Optimal Machinery Use Intensity for a Large Farm in West Central Manitoba

By

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Abstract

Farmers in Western Canada are continually assessing where to invest their next dollar. In considering a farm expansion and the machinery assets they need to match their current farm size or a possible expansion. What is the most efficient and therefore profitable farm land base in West Central Manitoba, specifically Crop Insurance Risk Area 6?

This study attempts to find the optimal farm size by creating a farm budget model that maximizes profit over a range of different farm sizes. The model focused on the seeding and harvest components of grain farming and an efficient machinery choice. The factors that affected maximum profit in the model were costs, commodity price, weather and timeliness of operations. Within the profit function price was varied according to historical price variation over the last 10 years. The model used historical weather patterns to determine the potential effects on seeding start date, length of time seeding, growing season, harvest start date and length of time harvesting. In this region of Manitoba the frost free growing period is only 95 – 105 days. Timeliness is affected by weather and farm size. As farm size increases there is more risk that inclement weather will lengthen the time needed for crop operations. Previous studies have shown that both seeding and harvest operations have optimum time windows in which they should occur for best yield results.

The results of this research showed that net mean profit was maximized around a 9,000 acre grain farm. For farm sizes above 9,000 acres losses associated with lack of field operation time could not be compensated by cropping additional acres. Although mean profit was maximized on the 9,000 acre farm, the risk associated with making additional profit was always increasing. The study results indicated that optimal farm size will be different for different individuals depending on their risk tolerance.

Acknowledgments

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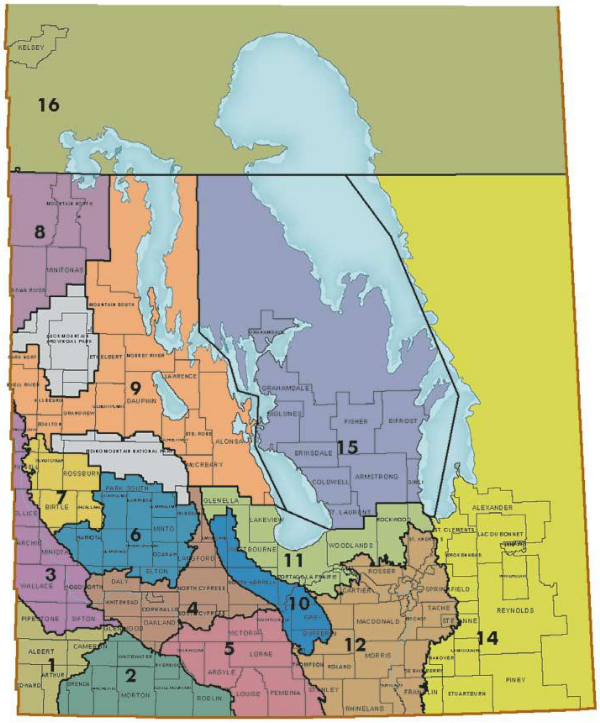
Chapter 1 – Introduction

All farms in Western Canada face choices about how much capital to invest in their equipment. The size of machinery has increased in recent years and so has the gap between different sizes of machinery. There are previous studies on how to minimise machinery costs for a certain size of farm, however, machinery sizes are fixed by manufacturers. None of these studies considered the unique choices facing a farmer in west central Manitoba. Farmers can only buy certain sizes of machinery and it would be useful to know what size of farm is most appropriate given pre-determined machinery and environmental choices.

When deciding to purchase or rent additional acres farmers must decide whether they can efficiently farm more acres with their current equipment or if they must make new machinery investments. The additional profit potential and/or cost savings of these decisions must be weighed against the risk that they may not be able complete field operations within acceptable time limits. One significant problem is that acceptable time limits can vary greatly from year to year. For example, one year a farmer may be able to harvest crops into November and the next year that window may close much earlier.

In order to compare the risk and rewards associated with machinery and farm size choices it would be useful to have a method to quantify environmental factors that affect machinery utilization. This has applications when comparing the competitive advantage of different areas in producing a particular crop. Different climatic areas have varying weather constraints and optimal seeding and harvest windows. Areas with longer growing seasons or drier climates will likely be able to farm more acres with the same equipment.

Farms are getting larger due to economies of scale; however, growing farms eventually experience diminishing returns to scale and this is a factor in determining the optimal farm size. The optimal farm will normally utilize the largest most efficient machinery and how many acres can be ideally farmed with this machinery is determined by local weather and climate conditions. Diminishing returns occur as a farm becomes very large because days available for farmers to complete major field operations are a limited resource.



Source: Manitoba Agricultural Services Corporation Insurance, 2011

Figure 1.1 Crop Insurance Risk Areas of Manitoba

1.1 Objective

The objective of this study is to determine the optimal grain farm size that maximizes expected profit for an area of west central Manitoba commonly referred to as the Parkland Region. More specifically I will look at Crop Insurance Risk area 6 which straddles the most western portion of Highway 16 (see 6 in Figure 1) south of Riding Mountain National Park (Manitoba Agricultural Services Corporation, 2011).

1.2 Relevance

Over the last number of years the farms in West Central Manitoba have been growing in acreage and revenue (see Table 1.1 below). This trend has social and economic ramifications for rural communities. As farms get larger there are fewer farmers and therefore fewer residents in rural areas. The issue of population decline occurring in many rural communities and how to address it is of great importance to these communities.

Table 1.1 Farms Grouped by Size in West Central Manitoba (Division No. 15)

Farms Grouped By Size In West Central Manitoba (Division No. 15)			
Size ($)	Number of Farms		Percent change
	2006	2001	
Under 10,000	244	260	-6%
10,000-24,999	289	270	7%
25,000-49,999	215	287	-25%
50,000-99,999	286	380	-25%
100,000-249,999	431	477	-10%
250,000-499,999	203	167	22%
500,000-999,999	59	49	20%
1,000,000-1,999,999	21	8	163%
2,000,000 and over	16	9	78%

Source: Statistics Canada, 2006 Census of Agriculture, Farm Data and Farm Operator, 2006

This study is also relevant to policy makers as they attempt to create programs in the face of a changing industry landscape. It is important for these individuals to understand the factors affecting grain farm size choice and the magnitude of government programs these farms may need to manage risk.

Chapter 2 - Previous research

The goal of this research is to assess the size of farm needed to maximize profits in the long run, given particular weather conditions and a fixed machinery base. Various aspects of this problem have been studied in some detail by previous researchers.

