damage to winter wheat and removal of winter wheat from fields takes time, so barley seeding is often delayed. AARD (2005) published relationships between seeding date and barley yields reported by farms from 1999 to 2001. Although the exact relationships vary across soil zones, the overall trend of yields shows that barley yield decreases as seeding is delayed. In this study, the yield of late seed barley is assumed to be 10% lower than the default barley yield. Late seeded barley is grown on the fields where winter wheat experiences complete winterkill. Different from other barley fields, late seeded barley may not need phosphorus application in spring since phosphorus is applied on the fields in fall already. In the Saskatchewan Black Soil Zone, phosphorus cost is about 10% of the total variable cost of barley, so the total variable cost of late seeded barley is 10% lower than the default total variable cost of barley. The relationships between winterkill, winter wheat, and late seeded barley are all included in Figure 4.1.

There are two other assumptions made to simplify the models. First is that all crops are seeded and harvested on time. This is especially vital for winter wheat since it is fall seeded, while all other crops are spring seeded and fall harvested. If the crop preceding winter wheat in a crop rotation is not harvested on time, winter wheat seeding will be delayed and even cancelled. Second, management issues are not modeled in this study. This study does not consider the restrictions on winter wheat crop production resulting from management issues, such as fall seed timing.

4.4 Overview of Analysis

NPVs are calculated by discounting cash flows associated with crop production over 30 years. After incorporating winter wheat, half the spring wheat acreage is replaced with winter wheat in each rotation. The acreage of other crops remains the same except for feed barley when there is complete winterkill. To compare the NPVs before and after incorporating winter wheat, a NPV difference is calculated by subtracting the NPV before incorporating winter wheat from the NPV after incorporating winter wheat. If the NPV difference is positive, the NPV with winter wheat is higher; if the NPV difference is negative, the NPV without winter wheat is higher. Since winter wheat only replaces spring wheat in rotations, the research question becomes how farmers can receive a higher NPV, by incorporating winter wheat or remaining with spring wheat.

The base case of this study is introduced, followed by eleven scenarios. Based upon scenario 1, six sensitivity analyses are introduced to examine the influences of some key assumptions on the final results. Two elasticity analyses are also presented. The purpose of each analysis is presented along with an explanation of the analysis itself.

The base case of this study is that farmers only grow spring wheat with other crops in a crop rotation. For each province-soil combination, the farm size is 2000 acres; discount rate is 10%; the crop rotation is listed as the rotation before incorporating winter wheat in Table 4.6. There are eleven scenarios to explore the economic feasibility of growing winter wheat in the Canadian Prairies and all of them switch 50% spring wheat acreage to winter wheat. Farm size and discount rate are the same as the base case. Crop rotations for all the scenarios are listed as the rotations after incorporating winter wheat in Table 4.6. Among the eleven scenarios, one scenario examines risk-free winter wheat production and the other ten scenarios (scenarios 1 – 10) examine winter wheat production with winterkill risk. Table 4.8 provides a summary comparison of the assumptions of the base case and alternative scenarios.

4.4.1 Risk-Free Winter Wheat Production

The scenario of risk-free winter wheat production involves winter wheat production without any risk of winterkill. In other words, there is zero probability of winterkill in this scenario, which is different from the following scenarios 1- 10 (Table 4.8). Except for spring wheat and winter wheat, other crop acres are constant. Its NPVs are compared to the NPVs of the base case. The purpose of this scenario is to explore the economic feasibility of growing winter wheat without winterkill risk based upon provincial crop budget data (Appendix E).

4.4.2 Winter Wheat Production with Winterkill Risk

Scenarios 1 - 10 study winter wheat production with winterkill risk (Table 4.8). Since there is risk of winterkill, complete winterkill and reseeding to feed barley may occur in any given year. Except for spring wheat and winter wheat, other crop acres are constant with an exception of feed barley when there is reseeding of winter wheat. These scenarios are compared to the base case in the same province – soil combination to investigate which one brings farmer higher NPVs, spring wheat production or winter wheat production with winterkill risk.

Scenarios 1 – 5 explore the economic feasibility of winter wheat production under different probabilities of complete winterkill, partial winterkill, default year, and above default (Table 4.8). Scenario 1 has 5% complete winterkill, 20% partial winterkill, 60% default year, and 15% above default. These probabilities are determined by expert opinion and some calculations as discussed earlier.

Based on scenario 1, sensitivity analyses are performed on some key parameters. These include the discount rate (+/- 2%), sunk variable cost of winter wheat when there is complete winterkill (+/- 5%), variable cost of late seeded barley (+/- 5%), yield of late seeded barley (+/- 5%), yield loss factor A (-0.05 and -0.1), and yield increase factor B (+/- 0.2). The effects of changing these parameters on final results are examined.

Scenario 2 simulates a higher incidence of winterkill. The probability of complete winterkill increases to 10% and the probability of partial winterkill increases to 25%. Above default is maintained at a probability of 15%. Accordingly, the probability of a default year decreases to 50%. This scenario is intended to explore the economic viability of winter wheat production under a higher risk of winterkill.

Contrary to scenario 2, scenario 3 examines the economic feasibility of winter wheat under a higher incidence of above default yield. Complete winterkill and partial winterkill maintain the same probabilities as scenario 1; 5% and 20% respectively. The probability of above default increases to 30% and the probability of a default year drops to 45%.

Scenario 4 eliminates any chance of yield being above default in winter wheat production. The probabilities of complete winterkill and partial winterkill remain the same as scenario 1. Default year increases up to 75% of the time. How NPV difference changes when maximum yield is the default yield is examined in the simulation models.

Scenario 5 examines cases when there are only two possibilities, complete winterkill and default year, and how the economic feasibility of winter wheat responds to the changes of the probabilities of complete winterkill and default year. Partial winterkill and above default are excluded in this case. This scenario investigates how NPV difference varies as the probability of complete winterkill increases by 1 percentage point each time, starting from zero.

Scenarios 6 – 8 examine switching points from growing spring wheat to winter wheat. A switching point is defined as the probability of complete winterkill at which farmers are indifferent between winter wheat and spring wheat. Farmers make the decision of growing winter wheat versus spring wheat based upon the comparison of NPVs before and after incorporating winter wheat, and the probability of complete winterkill directly affects the NPV after incorporating winter wheat. The switching point analysis is conducted by seeking a complete winterkill probability to make the NPV difference equal to zero using the goal seek function in @RISK 5.0. If the probability of complete winterkill is at the same level as the switching point, farmers are indifferent to the two types of wheat because the two NPVs are equal. In scenarios 6 – 8, the initial probabilities of complete winterkill, partial winterkill, default year, and above default are the same as scenario 1. The probability of partial winterkill and the probability of complete winterkill are always summed up to 25%. The probability of partial winterkill changes as the probability of complete winterkill changes.

Scenario 6 investigates switching point when winter wheat yield and price are at default values. Default values of winter wheat yield and price are in Appendix E. This scenario investigates cold tolerance of winter wheat in each province-soil combination.

Winter wheat usually outperforms spring wheat in terms of yield. Scenario 7 explores how the switching point changes as winter wheat increases its yield advantage relative to spring wheat. Yield difference is calculated by subtracting spring wheat yield from winter wheat yield. Default yield difference varies from 0.86bu/ac to 23.8bu/ac depending on the province-soil combination. Winter wheat yield increases by 1bu/ac in each simulation, and three simulations are performed for each province-soil combination. This scenario concentrates on the influences of improving yield on the economic viability of growing winter wheat.

Scenario 8 analyzes how switching point responds to the increase of winter wheat price. Price is a proxy of quality. Winter wheat has lower protein concentration than spring wheat, so it usually has lower prices than spring wheat. Price difference is calculated by subtracting spring wheat price from winter wheat price. Default price difference is from -$1/bu to -$0.36/bu for each province-soil combination. Winter wheat price increases by approximately one third of price difference ($0.12 – 0.34/bu) in each simulation until it reaches the same price as spring wheat. This scenario examines the effects of narrowing price gap (i.e., improving winter wheat quality) on the economic feasibility of winter wheat production.

Scenario 9 examines how the probability of above default changes as the probability of complete winterkill decreases from 5% to 0 when keeping the mean of average simulated winter wheat yield of 30 years equal to the default yield. The initial probabilities of complete winterkill, partial winterkill, default year, and above default are the same as scenario 1. The probability of partial winterkill and the probability of complete winterkill are always summed up to 25%; The probability of default year and the probability of above default are always summed up to 75%.

The last scenario examines the economic viability of winter wheat using 2005 and 2006 data (AARD, 2005 and 2006; SAF, 2005 and 2006; MAFRI, 2005 and 2006; MASC, 2006, 2007, and 2008). From provincial budget estimates from 2000 to 2008, an obvious increase has been found in crop prices and fertilizer costs in 2008 compared to previous years from 2000 to 2007. It is still early to determine whether such an increase is permanent or temporary. Scenario 10 uses data different from the default data but still in recent years to study the economic feasibility of winter wheat. Winterkill risk remains the same as scenario 1 (Table 4.8). The data used in this scenario are in Appendix H which provides a comparison to the default data in Appendix E.

The probabilities of the four yield outcomes in scenarios 2 – 9 are different from scenario 1, and some of the probabilities change in the process of performing the goal seek function. These changes result in an interpretation problem because the winter wheat yield model is $y = A \cdot x \cdot \overline{y}$, $A = 1$ (x $\in$[0.75, 0.95)) under partial winterkill, and $y = (1 + B \cdot x) \cdot \overline{y}$, $B = 1$ (x $\in$ [0, 0.15)) under above default (Table 4.7). The ranges of winter wheat yield under partial winterkill and above default are determined by the probabilities of the four yield outcomes from expect opinion and some calculations (the same probabilities are used in scenario 1). However, in scenarios 2 – 9, the probabilities of the yield outcome change (i.e., the range of x changes), as winter wheat yield under partial winterkill and above default changes its range. This is a model limitation resulting from the model structure.

4.4.3 Yield Elasticity of Switching Point and Price Elasticity of Switching Point

The effects of improving winter wheat yield/price on the switching points are preliminarily examined in scenarios 7 and 8. To understand the relationship in the form of elasticity, yield elasticity of switching point and price elasticity of switching point are calculated.

Yield elasticity of switching point is a measure of responsiveness in the switching point of complete winterkill probability as a result of change in winter wheat yield. It is calculated as follows:

$$E_y = \frac{(\Pr ob_2^y - \Pr ob_1^y)/\Pr ob_1^y}{(Y_2 - Y_1)/Y_1} \tag{4.8}$$

where E_y is the yield elasticity of switching point; Y_1 is the default winter wheat yield; Y_2 is the winter wheat yield which is 1bu/ac above the default yield; $\Pr ob_1^y$ is the probability of complete winterkill at Y_1; $\Pr ob_2^y$ is the probability of complete winterkill at Y_2.

Price elasticity of switching point is a measure of responsiveness in the switching point of complete winterkill probability as a result of change in winter wheat price. It is calculated as follows:

$$E_p = \frac{(\Pr ob_2^p - \Pr ob_1^p)/\Pr ob_1^p}{(P_2 - P_1)/P_1} \tag{4.9}$$

where E_p is the price elasticity of switching point; P_1 is the default winter wheat price; P_2 is the winter wheat price which is the same as spring wheat price; $\Pr ob_1^p$ is the probability of complete winterkill at P_1; $\Pr ob_2^p$ is the probability of complete winterkill at P_2.

Yield/price elasticity of switching point is used to measure the sensitivity of switching point with respect to yield/price. These two elasticities are sensitive to the choices of starting point and ending point, but can still reveal some useful information on the relationship between switching point and yield/price.

The representative farms, economic relationship, and stochastic implementation of winter wheat yield are presented in this chapter. Scenarios and sensitivity analyses are introduced to explore whether it is economically feasible to adapt winter wheat to the Canadian Prairies and the factors which influence the economic feasibility of winter wheat production. Two elasticity analyses are also presented to examine the relationships between some important factors in winter wheat production.

Table 4.1 - Farm Sizes in Saskatchewan 2006

Geography	Number of Farms Reporting	Total Farm Area (Acre)	Average Farm Size (Acre)
Division No. 1 - CD (470001000)	2,287	3,255,337	1,423
Division No. 2 - CD (470002000)	2,255	3,949,074	1,751
Division No. 3 - CD (470003000)	2,240	4,307,019	1,923
Division No. 4 - CD (470004000)	1,555	5,089,839	3,273
Division No. 5 - CD (470005000)	2,736	3,252,485	1,189
Division No. 6 - CD (470006000)	3,500	4,073,382	1,164
Division No. 7 - CD (470007000)	2,478	4,359,718	1,759
Division No. 8 - CD (470008000)	2,707	5,442,333	2,010
Division No. 9 - CD (470009000)	2,656	2,775,039	1,045
Division No. 10 - CD (470010000)	2,135	2,614,453	1,225
Division No. 11 - CD (470011000)	3,273	3,959,733	1,210
Division No. 12 - CD (470012000)	2,100	3,262,986	1,554
Division No. 13 - CD (470013000)	2,407	4,071,963	1,692
Division No. 14 - CD (470014000)	3,348	3,552,579	1,061
Division No. 15 - CD (470015000)	3,875	3,770,590	973
Division No. 16 - CD (470016000)1	2,518	3,286,856	1,305
Division No. 17 - CD (470017000)	2,259	3,230,459	1,430
Maximum of Average Size in all CDs			3,273
Minimum of Average Size in all CDs			973

Source: Adapted from Table 4.3-1 land Use - Total area of farms, census years 2006 and 2001, Statistics Canada.

Table 4.2 - Farm Sizes in Alberta 2006

Geography	Number of Farms Reporting	Total Farm Area (Acre)	Average Farm Size (Acre)
Division No. 1 - CD (481001000)	1,536	4,202,803	2,736
Division No. 2 - CD (482002000)	3,164	4,288,550	1,355
Division No. 3 - CD (483003000)	1,811	2,743,961	1,515
Division No. 4 - CD (481004000)	1,302	5,009,680	3,848
Division No. 5 - CD (482005000)	2,703	4,018,933	1,487
Division No. 6 - CD (483006000)	4,905	3,069,120	626
Division No. 7 - CD (484007000)	3,019	4,559,982	1,510
Division No. 8 - CD (485008000)	4,203	2,347,848	559
Division No. 9 - CD (485009000)	1,209	846,781	700
Division No. 10 - CD (484110000)	5,217	4,720,015	905
Division No. 11 - CD (485011000)	6,060	2,869,267	473
Division No. 12 - CD (486012000)1	2,530	2,462,573	973
Division No. 13 - CD (486013000)	4,476	3,043,952	680
Division No. 14 - CD (486014000)	785	512,896	653
Division No. 15 - CD (483015000)	130	510,460	3,927
Division No. 16	N/A	N/A	N/A
Division No. 17 - CD (487017000)	2,513	2,677,036	1,065
Division No. 18 - CD (487018000)	721	731,147	1,014
Division No. 19 - CD (487019000)	3,147	3,512,853	1,116
Maximum of Average Size in all CDs			3,927
Minimum of Average Size in all CDs			473

Source: Adapted from Table 4.3-1 land Use - Total area of farms, census years 2006 and 2001, Statistics Canada.

Table 4.3 - Farm Sizes in Manitoba 2006

Geography	Number of Farms Reporting	Total Farm Area (Acre)	Average Farm Size (Acre)
Division No. 1 - CD (461001000)	602	449,100	746
Division No. 2 - CD (460902000)	1,493	805,346	539
Division No. 3 - CD (460803000)	1,659	1,280,705	772
Division No. 4 - CD (460804000)	1,101	1,030,891	936
Division No. 5 - CD (460105000)	1,385	1,800,189	1,300
Division No. 6 - CD (460206000)	798	885,986	1,110
Division No. 7 - CD (460207000)	1,147	1,214,795	1,059
Division No. 8 - CD (460708000)	1,157	1,169,260	1,011
Division No. 9 - CD (460709000)	637	599,032	940
Division No. 10 - CD (460710000)	402	452,192	1,125
Division No. 11 - CD (460911000)	201	69,657	347
Division No. 12 - CD (460912000)	608	297,647	490
Division No. 13 - CD (461113000)	476	264,562	556
Division No. 14 - CD (461114000)	768	594,526	774
Division No. 15 - CD (460315000)	1,764	2,009,048	1,139
Division No. 16 - CD (460416000)	818	897,159	1,097
Division No. 17 - CD (460617000)	1,639	2,197,814	1,341
Division No. 18 - CD (461218000)	1,382	1,818,659	1,316
Division No. 19 - CD (461219000)1	110	267,480	2,432
Division No. 20 - CD (460520000)	798	855,046	1,071
Division No. 21 - CD (461221000)	109	113,911	1,045
Maximum of Average Size in all CDs			2,432
Minimum of Average Size in all CDs			347

Source: Adapted from Table 4.3-1 land Use - Total area of farms, census years 2006 and 2001, Statistics Canada.

Table 4.4 - Machinery Complement and Annual Machinery Replacement Cost for a 2000-Acre Crop Farm in Alberta Brown Soil Zone

Farming Activity	Equipment	Market Price (Used Equipment)	QTY	Amount
Tractor	250-299 hp	$174,900	1	$174,900
	150-199 hp	$79,154	1	$79,154
Separate seed out of plant	Combine	$240,451	1	$240,451
Harvest	Swather (36ft)	$83,250	1	$83,250
Spay chemicals and herbicide	Sprayer (100ft)	$25,394	1	$25,394
Seed	Seeder w Tank (50ft)	$76,450	1	$76,450
Do tillage	Field Cultivator (40ft)	$22,900	1	$22,900
Truck to pull grain trailer	Semi	$23,403	1	$23,403
	Grain Trailer	$18,000	1	$18,000
	Grain Truck	$6,500	1	$6,500
		sum		$750,402
		annual depreciation rate		8%
		annual machinery depreciation		$60,032
		farm size (acre)		2000
		annual machinery depreciation per acre		$30

Note: The table is established based upon suggestions from Koeckhoven (2008).

Table 4.5 - Recommendations on Stubble Choices for Winter Wheat

Source	Author and Year	Recommendations
Winter Wheat in the Parkland Area of Alberta	Salmon and McLelland, 1999	Barley or canola stubble is preferred.
Fall Seeding of Winter Cereals – Frequently Asked Questions	AARD, 2007	Cereal or canola stubble is preferred.
Agronomic Management of Winter Wheat in Alberta	McKenzie, 2007	Canola, mustard or pea stubble is preferred.
Winter Wheat - FAQs	SAF, 2008	Canola or mustard stubble is preferred. Barley and oat stubble can also be used.
Winter wheat – Production and Management	MAFRI, 2008	Canola stubble is preferred. Barley and oat stubble can also be used.
Personal Communication	Irvine, 2008	Canola, cereal grain cut for silage, and barley are preferred.

Table 4.6 - Crop Rotation Choices for Province - Soil Combinations

Province-Soil	Before/ After	Crop Rotation (acre)
AB Black	Before	sw (350) - barley (400) - canola (700) - sw(350)- oats (200)
	After	sw (350) - barley (400) - canola (700) - ww(350)- oats (200)
AB Brown	Before	fallow seeded sw (300) + fallow seeded dw (300) - canola (300) - sw (300) - barley (200) - fallow (600)
	After	fallow seeded sw (300) + fallow seeded dw (300) - canola (300) - ww (300) - barley (200) - fallow (600)
AB Dark Brown	Before	fallow seeded sw (400) - barley (400) - canola (400) - sw (400) - fallow (400)
	After	fallow seeded sw (400) - barley (400) - canola (400) - ww (400) - fallow (400)
AB Grey	Before	sw (300) - barley (500) - canola (700) - sw (300) - oats (200)
	After	sw (300) - barley (500) - canola (700) - ww (300) - oats (200)
AB Peace	Before	sw (400) - barley (300) - canola (700) - sw (400) - oats (200)
	After	sw (400) - barley (300) - canola (700) - ww (400) - oats (200)
SK Black	Before	sw (400) - barley (250) - canola (700) - sw (400) - oats (250)
	After	sw (400) - barley (250) - canola (700) - ww (400) - oats (250)
SK Brown	Before	sw (600) - barley (300) - fallow (500) - fallow seeded dw (500) - oats (100)
	After	sw (300) - barley (300) - ww (300)- fallow (500) - fallow seeded dw (500) - oats (100)
SK Dark Brown	Before	fallow seeded sw (400) - barley (300) - canola (500) - sw (400) - fallow (400)
	After	fallow seeded sw (400) - barley (300) - canola (500) - ww (400) - fallow (400)
MB	Before	sw (450) - barley (200) - canola (600) - sw (450) - oats (300)
	After	sw (450) - barley (200) - canola (600) - ww (450) - oats (300)

Note: Before/After means before/after incorporating winter wheat. Numbers in parentheses are crop acres. sw represents Canada Western Red Spring; ww represents winter wheat; dw represents durum wheat; barley represents feed barley; oats represent milling oats for Alberta and are not specified for Saskatchewan and Manitoba.

Table 4.7 - Random Variables, Scenarios and Yield Functions

Random Variable x	Yield Outcome in Winter Wheat Production	Winter Wheat Yield y
[0.95, 1]	Complete Winterkill	$y = 0$
[0.75, 0.95)	Partial Winterkill	$y = A \cdot x \cdot \bar{y}$, $A = 1$
[0.15, 0.75)	Default Year	$y = \bar{y}$
[0, 0.15)	Above Default	$y = (1 + B \cdot x) \cdot \bar{y}$, $B = 1$

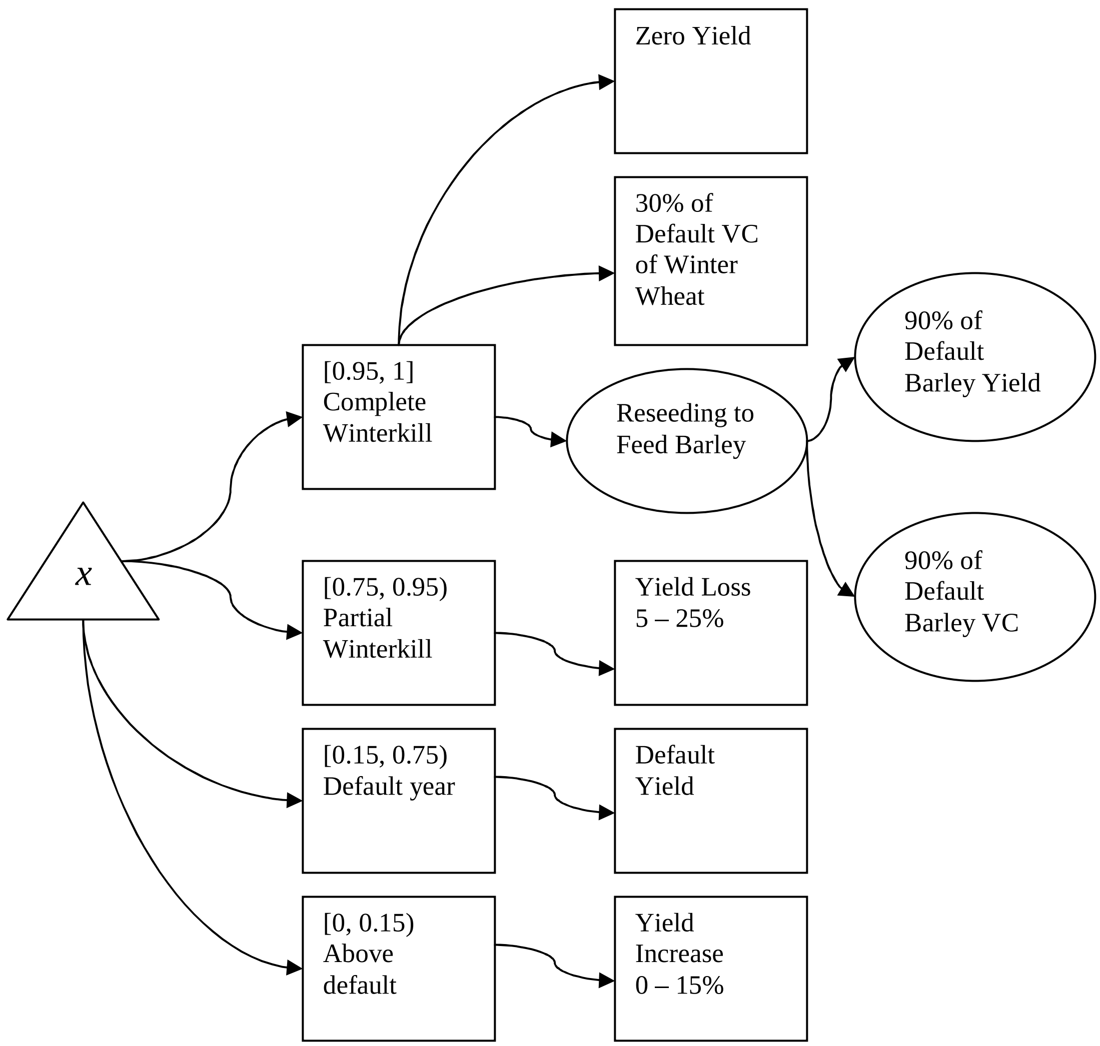
Note: x is a random variable related to cold tolerance, and determines a yield outcome in winter wheat production. $\bar{y}$ is default winter wheat yield which is the average of provincial estimated yields (AARD, 2007 and 2008; SAF, 2007 and 2008) or the average yield from MASC (2007 and 2008). A is yield loss factor. B is yield increase factor. The default values of A and B are both 1, and are varied in the sensitivity analysis.

Table 4.8 - Comparison across Base Case, Scenario of Risk-Free Winter Wheat Production, and Scenarios 1 - 10

	Base Case	Risk-Free WW	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Include WW	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WW Price	n/a	Default Price	Default Price	Default Price	Default Price	Default Price	Default Price	Default Price	Default Price	Varies	Default Price	05-06 Average Price
WW Yield	n/a	Default Yield	Default Yield	Default Yield	Default Yield	Default Yield	Default Yield	Default Yield	Varies	Default Yield	Default Yield	05-06 Average Yield
Prob. of Complete WK	n/a	0	5%	10%	5%	5%	Varies	Varies	Varies	Varies	Varies	5%
Prob. of Partial WK	n/a	0	20%	25%	20%	20%	0	25%-Prob. of Complete WK	25%-Prob. of Complete WK	25%-Prob. of Complete WK	25%-Prob. of Complete WK	20%
Prob. of Default Year	n/a	0	60%	50%	45%	75%	Varies	60%	60%	60%	75%-Prob. of Above Default	60%
Prob. of Above Default	n/a	0	15%	15%	30%	0	0	15%	15%	15%	Varies	15%

Note: WW represents winter wheat; WK represents winterkill; Prob. represents probability; S1- S10 represent scenarios 1 – 10 respectively; n/a represents not applicable. For sources of default prices and default yields refer to Appendix E. For sources of data for scenario 10 refer to Appendix H.

Figure 4.1 - Graphical Interpretation of Stochastic Implementation of Winter Wheat Yield



Note: Rectangle boxes relate to winter wheat; oval boxes relate to late seeded barley. VC is abbreviation of variable cost. x is a random variable related to cold tolerance.

Chapter 5 Results and Discussion

This chapter presents and discusses results of scenario analysis, sensitivity analysis, and elasticity analysis outlined in Chapter 4. NPV differences between the rotations before and after incorporating winter wheat are reported and analyzed as the most important final results. As earlier discussed, the base case includes spring wheat but no winter wheat in crop rotation. The scenario of risk-free winter wheat production and scenarios 1 – 10 are compared to the base case based upon key outputs. Sensitivity analysis on key parameters is compared to scenario 1. Elasticity analysis is done to investigate relationships between some important traits of winter wheat.

Table 5.1 compares provincial average yields, default yields, and average simulated yields over a 30-year period. Provincial average yields are calculated using annual winter wheat yield at a provincial level from 2003 to 2007 from CANSIM II (2009). Default yields, used in the scenario of risk-free winter wheat production, are winter wheat yields without winterkill risk from provincial budget estimates (Appendix E). An average simulated yield is the average yield over 30 year period, and changes value in each iteration. The mean, 5th percentile, and 95th percentile of the 30-year average simulated yield from one simulation (5000 iterations) are reported for scenarios 1 – 4 for each province-soil combination. Provincial average yields are not divided by soil zone, but these lie in the ranges of default yields of all soil zones within one province for Alberta and Saskatchewan. For Manitoba, the provincial average yield is 14.4% smaller than the default yield. The difference may be explained by the fact that provincial level yields are reported after harvesting, while default yields are budget estimates for crop planning, so the former data reflect crop production risk, while the latter does not.