2.1 Size Effects and Economies of Scale

Kumbhakar (1993) studied dairy farms in Utah and concluded that large farms are more efficient with lower costs when compared to small farms. Larger farms were able to remain profitable at lower milk prices when compared to smaller farms and Kumbhakar deduced that this explained the trend towards larger farms. Dashnyam (2007) concluded that in both western and eastern Saskatchewan increasing farm size had a decreasing effect on expense per acre. This study used farm financial data from farms in western and eastern Saskatchewan sorted by size to compare individual expenses on a per acre basis and found that almost all costs decreased per acre as farm size increased.

Brown and Schoney (1985) created a spreadsheet model to determine the least cost size of farm machinery for various sizes of farms in Saskatchewan. They took into account not only the fixed and variable costs of operating the machinery but also cost associated with lack of timeliness of field operations. This study found that properly sized machinery can save farmers money and that there is a trade off between the cost savings of operating smaller machinery and the loss in timeliness by not completing tasks as quickly with the smaller machines.

Franks (2009) studied farm revenue, cost and income data from British farms in less productive areas and found that larger farms tend to be more profitable due to lower fixed costs. However, some small farms in the city were as profitable as large ones and there were also large farms that were unprofitable therefore he concluded size alone is not a guarantee of profitability. Diversification was thought to be a factor in the higher profitability of some smaller farms.

Watkins (2011) created a mixed integer programming model to compare three different sizes (1200, 2400 and 3600ac) of conventional till and no till rice farms in Arkansas. He found that both farm types benefited from a size increase due to greater economies of scale and ultimately higher profitability with lower variability of returns.

Langemeier (2009) studied the relative efficiencies of wheat farms in Kansas. He sorted actual farm data into top third and bottom third by profitability and found that size was a significant factor in determining profitability. The farms included in the top third by profitability group also had higher efficiency and asset turnover ratios.

2.2 Field Workdays Calculation

There have been numerous studies attempting to model field workdays available taking into account moisture and soil type. Rounsevell and Jones (1993) built on the previous work of Smith (1977) to create a model to estimate the number of days that the soil is suitable for tillage in the spring and fall periods. The study had two field criteria; one was the soil's ability to support equipment and the other was having the soil in a state where the tillage operation would not compromise the soil structure and thus limit crop yields due to compaction or smearing of the soil.

2.3 Net Present Value

Net present value (NPV) is the sum of discounted future revenues less current and discounted future costs. It is one of the standards by which businesses assess the current value of an investment that will be used over a particular time horizon. Machinery acquisitions and machinery investments usually involve significant dollar values and NPV is often used as a criterion for assessing these decisions. Reid and Bradford (1987) used the NPV approach to model the costs of differing farm machinery and assess purchase and replacement decisions. They conclude that it is important to take a whole farm approach when assessing investments because of the disjointed nature of machinery sizes. They also conclude that a particular size farm may not be able to attain the highest NPV due to the lumpiness and various sizes of machinery involved.

Net present value is used to make investment decision based on future income flows. In farming however, future income flows are extremely variable and unknown due to the unpredictable effects of weather and market price.

2.4 Monte Carlo Simulations

NPV and other methods become a difficult method to determine the optimal farm size under specific machinery choices and weather conditions. In farming, year to year costs are fairly predictable and do not change significantly once the crop year has begun. A more tractable method to determine investment decisions is to estimate fixed yearly costs and compare costs to a range of possible income. Previous researchers have focused on the stochastic nature of weather in farm size but none have focused on the specific distributions to be discussed in this paper.

Just and Zilberman (1983) and others (Carter, (1984) and Srinivasan (1972)) developed detailed models of weather in farm size choices for developing and subsistence farmers which may face inverse relationships to size and productivity.

Luo et al (2005) did use a “Monte Carlo” random sampling technique to develop distributions to be used in a climate change model that would eventually affect wheat yields. This technique takes random draws from defined distributions many times and uses these numerous draws to simulate the range of outcomes facing producers.

The current paper also faces offsets between productivity and size. It will address the costs of farm size in terms of timely harvests against the gains from machinery use intensity. To address the stochastic nature of weather and prices it will adopt a Monte Carlo style random sampling drawing numerous times from the relevant distributions for seeding dates, harvest dates, maturity and commodity prices. In essence it combines the investment choices of Dashnyam and Brown and Schoney with the optimal farm size under weather model in Just and Zilberman using a Monte Carlo sampling technique.

Chapter 3 - Model

Economies of scale exist in primary agriculture because as farms get larger, they are able to spread their fixed costs over more productive acres. In Langemeier's study of wheat farms he found that the best efficiency and occurred on the larger farms. A significant factor driving these results is efficient use of machinery assets. The most efficient machinery assets are often the largest available because they can cover the most acres in the limited seeding and harvest window at a lower cost per acre if acreage is high.

All equipment, no matter the size, has limited time in the field due to weather restrictions on field workdays. Amount and frequency of precipitation has varying effect on field conditions. Each year brings different weather patterns and a different number of field workdays. Every geographic area where crops are grown has a specific time window where field operations are timed to manage yields to maximize expected profits. A farmer must size his/her farm to complete field operations during the most optimal time that maximizes potential yield.

As mentioned in the previous section, an annual farm budget based on fixed yearly costs compared to a range of possible incomes can be used to determine optimal farm size. Variability in possible income occurs due to varying weather patterns and price fluctuations. This paper will use the farm budget model and focus on the operations of seeding and harvest. It will also assume that the farm uses the largest equipment because it is the most efficient. It will also assume that the farm operator is risk neutral or indifferent to changes in the amount of risk associated with increasing his/her farm acreage. Acres farmed will be subject to seeding start date, days available to seed, optimal seeding date for wheat and canola, days to crop maturity, harvest start date and days available to harvest. Harvest will be linked to seeding date creating a situation where late seeding increases the chance of late harvest much like a real world farmer faces. The main focus of the model was to maximize expected profit by varying acres subject to probability distributions for the above variables assuming a fixed equipment line.

3.1 Objective Function

$$\pi = \{Y(\alpha) * P(\beta)\}x - Vx - F \qquad (1)$$

Where:

$$\pi = Profit\ (\$)$$

$$Y = Yield\ (bushels/acre)$$

$$\alpha = Yield\ coefficent$$

$$P = Price\ (\$/bushel)$$

$$\beta = Quality\ coefficent$$

$$x = acres\ farmed$$

$$V = Variable\ Costs\ (\$/acre)$$

$$F = Fixed\ Costs\ (\$)$$

3.2 Design and Assumptions

Economic theory states that a firm's main objective is to maximize expected profit. The objective function calculates net profit by subtracting fixed and variable costs from gross revenue.

3.2.1 Profit Calculation

Gross revenue is calculated by yield per acre multiplied by price multiplied by total acres as determined by model calculations. The model assumed all costs except machinery costs were variable. Direct crop production costs such as seed, chemical, fertilizer, fuel and land rent are expressed on a per acre basis and assumed to have a direct linear relationship with acres (*x*).

The only fixed costs in the model are those associated with machinery ownership. Overall machinery investment and costs are fixed in the model therefore as acres (x) increases machinery cost on a per acre basis decreases.

The model will be based on a 50/ 50 canola/wheat rotation meaning that half of the available acres seeded to wheat and half to canola as is common in Risk Area 6. Yields and costs will be separated for wheat and canola

3.2.2 Alpha Calculation

Alpha is a number expressed as a percentage that represents yield potential for an iteration of the model. Alpha is a function of seeding start date, weather during seeding and acres to be seeded. The faster seeding is completed the more favourable yield potential will be. If seeding start date is late and/or weather during seeding (SW) unfavourable yield potential is decreased represented by a low Alpha value. As acres increase there is a greater chance of late seeding completion because of the increased time required to seed. In a general form Alpha is:

$$\alpha = f(S, X, SW)\ (2)$$

Where;

$$S = seeding\ start\ date$$

$$X = acres\ farmed$$

$$SW = weather\ during\ seeding\ (\%\ of\ days\ suitable\ for\ seeding)$$

Section 4.5 will present justification for Alpha range function of:

$$\alpha = .45 < a < 1.15.$$

3.2.3 Beta Calculation

Beta is a number expressed as a percentage that represents grain quality potential and losses due to quality decreases. Beta is a function of harvest start date, weather during harvest and acres to be harvested. An earlier average harvest date will result in higher grain quality and lower harvest losses. As days to complete harvest increases quality potential decreases represented by a low beta value. As acres increase there will be a higher chance of beta being lower due to the increased requirement for harvest hours pushing the harvest later. Harvest start date is determined by seeding start date plus maturity which both vary from year to year. In a general form Beta is:

$$\beta = f(S, X, MC, HW) \quad (3)$$

Where;

$$S = seeding\ start\ date$$

$$X = acres\ farmed$$

$$MC = maturity\ time\ of\ the\ crop$$

$$HW = weather\ during\ harvest\ (\%\ of\ days\ suitable\ for\ harvest)$$

Section 4.8 will present justification for a Beta range of:

$$\beta = .45 < \beta < 1$$

3.2.4 Machinery Assets

The complete list of fixed machinery assets assumed for the model is available in section 4.9 and total machinery cost is included in fixed costs. Seeding and harvest equipment was specifically used in variable calculations because the timeliness of these operations is critical to yield potential.

3.2.4.1 Seeding

Fixed seeding machinery assets in the model are a 74ft wide air drill with a 700 bushel seed and fertilizer tank. This machinery is capable of seeding 120 acres per fill of seed and fertilizer and seeds and fertilizes in one pass. The machinery's cost and productivity data are based on a 5810AHD Bourgault air drill and a Bourgault 6700ST seed and fertilizer tank. These items are the largest currently available from Bourgault

(Bourgault, 2011) and the design is proven and widely accepted. Specifications, costs and productivity numbers of the above equipment is summarised in Table 3.1 below.

Table 3.1 Air Drill Productivity Statistics

Air Drill Productivity Summary				
Width (ft)	**Travel Speed (mph)**	**Field Efficiency**	**Net productivity (ac/hour)**	**Ac/day**
74	5.5	64%	31.62	442.64

The width of a 5810AHD Bourgault air drill is 74ft. Travel speed is the speed at which the air drill travels in the field. Field efficiency of 64% (Bourgault, 2011) means the air drill is seeding 64% of the time it is in the field. An air drill is not actually seeding 100% of the time it is in the field due to a number of factors:

- Turning at the end of the field,
- Stoppage to fill seed and fertilizer,
- Moving between fields,
- Maintenance or adjustment,
- Overlap,
- Operator personal time

Net productivity was calculated by multiplying gross productivity with field efficiency. Gross productivity was calculated as follows:

$$P = \frac{(W * S * 5280)}{43650}$$

Where;

$$P = Productivity\ in\ \frac{acres}{hour}$$

$$W = Width\ of\ implement\ (ft)$$

$$S = Travel\ speed\ of\ implement\ (mph)$$

$$5280 = Feet\ per\ mile$$

$$43560 = Square\ feet\ in\ an\ acre$$

I assumed one operator could seed 14 hours per working day as is common in Risk Area 6 and acres per day was calculated by multiplying net productivity per hour by 14.

Table 3.1 above illustrates that with perfect weather seeding could be advanced at a rate of 442.64 acres per day every working day.

$$Seeding\ Days_i = \frac{Acres}{Acres/Day(SWi)}$$

Seeding days above is the total number of days needed to complete seeding in a given iteration of the model. Seeding days are calculated by reducing the maximum seeding rate in Table 3.1 by the spring weather coefficient explained in Section 3.2.2. above.

3.2.4.2 Harvest

Fixed harvest machinery assets in the model are two Class 8 combines. This class is the largest size widely available in North America and both a Case International 8120 and a John Deere 9870 would fall into the class 8 Category. The model assumed the productivity of the machines to be similar and this productivity is summarised in Table 3.2 below.

Table 3.2 Combine productivity statistics

Combine Productivity Summary				
Width (ft)	**Travel Speed (mph)**	**Field Efficiency**	**Net productivity (ac/hour)**	**Ac/day**
70	4	80%	27.19	271.89

Combine width is the sum width of the two combines assuming either two 35ft straight cut headers or two pickup headers picking up 35ft swaths. This is the widest header commonly available among both Case and John Deere. (Case, 2011; John Deere, 2011) Travel speed is the speed at which each of the combines travels while harvesting. Field efficiency is the percent of time the combine is actually harvesting. A combine cannot be harvesting grain 100% of the time it is in the field. Non productive time is caused by many of the same items listed for the air drill in section 3.2.1.1. A combine, however, does not have stoppage due to filling like an air drill and therefore its field efficiency is much higher. Because a combine is self propelled and used for only one operation on a farm (versus the tractor pulling the air drill) each combine has an hour meter built in to measure the historical field efficiency of the machine. The meter measures the number of engine hours that the machine is running and the number of hours the separator (harvesting component) is turned on while the machine is running. There is incentive for a producer to keep separator hours to a minimum as resale of the machine is largely based on this measurement. (John Deere, 2011) Field efficiency of 80% was attained from an average of engine vs. separator hours on 20 different John Deere combines at S. H. Dayton Ltd. Net productivity was calculated in the same manner as seeding net productivity in section 3.2.1.1. Acres/day assumes an average of 10 hours per working day are suitable for harvest.