Scenarios 1 – 4 have different probabilities of winterkill, default year, and above default, which are discussed in section 4.4. A comparison of the means and 90% confidence intervals shows that scenarios 1, 2, and 4 generally have a lower average simulated yield than the default yield, which corresponds to the fact that these scenarios incorporate winterkill risk. The average simulated yield in scenario 2 is the lowest among all these scenarios, and this scenario has the highest probability of winterkill. Scenario 3 may have higher average simulated yield than the default yield, which corresponds to the fact that a higher probability of above default yield is simulated in this scenario. These findings conform to the model expectations and expert opinions, so verify the winter wheat yield models discussed in chapter 4.

Table 5.2 provides a comparison of the default prices, yields, and input costs between winter wheat and spring wheat in each province-soil combination. The price differences (winter wheat price – spring wheat price) range from -$1/bu to -$0.36/bu. The yield differences (winter wheat yield – spring wheat yield) differ across provinces: 0.86 bu/ac – 1.57 bu/ac in Alberta; 5.69 bu/ac – 7.95 bu/ac in Saskatchewan; and 23.80 bu/ac in Manitoba. The cost differences (winter wheat cost- spring wheat cost) also differ across provinces: -$64.33/ac – -$14.97/ac in Alberta; -$6.38/ac – -$4.71/ac in Saskatchewan; and $1.38/ac in Manitoba. This table, combined with Table 5.1, may help explain the differences in NPV results between the province-soil combinations. The details are discussed below.

5.1 Scenario of Risk-Free Winter Wheat Production

The scenario of risk-free winter wheat production replaces half spring wheat acreage with winter wheat without winterkill risk. Table 5.3 summaries the NPVs of the base case and the scenario, and calculates the NPV differences between them. Compared to the NPVs without winter wheat, the NPVs with risk-free winter wheat are $20,285.43 to $43,864.06 (0.9% - 5.4%) higher for the soil zones in Alberta and Saskatchewan. In Manitoba which has the highest winter wheat yield advantage among all the province-soil combinations, the NPV with risk-free winter wheat is $229,519.44 (21.0%) higher than the NPV without winter wheat. Thus, winter wheat is economically feasible when there is no winterkill risk based upon the default yields and prices from provincial crop budget estimates. This might explain recent government efforts to increase winter wheat acreage.

5.2 Scenarios 1 – 10 and Sensitivity Analyses

Scenarios 1 – 10 and sensitivity analyses all switch half spring wheat acreage to winter wheat and incorporate winterkill risk. The details are as follows:

5.2.1 Scenario 1: 5% Complete Winterkill, 20% Partial Winterkill, 60% Default Year, and 15% Above Default

Scenario 1 incorporates winterkill risk based upon expert opinions. Table 5.4 summaries mean, standard deviation, minimum, maximum, 5^{th} percentile, and 95^{th} percentile (i.e., 90% confidence interval) of the NPV difference for each province-soil combination. The percentage of positive NPV difference, representing how often a positive NPV difference is observed, is also reported.

The Alberta Black Soil Zone is arbitrarily chosen as an example to discuss NPV results in this scenario, which is the same as the following scenarios and sensitivity analyses. The mean NPV difference is -$18,084.61, which means that incorporating winter wheat with winterkill risk reduces farmers' wealth compared to only growing spring wheat with other crops in a rotation. The standard deviation[6] of the NPV difference is $30,340.55, reflecting high variability of the NPV difference. The minimum NPV difference is -$161,984.56 and the maximum is $60,388.08. For the Alberta Dark Brown Soil Zone and Alberta Grey Soil Zone, it is also wealth decreasing to grow winter wheat since the NPV differences are both negative. For the Alberta Brown Soil Zone, Alberta Peace Region and all the soil zones in Saskatchewan, growing winter wheat increases farmers' NPVs by $2,384.33 – 6,626.57 compared to the original rotations. Manitoba has a mean NPV difference of $174,775.38 and a positive NPV difference 100% of the time. The 95^{th} percentile of the 30-year average simulated yield in scenario 1 is lower than the default yield for each province-soil combination (Table 5.1), which explains the negative NPV differences and the small positive NPV differences (relative to base case NPVs) except for Manitoba. Manitoba still has a large positive NPV difference because that the 30-year

[6] The standard deviation equals the square root of the variance, and the variance is calculated as the average of the squared deviations about the mean.

average simulated yield of winter wheat (Table 5.1) is still much larger than spring wheat yield in the province (Table 5.2).

In three out of five soil zones in Alberta, growing winter wheat is wealth decreasing. In Alberta, the price difference is the smallest and the cost difference is the largest (both in absolute value) among the three Prairie Provinces, but the yield difference is the smallest (Table 5.2). Moreover, simulated yields are lower than the default yields, which makes the simulated yield difference smaller than the default yield difference (Table 5.1). The advantages in price and cost cannot make up for the disadvantages of yield. By contrast, it is wealth increasing to grow winter wheat in all the soil zones in Saskatchewan and Manitoba due to their larger yield advantages compared to Alberta. For Manitoba, regardless that it has the largest price difference (in absolute value) and its winter wheat cost is even higher than spring wheat, it still has the largest positive NPV difference due to its higher yield advantage among the three provinces.

Sensitivity analysis is performed on scenario 1. If a change in a parameter changes the sign on the mean NPV difference (i.e., change the economic feasibility/infeasibility of winter wheat production), final results are suggested to be sensitive to the parameter. If a change in a parameter does not change the sign on the mean NPV difference, but changes the mean NPV difference more than 50% in size, final results are suggested to have potential sensitivity to the parameter and a comparison between the change and the NPV of risk-free winter wheat is required. In each sensitivity analysis, other assumptions other than the parameter of interest remain the same as in scenario 1.

5.2.1.1 Sensitivity Analysis 1: Discount Rate

Sensitivity analysis 1 investigates how final results respond to the changes in the discount rate. The discount rate used for the representative farms in this study is 10%. Alternatively, 8% and 12% are used in additional simulations respectively. Table 5.5 displays the mean NPV difference, percentage change of the mean NPV difference relative to scenario 1, and probability of positive NPV difference for each province-soil combination.

In the Alberta Black Soil Zone, the discount rate of 8% decreases the mean NPV difference, whereas the discount rate of 12% increases the mean NPV difference compared to the initial discount rate. The sizes of the changes are both close to 20% of the mean NPV difference in scenario 1. The probability of positive NPV difference does not change much in either case. It is still wealth decreasing to grow winter wheat in the Alberta Black Soil Zone because of the negative sign on the NPV difference. For other province-soil combinations, the economic feasibility/infeasibility of winter wheat production does not change either. Thus, final results are not sensitive to discount rate.

5.2.1.2 Sensitivity Analysis 2: Sunk Variable Cost of Winter Wheat when there is Complete Winterkill

When there is a complete winterkill, the variable cost of winter wheat becomes a sunk cost. The sunk variable cost of winter wheat is 30% of the default variable cost of winter wheat. In scenario 2, two cases are presented to examine the sensitivity of results to change in this parameter: 25% and 35% of the default variable cost respectively. Results on NPV differences are reported in Table 5.6.

The two changes influence the mean NPV difference in opposite directions but of similar magnitude of 6 - 7% in the Alberta Black Soil Zone. The probability of positive NPV difference does not change much in either case. The conclusion that it is not economically viable to grow winter wheat still holds. In other province-soil combinations, the signs on NPV difference do not change either. The largest size change in the NPV difference is 53.9% of the initial value in the Saskatchewan Brown Soil Zone, but the value of the change, $1284.06, is small relative to the mean NPV of risk-free winter wheat, $600,167.97. Thus, the economic feasibility/infeasibility of winter wheat production is not affected by small changes in the sunk variable cost of winter wheat when there is complete winterkill.

5.2.1.3 Sensitivity Analysis 3: Variable Cost of Late Seeded Barley

Winter wheat which experiences complete winterkill is reseeded to feed barley in late spring. The variable cost of late seeded barley is investigated in the third sensitivity analysis. It is assumed to be 90% of the default variable cost of barley in scenario 1. To examine the sensitivity of final results to changes in this parameter, two additional simulations are preformed. One decreases the variable cost to 85% of the default variable cost, whereas the other one increases the variable cost to 95% of the default variable cost. Table 5.7 displays the changes in NPV difference relative to scenario 1.

The Alberta Black Soil Zone mean NPV difference changes less than 10% in size and the probability of positive NPV difference changes little. Change in the parameter has little impact on the economic infeasibility of winter wheat production in this area. The economic feasibility/infeasibility for other province-soil combinations does not change either when changing the parameter, which suggests that final results are not sensitive to the variable cost of late seeded barley.

5.2.1.4 Sensitivity Analysis 4: Yield of Late Seeded Barley

The impact of the yield of late seeded barley on final results is examined in this sensitivity analysis. In the initial assumptions, the yield of late seeded barley is assumed to be 10% lower than the default barley yield. Two simulations are performed to investigate the influences of this parameter: 5% and 15% lower yield than the default barley yield respectively. All the changes in NPV difference are listed in Table 5.8.

In the Alberta Black Soil Zone, the economic infeasibility of winter wheat production does not change since the mean NPV difference remains negative. The 5% lower yield increases the mean NPV difference by 11.4%, whereas the 15% lower yield decreases the mean NPV difference by 12.0%. The probabilities of positive NPV difference do not change much as yield loss rate changes. For other province-soil combinations, the signs on mean NPV differences do not change either. Only the Alberta Dark Brown Soil Zone changes its mean NPV difference larger than 50%, but the values of the changes, $1,617.47 and $2,090.44 respectively, are small relative to the mean NPV of risk-free winter wheat, $1,116,811.04. Thus, small changes in the yield of late seeded barley have no significant influence on the final results.

5.2.1.5 Sensitivity Analysis 5: Yield Loss Factor when there is Partial Winterkill

The yield loss factor A in the yield response function of partial winterkill $y = A \cdot x \cdot \overline{y}$ (Table 4.7) is another interest in this study. In scenario 1, $A = 1$, resulting in a yield loss of 5 - 25% when there is partial winterkill. Some experts suggested that there may be a higher level of yield loss (Irvine, 2008), so sensitivity analysis considers two alternatives, $A = 0.95$ and $A = 0.9$, which suggest a potential yield loss of 9.8 - 28.8% and 14.5 - 32.5% respectively. Table 5.9 summarizes the simulation results.

Using the Alberta Black Soil Zone as an example, the conclusion of the economic infeasibility does not change. The percentage change of the mean NPV difference is 98.5% resulting from the yield loss factor of 0.9, but the change of $17,816.75 is small relative to the mean NPV of risk-free winter wheat, $3,073,526.95. The probability of positive NPV difference falls by about 10 and 15 percentage points respectively relative to scenario 1. The Alberta Dark Brown Soil Zone, Alberta Grey Soil Zone, and Manitoba do not change the economic infeasibility of winter wheat either. On the contrary, in the Alberta Brown Soil Zone, Alberta Peace Region, and all soil zones in Saskatchewan, decreasing A changes the mean NPV difference from positive to negative, so final results are sensitive to the partial winterkill yield loss factor in these province-soil combinations.

5.2.1.6 Sensitivity Analysis 6: Yield Increase Factor when there is Above Default

The sensitivity of results to the yield increase factor B in yield response function of above default $y = (1 + B \cdot x) \cdot \overline{y}$ (Table 4.7) is investigated. The initial setting of this factor is $B = 1$ which implies a yield increase of 0 - 15% relative to the default yield. Since both a larger yield increase and a smaller yield increase are possible, two additional simulations are conducted to simulate different levels of yield increase: $B = 0.8$ implying a yield increase of 0 - 12% and $B = 1.2$ implying a yield increase of 0 - 18% relative to the default yield. Simulation results are summarized in Table 5.10.

From the simulation results of the Alberta Black Soil Zone, the two changes in the yield increase factor do not change the economic infeasibility of winter wheat and change the probabilities of positive NPV difference little. For other province-soil combinations, the signs on the mean NPV difference do not change either. Only the Alberta Dark Brown Soil Zone has a change larger than 50% in the mean NPV difference, but the change is small relative to the mean NPV of risk-free winter wheat. Thus, the yield increase factor affects final results little in all the province-soil combinations.

5.2.2 Scenario 2: 10% Complete Winterkill, 25% Partial Winterkill, 50% Default Year, and 15% Above Default

This scenario examines the economic feasibility of winter wheat under high incidence of winterkill. Compared to scenario 1, the probability of complete winterkill increases from 5% to 10%, and the probability of partial winterkill increases from 20% to 25% (Table 4.8). Accordingly, the probability of default year decreases from 60% to 50%. Other assumptions remain the same as scenario 1. Summary statistics for this scenario are listed in Table 5.11.

Using the Alberta Black Soil Zone as an example, the mean NPV difference of -$70,075.19 implies that the rotation with winter wheat generates a lower NPV than the rotation without winter wheat. The standard deviation of NPV difference is $40,337.37, representing high volatility of NPVs generated from winter wheat. The maximum NPV difference is $36,703.22 and the minimum is -$250,779.58. There is merely a 3% chance that farmers can receive higher NPV from incorporating winter wheat versus growing only spring wheat in rotations. Other province – soil combinations, excluding Manitoba, have a negative mean NPV difference and a small probability of positive NPV difference as well. Manitoba has a mean NPV difference of $111,339.86 and a probability of positive NPV difference of 97.7%. To summarize, winter wheat production is economically infeasible in all province-soil combinations except Manitoba under the high probabilities of winterkill. The 30-year average simulated winter wheat yield in this scenario is lower than scenario 1 for each province-soil combination (Table 5.1). Manitoba is an exception due to its larger yield advantage of winter wheat relative to spring wheat (Table 5.2). Compared to scenario 1, the mean NPV difference and the probability of positive NPV difference are both lower for each province-soil combination, so a higher probability of winterkill lowers the economic feasibility of winter wheat production.

5.2.3 Scenario 3: 5% Complete Winterkill, 20% Partial Winterkill, 45% Default Year, and 30% Above Default

A scenario with a high probability of above default yield in winter wheat production is simulated. Above default yield happens up to 30% of the time versus 15% in scenario 1. The probabilities of winterkill remain the same as scenario 1. Default year happens 45% of the time. The results of scenario 3 are reported in Table 5.12.

For the Alberta Black Soil Zone, the positive mean NPV difference of $18,536.27 implies that the rotation with winter wheat generates a higher NPV than the original rotation. The standard deviation of NPV difference is $39,125.22; the maximum is $131,037.10; the minimum is -$159,323.84. A positive mean NPV difference can be observed 69.0% of the time. All other province – soil combinations have a positive mean NPV difference and a probability of positive NPV difference larger than 50%. Under the high probability of above default yield, winter wheat increases farmers' wealth in all provinces and soil zones. The economic feasibility of winter wheat is improved relative to scenario 1, which is explained by the higher simulated yields in scenario 3 relative to scenario 1(Table 5.1). Both the mean NPV difference and the probability of positive NPV difference are higher compared to scenario 1 for each province-soil combination.

5.2.4 Scenario 4: 5% Complete Winterkill, 20% Partial Winterkill, and 75% Default Year

There is no above default yield included in scenario 4. The probabilities of winterkill are the same as scenario 1, and the probability of default year increases up to 75%. Table 5.13 displays a summary of statistics of NPV differences.

Winter wheat production without above default yield is financially unattractive compared to scenario 1 in the Alberta Black Soil Zone. The mean NPV difference is -$29,930.03 and there is a 13.3% chance of a positive NPV difference. Other province-soil combinations, excluding Manitoba, all have negative mean NPV differences. The reason behind it is that the 30-year average simulated yields are lower than the default yields since there is no above default yield (Table 5.1). Manitoba, where winter wheat yield is much higher than spring wheat, has a mean NPV difference of $162,300.23 and a positive NPV difference 100% of the time. Thus, winter wheat production is only economic viable in Manitoba when there is no yield being above default. For each province-soil combination, the mean NPV difference and the probability of positive NPV difference are both lower than scenario 1 because the 30-year average simulated yield is lower than scenario 1.

5.2.5 Scenario 5: Only Two Possibilities - Complete Winterkill and Default Year

This scenario investigates how the economic feasibility of winter wheat changes when there are only two possibilities, complete winterkill and default year, with probability of each being varied. Other assumptions remain the same as in scenario 1 (Table 4.8).

As the probability of complete winterkill increases, the mean NPV difference decreases as well as the probability of positive NPV difference in the Alberta Black Soil Zone (Figure 5.1). If the probability of complete winterkill does not exceed 5%, the mean NPV difference is positive; if the probability of complete winterkill does not exceed 6%, positive NPV difference is observed slightly more than 50% of the time (Figure 5.1). Figures 5.2 – 5.9 displays the relationship between the probability of complete winterkill and the economic feasibility of winter wheat for other province-soil combinations. The mean NPV difference and the probability of positive NPV difference both decrease as the probability of complete winterkill increases in these areas.

In general, incorporating winter wheat without winterkill risk generates higher NPVs than only growing spring wheat in a diversified crop rotation based upon default data (the scenario of risk-free winter wheat production versus base case). That is, it is economically feasible to grow winter wheat in the Canadian Prairies if winterkill risk is zero. However, when winterkill risk is taken into account, the economic viability of winter wheat varies across province-soil combinations and is influenced by the changes in the probabilities of complete winterkill, partial winterkill, default year, and above default (scenarios 1 - 5). A higher probability of winterkill decreases the mean NPV of winter wheat production (scenario 2 versus scenario 1); a higher probability of above default yield increases the mean NPV (scenario 3 versus scenario 1); lack of above default yield decreases the mean NPV (scenario 4 versus scenario 1). The conclusion that a higher probability of winterkill lowers the mean NPV of winter wheat production also holds when there are only two possibilities, complete winterkill and default year (scenario 5).

Some insights are provided into the target levels of winterkill and above default yield probability. For example, 30% above default, with 5% complete winterkill and 20% partial winterkill, can make winter wheat generate higher NPVs than spring wheat across all the province – soil combinations. The following scenarios 6 – 8 are switching point analyses which reveal more information about the target levels of winterkill as well as winter wheat yield and price.

5.2.6 Scenario 6: Switching Point at Default Yield and Price

Scenario 6 seeks the switching point (i.e., the probability of complete winterkill at which farmers are indifferent between winter wheat and spring wheat) when winter wheat yield and price are at default values. The probabilities of complete winterkill and partial winterkill are changing to make the mean NPV difference equal to zero. Other assumptions remain the same as in scenario 1 (Table 4.8).

Figure 5.10 shows switching points for all the province-soil combinations. For the Alberta Black Soil Zone, the switching point is 1.0% which means that at default yield and price, farmers in this area are willing to switch 50% spring wheat acreage to winter wheat if the probability of complete winterkill is lower than 1.0%. That is, only if complete winterkill happens less than 1 year out of 100, farmers may switch. It is a very small probability, so it can be concluded that if price/yield of winter wheat does not change, winter wheat production in the Alberta Black Soil Zone is unlikely to be preferred to by farmers. The highest switching point is 36.3% in Manitoba which means that Manitoba farmers are willing to do the switch if the probability of complete winterkill is lower than 36.3%. Such a high level of acceptance comes from the high winter wheat yield advantage in Manitoba. Except for the Alberta Black Soil Zone and Manitoba, other areas have a switching point of 2.5% - 7.1%. If research can improve cold tolerance of winter wheat to make the probability of complete winterkill below those switching points in Figure 10, farmers may be more willing to do the switch from spring wheat to winter wheat at default yield and price.

5.2.7 Scenario 7: Switching Point when Default Winter Wheat Yield Increases

Scenario 7 examines the influences of winter wheat yield on the economic viability. This scenario examines how the switching point changes as default winter wheat yield increases (i.e., default yield difference increases). The probability of partial winterkill changes as the probability of complete winterkill changes to maintain zero mean NPV difference.

For the Alberta Black Soil Zone, the default yield difference is 1.57bu/ac between winter wheat and spring wheat and the switching point is 1.0% complete winterkill initially. If the yield difference increases by 1bu/ac, the switching point increases to 5.0% which means that farmers are willing to do the switch if the probability of complete winterkill is lower than 5.0%. As yield advantage of winter wheat increases, the switching point increases as well (Figure 5.11). If yield difference increases to 4.57bu/ac, farmers can accept winter wheat if complete winterkill probability is below 13.6%. Thus, improving default yield has a great significance in winter wheat production in this area. In Figure 5.11, if the probability of complete winterkill is below the line, farmers are willing to switch 50% spring wheat acreage to winter wheat; if the probability is above the line, farmers are willing to grow only spring wheat in rotations. For other province – soil combinations, switching point increases as default yield increases as well (Figure 5.12 - 5.19).

5.2.8 Scenario 8: Switching Point when Default Winter Wheat Price Increases

Winter wheat price increases as winter wheat quality improves. Scenario 8 investigates how switching point changes as default winter wheat price increases relative to hard red spring wheat (i.e., the default price gap narrows down) to keep zero mean NPV difference. The changing probability of complete winterkill results in changing of the probability of partial winterkill. Price difference is negative since winter wheat price is lower than spring wheat price.

Using the Alberta Black Soil Zone as an example, the default winter wheat price is $0.36/bu lower than spring wheat price and the switching point is 1.0% complete winterkill initially. If the absolute value of price difference decreases to $0.24/bu, the switching point increases to 5.5%, which means that farmers can accept a higher probability of complete winterkill. The switching point increases as the absolute value of price difference decreases (Figure 5.20). If winter wheat has the same price as spring wheat, the switching point is 15.4% which means that farmers are willing to switch to winter wheat when complete winterkill happens less than 15.4% of the time. The line in Figure 5.20 represents the threshold of farmer choice of growing winter wheat versus spring wheat. For other province – soil combinations, switching point increases as the default winter wheat price increases too (Figure 5.21 - 5.28).

To summarize, scenario 7 reveals target levels of cold tolerance, keeping winter wheat yield and price at default values. Scenarios 8 – 9 provide some insights into how improving winter wheat yield or price affects switching points, which are summarized in Table 5.14. Switching points increase due to winter wheat yield or price increase varies across province-soil combinations. The ratios of the increase of switching point from yield/price increase to the initial switching point are calculated. Based upon the ratios, the largest switching point increase due to yield/price increase occurs in the Alberta Black

Soil Zone; the smallest switching point increase due to yield/price increase occurs in Manitoba.

5.2.9 Scenario 9: Relationship between the Probability of Above Default and the Probability of Complete Winterkill

This scenario examines how the probability of above default responds to the decrease of the probability of complete winterkill from 5% to 0, while keeping the mean of the 30-year average simulated yield equal to the default yield. The probabilities of partial winterkill and default year change as well (Table 4.8). Other assumptions remain the same as scenario 1.

In the Alberta Black Soil Zone, the default winter wheat yield is 56.57bu/ac. As the probability of complete winterkill decreases, the probability of above default decreases as well to keep the mean of the average simulated yield equal to the default yield (Figure 5.29). When the probability of complete winterkill is 5%, the probability of above default has to be 41.8% to keep the mean at 56.57bu/ac; when the probability of complete winterkill falls to 0%, the probability of above default has to be 24.9%. Other province – soil combinations also have an overall decreasing trend of the probability of above default when the probability of complete winterkill decreases to maintain default yield (Figure 5.30-5.37).

5.2.10 Scenario 10: Using 2005 and 2006 Estimates as Model Inputs

Scenario 10 examines the economic feasibility of winter wheat production using data from 2005 and 2006. The crop data for the rotations before and after incorporating winter wheat are all averages of 2005 and 2006 data. All the assumptions remain the same as scenario 1.

In the Alberta Black Soil Zone, the mean NPV difference of -$50,926.08 implies that incorporating winter wheat generates a lower NPV than growing only spring wheat in rotations (Table 5.15). The standard deviation of NPV difference is $14,267.25, reflecting a high variability of the economic feasibility. The minimum and maximum of NPV differences are -$113,999.09 and -$13,292.59 respectively. A positive mean NPV difference cannot be found any time in this area. Winter wheat is also economically infeasible in the Alberta Dark Brown Soil Zone, Alberta Grey Soil Zone, Alberta Peace Region, and Manitoba for the negative mean NPV differences as well as 0% chance to obtain a positive NPV difference. The Alberta Brown Soil Zone and all the soil zones in Saskatchewan have a positive mean NPV difference from $16,907.34 to $34,200.69 and 92.9 - 100% of the time to obtain a positive NPV difference, so winter wheat production is economically viable in these areas.

Based upon the comparison between scenario 10 and scenario 1, it can be determined that the differences in crop yields, prices, and input costs between these two scenarios explain the differences in economic feasibility. Except for the Brown Soil Zone, the economic feasibility of winter wheat in other soil zones in Alberta is lower in scenario 10 than scenario 1 mainly because the price difference between winter wheat and spring wheat (in absolute value) is larger in scenario 10. On the contrary, in all the soil zones in Saskatchewan, it is more wealth increasing to grow winter wheat in scenario 10 than the first scenario. The reasons behind this result are that in scenario10, the price difference is smaller in absolute value; yield advantage is larger; and cost difference is larger in absolute value compared to scenario 1. For Manitoba, it is economically feasible to grow winter wheat in scenario 1 (NPV difference = $174,775.38), but the opposite is true in scenario 10 (NPV difference = -$140,847.03). Relative to the first scenario, the smaller yield advantage, combined with a larger price difference in absolute value and higher cost than spring wheat, results in a negative NPV difference for scenario 10. The final results from the two data sets are different. Which data set reflects the current crop production more accurately depends upon whether the increase of crops prices and fertilizer costs in 2008 are temporary or not.

5.3 Yield Elasticity of Switching Point and Price Elasticity of Switching Point

Table 5.16 summarizes yield elasticities of switching point and price elasticities of switching point for all the province-soil combinations. The default yields and default prices are compared across province-soil combinations. The switching points of complete winterkill probability at default yields and prices are from the results of scenario 6. Based upon the default yield and price data of all province-soil combinations, 1% change of yield amounts to 0.31 – 0.65bu/ac; 1% change of price amounts to $0.04 – 0.06/bu. Complete winterkill probability is 5% initially, and 1% change amounts to 0.05% complete winterkill.

Using the Alberta Black Soil Zone as an example, the initial switching point is 1.0% complete winterkill at default yield and price. 1% increase of winter wheat yield increases the switching point by 239.2%, so the switching point becomes 3.4% complete winterkill. 1% increase of winter wheat price increases the switching point by 243.3%, so the switching point becomes 3.4% complete winterkill. Other province-soil combinations, except Manitoba, have yield elasticity of switching point of 32.4 – 77.0, and price elasticity of switching point of 22.91 – 76.54. Manitoba has yield elasticity of switching point of 2.86 and price elasticity of switching point of 2.14. Thus, improving yield and price have the largest effect in the Alberta Black Soil Zone and the smallest effect in Manitoba. These findings match up the results in Table 5.13. The possible reasons are that the Alberta Black Soil zone has the lowest switching point at default yield and price, so it has the largest possibility to increase the switching point; Manitoba has the highest switching point at default yield and price, so it has the smallest possibility to increase the switching point.

The elasticities are all larger than one, suggesting that 1% increase in yield or price increases the switching point more than 1% in all the province-soil combinations. Moreover, the effects of improving yield and the effects of improving price on switching point are in similar size in Alberta and Manitoba. In Saskatchewan, improving yield leads to a larger increase of switching point.

In summary, there are one base case, eleven scenarios, six sensitivity analyses, and two elasticity analyses discussed in this chapter. The economic feasibility of winter wheat is examined through a comparison of NPVs before and after incorporating winter wheat.

Three important traits of winter wheat, cold tolerance, yield, and quality, are examined through the analysis.

Table 5.1 – Provincial Average Yields, Default Winter Wheat Yields, and Average Simulated Winter Wheat Yields over a 30-Year Period (bu/ac)

Province - Soil	2003-2007 Provincial Average Yield	Statistics	Default Yields (Without Winterkill)	Average Simulated Yields (With Winterkill)			
			Risk-Free	S1	S2	S3	S4
AB Black	49.67	Mean	56.57	52.68	48.29	54.62	52.02
		5th Per	56.57	48.57	42.72	49.93	47.83
		95th Per	56.57	56.13	53.19	58.47	55.26
AB Brown		Mean	30.86	28.76	26.40	29.82	28.39
		5th Per	30.86	26.46	23.38	27.40	26.07
		95th Per	30.86	30.59	29.01	31.90	30.14
AB Dark Brown		Mean	36.00	33.56	30.78	34.70	33.14
		5th Per	36.00	30.88	27.20	31.85	30.47
		95th Per	36.00	35.69	33.83	37.14	35.19
AB Grey		Mean	51.43	47.96	43.95	49.63	47.35
		5th Per	51.43	44.12	38.96	45.47	43.54
		95th Per	51.43	51.01	48.41	53.13	50.27
AB Peace		Mean	41.14	38.32	35.18	39.67	37.81
		5th Per	41.14	35.14	31.20	36.27	34.64
		95th Per	41.14	40.78	38.64	42.52	40.24
SK Black	38.36	Mean	44.90	41.81	38.42	43.28	41.31
		5th Per	44.90	38.42	34.13	39.44	37.99
		95th Per	44.90	44.47	42.15	46.30	43.88
SK Brown		Mean	32.14	29.97	27.47	31.04	29.58
		5th Per	32.14	27.51	24.38	28.43	27.21
		95th Per	32.14	31.87	30.24	33.23	31.44
SK Dark Brown		Mean	37.91	35.29	32.37	36.56	34.83
		5th Per	37.91	32.38	28.57	33.49	32.03
		95th Per	37.91	37.56	35.57	39.13	37.06
MB	55.91	Mean	65.30	60.82	55.87	63.05	60.11
		5th Per	65.30	55.93	49.31	57.93	55.36
		95th Per	65.30	64.76	61.54	67.41	63.81

Note: 2003-2007 provincial average yields are average annual yields from 2003 to 2007 at a provincial level from CANSIM II (2009). For sources of default yields refer to Appendix E. Default yields are used in the Scenario of Risk-Free which is the scenario of risk-free winter wheat production. S1-S4 represent scenarios 1-4 respectively. All simulated yields are from Monte Carlo simulations in @risk 5.0. Number of iteration = 5000. Per represents percentile.

Table 5.2 – Comparison of Default Data across Province-Soil Combinations

Province - Soil	Winter Wheat Price ($/bu)	Spring Wheat Price ($/bu)	Price Difference ($/bu)
AB Black	5.82	6.18	-0.36
AB Brown	6.18	6.55	-0.37
AB Dark Brown	6.18	6.55	-0.37
AB Grey	5.82	6.18	-0.36
AB Peace	5.82	6.18	-0.36
SK Black	4.50	5.38	-0.88
SK Brown	4.50	5.38	-0.88
SK Dark Brown	4.50	5.38	-0.88
MB	4.08	5.08	-1.00
Province - Soil	Winter Wheat Yield (bu/ac)	Spring Wheat Yield (bu/ac)	Yield Difference (bu/ac)
AB Black	56.57	55.00	1.57
AB Brown	30.86	30.00	0.86
AB Dark Brown	36.00	35.00	1.00
AB Grey	51.43	50.00	1.43
AB Peace	41.14	40.00	1.14
SK Black	44.90	36.95	7.95
SK Brown	32.14	26.45	5.69
SK Dark Brown	37.91	31.20	6.71
MB	65.30	41.50	23.80
Province - Soil	Winter Wheat Cost ($/ac)	Spring Wheat Cost ($/ac)	Cost Difference ($/ac)
AB Black	141.70	206.03	-64.33
AB Brown	141.54	156.51	-14.97
AB Dark Brown	155.61	171.99	-16.38
AB Grey	182.23	201.27	-19.04
AB Peace	167.37	186.69	-19.32
SK Black	130.82	137.20	-6.38
SK Brown	106.85	111.56	-4.71
SK Dark Brown	119.22	125.43	-6.21
MB	161.19	159.81	1.38

Note: For sources of default data refer to Appendix E

Table 5.3 - Summary Statistics of NPV of the Base Case and the Scenario of Risk-Free Winter Wheat Production

Province - Soil	NPV of Base Case (Only Spring Wheat with Other Crops in Rotation)	NPV of Risk-Free Winter Wheat Production	NPV Difference (NPV of Risk-free Winter Wheat Production – NPV of Base Case)	NPV Difference / NPV of Base Case
AB Black	$3,100,257.64	$3,126,988.33	$26,730.69	0.9%
AB Brown	$792,821.01	$818,295.61	$25,474.60	3.2%
AB Dark Brown	$1,152,388.22	$1,187,965.40	$35,577.18	3.1%
AB Grey	$2,298,691.82	$2,325,876.97	$27,185.15	1.2%
AB Peace	$1,455,836.11	$1,499,700.17	$43,864.06	3.0%
SK Black	$1,128,047.26	$1,165,103.14	$37,055.88	3.3%
SK Brown	$620,453.40	$640,738.83	$20,285.43	3.3%
SK Dark Brown	$635,263.27	$669,625.78	$34,362.51	5.4%
MB	$1,095,600.71	$1,325,120.16	$229,519.44	21.0%

Table 5.4 - Summary Statistics of NPV Difference of Scenario 1 (5% Complete Winterkill, 20% Partial Winterkill, 60% Default Year, and 15% Above Default)

Province - Soil	Mean NPV Difference	Std. Dev. of NPV Difference	Minimum of NPV Difference	Maximum of NPV Difference	5th Percentile of NPV Difference	95th Percentile of NPV Difference	Probability of Positive NPV Difference
AB Black	-$18,084.61	$30,340.55	-$161,984.56	$60,388.08	-$72,581.05	$26,273.72	30.0%
AB Brown	$3,508.88	$14,731.39	-$65,277.58	$42,855.87	-$22,788.51	$24,939.79	61.8%
AB Dark Brown	-$2,944.34	$26,336.08	-$116,984.25	$69,671.60	-$50,416.17	$33,811.53	50.2%
AB Grey	-$10,994.61	$25,590.85	-$138,418.40	$57,924.16	-$57,529.09	$25,808.25	37.2%
AB Peace	$6,626.57	$25,306.16	- $106,258.03	$70,661.09	-$39,386.23	$43,627.38	63.8%
SK Black	$5,220.01	$21,611.69	- $131,299.47	$66,219.31	-$32,795.24	$36,877.91	63.1%
SK Brown	$2,384.33	$12,549.10	-$49,540.98	$31,819.34	-$20,580.80	$20,152.03	61.9%
SK Dark Brown	$6,601.89	$18,812.25	-$78,582.71	$52,473.64	-$27,288.20	$33,844.41	67.1%
MB	$174,775.38	$38,478.02	$6,000.30	$262,161.95	$103,664.08	$227,590.46	100%

Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.5 - Sensitivity Analysis 1: Discount Rate

Province - Soil	Discount Rate	Mean NPV Difference	% Change of Mean	Probability of Positive NPV Difference
AB Black	8%	-$21,560.94	-19.2%	27.6%
	10%	-$18,084.61	n/a	30.0%
	12%	-$14,653.78	19.0%	32.7%
AB Brown	8%	$4,326.42	23.3%	63.3%
	10%	$3,508.88	n/a	61.8%
	12%	$2,799.38	-20.2%	61.8%
AB Dark Brown	8%	-$2,613.66	11.2%	50.6%
	10%	-$2,944.34	n/a	50.2%
	12%	-$3,007.69	-2.2%	50.8%
AB Grey	8%	-$12,383.34	-12.6%	35.8%
	10%	-$10,994.61	n/a	37.2%
	12%	-$8,762.79	20.3%	39.9%
AB Peace	8%	$7,610.26	14.8%	64.0%
	10%	$6,626.57	n/a	63.8%
	12%	$5,257.04	-20.7%	63.0%
SK Black	8%	$6,911.44	32.4%	64.8%
	10%	$5,220.01	n/a	63.1%
	12%	$4,161.98	-20.3%	62.8%
SK Brown	8%	$2,865.61	20.2%	62.1%
	10%	$2,384.33	n/a	61.9%
	12%	$1,651.73	-30.7%	59.7%
SK Dark Brown	8%	$8,442.53	27.9%	68.6%
	10%	$6,601.89	n/a	67.1%
	12%	$5,648.33	-14.4%	67.0%
MB	8%	$209,195.92	19.7%	100.0%
	10%	$174,775.38	n/a	100.0%
	12%	$149,771.63	-14.3%	99.9%

Note: This sensitivity analysis is based upon the assumptions of scenario 1. The discount rate is 10% initially. NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.6 - Sensitivity Analysis 2: Sunk Variable Cost of Winter Wheat when there is Complete Winterkill

Province - Soil	Percentage of Default Variable Cost	Mean NPV Difference	% Change of Mean	Probability of Positive NPV Difference
AB Black	25%	-$16,909.27	6.5%	30.5%
	30%	-$18,084.61	n/a	30.0%
	35%	-$19,188.37	-6.1%	28.9%
AB Brown	25%	$4,710.18	34.2%	66.0%
	30%	$3,508.88	n/a	61.8%
	35%	$2,698.36	-23.1%	61.5%
AB Dark Brown	25%	-$2,362.98	19.8%	50.8%
	30%	-$2,944.34	n/a	50.2%
	35%	-$3,933.55	-33.6%	49.8%
AB Grey	25%	-$9,826.22	10.6%	39.7%
	30%	-$10,994.61	n/a	37.2%
	35%	-$11,746.85	-6.8%	36.4%
AB Peace	25%	$7,692.26	16.1%	64.9%
	30%	$6,626.57	n/a	63.8%
	35%	$5,787.50	-12.7%	62.2%
SK Black	25%	$5,960.83	14.2%	64.8%
	30%	$5,220.01	n/a	63.1%
	35%	$4,039.07	-22.6%	61.5%
SK Brown	25%	$2,846.39	19.4%	63.0%
	30%	$2,384.33	n/a	61.9%
	35%	$1,100.27	-53.9%	58.0%
SK Dark Brown	25%	$7,741.84	17.3%	69.4%
	30%	$6,601.89	n/a	67.1%
	35%	$5,980.74	-9.4%	65.4%
MB	25%	$176,702.02	1.1%	100.0%
	30%	$174,775.38	n/a	100.0%
	35%	$173,864.92	-0.5%	100.0%

Note: This sensitivity analysis is based upon the assumptions of scenario 1. The sunk variable cost of winter wheat when there is complete winterkill is 30% of the default variable cost of winter wheat initially. NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.7 - Sensitivity Analysis 3: Variable Cost of Late Seeded Barley

Province - Soil	Percentage of Default Variable Cost	Mean NPV Difference	% Change of Mean	Probability of Positive NPV Difference
AB Black	85%	-$16,604.17	8.2%	31.4%
	90%	-$18,084.61	n/a	30.0%
	95%	-$19,420.80	-6.9%	29.7%
AB Brown	85%	$4,081.34	16.3%	64.4%
	90%	$3,508.88	n/a	61.8%
	95%	$2,909.14	-17.1%	61.3%
AB Dark Brown	85%	-$1,827.27	37.9%	51.3%
	90%	-$2,944.34	n/a	50.2%
	95%	-$4,032.29	-37.0%	50.0%
AB Grey	85%	-$9,535.78	13.3%	39.1%
	90%	-$10,994.61	n/a	37.2%
	95%	-$11,801.08	-7.3%	36.2%
AB Peace	85%	$7,780.33	17.4%	65.1%
	90%	$6,626.57	n/a	63.8%
	95%	$5,154.05	-22.2%	61.6%
SK Black	85%	$6,096.19	16.8%	65.2%
	90%	$5,220.01	n/a	63.1%
	95%	$4,033.26	-22.7%	61.2%
SK Brown	85%	$2,490.42	4.5%	62.4%
	90%	$2,384.33	n/a	61.9%
	95%	$1,277.68	-46.4%	58.4%
SK Dark Brown	85%	$7,563.31	14.6%	68.6%
	90%	$6,601.89	n/a	67.1%
	95%	$5,808.37	-12.0%	65.4%
MB	85%	$176,693.78	1.1%	100.0%
	90%	$174,775.38	n/a	100.0%
	95%	$172,903.78	-1.8%	100.0%

Note: This sensitivity analysis is based upon the assumptions of scenario 1. The variable cost of late seeded barley is 90% of default variable cost of barley initially. NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.8 - Sensitivity Analysis 4: Yield of Late Seeded Barley

Province - Soil	% Lower than Default Yield	Mean NPV Difference	% Change of Mean	Probability of Positive NPV Difference
AB Black	5%	-$16,017.64	11.4%	31.2%
	10%	-$18,084.61	n/a	30.0%
	15%	-$20,258.69	-12.0%	28.9%
AB Brown	5%	$4,980.73	42.0%	66.6%
	10%	$3,508.88	n/a	61.8%
	15%	$2,424.04	-30.9%	60.7%
AB Dark Brown	5%	-$853.90	71.0%	53.3%
	10%	-$2,944.34	n/a	50.2%
	15%	-$4,561.81	-54.9%	49.1%
AB Grey	5%	-$8,987.94	18.3%	39.8%
	10%	-$10,994.61	n/a	37.2%
	15%	-$12,341.49	-12.25%	37.1%
AB Peace	5%	$8,221.25	24.06%	66.7%
	10%	$6,626.57	n/a	63.8%
	15%	$4,156.77	-37.3%	60.3%
SK Black	5%	$6,309.53	20.9%	64.5%
	10%	$5,220.01	n/a	63.1%
	15%	$3,479.28	-33.4%	60.5%
SK Brown	5%	$3,174.97	33.2%	64.6%
	10%	$2,384.33	n/a	61.9%
	15%	$1,290.42	-45.9%	58.7%
SK Dark Brown	5%	$8,382.25	27.0%	70.4%
	10%	$6,601.89	n/a	67.1%
	15%	$5,406.48	-18.1%	64.4%
MB	5%	$176,508.88	1.0%	100.0%
	10%	$174,775.38	n/a	100.0%
	15%	$173,541.13	-0.7%	100.0%

Note: This sensitivity analysis is based upon the assumptions of scenario 1. The yield of late seeded barley is 10% less than the default barley yield initially. NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.9 - Sensitivity Analysis 5: Yield Loss Factor when there is Partial Winterkill

Province - Soil	Yield Loss Factor A	Mean NPV Difference	% Change of Mean	Probability of Positive NPV Difference
AB Black	1	-$18,084.61	n/a	30.0%
	0.95	-$26,869.53	-48.6%	20.4%
	0.9	-$35,901.36	-98.5%	15.5%
AB Brown	1	$3,508.88	n/a	61.8%
	0.95	-$1,095.09	-131.2%	50.9%
	0.9	-$5,663.61	-261.4%	39.6%
AB Dark Brown	1	-$2,944.34	n/a	50.2%
	0.95	-$8,787.00	-198.4%	41.3%
	0.9	-$17,159.73	-482.8%	29.8%
AB Grey	1	-$10,994.61	n/a	37.2%
	0.95	-$17,678.56	-60.8%	28.1%
	0.9	-$24,812.21	-125.7%	19.9%
AB Peace	1	$6,626.57	n/a	63.8%
	0.95	-$1,449.81	-121.9%	51.7%
	0.9	-$9,183.56	-238.6%	40.2%
SK Black	1	$5,220.01	n/a	63.1%
	0.95	-$719.71	-113.8%	51.8%
	0.9	-$7,743.97	-248.4%	40.3%
SK Brown	1	$2,384.33	n/a	61.9%
	0.95	-$1,496.38	-162.8%	50.0%
	0.9	-$4,946.25	-307.5%	39.6%
SK Dark Brown	1	$6,601.89	n/a	67.1%
	0.95	$1,561.43	-76.4%	56.5%
	0.9	-$4,595.14	-169.6%	45.0%
MB	1	$174,775.38	n/a	100.0%
	0.95	$165,406.86	-5.4%	99.9%
	0.9	$155,704.16	-10.9%	99.9%

Note: This sensitivity analysis is based upon the assumptions of scenario 1. The yield loss factor A is 1 initially. NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.10 - Sensitivity Analysis 6: Yield Increase Factor when there is Above Default

Province - Soil	Yield Increase Factor B	Mean NPV Difference	% Change of Mean	Probability of Positive NPV Difference
AB Black	0.8	-$19,609.04	-8.4%	26.8%
	1	-$18,084.61	n/a	30.0%
	1.2	-$14,801.42	18.2%	34.3%
AB Brown	0.8	$2,439.67	-30.5%	61.2%
	1	$3,508.88	n/a	61.8%
	1.2	$5,129.48	46.2%	66.4%
AB Dark Brown	0.8	-$5,299.21	-80.0%	47.4%
	1	-$2,944.34	n/a	50.2%
	1.2	-$178.59	93.9%	54.5%
AB Grey	0.8	-$12,764.09	-16.1%	35.0%
	1	-$10,994.61	n/a	37.2%
	1.2	-$8,873.71	19.3%	40.9%
AB Peace	0.8	$4,843.14	-26.9%	61.7%
	1	$6,626.57	n/a	63.8%
	1.2	$8,152.48	23.0%	65.4%
SK Black	0.8	$3,772.41	-27.7%	60.8%
	1	$5,220.01	n/a	63.1%
	1.2	$7,052.86	35.1%	65.8%
SK Brown	0.8	$1,393.91	-41.5%	59.5%
	1	$2,384.33	n/a	61.9%
	1.2	$3,037.42	27.4%	62.8%
SK Dark Brown	0.8	$5,047.34	-23.6%	64.5%
	1	$6,601.89	n/a	67.1%
	1.2	$8,319.10	26.0%	69.6%
MB	0.8	$172,519.83	-1.3%	100.0%
	1	$174,775.38	n/a	100.0%
	1.2	$177,438.31	1.5%	100.0%

Note: This sensitivity analysis is based upon the assumptions of scenario 1. The yield increase factor B is 1 initially. NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.11 - Summary Statistics of NPV Difference of Scenario 2 (10% Complete Winterkill, 25% Partial Winterkill, 50% Default Year, and 15% Above Default)

Province - Soil	Mean NPV Difference	Std. Dev. Of NPV Difference	Minimum of NPV Difference	Maximum of NPV Difference	5th Percentile of NPV Difference	95th Percentile of NPV Difference	Probability of Positive NPV Difference
AB Black	-$70,075.19	$40,337.37	-$250,779.58	$36,703.22	- $139,304.50	- $8,419.34	3.0%
AB Brown	-$21,891.27	$20,388.04	-$106,433.88	$34,988.92	- $57,366.22	$8,663.80	14.4%
AB Dark Brown	-$47,714.89	$35,949.68	- $200,597.13	$54,660.19	- $112,036.07	$6,380.17	7.7%
AB Grey	-$54,905.53	$35,226.41	- $203,920.22	$44,491.88	- $115,800.37	- $943.97	4.7%
AB Peace	-$38,188.29	$34,298.84	-$171,012.44	$64,536.00	- $97,194.22	$14,861.45	13.2%
SK Black	-$32,411.62	$29,621.68	-$145,449.76	$53,104.03	-$83,904.62	$14,094.57	14.1%
SK Brown	-$19,129.55	$16,913.07	-$85,244.24	$31,844.18	-$48,711.68	$7,056.38	13.0%
SK Dark Brown	-$25,637.10	$25,541.60	-$117,400.20	$41,553.12	-$70,156.33	$13,632.58	15.9%
MB	$111,339.86	$52,486.71	-$91,935.87	$257,678.78	$19,044.17	$190,828.10	97.7%

Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.12 - Summary Statistics of NPV Difference of Scenario 3 (5% Complete Winterkill, 20% Partial Winterkill, 45% Default Year, and 30% Above Default)

Province - Soil	Mean NPV Difference	Std. Dev. Of NPV Difference	Minimum of NPV Difference	Maximum of NPV Difference	5th Percentile of NPV Difference	95th Percentile of NPV Difference	Probability of Positive NPV Difference
AB Black	$18,536.27	$39,125.22	-$159,323.84	$131,037.10	-$48,253.92	$80,360.67	69.0%
AB Brown	$22,034.16	$19,316.57	-$48,823.92	$86,367.57	-$10,303.46	$52,813.60	87.4%
AB Dark Brown	$25,708.13	$32,361.88	-$110,749.16	$116628.64	-$31,100.48	$76,074.45	79.2%
AB Grey	$17,872.58	$33,026.66	-$132,965.81	$123,712.98	-$40,805.09	$67,817.75	71.9%
AB Peace	$37,520.68	$32,327.11	-$124,421.07	$150,493.47	-$17,945.17	$87,482.43	87.7%
SK Black	$30,642.94	$28,341.71	-$102,868.07	$111,672.00	-$17,400.81	$75,399.84	86.0%
SK Brown	$15,846.08	$15,483.08	-$50,020.46	$68,250.68	-$10,234.15	$40,113.96	84.6%
SK Dark Brown	$28,410.02	$23,759.17	-$74,175.22	$106,080.41	-$12,488.09	$66,287.92	88.2%
MB	$213,087.19	$46,230.49	-$3.076.30	$343,445.23	$131,825.46	$282,527.99	100%

Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.13 - Summary Statistics of NPV Difference of Scenario 4 (5% Complete Winterkill, 20% Partial Winterkill, and 75% Default Year)

Province - Soil	Mean NPV Difference	Std. Dev. Of NPV Difference	Minimum of NPV Difference	Maximum of NPV Difference	5th Percentile of NPV Difference	95th Percentile of NPV Difference	Probability of Positive NPV Difference
AB Black	-$29,930.03	$27,896.61	-$169,060.21	$25,142.84	-$81,275.75	$8,670.23	13.3%
AB Brown	-$2,297.18	$13,443.21	-$68,231.57	$24,969.20	-$26,571.18	$16,954.95	48.0%
AB Dark Brown	-$12,466.46	$25,013.92	-$176,063.68	$35,577.18	-$58,917.89	$21,127.56	35.4%
AB Grey	-$19,930.99	$24,172.08	-$183,663.08	$25,859.38	-$64,652.55	$13,060.77	21.8%
AB Peace	-$4,449.31	$23,730.72	-$110,532.82	$43,864.06	-$48,789.21	$28,788.69	48.1%
SK Black	-$2,797.21	$19,798.64	-$100,027.09	$37,055.88	-$38,594.51	$24,984.59	50.0%
SK Brown	-$2,516.93	$11,640.73	-$67,312.98	$19,742.28	-$23,319.22	$13,700.46	46.9%
SK Dark Brown	-$511.26	$17,732.07	-$106,262.46	$34,362.51	-$34,166.26	$23,904.64	54.9%
MB	$162,300.23	$36,224.97	-$22,609.60	$228,627.15	$94,786.60	$211,032.47	100%

Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.14 - Summary of Switching Point Increase from Yield Increase and Price Increase

		Scenario 7		Scenario 8	
Province-Soil	Initial Switching Point at Default Yield and Price	Switching Point Increase from Yield Increase of 1bu/ac	Increase of Switching Point / Initial Switching Point	Switching Point Increase from Price Increase of 1/3 price gap	Increase of Switching Point / Initial Switching Point
AB Black	1.0%	4.0%	4.00	4.5%	4.50
AB Brown	6.8%	9.1%	1.34	5.6%	0.82
AB Dark Brown	4.2%	5.5%	1.31	4.2%	1.00
AB Grey	2.5%	3.6%	1.44	3.6%	1.44
AB Peace	7.0%	5.9%	0.78	4.8%	0.69
SK Black	6.6%	5.4%	0.82	14.9%	2.26
SK Brown	6.0%	6.5%	1.08	12.6%	2.10
SK Dark Brown	7.1%	6.1%	0.86	14.3%	2.01
MB	36.3%	1.6%	0.04	7.6%	0.21

Note: Price gap is the absolute value of price difference (= winter wheat price – spring wheat price). Price increase of 1/3 price gap means that winter wheat price increases by one third of the price gap. For example, in the Alberta Black Soil Zone, winter wheat price is $5.82/bu, and spring wheat price is $6.18/bu. The price gap is $0.36/bu, and 1/3 price gap is $0.12/bu. So increase of winter wheat price by 1/3 price gap means that winter wheat price increases by $0.12/bu to $5.94/bu. Increase of switching point / initial switching point is the ratio of the increase of switching point from yield/price increase to the initial switching point.

Table 5.15 - Summary Statistics of NPV Difference of Scenario 10 (Using Averages of 2005 and 2006 Data)

Province - Soil	Mean NPV Difference	Std. Dev. of NPV Difference	Minimum of NPV Difference	Maximum of NPV Difference	5th Percentile of NPV Difference	95th Percentile of NPV Difference	Probability of Positive NPV Difference
AB Black	-$50,926.08	$14,267.25	-$113,999.09	-$13,292.59	-$76,242.64	-$30,032.79	0%
AB Brown	$34,200.69	$8,280.58	-$3,603.64	$56,341.18	$19,295.10	$46,316.91	100%
AB Dark Brown	-$31,867.85	$13,289.31	-$90,260.43	$847.92	-$56,361.56	-$13,142.30	0%
AB Grey	-$39,868.10	$10,957.84	-$89,238.75	-$10,730.33	-$60,218.81	-$24,313.90	0%
AB Peace	-$42,616.49	$13,586.23	-$104,017.72	-$10,556.62	-$67,091.02	-$23,374.84	0%
SK Black	$28,218.76	$18,041.97	-$59,407.18	$71,053.13	-$4,981.71	$52,953.54	92.9%
SK Brown	$16,907.34	$10,316.21	-$28,949.60	$39,758.59	-$2,470.78	$30,655.50	93.2%
SK Dark Brown	$27,811.43	$16,217.02	-$44,254.45	$69,601.35	-$2,870.16	$49,643.92	93.5%
MB	-$140,847.03	$22,261.56	-$246,908.74	-$85,958.13	-$182,225.10	-$110,249.70	0%

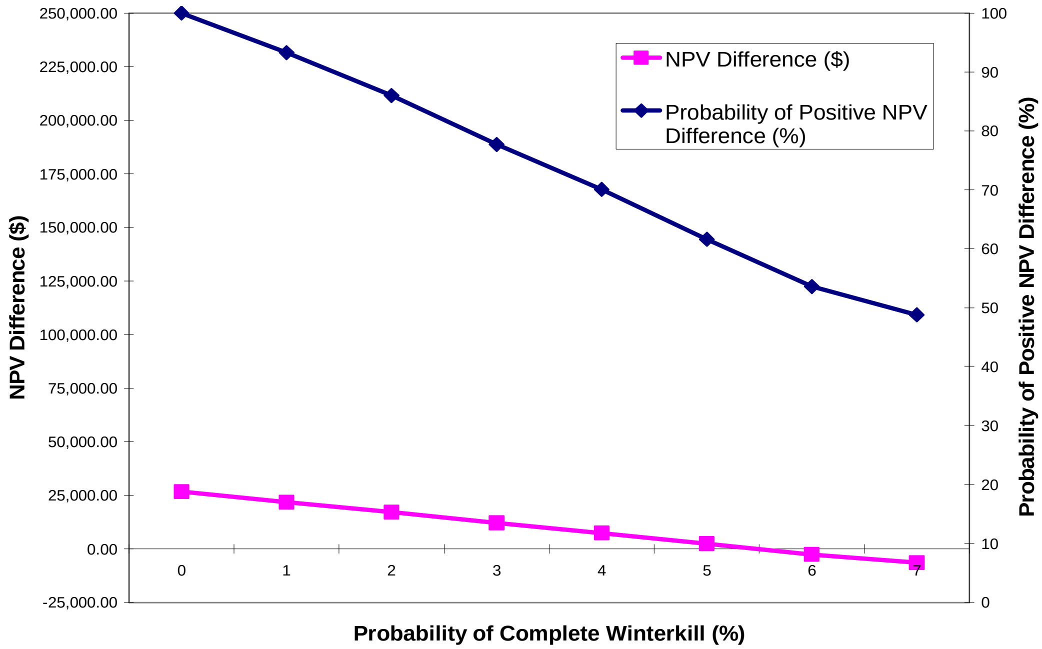
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Table 5.16 - Comparison of Yield Elasticity of Switching Point and Price Elasticity of Switching Point across Province – Soil Combinations

	AB Black	AB Brown	AB Dark Brown	AB Grey	AB Peace	SK Black	SK Brown	SK Dark Brown	MB
Default Yield	56.57	30.86	36.00	51.43	41.14	44.90	32.14	37.91	65.30
Default Price	5.82	6.18	6.18	5.82	5.82	4.50	4.50	4.50	4.08
P (%)	1.0	6.8	4.2	2.5	7.0	6.6	6.0	7.1	36.3
Ey	239.2	41.0	46.6	77.0	34.9	36.8	34.7	32.4	2.9
Ep	243.3	41.0	46.3	76.5	35.3	25.1	26.0	22.9	2.1

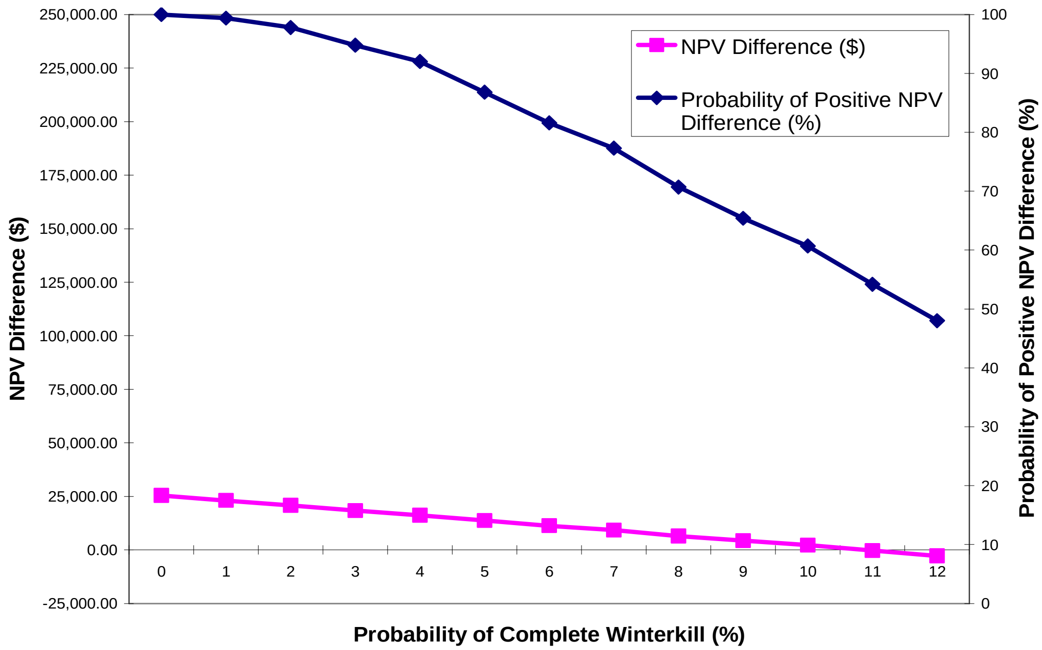
Note: The sources of default yields and default prices refer to Appendix E. P represents the switching point of complete winterkill probability when yield and price are at default values. Ey represents yield elasticity of switching point. Ep represents price elasticity of switching point.