Table 3.2 illustrates that with perfect weather harvest could be advanced at a rate of 271.89 acres per day every working day.

$$Harvest\ Days_i = \frac{Acres}{Acres/\ Day(HWi)}$$

Harvest days above is the total number of days needed to complete harvest in a given iteration of the model. Harvest days are calculated by reducing the maximum harvest rate in Table 3.2 by the harvest weather coefficient explained in Section 3.2.3 above.

3.2.5 Seeding Start Date (S)

Seeding start date is based on a triangle distribution of historical seeding start dates in the region. This distribution is most appropriate because a triangle distribution chooses the average seeding date or distribution point value most often and values towards either end point are chosen least often. This accurately simulates a yearly seeding start date which is chosen stochastically from a distribution of possible start days between 1 and 20 that correspond to the dates April 21st through May 10th.

$$1 \leq S_i \leq 20$$

3.2.6 Field Workday Calculation (SW & HW)

Weather is not suitable for field operations 100% of the time and it is necessary to decrease the acres per day calculation above for seeding and harvest to allow for weather delays. Both seeding and harvest acres/day are multiplied by a respective spring and fall weather coefficient to account for delays due to rain during seeding and harvest operations. The spring and fall weather coefficients are independent of each other and are stochastic values between 0 and 1.

$$0 \leq SW \leq 1$$

$$0 \leq HW \leq 1$$

3.2.7 Maturity Distribution (MC)

The maturity distribution occurs between 90 and 130 and represents the amount of time in days needed to mature the seeded crop. This number is meant to reflect the variability in the amount of heat and moisture available to the crop which influences maturity. Seeding start date plus maturity time determined harvest start date in the model. The following range will be justified in Section 4.7.

$$90 \leq MC_i \leq 130$$

3.2.8 Risk

The objective function is written to maximize whole farm expected profit, with some uncertain variables, where the farm operator is risk neutral. This is an important assumption to note due to diminishing returns to scale and individual risk tolerances. In the model results, diminishing returns to scale will occur when adding one acre to a farm's size yields less mean profit than adding the acre before. Each additional acre may increase mean profit but it also increases the risk of negative profit. Diminishing returns is reached when expected mean profit increases with each additional acre at a slower rate than the risk of negative returns. Once this point is reached, individual risk preferences will dictate individual optimal farm size. A risk seeking producer is willing to take the risk associated with each additional acre in order to gain mean profit. A risk averse producer may not be willing to take this risk and therefore his/her individual optimal farm size will be smaller than the risk seeking producer. A risk neutral individual is indifferent to the amount of risk associated with increasing or decreasing farm size.

Chapter 4 – Data

4.1 Area Background

4.1.1 Geography

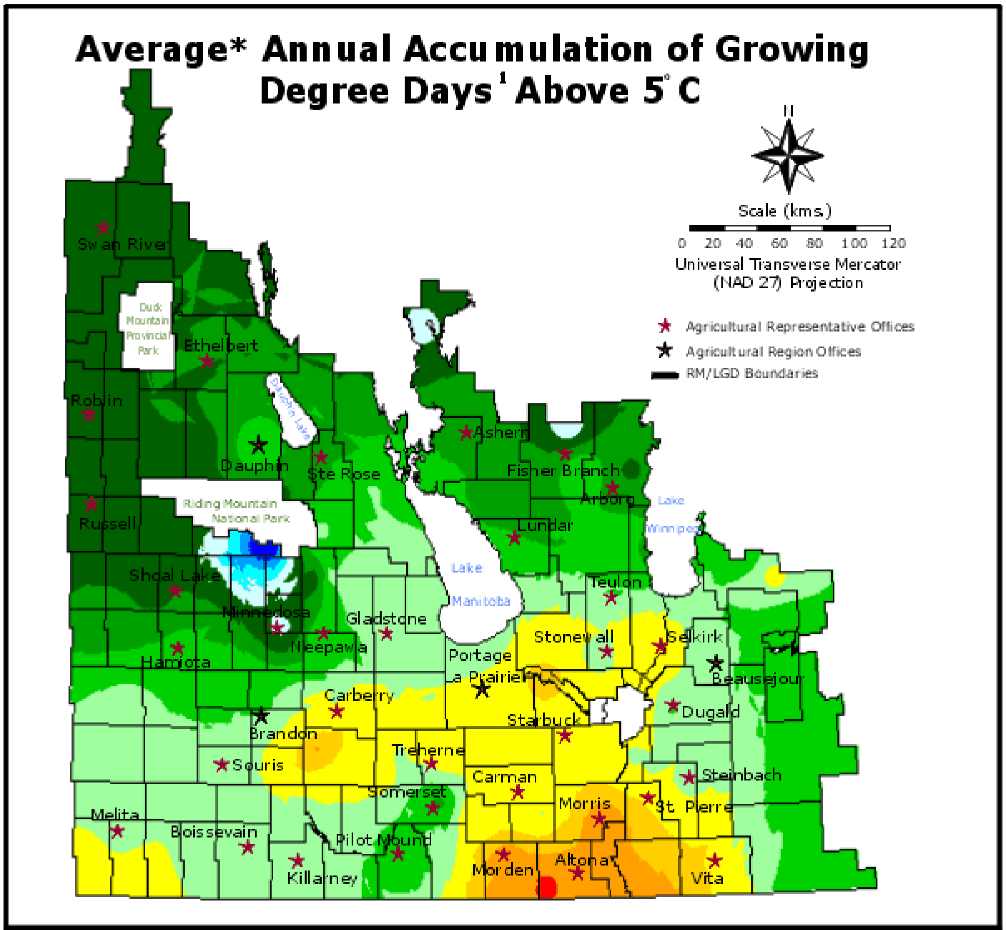
The parkland region of Manitoba is geographically diverse. Relief or slope is generally 2%-5% and the landscape is rolling with depressions and potholes that in some seasons hold water for part or all of the growing season. Permanent sloughs and lakes also dot much of the landscape making for irregular field shapes and sizes (Canada-Manitoba Soil Survey, Soils of the South Riding Mountain Planning District, 1990).