Figure 5.1 - Alberta Black Soil Zone - Scenario 5: Only Complete Winterkill and Default Year



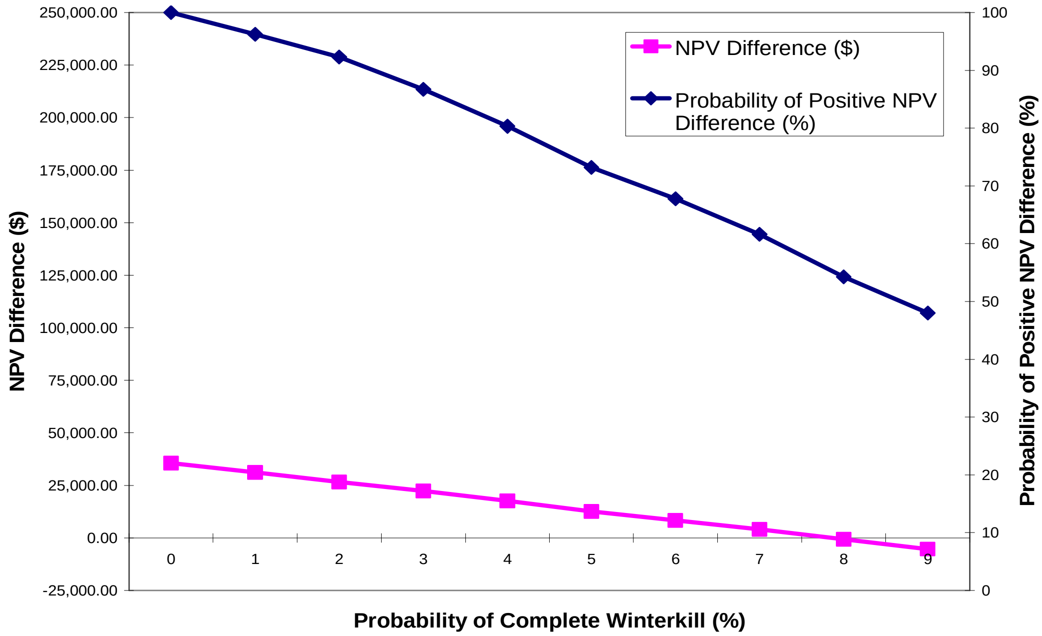
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.2 - Alberta Brown Soil Zone - Scenario 5: Only Complete Winterkill and Default Year



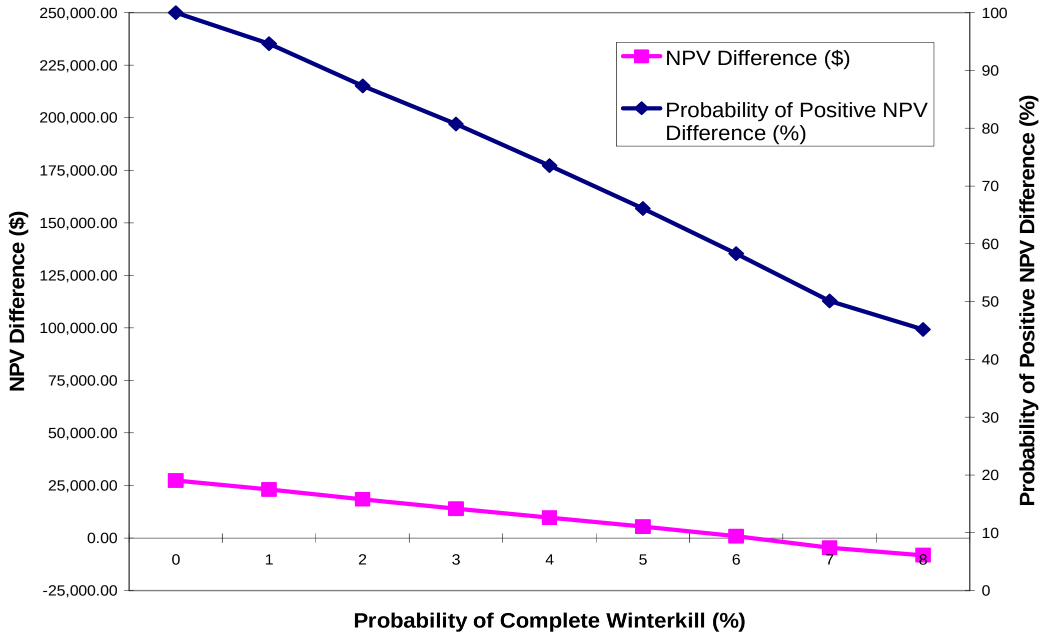
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.3 - Alberta Dark Brown Soil Zone - Scenario 5: Only Complete Winterkill and Default Year



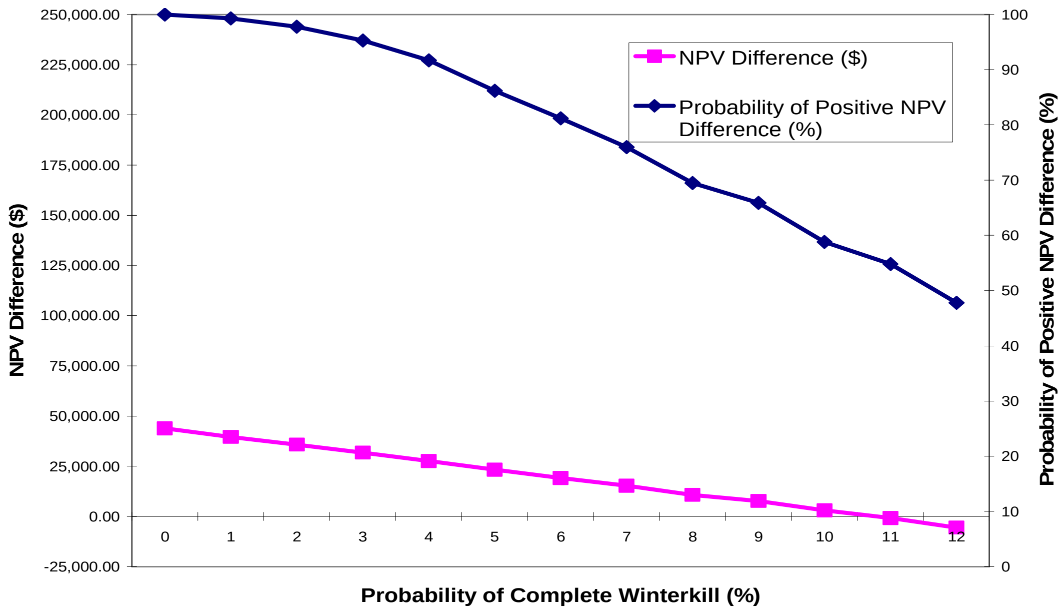
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.4 - Alberta Grey Soil Zone - Scenario 5: Only Complete Winterkill and Default Year



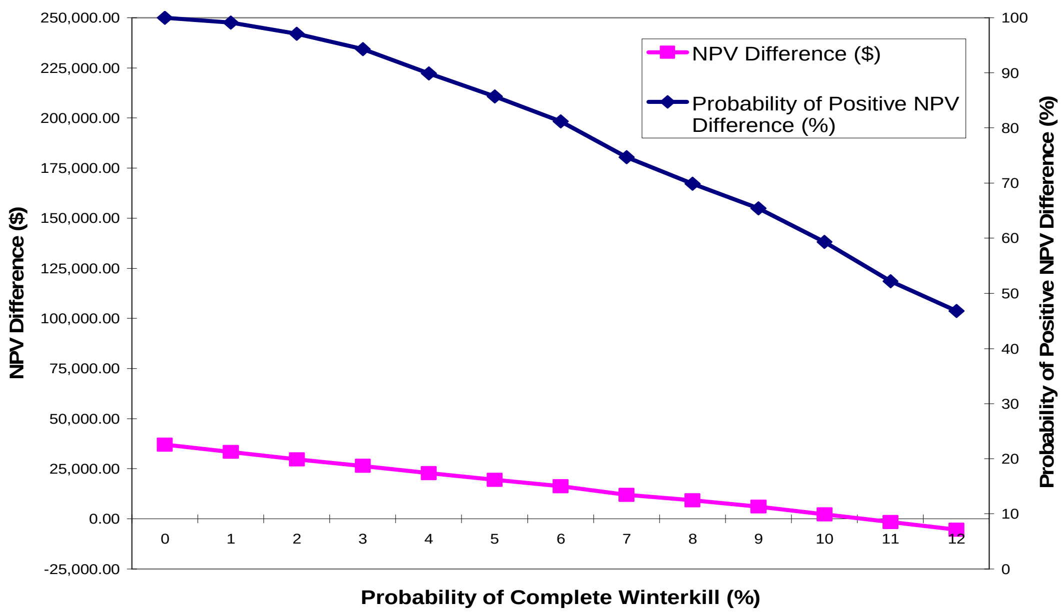
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.5- Alberta Peace Region - Scenario 5: Only Complete Winterkill and Default Year



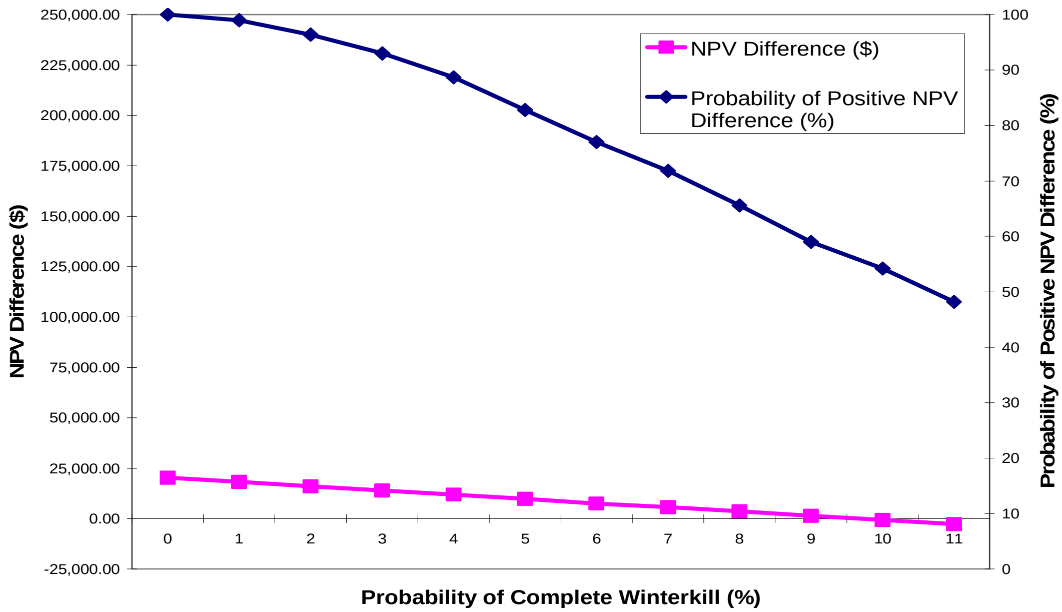
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.6 - Saskatchewan Black Soil Zone - Scenario 5: Only Complete Winterkill and Default Year



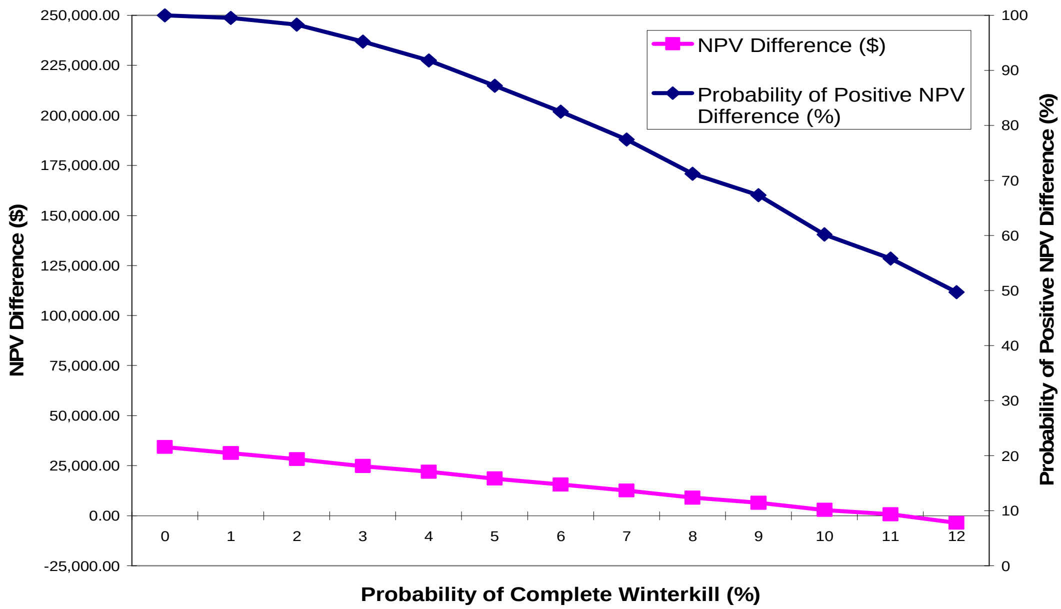
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.7 - Saskatchewan Brown Soil Zone - Scenario 5: Only Complete Winterkill and Default Year



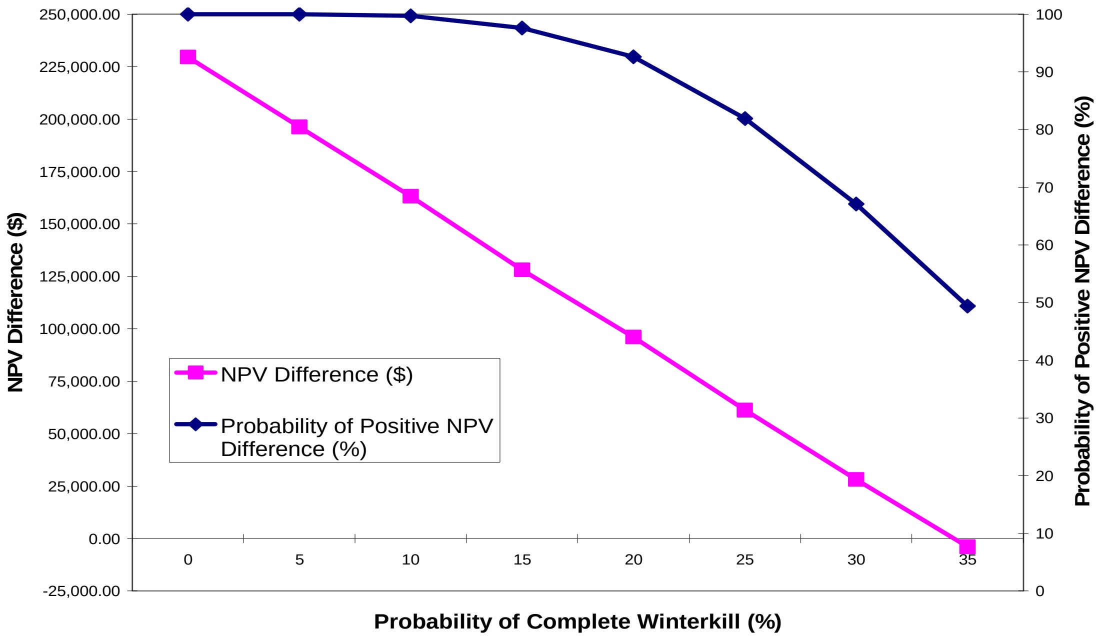
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.8 - Saskatchewan Dark Brown Soil Zone - Scenario 5: Only Complete Winterkill and Default Year



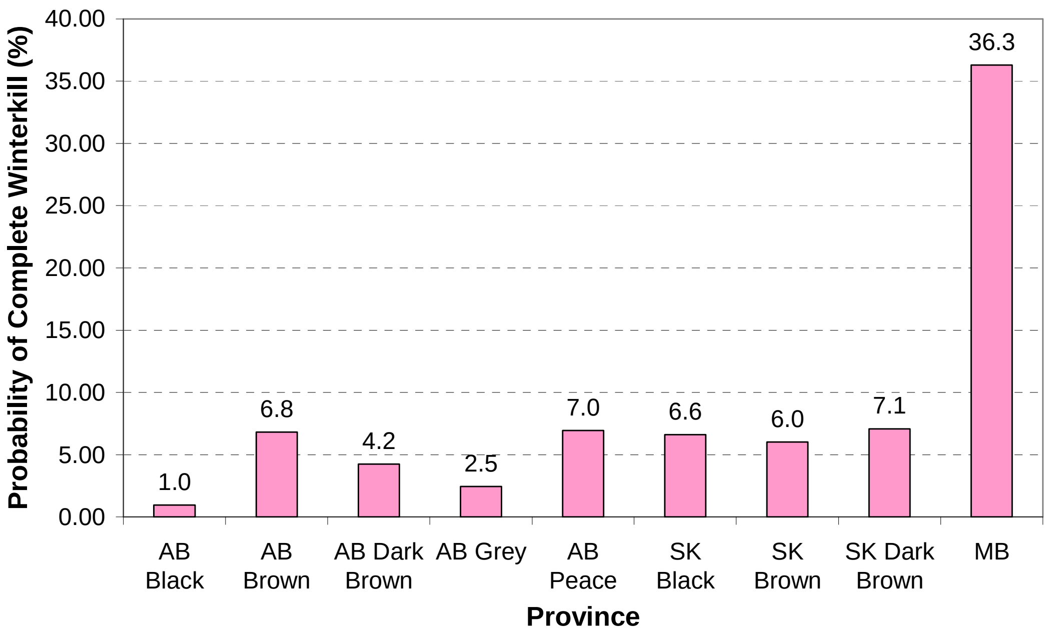
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.9 - Manitoba - Scenario 5: Only Complete Winterkill and Default Year



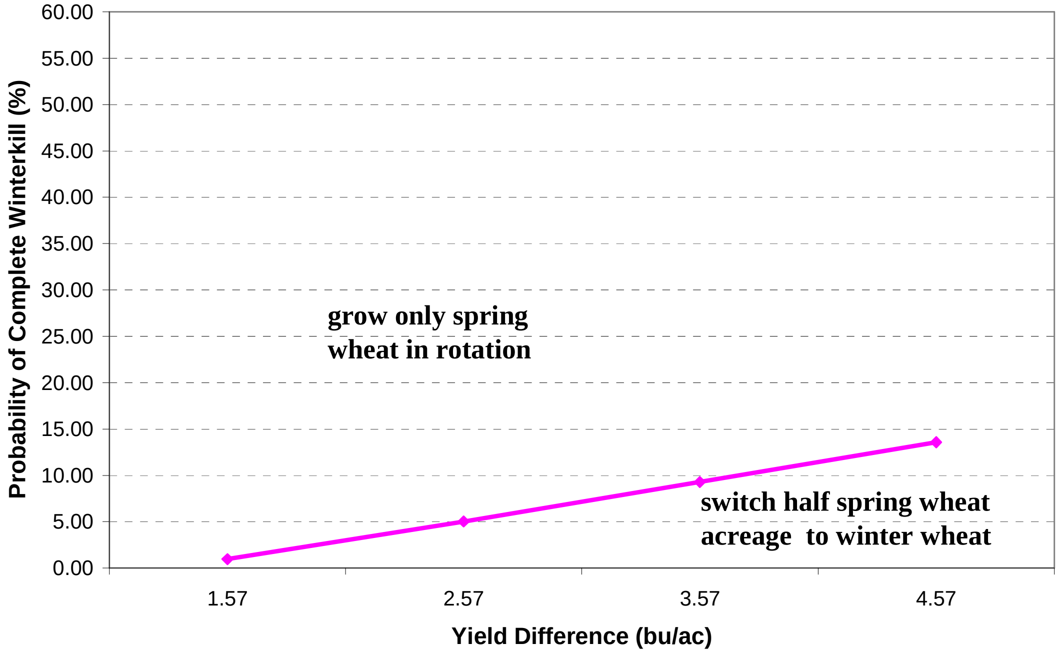
Note: NPV difference = NPV with winter wheat – NPV without winter wheat; number of iterations = 5000

Figure 5.10 - Scenario 6: Switching Point Analysis when the Probability of Complete Winterkill Changes



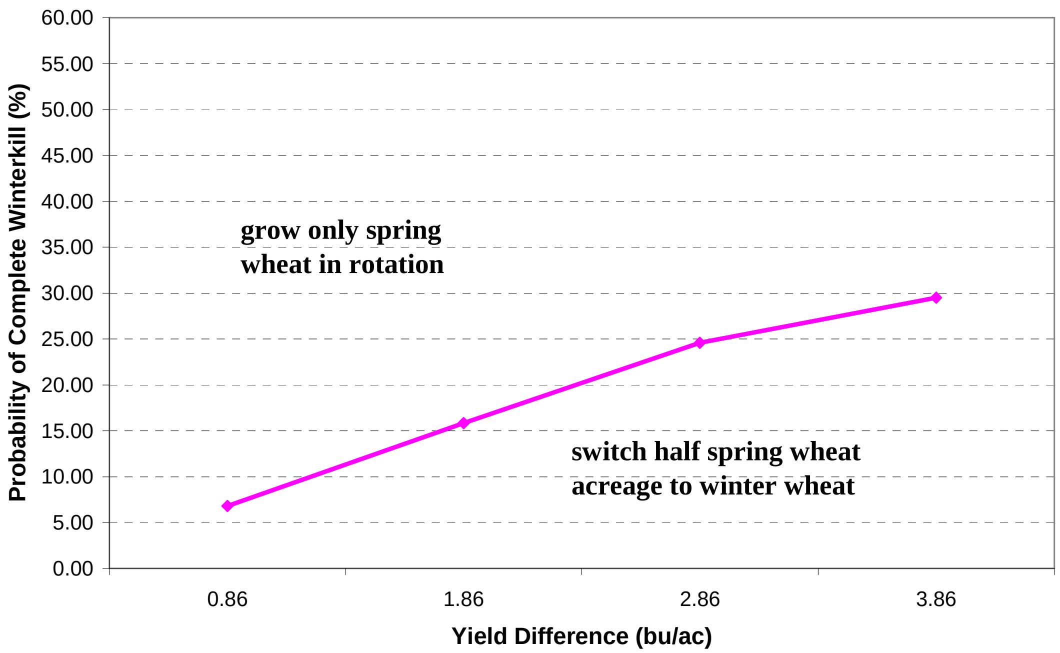
Note: Number of iterations = 5000. Number of simulations = 100. Target NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.11 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Alberta Black Soil Zone)



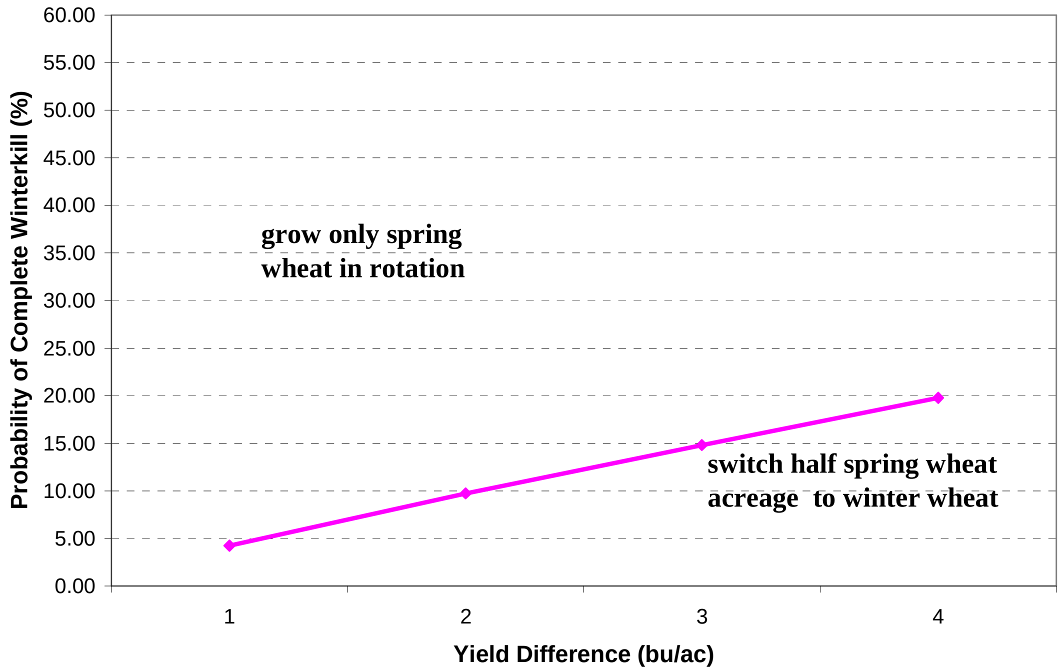
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.12 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Alberta Brown Soil Zone)