4.1.2 Soils

Soils are predominately clay loam rolling and smooth phase although sandy and peaty soils are present in some areas. Clay loam is a medium textured soil known for its ability to produce a crop under a variety of conditions form dry to wet (Canada-Manitoba Soil Survey, Soils of the South Riding Mountain Planning District, 1990).

4.1.3 Climate

The climate in risk area 6 is generally favourable to production of cool season crops with wheat, canola, barley, oats and flax accounting for the vast majority of acres in the area. Crops such as sunflowers, corn, edible beans and soy beans are not generally grown due to lack of heat (Figure 4.1) and length of growing season (Figure 4.2). The short growing season is of greater concern in northern areas of the risk area where average frost free days are below 90. This time frame is shorter than the time it takes to grow a canola or wheat crop (Manitoba Agriculture, Weather and Climate, 2010).



Legend and Interpretation

Growing Degree Days > 5°C		Hectares
🟦	1250 to 1300	(13,074)
🟦	1300 to 1350	(24,156)
🟦	1350 to 1400	(34,345)
⬜	1400 to 1450	(103,699)
🟩	1450 to 1500	(1,846,373)
🟩	1500 to 1550	(1,428,392)
🟩	1550 to 1600	(1,956,163)
🟩	1600 to 1650	(2,759,130)
🟨	1650 to 1700	(1,782,628)
🟨	1700 to 1750	(303,428)
🟧	1750 to 1800	(278,677)
🟥	1800 to 1850	(11,838)

[1] Growing degree days (GDD) are a measure of useful heat for the growth and development of plants and insects. GDD is calculated by subtracting the base temperature (the minimum developmental temperature for a specific crop or insect) from the daily mean temperature.

* An average map represents a **50%** risk. In other words, **1 out of 2 years** the number of growing degree days accumulated would be expected to be **lower** than the values given on this map.

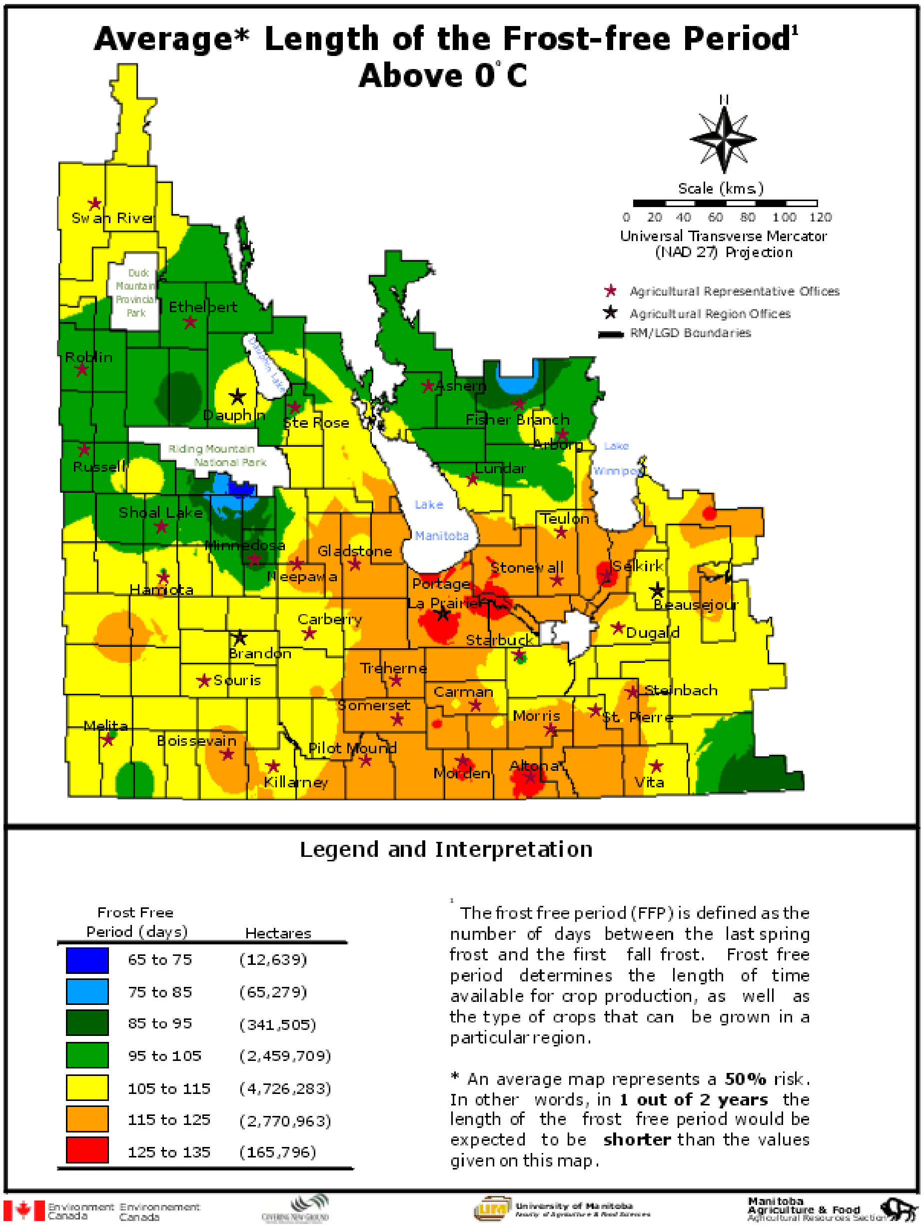
Environment Canada Environnement Canada

University of Manitoba Faculty of Agriculture & Food Sciences

Manitoba Agriculture & Food Agricultural Resources Section

Source: Manitoba Agriculture, Weather and Climate, 2010

Figure 4.1 Growing Degree Day Accumulation (Measurement of Heat) In the Crop Growing Areas of Manitoba



Legend and Interpretation

	Frost Free Period (days)	Hectares
🟦	65 to 75	(12,639)
🟦	75 to 85	(65,279)
🟩	85 to 95	(341,505)
🟩	95 to 105	(2,459,709)
🟨	105 to 115	(4,726,283)
🟧	115 to 125	(2,770,963)
🟥	125 to 135	(165,796)

[1] The frost free period (FFP) is defined as the number of days between the last spring frost and the first fall frost. Frost free period determines the length of time available for crop production, as well as the type of crops that can be grown in a particular region.