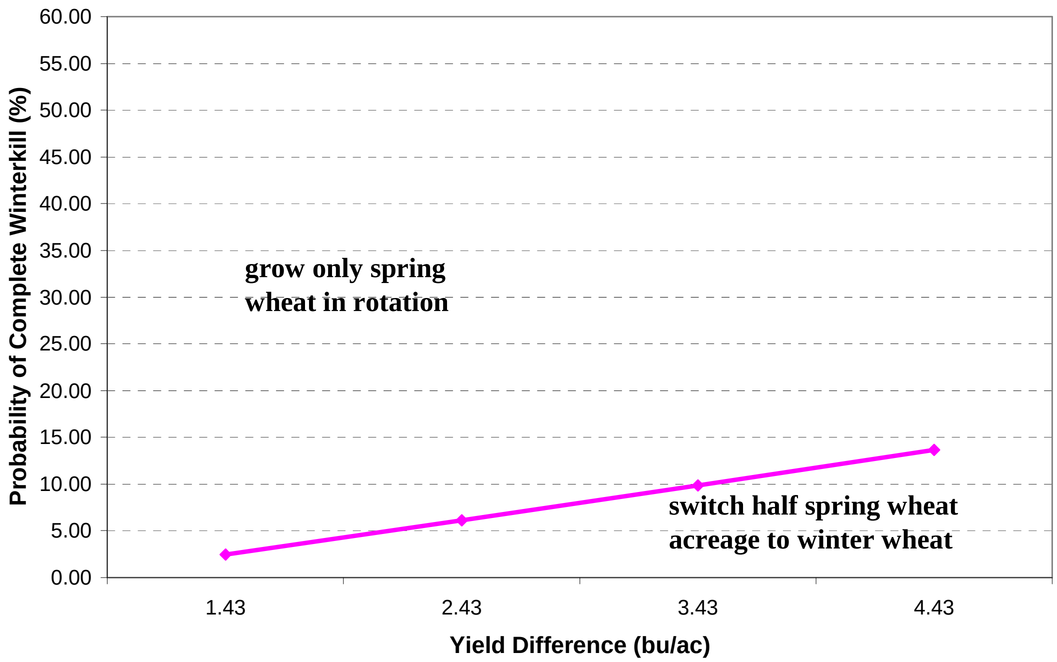
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.13 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Alberta Dark Brown Soil Zone)



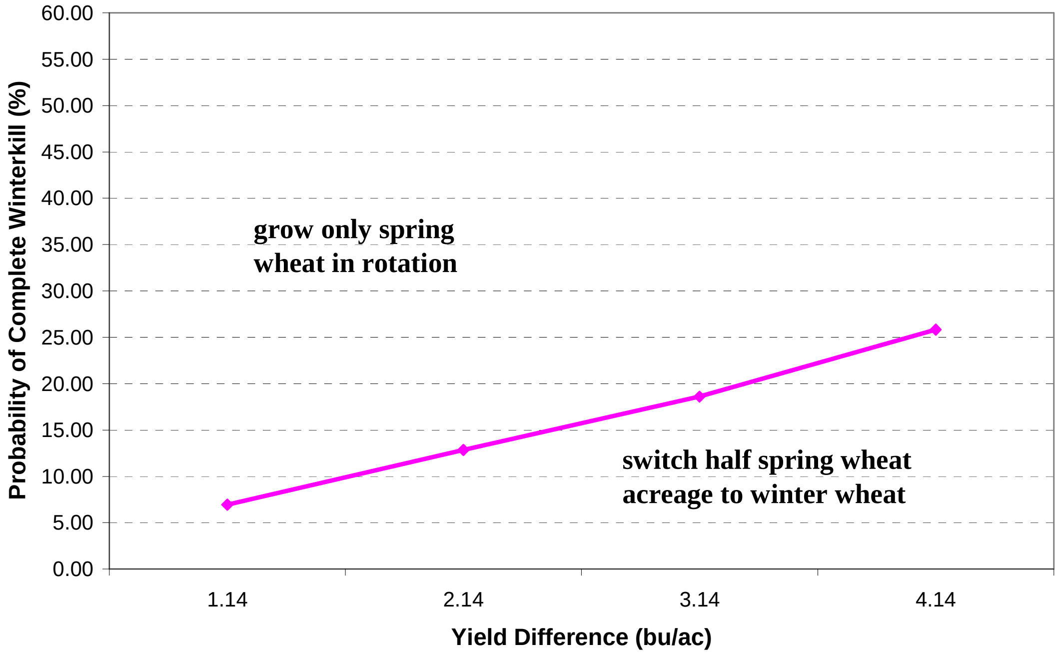
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.14 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Alberta Grey Soil Zone)



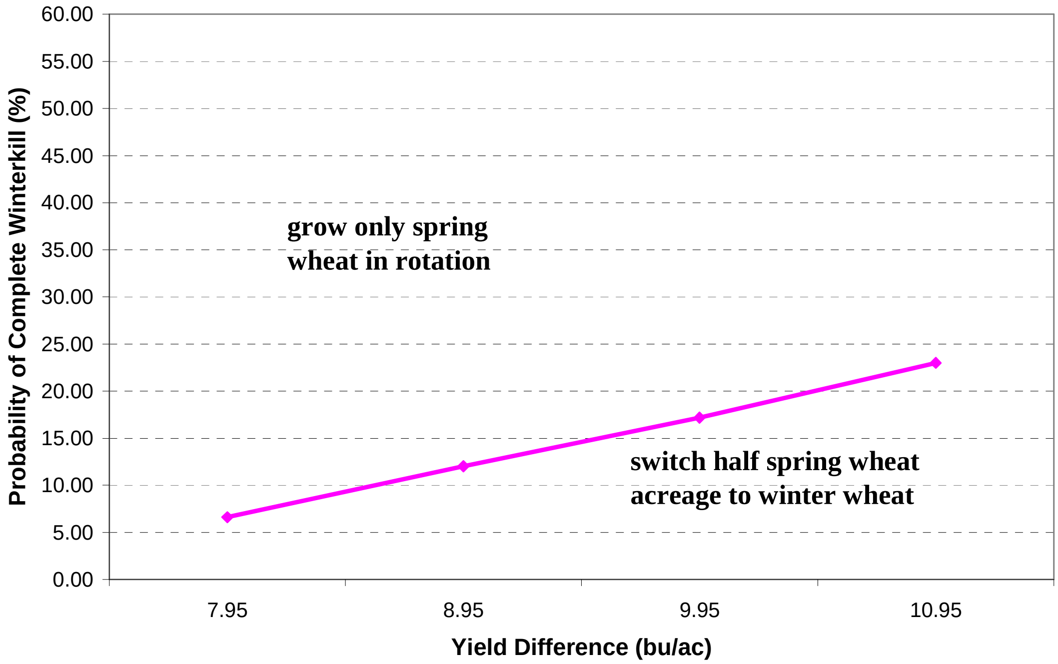
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.15 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Alberta Peace Region)



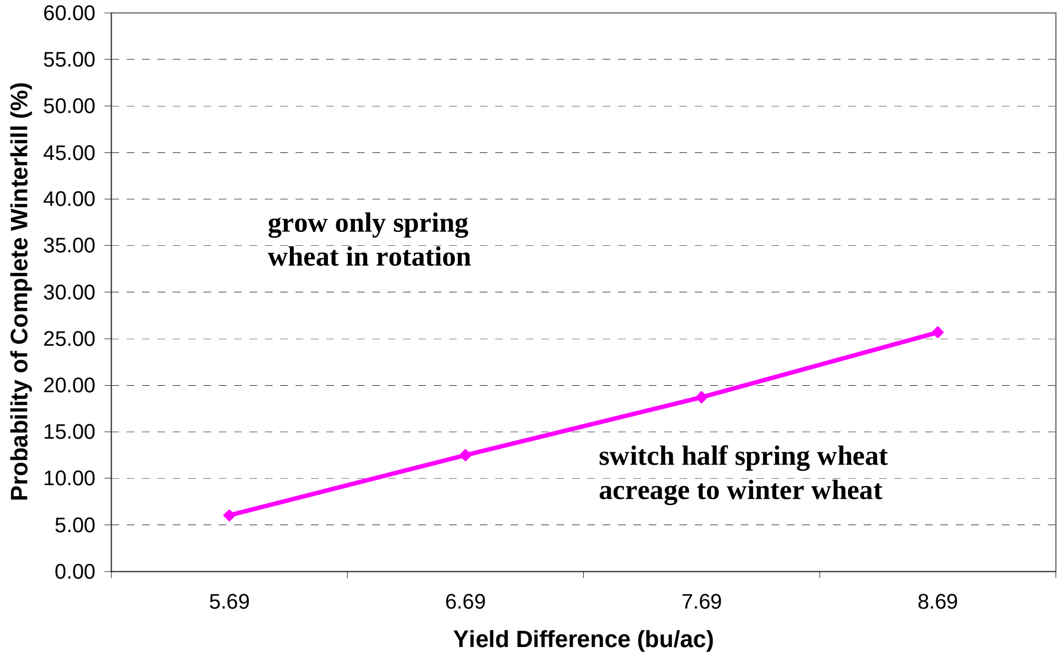
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.16 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Saskatchewan Black Soil Zone)



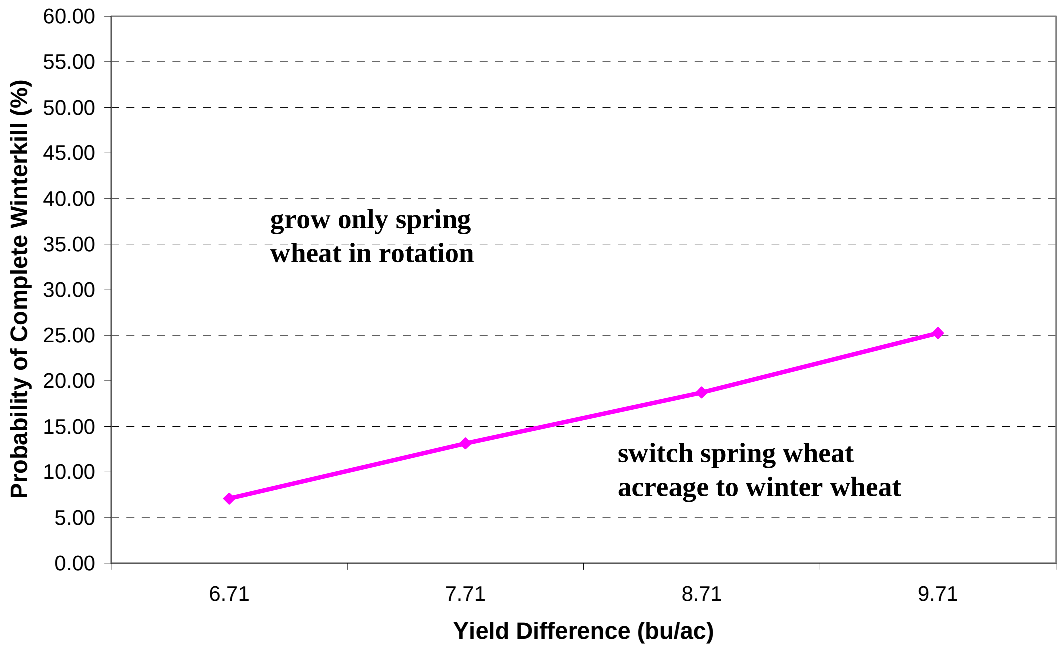
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.17 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Saskatchewan Brown Soil Zone)



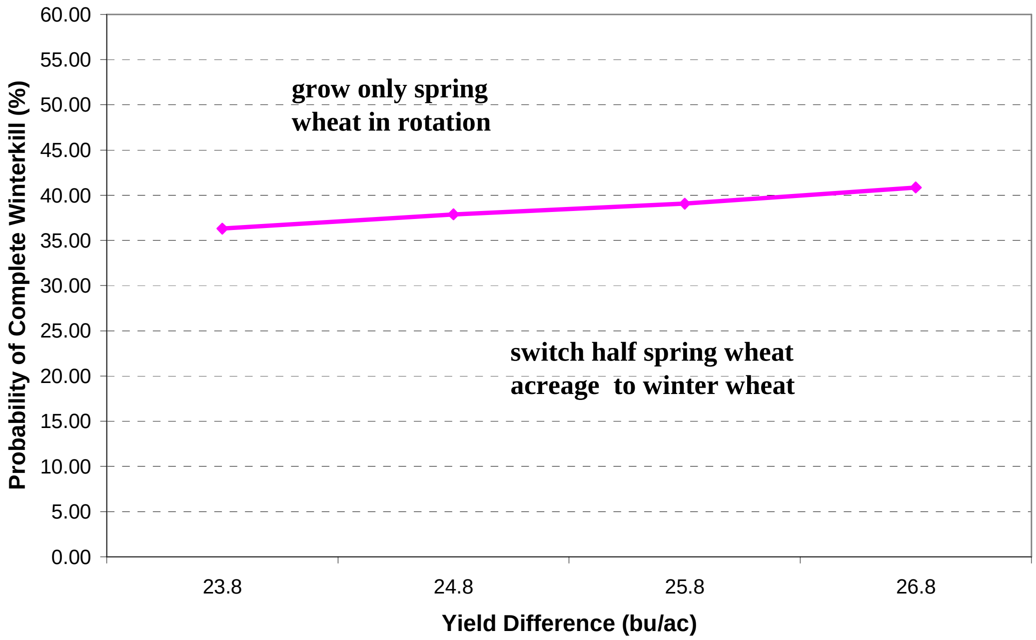
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.18 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Saskatchewan Dark Brown Soil Zone)



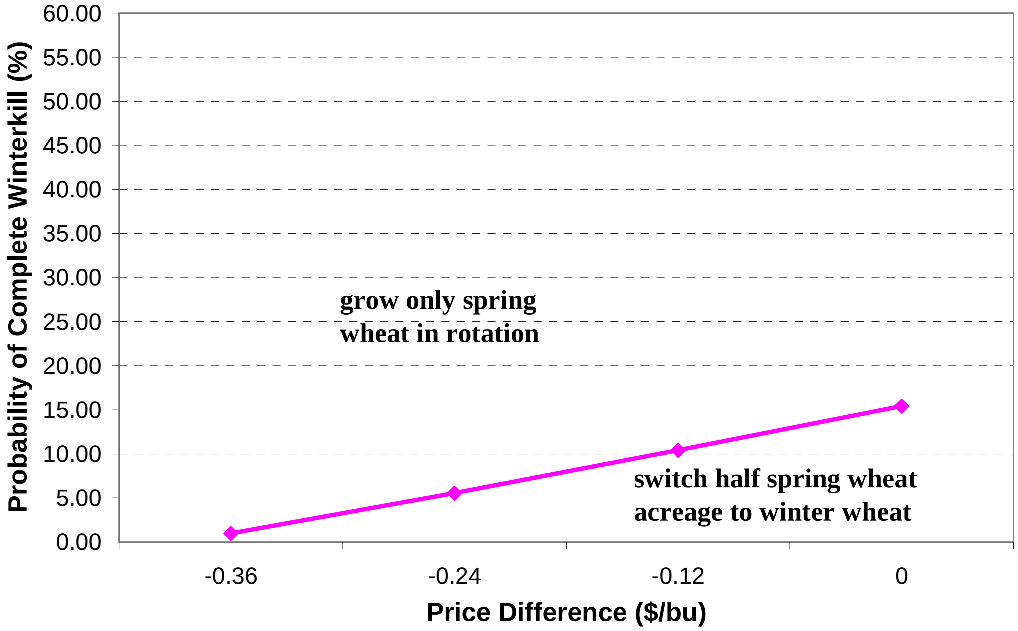
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.19 - Scenario 7: Switching Point Analysis when Default Winter Wheat Yield Changes (Manitoba)



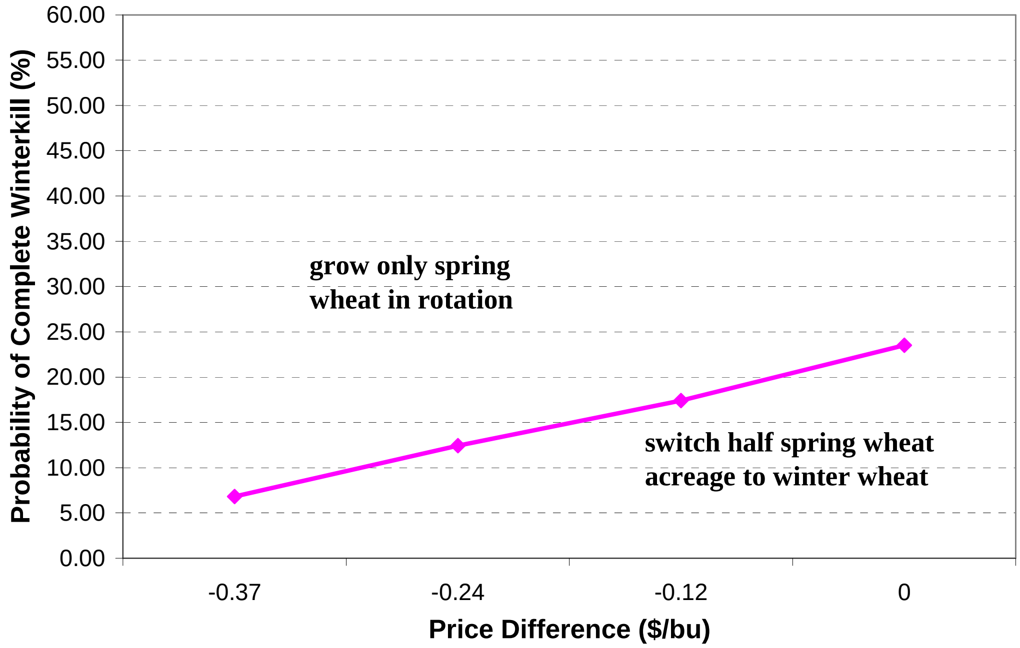
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.20 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Alberta Black Soil Zone)



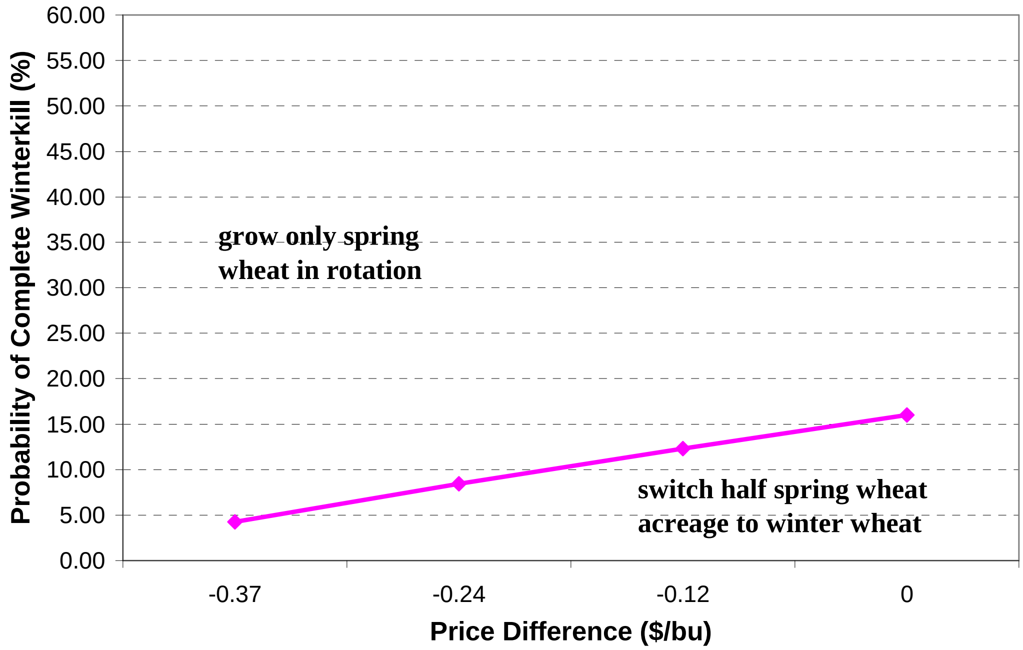
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.21 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Alberta Brown Soil Zone)



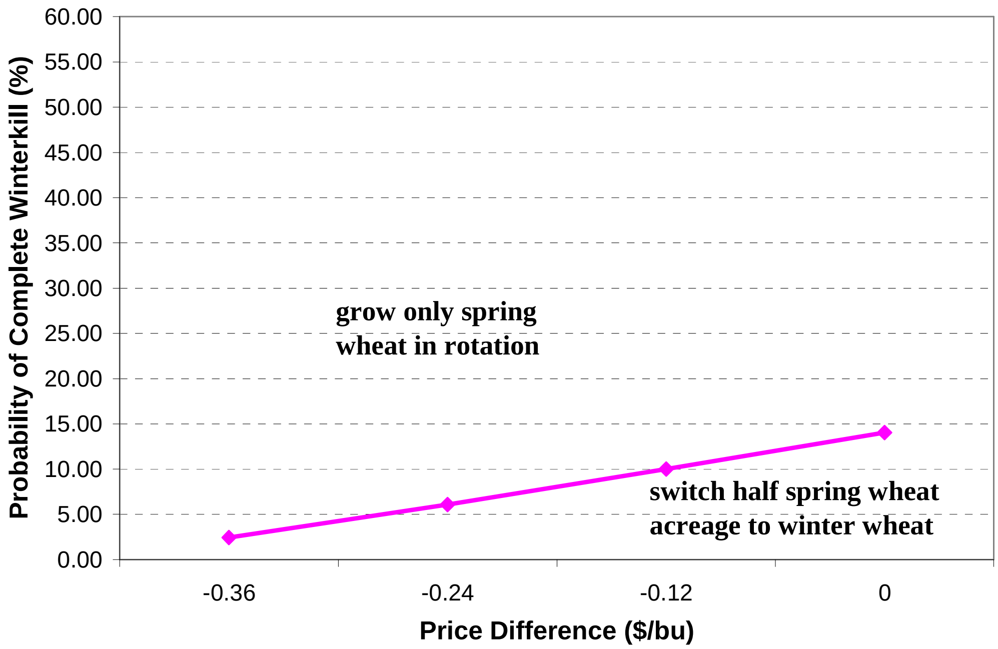
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.22 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Alberta Dark Brown Soil Zone)



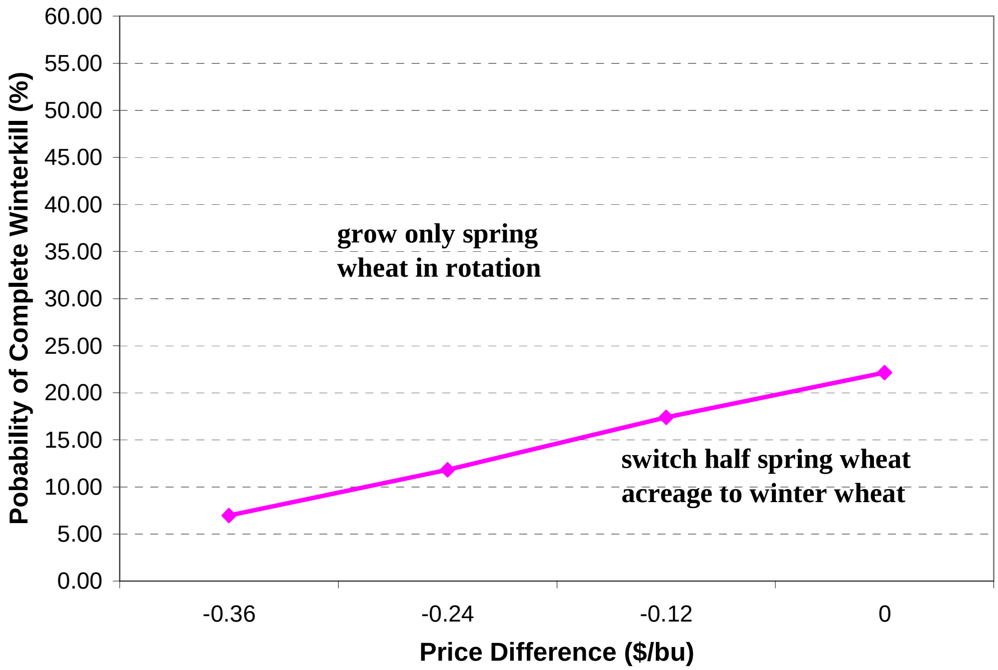
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.23 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Alberta Grey Soil Zone)



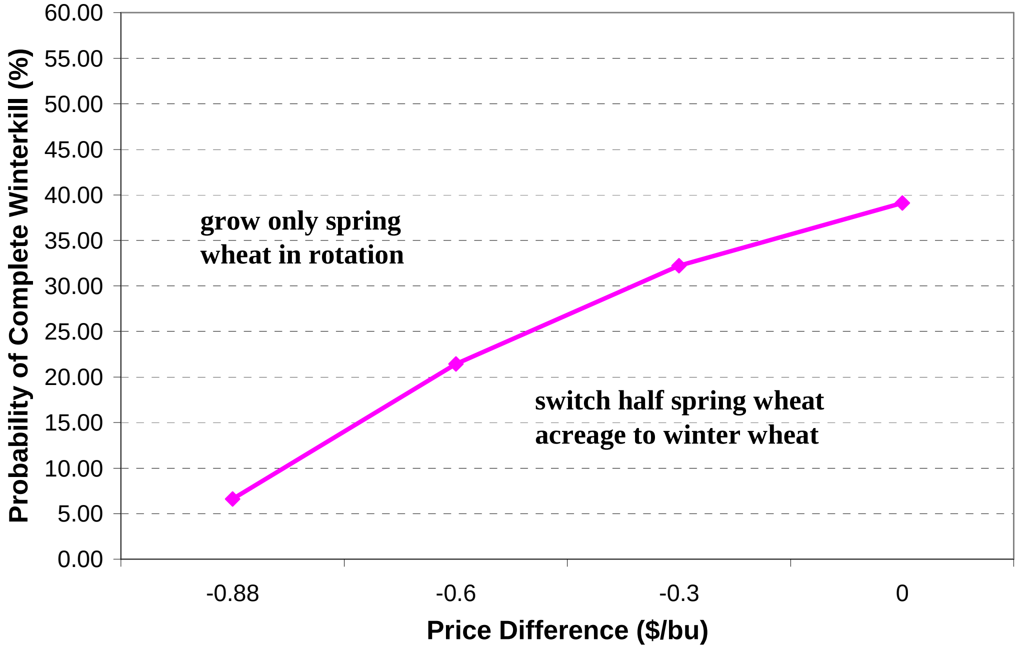
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.24 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Alberta Peace Region)



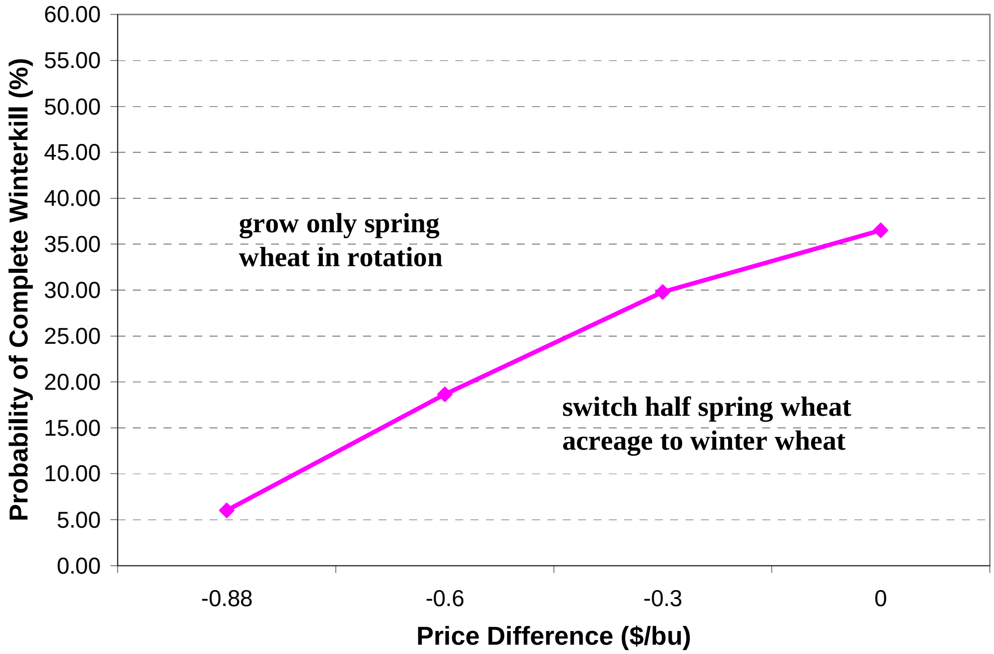
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.25 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Saskatchewan Black Soil Zone)



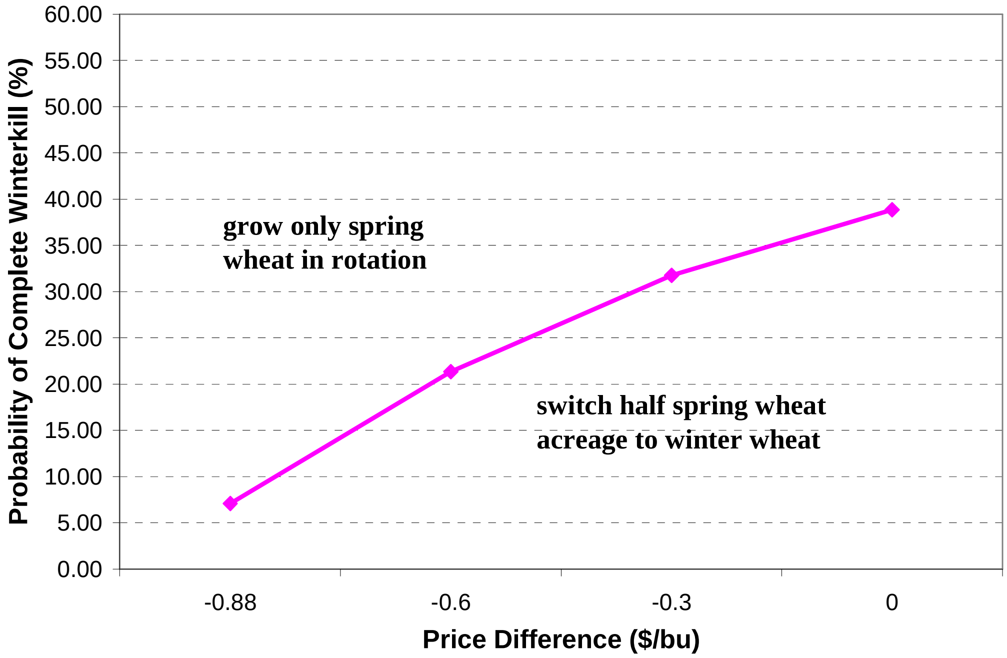
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.26 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Saskatchewan Brown Soil Zone)



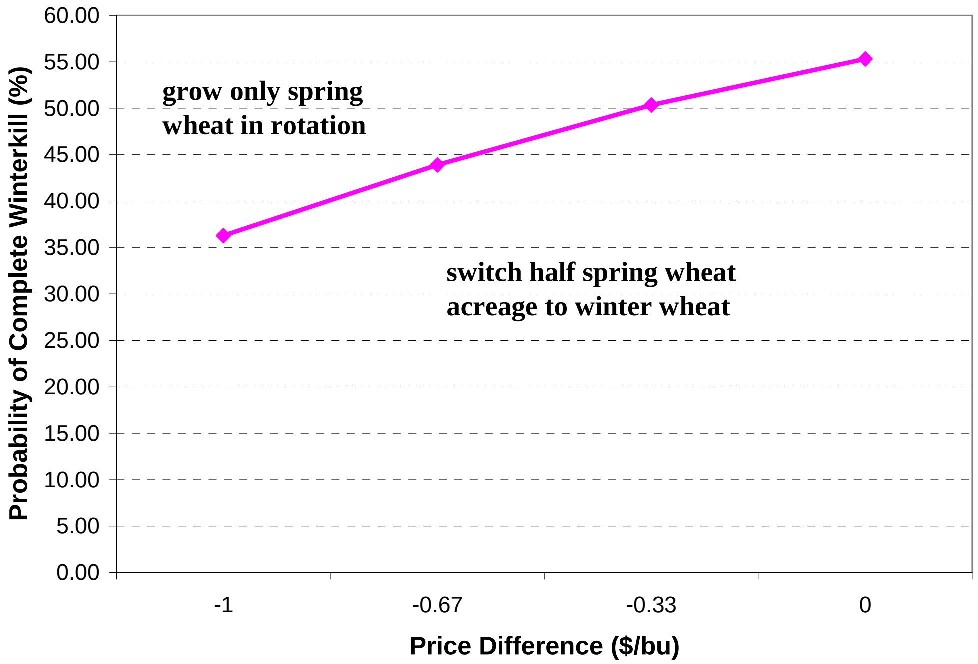
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.27 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Saskatchewan Dark Brown Soil Zone)



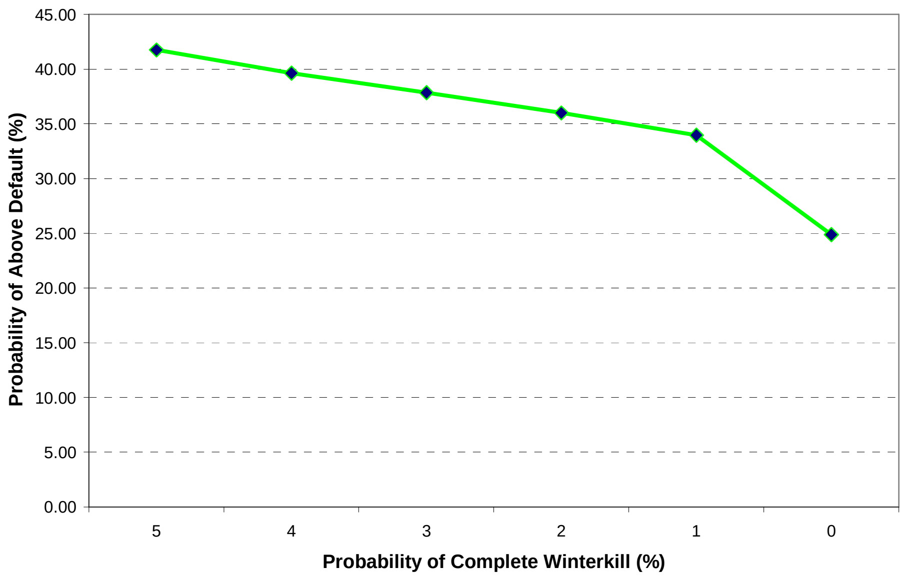
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.28 - Scenario 8: Switching Point Analysis when Default Winter Wheat Price Changes (Manitoba)



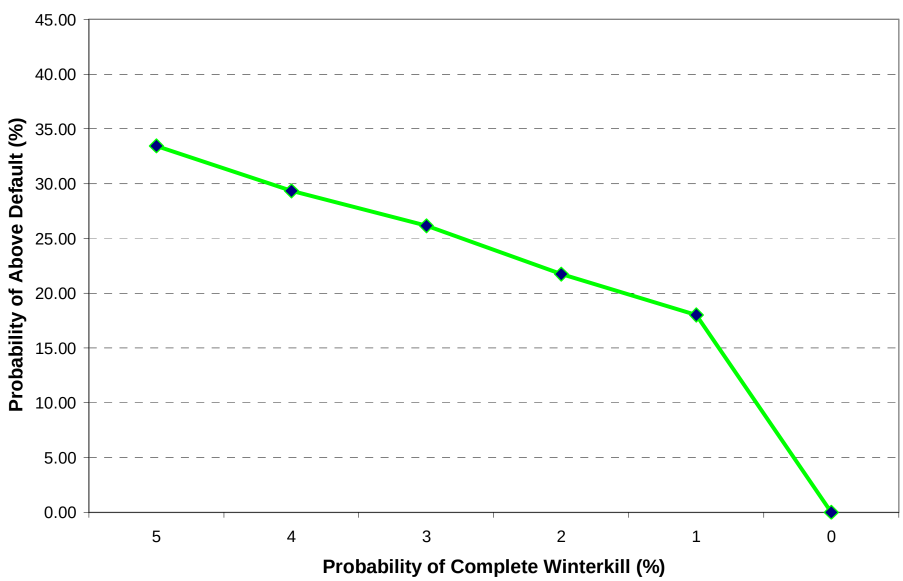
Note: Number of iterations = 5000. Number of simulations = 100. Target mean NPV Difference = 0 +/- $1000. The probability of complete winterkill changes from 0 to 1.

Figure 5.29 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Alberta Black Soil Zone)



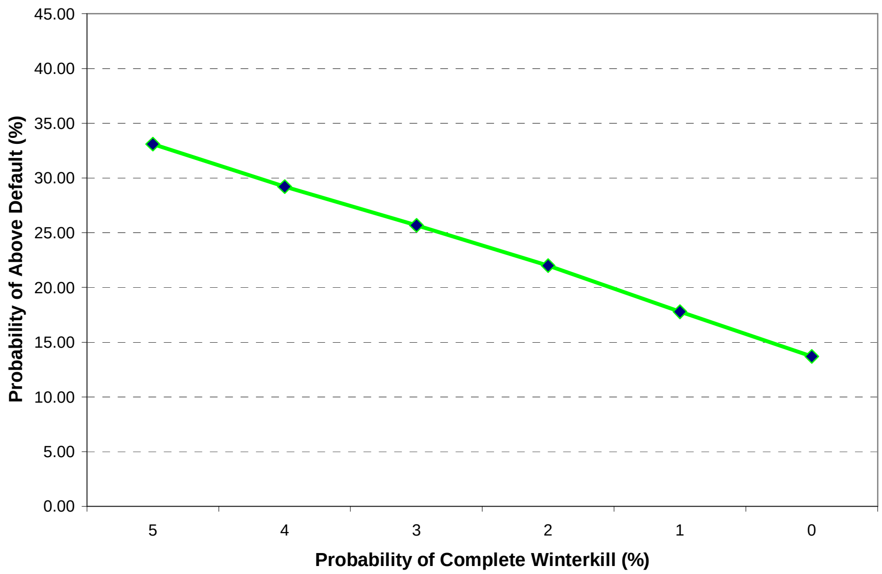
Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Figure 5.30 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Alberta Brown Soil Zone)



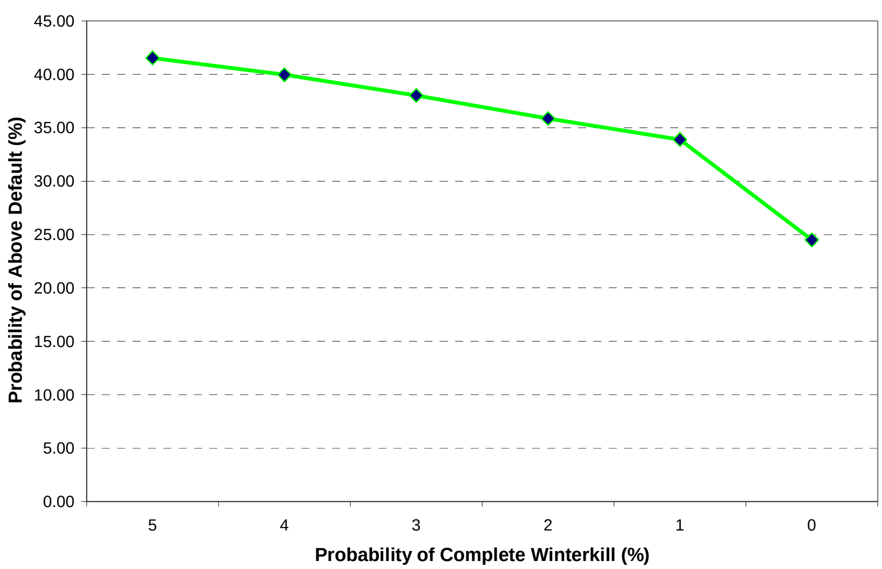
Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Figure 5.31 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Alberta Dark Brown Soil Zone)



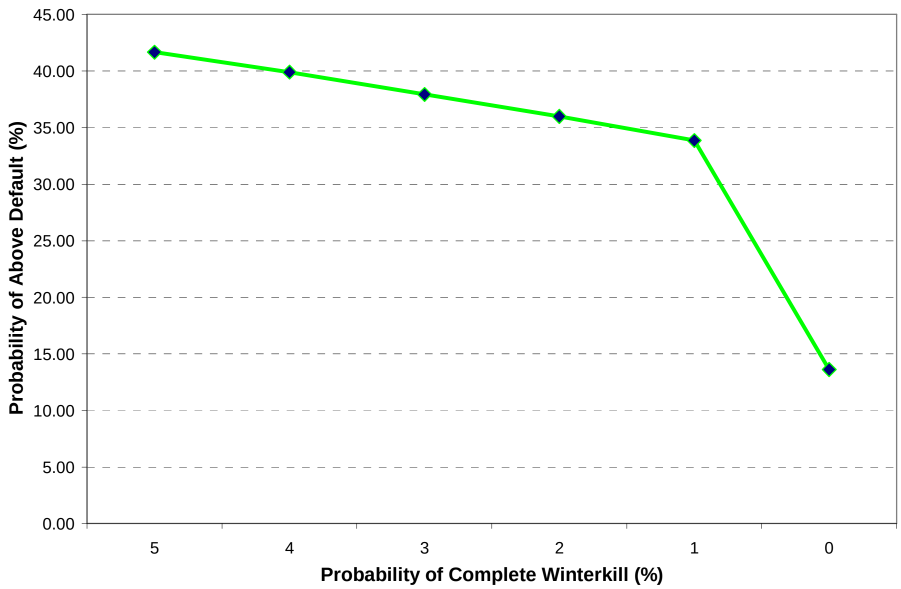
Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Figure 5.32 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Alberta Grey Soil Zone)



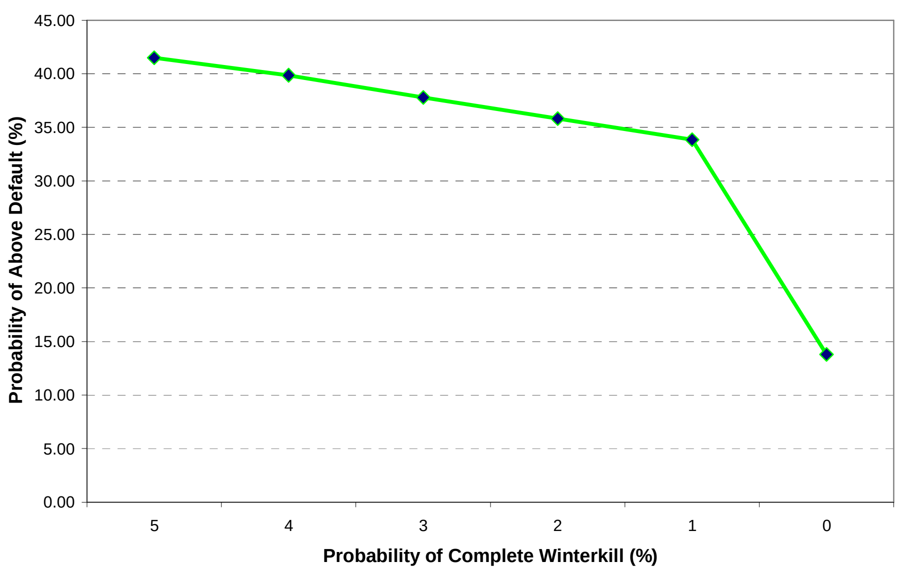
Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Figure 5.33 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Alberta Peace Region)



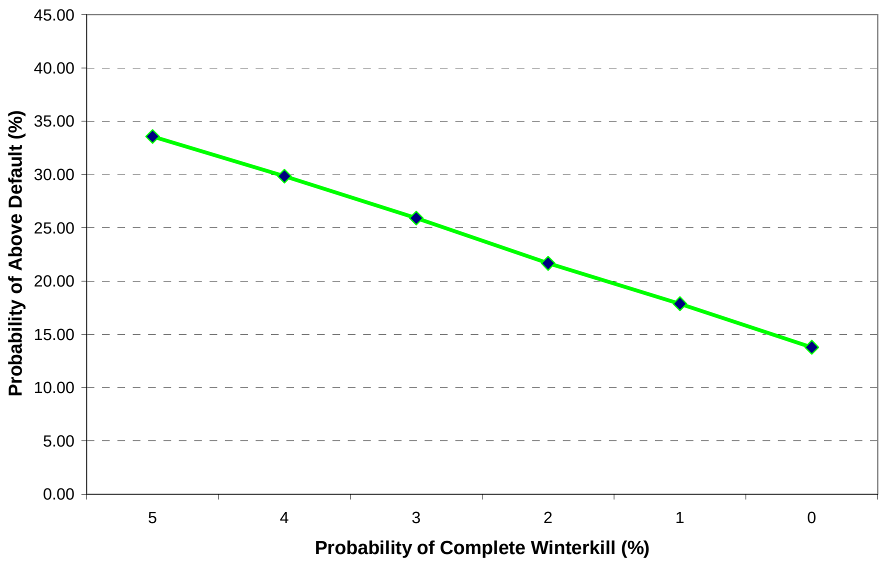
Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Figure 5.34 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Saskatchewan Black Soil Zone)



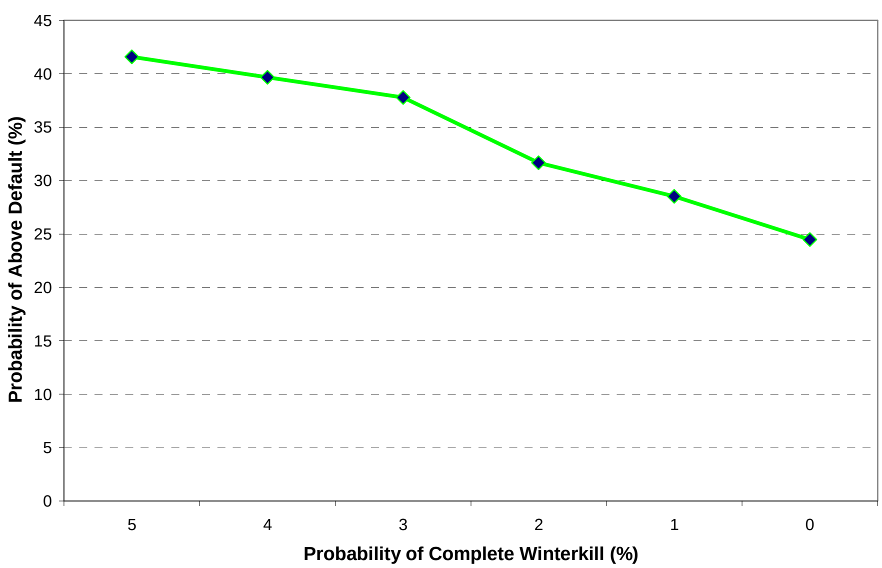
Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Figure 5.35 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Saskatchewan Brown Soil Zone)



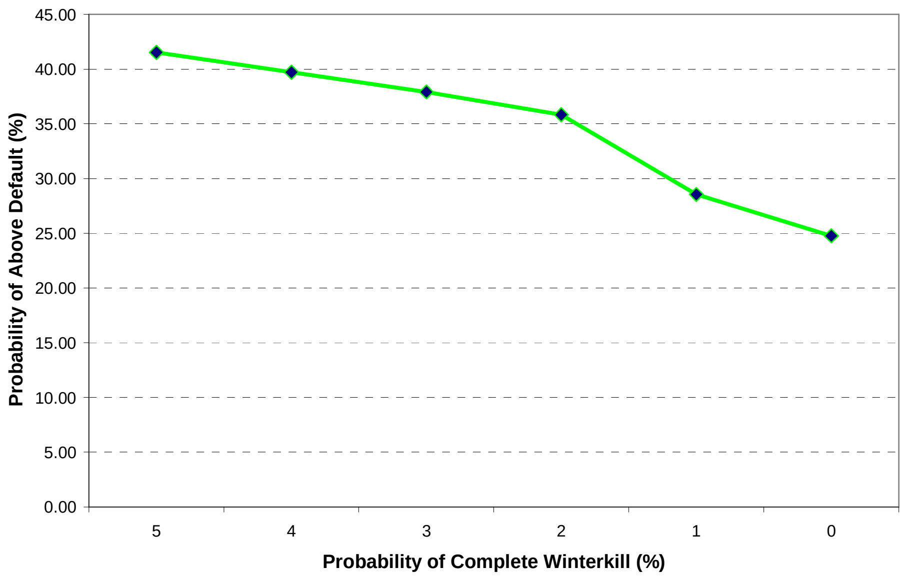
Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Figure 5.36 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Saskatchewan Dark Brown Soil Zone)



Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 0.5bu/ac. The probability of above default changes from 0 to 1.

Figure 5.37 - Scenario 9: How the Probability of Above Default Changes as the Probability of Complete Winterkill Changes to Keep Winter Wheat Yield at Default Value (Manitoba)



Note: Number of iterations = 5000. Number of simulations = 100. Target mean of 30-year average winter wheat yield = default yield +/- 1bu/ac. The probability of above default changes from 0 to 1.

Chapter 6 Conclusions, Model Limitations and Further Research

This study uses the capital budgeting technique of Net Present Value, combined with Monte Carlo simulation, to build cash flow farm models to examine the economic feasibility of winter wheat production in the Canadian Prairies by province and soil zone. For each province-soil combination, a representative farm is built with a unique crop rotation. Before incorporating winter wheat, farmers grow spring wheat with other types of crops (i.e., base case). After incorporating winter wheat, farmers replace half spring wheat acreage with winter wheat, keeping other crop acres constant with an exception of feed barley when there is complete winterkill. The scenario of risk-free winter wheat production does not consider winterkill, while scenarios 1 -10 incorporate winterkill risk into winter wheat production. NPV difference is calculated between the base case and any one of the scenarios. The conclusions of economic feasibility/infeasibility are made, accompanied by a comparison across province-soil combinations as well as a comparison between scenarios. Sensitivity analysis is performed to examine the impact of some key parameters on the final results. Elasticity analysis is conducted to investigate relationships between some important traits of winter wheat.

6.1 Model Conclusions

6.1.1 Scenario Analysis

Winter wheat production is economically feasible with the absence of winterkill in the Canadian Prairies. However, the economic feasibility of growing winter wheat varies across provinces and soil zones when winterkill risk is taken into account. In scenario 1[7], growing winter wheat has the largest positive influence on farmers' wealth in Manitoba, and also increases farmers' wealth in Saskatchewan, but decreases farm wealth in three out of five soil zones in Alberta. These results

[7] In scenario 1, there are 5% complete winterkill, 20% partial winterkill, 60% default year and 15% above default.

are mainly determined by the yield advantage of winter wheat over spring wheat used in the models. These yields are derived from the provincial government crop budget estimates. The probabilities of complete winterkill, partial winterkill, default year, and above default have an influence on winter wheat yields and then the NPVs with winter wheat. For example, an increase in both complete and partial winterkill probabilities by 5 percentage point makes growing winter wheat decrease farmers' wealth in eight out of nine province-soil combinations. By contrast, increasing the above default yield probability to 30% improves the economic feasibility of winter wheat production in all the study areas. Overall, increasing cold tolerance, in terms of reducing winterkill probability or increasing probability of above default yield, can make winter wheat more adaptable to the Canadian Prairies.

Based upon scenario 1, farmers' acceptable probability of complete winterkill to grow winter wheat differs across province-soil combinations, from 1.0 – 36.3%. So if cold tolerance can be improved to make the probability of complete winterkill fall below 1%, farmers in all the province-soil combinations are willing to grow winter wheat even if winter wheat yield and quality do not increase. Improvement of yield or quality makes winter wheat more acceptable to Prairie farmers. The higher the yield or price, the higher the probability of complete winterkill farmers can accept. More precisely, 2bu/ac increase in yield makes farmers accept 9.3 – 39.1% complete winterkill; $0.24 – 0.67/bu increase in price (2/3 the price gap between winter wheat and spring wheat) makes farmers accept 10.0 – 50.4% complete winterkill. Yield increase and price increase both have different impacts on the acceptable probability of complete winterkill across province-soil combinations. The smallest impacts of both yield increase and price increase are found in Manitoba, and the largest impacts are found in the Alberta Black Soil Zone.

Other conclusions from scenario analysis are: there is a negative relationship between the probability of complete winterkill and the probability of above default yield, keeping the mean of 30-year average simulated yield equal to the default yield for winter wheat. Compared to scenario 1 which uses 2007 and 2008 data, winter wheat production in the last scenario which uses 2005 and 2006 data is different in terms of farm NPV differences. Relative to scenario 1, the economic feasibility of winter wheat production in scenario 10 declined in the province of Manitoba and in all the soil zones in Alberta except the Brown Soil Zone, while it improved in all the soil zones in Saskatchewan. Differences in crop prices, crop yields, and input prices between 2005-2006 and 2007-2008 budget data explain these differences in the economic feasibility. Economic results are highly sensitive to the provincial crop budget data and the year to year variations in the budget data.

6.1.2 Sensitivity Analysis

Based upon scenario 1, the discount rate, sunk variable cost of winter wheat when there is complete winterkill, variable cost of late seeded barley, yield of late seeded barley, yield loss factor A, and yield increase factor B are investigated for their impacts on the final results respectively. Among all these factors, only the yield loss factor A influences the economic feasibility of winter wheat production in some province-soil combinations. All other factors have little impact on the final results. The insensitivity of the results to other factors might come from the fact that the changes in the parameters of interest are too small. The conclusion drawn from the current discussion is: reducing yield loss from winterkill increases the economic feasibility of winter wheat production.

6.1.3 Elasticity Analysis

The study on yield elasticity of switching point and price elasticity of switching point further reveals information on the influences of improving winter wheat yield and price (quality) on farmers' acceptable probability of complete winterkill. Switching points are sensitive to both the improvement of yield and the improvement of price. The sensitivity of switching point is similar to improving yield and improving price in Alberta and Manitoba. In Saskatchewan, switching point is more sensitive to improving yield than to improving price. Thus, improving winter wheat yield may receive largest effects in improving the economic feasibility of winter wheat production.

6.1.4 Conclusions of All the Analysis

This study provides producers and policy makers with some insights into the crop choice of growing winter wheat versus spring wheat in the Canadian Prairies from an economic aspect. Based upon 2007-2008 data, growing winter wheat has the greatest potential to increase farmers' wealth in Manitoba, followed by Saskatchewan and Alberta. The yield advantage of winter wheat is the largest in Manitoba, followed by Saskatchewan and Alberta. Cold tolerance, yield, and quality of winter wheat all influence the economic feasibility of winter wheat. If any one of these traits can be improved, Prairie farmers may be more willing to incorporate winter wheat into crop rotations. Some light is shed on the target levels of cold tolerance, yield, and quality, and the target levels differ across provinces and soil zones. The importance of the three traits in winter wheat production is compared, and the findings suggest that to improve the economic feasibility of winter wheat production in the Canadian Prairies, research increasing winter wheat yield may be the most effective way; research improving winter wheat quality may be the second most effective way; and research improving cold tolerance may be also useful but ranks as the least effective among the three traits.

6.2 Model Limitations

In the process of modeling farming activities of a 2000-acre crop farm, there are some issues worth further considering which are listed as follows:

First, budget estimates versus real farm data is an issue. As earlier discussed, the default data used in this study are budget estimates from provincial agricultural ministries (AARD, 2007 and 2008; SAF, 2007 and 2008; MARFI, 2007 and 2008), except that the crop yields in Manitoba are average yields from MASC (2007 and 2008). The Production Costs and Returns from AARD are established on a basis of "a compilation of the most current cost of production information from the AgriProfit$ Business Analysis & Research Program as well as forecasts of expected revenues and costs" (AARD, 2008). They can be used as a reference, but must be combined with individual farms' own cases when making cropping decisions (AARD, 2008). Similarly, SAF (2008) and MAFRI (2008) also states that the estimates they published only can be used as guidelines in decision-making process and farmers must take into account individual farm's conditions, such as climate, soil, and agronomic practices. Additionally, budget estimates do not consider winterkill risk, so they may provide a biased view of growing winter wheat. Although winterkill risk in incorporated into the models, the results are still sensitive to the provincial budget data. The results are driven by the differences in default price, yield, and input costs between winter wheat and spring wheat. Due to time and budget constraints of this study, real farm data representative for every province-soil combination in the Canadian Prairies are unavailable. The currently used default data are the only data available for this study at this time. Using these data in farm models may generate different results from using data from real farms.