* An average map represents a **50%** risk. In other words, in **1 out of 2 years** the length of the frost free period would be expected to be **shorter** than the values given on this map.

Source: Manitoba Agriculture, Weather and Climate, 2010

Figure 4.2 Frost Free Days in the Crop Growing Areas of Manitoba

On average, wheat and canola take 90-100 days to mature however under cool conditions time from planting to harvest can be as long as 130-140 days especially if harvest conditions are unfavourable (Manitoba Agriculture, Crops, 2010). Risk Area 6 has an average frost free period of 95 days with June 1st being the average date of the last spring frost and September 3rd the average date of the first fall frost (Figure 4.2).

4.2 Yield

The yield distribution for wheat and canola was based on the minimum, maximum and average yield for wheat and canola of 10 producers over the last five years in Risk Area 6 (MASC Management Plus Website). For wheat the model used a triangle distribution with 48 bushels/acre as the middle point and 35 and 61 bushels/acre as the minimum and maximum respectively. For canola the model used a triangle distribution with 38 bushels/acre as the middle point and 25 and 50 bushels/acre as the minimum and maximum respectively. Historical yields were available from Manitoba Crop Insurance, however, this data averages all producers in the area including hobby farmers. The model assumes a budget based on a modern commercial farm that employs the latest technologies to attain maximum yield. Variety and yield technology has improved significantly in the last 5 years (Manitoba Seed Guide, 2011) and MASC's aggregate data would include yield data from farmers who do not adopt these latest technologies. Also, this data is only available by area average, not by individual farmer. This averaging technique reduces the variability of the data set and does not accurately represent the true yield variability a producer faces.

Yields were assumed to be on a 50/50 split of the available acreage to reflect the rotation of wheat and canola.

4.3 Price

The price distribution for wheat was based on Canadian Wheat Board final pool return price from 2001 to 2010 for number one 13.5 Hard Red Spring Wheat. Based on this data the the triangle distribution median price was $5.46 per bushel with $3.81 and $8.58 per bushel as the minimum and maximum price respectively. Price input into the model is the selected CWB pool price net of current deductions for grain hauled to country elevators in Risk Area 6.

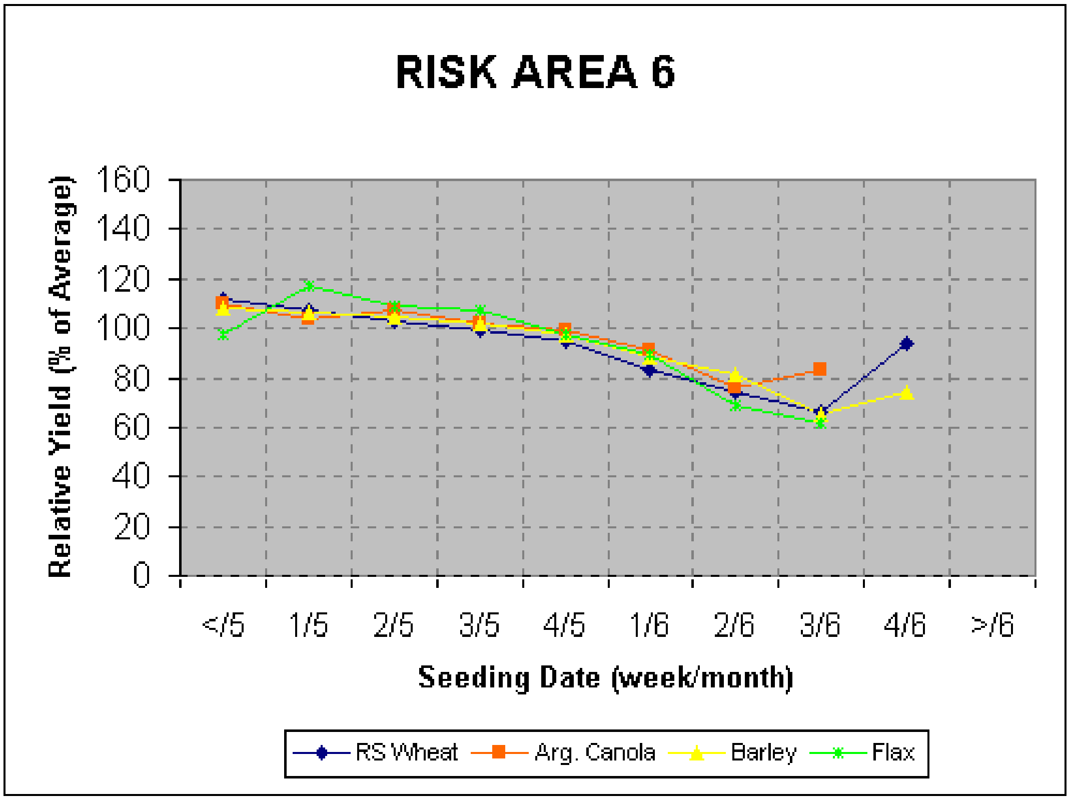
The price distribution for canola was based on crop year average canola price in store Vancouver from 2001 to 2010. (Canola Council, 2011) Based on this data the triangle distribution median price was $5.40 per bushel with $8.10 and $11.70 per bushel as the minimum and maximum price respectively. Price input into the model is the selected Canola Council price net of current deductions for grain hauled to country elevators in Risk Area 6.

4.4 Seeding Start Date

Seeding start date was based on my own farm data and interviews with five other farmers in Risk Area 6. Published data from Manitoba Crop Insurance was over ten years old and therefore irrelevant for use in this study. Based on the interview data a reasonable seeding start date ranged from April 21st to May 10th with a most likely start date of May 1st. I used a triangular distribution to fit this range with May 1st as the mean point of the distribution, April 21st as the earliest seeding start and May 10th the latest start date. Seeding start dates are based on the assumption that wheat will be sown first and seeding of wheat completed before canola is started.

4.5 Yield Potential Loss Associated with Seeding Date

MASC data shows the relationship between grain yield and seeding date for the main crops grown in risk area 6. This information is very accurate as it is based on field level data reported by producers and is calculated for the years 1996 to 2001 (MASC Managment plus website). The chart (Figure 4.3 below) shows that yield decreases as the crop is seeded later in the spring. This was used to justify the range used in the Alpha function above. The canola yield was 1.15 times average when average seeding is May 1 and then faces a declining trend to June 3. I used personal experience to continue that trend to .45 if seeding happened after June 15. I used MASC's data to determine the yield potential loss as the seeding start date is pushed later into the growing season. Relative yield refers to yield as a percent of the area average for each year. This was an important part of the model because there will be a direct trade off between acres farmed and yield obtained. As acres farmed increases there is a lower probability of completing seeding within the optimal window therefore lowering expected yields. Seeding date is described as the middle or median date during the seeding period.



Source: MASC Insurance management plus database, 2010

Figure 4.3 Observed Relationships between Seeding Date and Grain Yield for Major Crops in Risk Area 6

An early seeding date will have a greater chance of late spring frost and a later seeding date will have a greater chance of early fall frost. The MASC data set took this into account over the 20 year period because the data measured end yield. We assume the data period was long enough to exhibit normal weather patterns in the area and yield would have been negatively affected if there was a frost in any year and factored into the average percentage loss associated with seeding date.

4.6 Field Workdays Calculation

The main weather event to affect field workdays in both spring and fall is precipitation. Average field workdays were based on weather data from Environment Canada. Environment Canada calculated average days of precipitation at certain precipitation intervals (Table 4.1) for each month at each of its weather stations over the 30 year period of 1971 to 2000. For days of precipitation during seeding I used this data from the Shoal Lake weather station for the months of April and May. I assumed that any rainfall event over 2mm would stop seeding operations for one day. For average days of precipitation during harvest I used data from the Shoal Lake weather station for the months of August, September and October again assuming any rainfall event over 2mm would stop harvest for one day.

Table 4.1 Days of Rainfall at Environment Canada's Shoal Lake Weather Station

	Seeding		Harvest		
Amount	April	May	August	September	October
>= 0.2 mm	5.1	8.53	9.9	8	6.1
>= 5 mm	1.6	2.73	3.8	3	1.6
>= 10 mm	0.77	1.2	1.8	1.5	0.8
>= 25 mm	0.17	0.18	0.47	0.3	0.13
Wet days	7.64	12.64	15.97	12.8	8.63
Down days	7.64	12.64	15.97	12.8	8.63
Productive days	22.36	18.36	15.03	17.2	22.37
Down day %	25.47%	40.77%	51.52%	42.67%	27.84%
Productive day %	74.53%	59.23%	48.48%	57.33%	72.16%
Average Productive %	66.88%		59.33%		

Source: Environment Canada, 2011

Table 4.1 above shows that a producer can conduct operations 67% of the time during seeding and 60% of the time during harvest. This method of calculating field workdays is more straight-forward than other methods that take into account soil tractability, varying amount of daily rainfall and temperature. However, for the purposes of this study, days of precipitation were considered an accurate proxy for non-working days in both spring and fall.

4.7 Days to Maturity

Days to maturity was based on hard red spring wheat data from Seed Manitoba 2011. The check variety was AC Barrie with a Manitoba wide average days to maturity of 99. Because Risk Area 6 is cooler than the Manitoba average, I assumed average days to maturity would be 11 more or 110 days. I created a triangular distribution with 110 days as the point and 90 and 130 as the least and most possible days to maturity respectively. These points were chosen using my own farm data and interviews with ten farmers in Risk area 6.

Only wheat maturity was taken into account because this distribution determines harvest start date and it is assumed that once the first field of wheat is ready to be harvested, the rest of the crop will follow.

4.8 Harvest Losses

There was no data available to quantify quality losses due to a late harvest. Using my own farm data and interviews with ten farmers in Risk Area 6 I determined average harvest date would affect crop quality in the following way: Crop quality directly affects the value or price of the crop and buyers offer discounted prices as crop quality is degraded. Starting on September 1st, for each day that average harvest date is delayed, the price of the crop harvested decreases by 1% for wheat. Starting on September 16th, for each day that average harvest date is delayed, the price of the crop harvested decreases by 1% for canola. This pattern continues until average harvest date of December 8th. Harvest date is described as the middle or median date during the harvest period. The model assumes that wheat is harvested completely before harvesting of canola begins.

4.9 Variable Costs

All costs included in the model were assumed variable except for machinery costs. Per acre costs were based on Manitoba Agriculture, Food and Rural Initiatives (MAFRI) "Guidelines for Estimating Crop Production Costs 2011 – Western Manitoba" and either confirmed or adjusted using own farm data.

Table 4.2 Variable Costs per Acre – Wheat

Variable Costs per Acre - Wheat	
Seed & Treatment	$ 22.50
Fertilizer	$ 52.95
Herbicide	$ 25.68
Fungicide	$ 12.00
Fuel	$ 14.32
Crop Insurance	$ 7.00
Other	$ 7.75
Land	$ 35.00
Labour	$ 18.00
Storage	$ 4.80
TOTAL	$ 200.00

Table 4.3 Variable Costs per Acre – Canola

Variable Costs per Acre - Canola	
Seed & Treatment	$ 42.75
Fertilizer	$ 64.30
Herbicide	$ 19.60
Fungicide	$ 15.00
Fuel	$ 13.89
Crop Insurance	$ 9.96
Other	$ 7.70
Land	$ 35.00
Labour	$ 18.00
Storage	$ 3.80
TOTAL	$ 230.00

MAFRI lists land and storage as fixed costs, however, for the purposes of this study these two costs are assumed variable. It is reasonable to assume that at different farm sizes, these costs would truly vary, however, once a producer determines the acres he/she will seed these costs would remain fixed from year to year. Land cost was assumed to be market cash rent of $35/acre which is a historical market rate for risk area 6. There is no published data on market rental rate for various areas of the province. The assumption on $35/acre is largely based on my own farm data and conversations with other producers in the area.

4.10 Fixed Costs

As stated above the only fixed cost in the model are costs associated with machinery. Machinery assets additional to seeding and harvest were assumed to fit the needs of a 5810 air drill, seed tank and two 9870 combines. The fixed ownership costs of the equipment are summarised in Table 4.4 below.

Equipment of this size can be found in pre-owned condition; however, because the large pieces of equipment are assumed to be the most recent models from manufacturers this study assumes that a producer would purchase the machines brand new or slightly used given there are no capital constraints.