The second limitation is about model assumptions. Assumptions are made in this study to reduce the complexity of modeling crop production. For example, each province-soil combination is assumed to have one representative farm with one crop rotation over the period of study. In fact, crop rotations vary across individual fields within an area and changes over time. Additionally, the study assumes that if NPV difference is positive, it is economically feasible to grow winter wheat. For example, the NPV difference is $3,508.88 for the Alberta Brown Soil Zone in scenario 1. Using the current decision making rule, it is suggested to be economically feasible to grow winter wheat in this area since the NPV difference is positive. However, farmers may need more financial incentives to grow winter wheat rather than a little higher NPV of growing winter wheat than spring wheat. Since $3,508.88 is 0.4% of the base case NPV which is $792,821.01 in this area, farmers may not be willing to switch from spring wheat to winter wheat for such a small increase in NPV, with regard to the extra effort in farm management practices needed for winter wheat and increase in yield variance with winter wheat. A larger economic incentive is expected, but hard to decide.

Third, as earlier discussed in section 4.4.2, the structure of winter wheat yield models is a model limitation. More specifically, the range of winter wheat yield under partial winterkill and above default changes as the probabilities of the yield outcomes change.

6.3 Further Research

This study simulates crop production with only one stochastic element: winter wheat yield. In future study, winter wheat price can be made stochastic to capture market fluctuations. Furthermore, spring wheat yield and price can become stochastic as well since any change in spring wheat directly affects the comparison of economic benefits and costs between the two types of wheat. Meanwhile, although the importance of cold tolerance, yield, and price in winter wheat production is studied and some preliminary efforts are made to rank the importance of these traits of winter wheat, such as switching point analysis and elasticity analysis, further efforts are required to better define methods to rank these factors. Additionally, a comprehensive understanding of the biological mechanism behind winter wheat growth is desirable, which is helpful to build a bio-economic model to fully explore the economics of winter wheat production.

The crop choice of growing winter wheat versus spring wheat is based upon economic benefits and costs of crop production, otherwise known as private benefits and costs. However, winter wheat has some environmental benefits as earlier discussed. These benefits are not traded in a market, so cannot bring farmers direct economic returns. However, farmers may take into account these environmental benefits when making cropping decisions. To fully understand the influences of winter wheat production in the Canadian Prairies, environmental and social benefits/costs need to be evaluated. Policy makers and farmers will benefit more from an overall understanding of winter wheat production.

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Appendix A

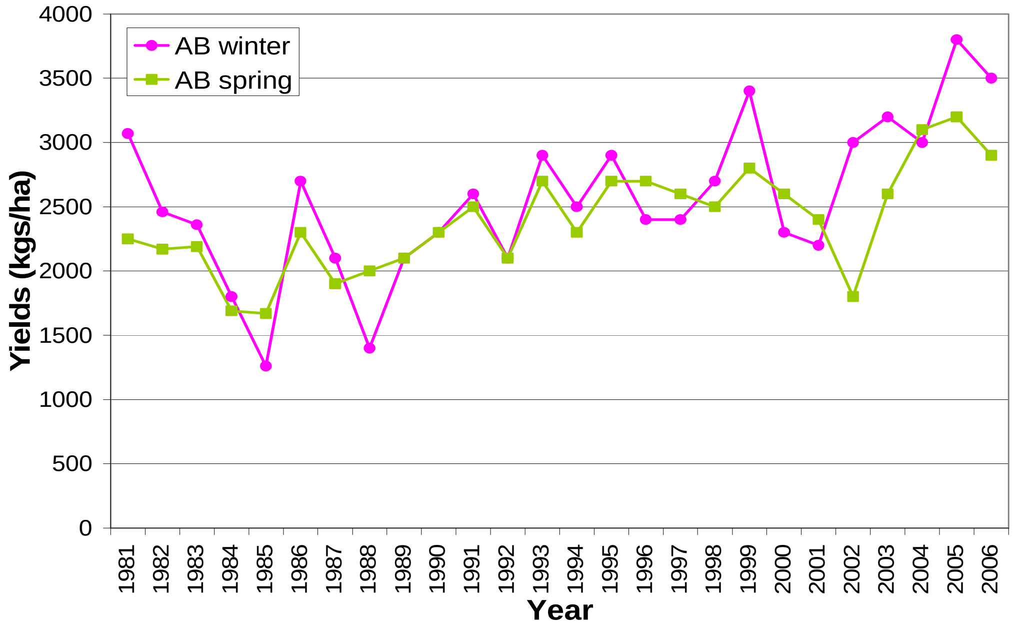
Definitions of Tillage Systems

Tillage Method		Definition
Conventional tillage		A system that traditionally uses moldboard plows or chisel plows with sweeps, followed by disking, harrowing or other secondary tillage operations to incorporate residue, prepare a seedbed and control weeds.
Conservation tillage	Reduced tillage	A system which remove one or more tillage operations to increase residue cover on the soil, reduce fuel costs and to use standing stubble to trap snow to increase soil moisture and permit the winter survival of winter wheat.
	Zero tillage (No-till)	A system in which crops are planted into previously undisturbed soil by opening a narrow slot of sufficient width and depth to obtain proper seedbed coverage. No tillage operation for the purpose of weed control is conducted, but this allows for tillage with low disturbance openers (knives, spikes, etc) for fall banding of fertilizer, filling in ruts, and the use of heavy harrows for crop residue management.

Source: MAFRI (2006)

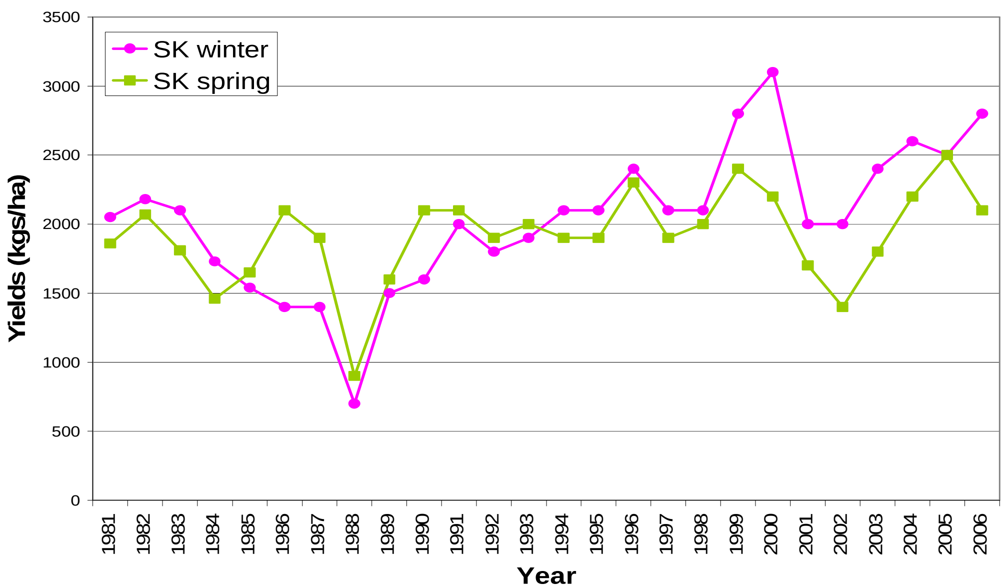
Appendix B

Figure B.1 - Winter Wheat Yields versus Spring Wheat Yields in Alberta (1981-2006)



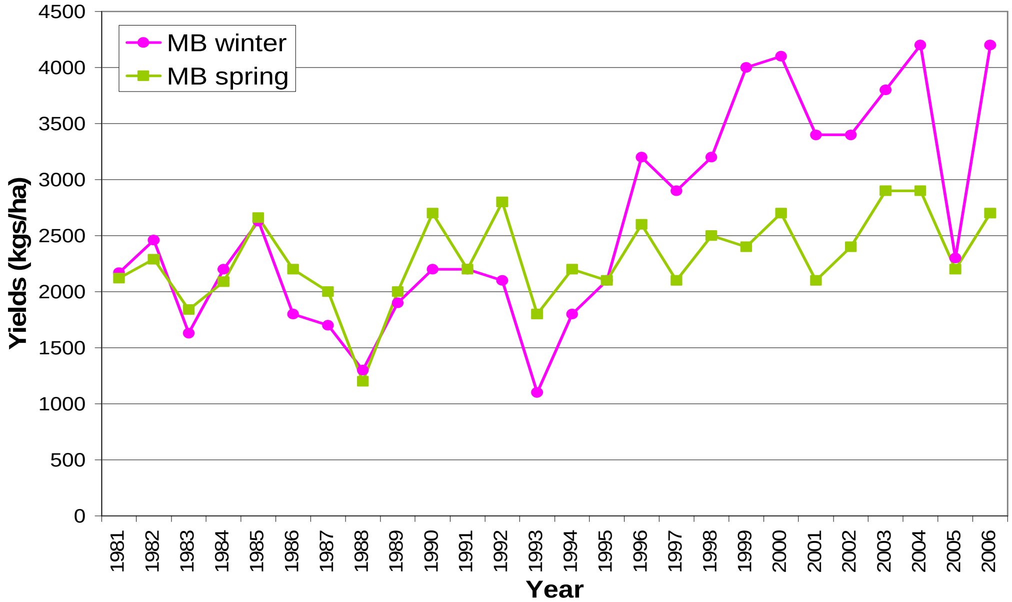
(Source: Yang et al., 2007)

Figure B.2 - Winter Wheat Yields versus Spring Wheat Yields in Saskatchewan (1981-2006)



(Source: Yang et al., 2007)

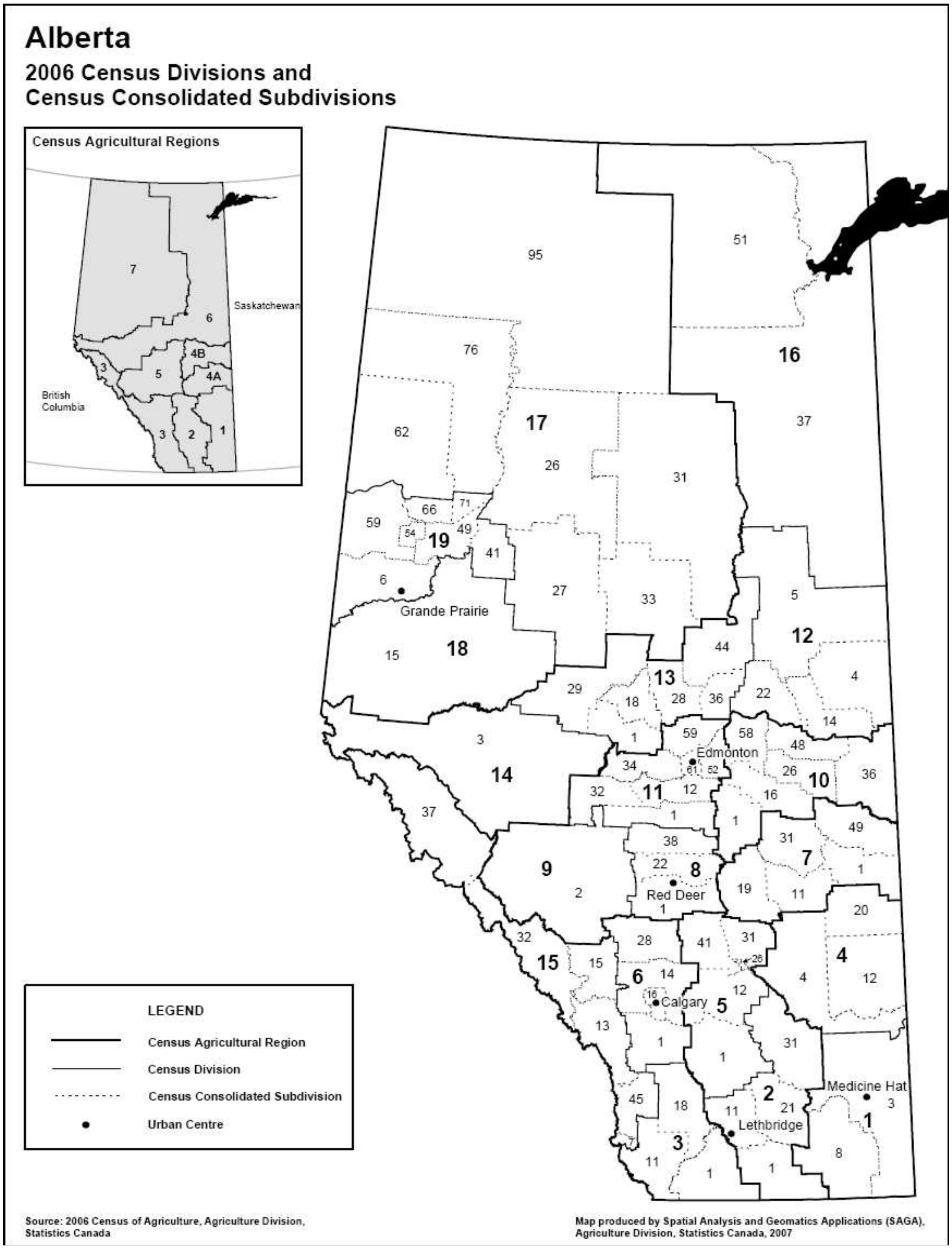
Figure B.3 - Winter Wheat Yields versus Spring Wheat Yields in Manitoba (1981-2006)



(Source: Yang et al., 2007)

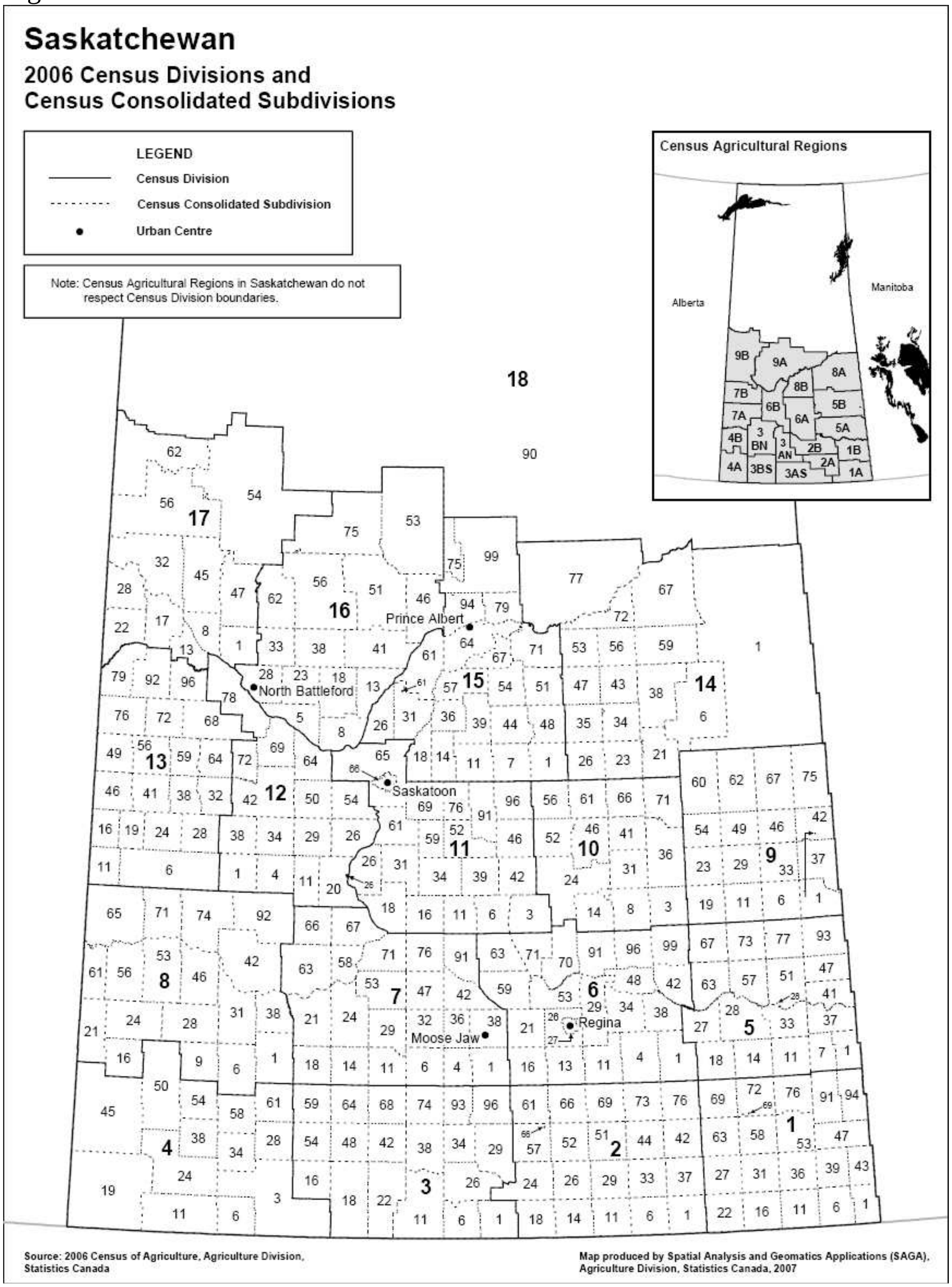
Appendix C

Figure C.1



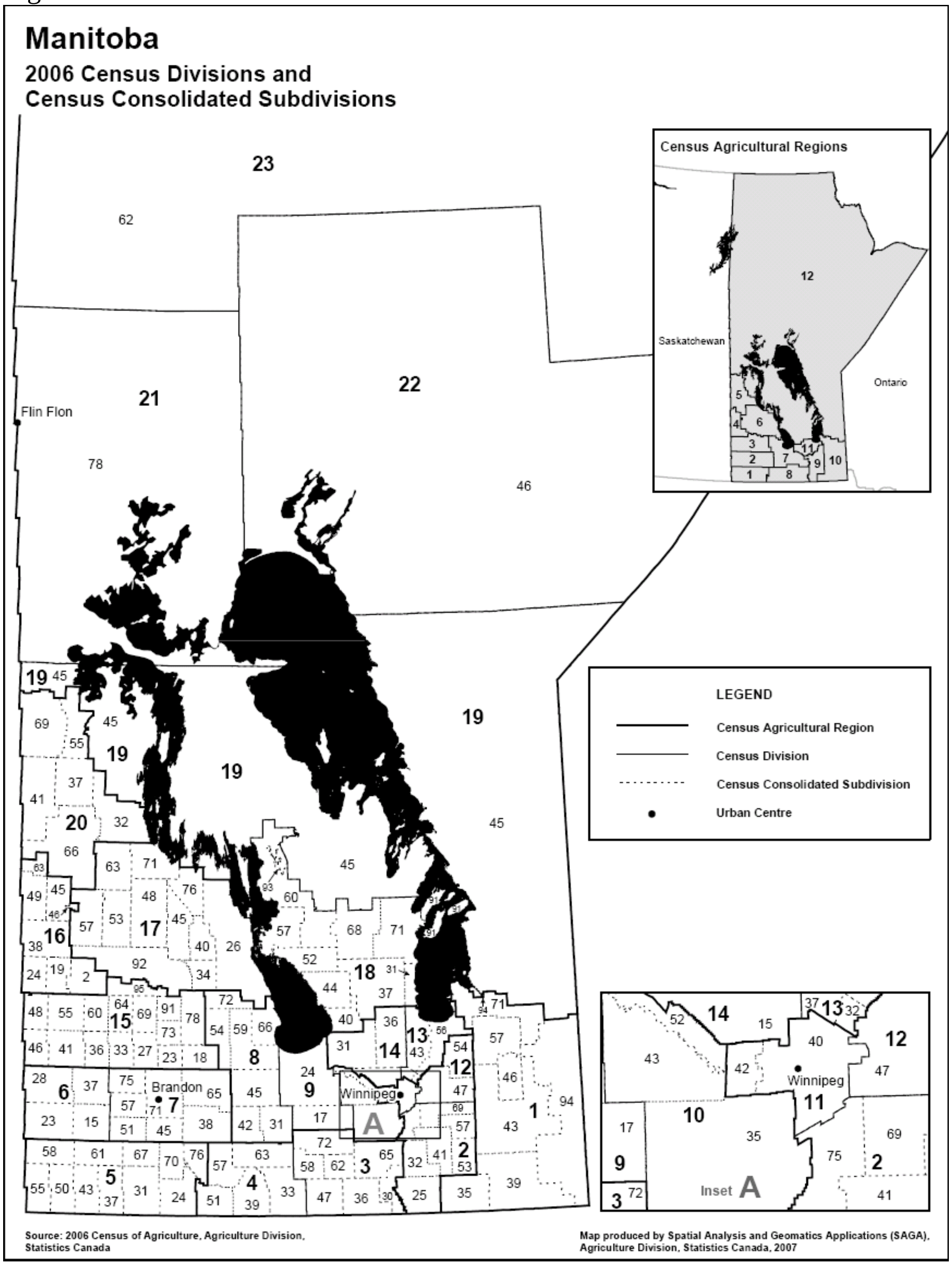
Source: 2006 Census of Agriculture, Agriculture Division, Statistics Canada

Figure C.2



Source: 2006 Census of Agriculture, Agriculture Division, Statistics Canada

Figure C.3



Source: 2006 Census of Agriculture, Agriculture Division, Statistics Canada

Appendix D

Table D.1 Crop Acres in CD 10 - Alberta Black Soil Zone (2006)

CD 10	Acre
spring wheat	781,133
durum wheat	3,960
winter wheat	3,769
barley	455,736
canola	791,924
oats	164,877
flax	4,016
summerfallow	122,494

Source: 2006 Census of Agriculture, Statistics Canada

Table D.2 Crop Acres in CD 4 - Alberta Brown Soil Zone (2006)

CD 4	Acre
spring wheat	371,863
durum wheat	69,153
winter wheat	2,384
barley	119,928
canola	50,101
oats	91,637
flax	5,148
summerfallow	427,686

Source: 2006 Census of Agriculture, Statistics Canada

Table D.3 Crop Acres in CD 5 - Alberta Dark Brown Soil Zone (2006)

CD 5	Acre
spring wheat	1,017,935
durum wheat	73,076
winter wheat	12,577
barley	573,658
canola	450,476
oats	32,469
flax	13,783
summerfallow	325,132

Source: 2006 Census of Agriculture, Statistics Canada

Table D.4 Crop Acres in CD 11 - Alberta Grey Soil Zone (2006)

CD 11	Acre
spring wheat	272,222
durum wheat	5,466
winter wheat	4,249
barley	235,315
canola	346,362
oats	100,500
flax	1,771
summerfallow	46,829

Source: 2006 Census of Agriculture, Statistics Canada

Table D.5 Crop Acres in CD 19 - Alberta Peace Region (2006)

CD 19	Acre
spring wheat	484,519
durum wheat	7,190
winter wheat	4,044
barley	172,063
canola	615,827
oats	124,471
flax	6,726
summerfallow	136,111

Source: 2006 Census of Agriculture, Statistics Canada

Table D.6 Crop Acres in CD 14 – Saskatchewan Black Soil Zone (2006)

CD 14	Acre
spring wheat	635,403
durum wheat	3,459
winter wheat	3,667
barley	231,616
canola	699,738
oats	240,877
flax	56,968
summerfallow	223,617

Source: 2006 Census of Agriculture, Statistics Canada

Table D.7 Crop Acres in CD 3 – Saskatchewan Brown Soil Zone (2006)

CD 3	Acre
spring wheat	597,156
durum wheat	461,163
winter wheat	20,080
barley	138,390
canola	54,756
oats	74,785
flax	63,510
summerfallow	469,014

Source: 2006 Census of Agriculture, Statistics Canada

Table D.8 Crop Acres in CD 11 – Saskatchewan Dark Brown Soil Zone (2006)

CD 11	Acre
spring wheat	772,610
durum wheat	91,587
winter wheat	24,660
barley	265,013
canola	559,348
oats	140,948
flax	141,981
summerfallow	335,737

Source: 2006 Census of Agriculture, Statistics Canada

Table D.9 Crop Acres in CD 17 – Manitoba (2006)

CD 17	Acre
spring wheat	256,878
durum wheat	1,692
winter wheat	4,624
barley	61,547
canola	196,291
oats	63,773
flax	16,237

Source: 2006 Census of Agriculture, Statistics Canada

Appendix E

Table E.1 Default Data for the Alberta Black Soil Zone

	spring wheat	feed barley	Argentine canola	winter wheat	milling oats
Inflow					
Yield (bu/ac)	55.00	75.00	45.00	56.57	85.00
Market Price ($/bu)	6.18	3.80	10.63	5.82	3.03
Crop Sales ($/ac)	**339.63**	**285.00**	**478.13**	**329.24**	**257.13**
Outflow					
Variable Expenses					
Seed	15.97	13.00	32.50	16.97	13.13
Fertilizer (NPKS blend)	67.25	60.75	71.00	74.50	43.00
Chemicals	35.00	29.50	30.50	11.51	11.50
Trucking and Marketing	4.00	4.00	7.00	4.00	4.00
Fuel, Oil & Lube.	13.46	14.02	14.02	13.46	14.02
Machinery Repairs	10.00	10.00	12.50	10.00	10.00
Building Repairs	1.50	1.50	1.50	1.50	1.50
Custom Work & Hired Labor	8.25	6.25	6.25	5.00	6.25
Utilities & Miscellaneous	9.00	9.00	9.00	9.00	9.00
Total Variable Expense ($/ac)	**164.43**	**148.02**	**184.27**	**145.94**	**112.40**
Other Expenses					
Machinery Replacement	30.00	30.00	30.00	30.00	30.00
Building Replacement	1.60	1.60	1.60	1.60	1.60
Licenses and insurance	5.00	5.00	5.00	5.00	5.00
Property Tax	5.00	5.00	5.00	5.00	5.00
Total Other Expense ($/ac)	**41.60**	**41.60**	**41.60**	**41.60**	**41.60**
Total Expense ($/ac)	**206.03**	**189.62**	**225.87**	**187.54**	**154.00**
Net Cash Flow ($/ac)	**133.60**	**95.38**	**252.26**	**141.70**	**103.13**

Note: The data are averages of 2007 and 2008 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2007 and 2008)

Table E.2 Default Data for the Alberta Brown Soil Zone

	spring wheat	feed barley	Argentine canola	winter wheat	fallow seeded spring wheat
Inflow					
Yield (bu/ac)	30.00	45.00	30.00	30.86	31.07
Market Price ($/bu)	6.55	4.00	10.63	6.18	6.55
Crop Sales ($/ac)	**196.50**	**180.00**	**318.75**	**190.54**	**203.52**
Outflow					
Variable Expenses					
Seed	13.69	9.75	26.00	14.55	13.69
Fertilizer (NPKS blend)	42.25	42.25	45.75	46.81	28.17
Chemicals	26.25	14.75	27.45	8.63	16.76
Trucking and Marketing	3.50	3.00	5.00	3.50	3.50
Fuel, Oil & Lube.	11.22	11.22	11.22	11.22	11.22
Machinery Repairs	8.50	8.50	8.50	8.50	8.50
Building Repairs	1.00	1.00	1.00	1.00	1.00
Custom Work & Hired Labor	7.00	6.00	6.00	4.24	7.00
Utilities & Miscellaneous	8.50	8.50	8.50	8.50	8.50
Total Variable Expense ($/ac)	**121.91**	**104.97**	**139.42**	**106.94**	**98.34**
Other Expenses					
Machinery Replacement	25.00	25.00	25.00	25.00	25.00
Building Replacement	1.60	1.60	1.60	1.60	1.60
Licenses and insurance	3.00	3.00	3.00	3.00	3.00
Property Tax	5.00	5.00	5.00	5.00	5.00
Total Other Expense ($/ac)	**34.60**	**34.60**	**34.60**	**34.60**	**34.60**
Total Expense ($/ac)	**156.51**	**139.57**	**174.02**	**141.54**	**132.94**
Net Cash Flow ($/ac)	**40.00**	**40.44**	**144.74**	**49.00**	**70.58**

Note: The data are averages of 2007 and 2008 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2007 and 2008)

Table E.2 Default Data for the Alberta Brown Soil Zone (Continued)

	fallow seeded durum	**tillage fallow**
Inflow		
Yield (bu/ac)	32.90	
Market Price ($/bu)	7.65	
Crop Sales ($/ac)	**251.69**	**0.00**
Outflow		
Variable Expenses		
Seed	18.00	
Fertilizer (NPKS blend)	28.17	
Chemicals	16.76	16.50
Trucking and Marketing	3.50	
Fuel, Oil & Lube.	11.22	8.98
Machinery Repairs	8.50	6.00
Building Repairs	1.00	1.00
Custom Work & Hired Labor	7.00	7.00
Utilities & Miscellaneous	8.50	4.00
Total Variable Expense ($/ac)	**102.65**	**43.48**
Other Expenses		
Machinery Replacement	25.00	5.10
Building Replacement	1.60	1.60
Licenses and insurance	3.00	3.00
Property Tax	5.00	5.00
Total Other Expense ($/ac)	**34.60**	**14.70**
Total Expense ($/ac)	**137.25**	**58.18**
Net Cash Flow ($/ac)	**114.44**	**-58.18**

Note: The data are averages of 2007 and 2008 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2007 and 2008)

Table E.3 Default Data for the Alberta Dark Brown Soil Zone

	spring wheat	feed barley	Argentine canola	winter wheat	fallow seeded spring wheat	tillage fallow
Inflow						
Yield (bu/ac)	35.00	45.00	35.00	36.00	37.33	
Market Price ($/bu)	6.55	4.00	10.63	6.18	6.55	
Crop Sales ($/ac)	**229.25**	**180.00**	**371.88**	**222.30**	**244.53**	**0.00**
Outflow						
Variable Expenses						
Seed	15.06	11.38	32.50	16.00	15.06	
Fertilizer (NPKS blend)	51.00	48.50	55.75	56.50	27.32	16.50
Chemicals	29.75	22.13	30.50	9.78	24.29	
Trucking and Marketing	3.50	3.00	5.00	3.50	3.50	
Fuel, Oil & Lube.	12.34	12.34	12.34	12.34	12.34	8.93
Machinery Repairs	9.00	9.00	9.00	9.00	9.00	6.00
Building Repairs	1.00	1.00	1.00	1.00	1.00	1.00
Custom Work & Hired Labor	7.25	6.25	6.25	4.39	7.25	0.00
Utilities & Miscellaneous	8.50	8.50	8.50	8.50	8.50	4.00
Total Variable Expense ($/ac)	**137.39**	**122.10**	**160.84**	**121.01**	**108.25**	**36.43**
Other Expenses						
Machinery Replacement	25.00	25.00	25.00	25.00	25.00	7.05
Building Replacement	1.60	1.60	1.60	1.60	1.60	1.60
Licenses and insurance	3.00	3.00	3.00	3.00	3.00	3.00
Property Tax	5.00	5.00	5.00	5.00	5.00	5.00
Total Other Expense ($/ac)	**34.60**	**34.60**	**34.60**	**34.60**	**34.60**	**16.65**
Total Expense ($/ac)	**171.99**	**156.70**	**195.44**	**155.61**	**142.85**	**53.08**
Net Cash Flow ($/ac)	**57.26**	**23.31**	**176.44**	**66.70**	**101.69**	**-53.08**

Note: The data are averages of 2007 and 2008 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2007 and 2008)

Table E.4 Default Data for the Alberta Grey Soil Zone

	spring wheat	feed barley	Argentine canola	winter wheat	milling oats
Inflow					
Yield (bu/ac)	50.00	70.00	40.00	51.43	80.00
Market Price ($/bu)	6.18	3.40	10.63	5.82	3.03
Crop Sales ($/ac)	**308.75**	**238.00**	**425.00**	**299.32**	**242.00**
Outflow					
Variable Expenses					
Seed	15.97	11.38	32.50	16.97	11.82
Fertilizer (NPKS blend)	58.50	52.25	68.50	64.81	40.75
Chemicals	35.00	29.50	30.50	11.51	11.50
Trucking and Marketing	4.00	4.00	7.00	4.00	4.00
Fuel, Oil & Lube.	15.70	15.70	17.95	15.70	15.70
Machinery Repairs	12.00	12.00	14.50	12.00	12.00
Building Repairs	1.50	1.50	1.50	1.50	1.50
Custom Work & Hired Labor	7.25	6.25	6.25	4.39	6.25
Utilities & Miscellaneous	9.75	9.75	12.00	9.75	9.75
Total Variable Expense ($/ac)	**159.67**	**142.33**	**190.70**	**140.63**	**113.27**
Other Expenses					
Machinery Replacement	30.00	30.00	30.00	30.00	30.00
Building Replacement	1.60	1.60	1.60	1.60	1.60
Licenses and insurance	5.00	5.00	5.00	5.00	5.00
Property Tax	5.00	5.00	5.00	5.00	5.00
Total Other Expense ($/ac)	**41.60**	**41.60**	**41.60**	**41.60**	**41.60**
Total Expense ($/ac)	**201.27**	**183.93**	**232.30**	**182.23**	**154.87**
Net Cash Flow ($/ac)	**107.48**	**54.07**	**192.71**	**117.09**	**87.14**

Note: The data are averages of 2007 and 2008 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2007 and 2008)

Table E.5 Default Data for the Alberta Peace Region

	spring wheat	feed barley	Argentine canola	winter wheat	milling oats
Inflow					
Yield (bu/ac)	40.00	64.00	30.00	41.14	75.00
Market Price ($/bu)	6.18	3.40	10.63	5.82	3.03
Crop Sales ($/ac)	**247.20**	**217.60**	**318.90**	**239.51**	**227.25**
Outflow					
Variable Expenses					
Seed	13.69	9.75	26.00	14.55	10.50
Fertilizer (NPKS blend)	57.25	52.25	68.50	63.42	43.00
Chemicals	35.00	29.50	30.50	11.51	11.50
Trucking and Marketing	3.50	3.50	6.50	3.50	3.50
Fuel, Oil & Lube.	12.90	12.90	14.02	12.90	12.90
Machinery Repairs	12.50	12.50	14.50	12.50	12.50
Building Repairs	1.50	1.50	1.50	1.50	1.50
Custom Work & Hired Labor	7.25	6.25	6.25	4.39	6.25
Utilities & Miscellaneous	8.50	8.50	8.50	8.50	8.50
Total Variable Expense ($/ac)	**152.09**	**136.65**	**176.27**	**132.77**	**110.15**
Other Expenses					
Machinery Replacement	25.00	25.00	25.00	25.00	25.00
Building Replacement	1.60	1.60	1.60	1.60	1.60
Licenses and insurance	3.00	3.00	3.00	3.00	3.00
Property Tax	5.00	5.00	5.00	5.00	5.00
Total Other Expense ($/ac)	**34.60**	**34.60**	**34.60**	**34.60**	**34.60**
Total Expense ($/ac)	**186.69**	**171.25**	**210.87**	**167.37**	**144.75**
Net Cash Flow ($/ac)	**60.51**	**46.35**	**108.03**	**72.14**	**82.50**

Note: The data are averages of 2007 and 2008 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2007 and 2008)

Table E.6 Default Data for the Saskatchewan Black Soil Zone

	spring wheat	**feed barley**	**canola**	**winter wheat**	**oats**
Inflow					
Yield (bu/ac)	36.95	58.60	26.20	44.90	70.10
Market Price ($/bu)	5.38	3.00	8.63	4.50	2.38
Estimated Gross Revenue ($/ac)	**198.61**	**175.80**	**225.98**	**202.05**	**166.49**
Outflow					
Variable Expenses					
Seed	11.37	8.92	26.48	11.55	13.32
Fertilizer - Nitrogen	28.80	28.80	28.80	36.00	28.80
- Phosphorus	10.20	10.20	6.80	10.20	10.20
- Sulfur & Other	0.00	0.00	4.60	0.00	0.00
Chemical - Herbicides	19.48	19.46	26.97	11.30	10.84
- Insecticides/Fungicides	2.34	0.00	1.07	0.00	0.00
- Others	2.70	2.38	0.00	2.70	3.06
Machinery Operating - Fuel	10.99	10.99	11.78	10.99	10.99
- Repair	5.94	5.94	5.94	5.94	5.94
Custom Work & Hired Labor	8.25	6.25	6.25	5.00	6.25
Crop Insurance Premium	0.00	0.00	0.00	0.00	0.00
Utilities & Miscellaneous	5.36	5.36	5.36	5.36	5.36
Building Repair	1.60	1.60	1.60	1.60	1.60
Total Variable Expenses ($/ac)	**107.02**	**99.89**	**125.63**	**100.64**	**96.36**
Other Expenses					
Property Taxes	6.36	6.36	6.36	6.36	6.36
Insurance & Licenses	2.42	2.42	2.42	2.42	2.42
Machinery Replacement	19.80	19.80	19.80	19.80	19.80
Building Replacement	1.60	1.60	1.60	1.60	1.60
Total Other Expenses ($/ac)	**30.18**	**30.18**	**30.18**	**30.18**	**30.18**
Total Expenses ($/ac)	**137.20**	**130.07**	**155.81**	**130.82**	**126.54**
Net Cash Flow ($/ac)	**61.41**	**45.73**	**70.17**	**71.24**	**39.95**

Note: The data are averages of 2007 and 2008 data.
Source: Crop Planning Guides (SAF, 2007 and 2008)

Table E.7 Default Data for the Saskatchewan Brown Soil Zone

	spring wheat	feed barley	winter wheat	oats	fallow seeded durum wheat	tillage fallow
Inflow						
Yield (bu/ac)	26.45	40.25	32.14	45.00	37.00	
Market Price ($/bu)	5.38	3.00	4.50	2.38	5.90	
Estimated Gross Revenue ($/ac)	**142.17**	**120.75**	**144.63**	**106.8 8**	**218.30**	**0.00**
Outflow						
Variable Expenses						
Seed	11.37	8.11	11.55	11.10	14.72	
Fertilizer - Nitrogen	21.60	21.60	27.00	21.60	9.60	
- Phosphorus	10.20	10.20	10.20	10.20	10.20	
- Sulfur & Other	0.00	0.00	0.00	0.00	0.00	
Chemical - Herbicides	15.16	15.18	8.79	10.84	12.49	3.83
- Insecticides/Fungicides	1.17	0.00	0.00	0.00	1.17	0.00
- Others	2.70	2.16	2.70	2.55	2.70	0.00
Machinery Operating - Fuel	10.99	10.99	10.99	10.99	13.35	7.85
- Repair	4.47	4.47	4.47	4.47	4.47	1.53
Custom Work & Hired Labor	7.00	6.00	4.24	6.00	7.00	0.00
Crop Insurance Premium	0.00	0.00	0.00	0.00	0.00	0.00
Utilities & Miscellaneous	3.56	3.56	3.56	3.56	3.56	3.56
Building Repair	0.90	0.90	0.90	0.90	0.90	0.90
Total Variable Expenses ($/ac)	**89.11**	**83.16**	**84.40**	**82.21**	**80.16**	**17.67**
Other Expenses						
Property Taxes	5.30	5.30	5.30	5.30	5.30	5.30
Insurance & Licenses	1.35	1.35	1.35	1.35	1.35	1.35
Machinery Replacement	14.90	14.90	14.90	14.90	14.90	5.10
Building Replacement	0.90	0.90	0.90	0.90	0.90	0.90
Total Other Expenses ($/ac)	**22.45**	**22.45**	**22.45**	**22.45**	**22.45**	**12.65**
Total Expenses ($/ac)	**111.56**	**105.61**	**106.85**	**104.6 6**	**102.61**	**30.32**
Net Cash Flow ($/ac)	**30.61**	**15.14**	**37.78**	**2.22**	**115.69**	**-30.32**

Note: The data are averages of 2007 and 2008 data.
Source: Crop Planning Guides (SAF, 2007 and 2008)

Table E.8 Default Data for the Saskatchewan Dark Brown Soil Zone

	spring wheat	feed barley	canola	winter wheat	tillage fallow	fallow seeded spring wheat
Inflow						
Yield (bu/ac)	31.20	49.50	23.70	37.91		33.30
Market Price ($/bu)	5.38	3.00	8.63	4.50		5.38
Estimated Gross Revenue ($/ac)	**167.70**	**148.50**	**204.41**	**170.61**	**0.00**	**178.99**
Outflow						
Variable Expenses						
Seed	11.37	8.92	26.48	11.55		11.37
Fertilizer - Nitrogen	24.00	24.00	24.00	30.00		12.00
- Phosphorus	10.20	10.20	6.80	10.20		10.20
- Sulfur & Other	0.00	0.00	3.45	0.00		0.00
Chemical - Herbicides	19.93	19.46	26.97	11.56	3.83	16.81
- Insecticides/Fungicides	1.17	0.00	1.07	0.00	0.00	1.17
- Others	2.70	2.38	0.00	2.70	0.00	2.70
Machinery Operating - Fuel	10.99	10.99	11.78	10.99	7.85	13.35
- Repair	5.18	5.18	5.18	5.18	2.12	5.18
Custom Work & Hired Labor	7.25	6.25	6.25	4.39	0.00	7.25
Crop Insurance Premium	0.00	0.00	0.00	0.00	0.00	0.00
Utilities & Miscellaneous	5.26	5.26	5.26	5.26	5.26	5.26
Building Repair	1.20	1.20	1.20	1.20	1.20	1.20
Total Variable Expenses ($/ac)	**99.24**	**93.83**	**118.42**	**93.03**	**20.26**	**86.47**
Other Expenses						
Property Taxes	5.69	5.69	5.69	5.69	5.69	5.69
Insurance & Licenses	2.05	2.05	2.05	2.05	2.05	2.05
Machinery Replacement	17.25	17.25	17.25	17.25	7.05	17.25
Building Replacement	1.20	1.20	1.20	1.20	1.20	1.20
Total Other Expenses ($/ac)	**26.19**	**26.19**	**26.19**	**26.19**	**15.99**	**26.19**
Total Expenses ($/ac)	**125.43**	**120.02**	**144.61**	**119.22**	**36.25**	**112.66**
Net Cash Flow ($/ac)	**42.28**	**28.48**	**59.80**	**51.39**	**-36.25**	**66.33**

Note: The data are averages of 2007 and 2008 data.
Source: Crop Planning Guides (SAF, 2007 and 2008)

Table E.9 Default Data for Manitoba

	spring wheat	winter wheat	feed barley	canola	oats
Inflow					
Yield (bu/acre)	41.50	65.30	60.75	31.85	82.50
Market Price($/bu)	5.08	4.08	2.88	8.68	2.48
Estimated gross revenue ($/ac)	**210.61**	**266.10**	**174.66**	**276.30**	**204.19**
Outflow					
Variable Expenses					
Seed & Treatment	15.52	16.75	14.50	31.35	15.94
Fertilizer	38.20	57.59	38.20	44.97	35.25
Herbicide	22.00	5.75	22.00	26.00	5.75
Fungicide	10.50	15.25	5.38	26.13	8.50
Insecticide	0.00	0.00	0.00	0.00	0.00
Fuel	14.75	12.25	14.75	14.75	14.75
Machinery Operating	10.00	8.00	10.00	10.00	10.00
Crop Insurance	0.00	0.00	0.00	0.00	0.00
Other Costs (Utilities and Miscellaneous)	7.50	7.50	7.50	7.50	7.50
Drying Costs	0.00	0.00	0.00	0.00	0.00
Custom Work & Hired Labor	8.25	5.00	6.25	6.25	6.25
Building Repairs	1.50	1.50	1.50	1.50	1.50
Total Operating ($/ac)	**128.21**	**129.59**	**120.07**	**168.44**	**105.44**
Other Expenses					
Machinery Replacement	25.00	25.00	25.00	25.00	25.00
Building Replacement	1.60	1.60	1.60	1.60	1.60
License and insurance	Included in the expense of Machinery Operating				
Land Taxes	5.00	5.00	5.00	5.00	5.00
Total Other Expense ($/ac)	**31.60**	**31.60**	**31.60**	**31.60**	**31.60**
Total Expense ($/ac)	**159.81**	**161.19**	**151.67**	**200.04**	**137.04**
Net Cash Flow ($/ac)	**50.80**	**104.91**	**22.99**	**76.26**	**67.15**

Note: The data are averages of 2007 and 2008 data.

Source: Guidelines for Estimating Crop Production Costs (MAFRI, 2007 and 2008); Yield Manitoba (MASC, 2007 and 2008)

Appendix F

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Appendix G

Cash Flows before Incorporating Winter Wheat - Alberta Black Soil Zone

Inflow	Year 0	Year 1	Year 2	Year 3	...	Year 28	Year 29	Year 30
spring wheat		118,868.75	118,868.75	118,868.75	...	118,868.75	118,868.75	118,868.75
feed barley		114,000.00	114,000.00	114,000.00	...	114,000.00	114,000.00	114,000.00
Argentine canola		334,687.50	334,687.50	334,687.50	...	334,687.50	334,687.50	334,687.50
spring wheat		118,868.75	118,868.75	118,868.75	...	118,868.75	118,868.75	118,868.75
milling oats		51,425.00	51,425.00	51,425.00	...	51,425.00	51,425.00	51,425.00
Total Inflow		737,850.00	737,850.00	737,850.00	...	737,850.00	737,850.00	737,850.00

Note: inflow = price x yield x acre

Outflow	Year 0	Year 1	Year 2	Year 3	...	Year 28	Year 29	Year 30
spring wheat		72,110.50	72,110.50	72,110.50	...	72,110.50	72,110.50	72,110.50
feed barley		75,848.00	75,848.00	75,848.00	...	75,848.00	75,848.00	75,848.00
Argentine canola		158,109.00	158,109.00	158,109.00	...	158,109.00	158,109.00	158,109.00
spring wheat		72,110.50	72,110.50	72,110.50	...	72,110.50	72,110.50	72,110.50
milling oats		30,799.00	30,799.00	30,799.00	...	30,799.00	30,799.00	30,799.00
Total Outflow		408,977.00	408,977.00	408,977.00	...	408,977.00	408,977.00	408,977.00

Note: outflow = (variable expenses + other expenses) x acre

Net Cash Flow		328,873.00	328,873.00	328,873.00	...	328,873.00	328,873.00	328,873.00
Discounted Cash Flow		298,975.45	271,795.87	247,087.15	...	22,805.16	20,731.96	18,847.24

NPV	**3,100,257.64**

Note: All cash flows are in Canadian dollar. Discount Rate = 10%.

Appendix H

Table H.1 Data for the Alberta Black Soil Zone - Scenario 10

	spring wheat	**feed barley**	**Argentine canola**	**winter wheat**	**milling oats**
Inflow					
Yield (bu/ac)	52.50	72.50	32.00	59.77	52.50
Market Price ($/bu)	3.45	2.40	6.00	2.59	3.45
Crop Sales ($/ac)	**181.13**	**174.00**	**192.00**	**154.65**	**181.13**
Outflow					
Total Variable Expense ($/ac)	120.86	114.49	137.62	103.42	101.99
Total Other Expense ($/ac)	40.10	40.10	39.60	40.10	40.10
Total Expense ($/ac)	**160.96**	**154.59**	**177.22**	**143.52**	**142.09**
Net Cash Flow ($/ac)	**20.17**	**19.41**	**14.78**	**11.13**	**23.66**

Note: The data are averages of 2005 and 2006 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2005 and 2006)

Table H.2 Data for the Alberta Brown Soil Zone – Scenario 10

	spring wheat	**feed barley**	**Argentine canola**	**winter wheat**	**fallow seeded spring wheat**
Inflow					
Yield (bu/ac)	26.00	42.00	15.85	34.50	29.00
Market Price ($/bu)	4.00	2.60	6.96	3.00	4.00
Crop Sales ($/ac)	**104.00**	**109.20**	**110.24**	**103.50**	**116.00**
Outflow					
Total Variable Expense ($/ac)	90.24	76.43	103.30	73.23	73.57
Total Other Expense ($/ac)	25.10	25.10	24.67	25.10	25.10
Total Expense ($/ac)	**115.34**	**101.53**	**127.97**	**98.33**	**98.67**
Net Cash Flow ($/ac)	**-11.34**	**7.67**	**-17.72**	**5.17**	**17.33**

Note: The data are averages of 2005 and 2006 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2005 and 2006)

Table H.2 Data for the Alberta Brown Soil Zone – Scenario 10 (Continued)

	fallow seeded durum	**tillage fallow**
Inflow		
Yield (bu/ac)	32.50	
Market Price ($/bu)	4.03	
Crop Sales ($/ac)	**130.98**	**0.00**
Outflow		
Total Variable Expense ($/ac)	76.15	16.25
Total Other Expense ($/ac)	25.10	11.57
Total Expense ($/ac)	**101.25**	**27.82**
Net Cash Flow ($/ac)	**29.73**	**-27.82**

Note: The data are averages of 2005 and 2006 data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2005 and 2006)

Table H.3 Data for the Alberta Dark Brown Soil Zone – Scenario 10

	spring wheat	**feed barley**	**HT canola**	**winter wheat**	**fallow seeded spring wheat**	**tillage fallow**
Inflow						
Yield (bu/ac)	32.50	48.00	27.50	37.00	36.00	
Market Price ($/bu)	4.00	2.55	5.75	3.00	4	
Crop Sales ($/ac)	**130.00**	**122.40**	**158.13**	**111.00**	**144.00**	**0.00**
Outflow						
Total Variable Expense ($/ac)	101.46	95.95	125.69	85.83	84.18	18.41
Total Other Expense ($/ac)	33.10	33.10	33.10	33.10	33.10	14.87
Total Expense ($/ac)	**134.56**	**129.05**	**158.79**	**118.93**	**117.28**	**33.28**
Net Cash Flow ($/ac)	**-4.56**	**-6.65**	**-0.66**	**-7.93**	**26.72**	**-33.28**

Note: The data are averages of 2005 and 2006 data. HT canola is incorporated into the crop rotation instead of Argentine canola because data on Argentine canola are not available in 2005 and 2006.
Source: AgriProfit$ Cropping Alternatives (AARD, 2005 and 2006)

Table H.4 Data for the Alberta Grey Soil Zone – Scenario 10

	spring wheat	feed barley	HT canola	winter wheat	milling oats
Inflow					
Yield (bu/ac)	45.00	65.00	37.50	51.23	77.50
Market Price ($/bu)	3.44	2.35	5.75	2.58	1.95
Crop Sales ($/ac)	**154.80**	**152.75**	**215.63**	**132.17**	**151.13**
Outflow					
Total Variable Expense ($/ac)	114.48	112.16	147.84	100.39	99.76
Total Other Expense ($/ac)	38.60	38.60	38.60	38.60	38.60
Total Expense ($/ac)	**153.08**	**150.76**	**186.44**	**138.99**	**138.36**
Net Cash Flow ($/ac)	**1.72**	**2.00**	**29.19**	**-6.81**	**12.77**

Note: The data are averages of 2005 and 2006 data. HT canola is incorporated into the crop rotation instead of Argentine canola because data on Argentine canola are not available in 2005 and 2006.
Source: AgriProfit$ Cropping Alternatives (AARD, 2005 and 2006)

Table H.5 Data for the Alberta Peace Region – Scenario 10

	spring wheat	feed barley	HT canola	winter wheat	milling oats
Inflow					
Yield (bu/ac)	40.50	59.50	32.50	46.11	72.50
Market Price ($/bu)	3.40	2.30	5.75	2.55	1.85
Crop Sales ($/ac)	**137.70**	**136.85**	**186.88**	**117.58**	**134.13**
Outflow					
Total Variable Expense ($/ac)	112.23	109.91	144.09	98.12	86.88
Total Other Expense ($/ac)	35.60	35.60	35.60	35.60	35.60
Total Expense ($/ac)	**147.83**	**145.51**	**179.69**	**133.72**	**122.48**
Net Cash Flow ($/ac)	**-10.13**	**-8.66**	**7.19**	**-16.14**	**11.65**

Note: The data are averages of 2005 and 2006 data. HT canola is incorporated into the crop rotation instead of Argentine canola because data on Argentine canola are not available in 2005 and 2006. Oats data are averages of 2005 milling oats data and 2006 feed oats data.
Source: AgriProfit$ Cropping Alternatives (AARD, 2005 and 2006)

Table H.6 Data for the Saskatchewan Black Soil Zone – Scenario 10

	spring wheat	**feed barley**	**canola**	**winter wheat**	**oats**
Inflow					
Yield (bu/ac)	35.90	57.50	25.40	45.45	67.90
Market Price ($/bu)	3.62	1.91	5.88	2.95	1.76
Estimated Gross Revenue ($/ac)	**129.96**	**109.83**	**149.23**	**133.85**	**119.16**
Outflow					
Total Variable Expenses ($/ac)	97.13	91.11	119.82	86.67	86.02
Total Other Expenses ($/ac)	28.60	28.60	28.60	28.60	28.60
Total Expenses ($/ac)	**125.72**	**119.71**	**148.41**	**115.27**	**114.61**
Net Cash Flow ($/ac)	**4.24**	**-9.88**	**0.81**	**18.59**	**4.55**

Note: The data are averages of 2005 and 2006 data.
Source: Crop Planning Guides (SAF, 2005 and 2006)

Table H.7 Data for the Saskatchewan Brown Soil Zone – Scenario 10

	spring wheat	**feed barley**	**winter wheat**	**oats**	**fallow seeded durum wheat**	**tillage fallow**
Inflow						
Yield (bu/ac)	24.75	37.35	31.33	43.15	35.30	
Market Price ($/bu)	3.62	1.91	2.95	1.76	3.80	
Estimated Gross Revenue ($/ac)	**89.60**	**71.34**	**92.42**	**75.94**	**134.14**	**0.00**
Outflow						
Total Variable Expenses ($/ac)	79.53	75.33	71.27	73.31	68.61	16.25
Total Other Expenses ($/ac)	21.07	21.07	21.07	21.07	21.07	11.57
Total Expenses ($/ac)	**100.60**	**96.40**	**92.34**	**94.38**	**89.68**	**27.82**
Net Cash Flow ($/ac)	**-11.00**	**-25.06**	**0.09**	**-18.44**	**44.46**	**-27.82**

Note: The data are averages of 2005 and 2006 data.
Source: Crop Planning Guides (SAF, 2005 and 2006)

Table H.8 Data for the Saskatchewan Dark Brown Soil Zone – Scenario 10

	spring wheat	feed barley	canola	winter wheat	tillage fallow	fallow seeded spring wheat
Inflow						
Yield (bu/ac)	30.10	46.75	22.15	38.11		33.10
Market Price ($/bu)	3.62	1.91	5.88	2.95		3.62
Estimated Gross Revenue ($/ac)	108.96	89.29	130.24	112.42	0.00	119.82
Outflow						
Total Variable Expenses ($/ac)	89.25	85.34	112.85	79.34	19.01	77.30
Total Other Expenses ($/ac)	24.85	24.85	24.85	24.85	15.05	24.85
Total Expenses ($/ac)	114.10	110.19	137.70	104.19	34.06	102.15
Net Cash Flow ($/ac)	-5.14	-20.90	-7.46	8.23	-34.06	17.67

Note: The data are averages of 2005 and 2006 data.
Source: Crop Planning Guides (SAF, 2005 and 2006)

Table H.9 Data for Manitoba – Scenario 10

	spring wheat	winter wheat	feed barley	canola	oats
Inflow					
Yield (bu/ac)	38.75	49.85	53.65	30.95	63.9
Market Price ($/bu)	4.38	3.05	2.08	6.28	1.95
Estimated gross revenue ($/ac)	169.73	152.04	111.59	194.37	124.61
Outflow					
Total Operating ($/ac)	116.34	124.28	108.84	151.07	91.78
Total Other Expense ($/ac)	29.35	29.35	29.35	29.35	29.35
Total Expense ($/ac)	145.69	153.63	138.19	180.42	121.13
Net Cash Flow ($/ac)	24.04	-1.59	-26.59	13.95	3.48

Note: The data are averages of 2005 and 2006 data.
Source: Guidelines for Estimating Crop Production Costs (MAFRI, 2005 and 2006); Yield Manitoba (MASC, 2006, 2007, and 2008)