Table 4.4 Fixed Equipment Ownership Costs

Fixed Equipment Ownership Costs		
Item		**Value**
74ft Bourgault Air Drill		$ 155,000
6700 Seed Tank		$ 125,000
9870 Combine x 2		$ 800,000
4930 John Deere Sprayer		$ 250,000
535 Cast IH Tractor		$ 250,000
Other tractors		$ 200,000
Grain cart		$ 40,000
Semi		$ 50,000
Super B trailers		$ 50,000
Augers x 2		$ 25,000
Harrows and Tillage		$ 30,000
Miscellaneous		$ 20,000
Total Equipment		$ 1,995,000
Cost	**Rate**	**Total**
Depreciation	7.5%	$ 149,625
Cost of Capital	5%	$ 99,750
Total cost		**$ 249,375**

Source: Chabot Implements, 2011 and S.H. Dayton Ltd., 2011

Depreciation was calculated on a declining balance at 7.5% each year. Normal accrual accounting practices use a declining balance of 10%, however, because the equipment in this study is assumed to be less than one year old, 10% gives an unreasonably high depreciation cost for the first year.

Cost of capital is the opportunity cost of the producer's capital that is invested in machinery. Cost of capital has been calculated at 5% which is a percentage generally accepted by economic and financial theorists for this purpose. Total equipment ownership costs in the first year are $249,375.

Chapter 5 - Results

The theoretical objective function of $\pi = \{Y(\alpha) * P(\beta)\}x - Vx - F$ was populated using the data and distributions as described above. The empirical function is presented below

5.1 Empirical Objective and Alpha/Beta Functions

5.1.1 Objective Function

$$\pi = \{(48^i Yw(\alpha w^i) * 5^i \; Qw(\beta w^i))(.5x) + (38^i Yc(\alpha c^i) * 8.1^i \; Qc(\beta c^i))(.5x)\}$$
$$- (200(.5x) + 230(.5x)) - 249375$$

Where:

- *i* denotes a number that changes with each random draw and x is total acres farmed.
- Yield is a triangular distribution, 48 is the midpoint for wheat and 38 is the midpoint for canola.
- Price is a triangular distribution, \$5 is the midpoint for wheat and \$8.1 is the midpoint for canola.
- Variable costs are \$200 for wheat and \$230 for canola
- Revenues and costs and multiplied by .5x because x represents total acres cultivated and half are seeded to wheat and half to canola.
- Machinery costs are \$249,375
- αw^i and αc^i are the average seeding dates for wheat and canola respectively and βw^i and βc^i are harvest dates.
- *Yw* and *Yc* are the yield apha functions driven by the average seeding dates for wheat and canola respectively and Qw and Qc are the quality beta functions driven by harvest dates.

See Table 5.1 below for all variables and distributions.

Table 5.1 Factors in the Empirical Objective Function Used in Simulations

Median value or symbol	**Description**	**Static?**	**Distribution Description**	**Limits**
X	Acres farmed	No	Changes with?	3,000 – 12,500
Y	Crop yield	No	Triangle	Wheat: 35,48,61 Canola: 25,38,50
P	Price	No	Triangle	Wheat: \$3.81, \$5.46, \$8.58 Canola: \$5.40, \$8.10, \$11.70
V	Variable Cost	Yes	Variable cost per acre	Wheat:\$200 Canola: \$230
F	Fixed Cost	Yes	Fixed annual machinery cost for all farm sizes	\$249,375
Alpha (a)				
S	Seeding start date	No	Triangle	Numbers 1 thru 20 representing start date of April 21st thru May 10th 1,.10,20
SW	% of days too wet to seed	No	Triangle	0%, 67%, 100%
SPr	Productivity in acres/day	Yes	Acres per day that could be seeded under perfect conditions	442.64 acres/day
Beta (b)				
HW	% of days too wet to harvest	No	Triangle	0%, 59%, 100%
HPr	Productivity in acres/day	Yes	Acres per day that could be harvest under perfect conditions	271.89 acres/day
MC	Maturity time of crop in days	No	Triangle	Wheat only: 90, 110, 130

5.1.2 Alpha Calculation

The alpha calculation begins with the seeding date:

$$Average\ wheat\ seeding\ date(\alpha w) = \frac{\left(10^{i} + \frac{\left(\frac{.5x}{443}\right)}{.67^{i}}\right) + 10^{i}}{2}\ .$$

Where:

- 10^i represents the seeding start date and it is a triangle distribution that ranges from 1 to 20. Day 1 corresponds to April 21st and day 20 corresponds to May 10th.
- X represents seeded acres and is multiplied by .5 because fifty percent of the acreage is wheat.
- 443 is the amount of acres that can be seeded in one day under perfect conditions.
- $.67^i$ (67%) is the amount of days in the spring that are suitable for seeding This variable is modeled using a triangle distribution with minimum of 0, midpoint of .67 and a maximum of 1.
- The average wheat seeding date corresponds to an alpha value starting at 1.15 on April 21 (*aw* =1) with a 0.01 decrease per day after that.

$$Average\ canola\ seeding\ date(\alpha c)$$

$$= \frac{\left(\left(10^{i} + \frac{\left(\frac{.5x}{443}\right)}{.67^{i}}\right) + \frac{\left(\frac{.5x}{443}\right)}{.67^{i}}\right) + \left(10^{i} + \frac{\left(\frac{.5x}{443}\right)}{.67^{i}}\right)}{2}$$

- It is assumed that canola seeding begins when wheat seeding is complete therefore canola seeding start date is the wheat seeding end date. This calculation is the same as the average wheat seeding date calculation above.
- The average canola seeding date corresponds to an alpha value starting at 1.10 on May 10 (*ac* =20) with a 0.01 decrease per day after that.

5.1.3 Beta Calculation

The beta calculation begins with the harvest date:

$$Average\ wheat\ harvest\ date(\beta w) = \frac{\left(10^i + 110^i + \left(\frac{\left(\frac{.5x}{271}\right)}{.59^i}\right)\right) + \left(10^i + 110^i\right)}{2}$$

Where:

- Seeding start date plus maturity coefficient (110^i) which is also drawn randomly from a triangular distribution is the Wheat harvest start date.
- 271 is the number of acres harvested in one day.
- .59 (59%) is the percent of fall days that are suitable for harvesting and this variable is modeled using a triangle distribution with minimum of 0, midpoint of .59 and a maximum of 1.
- The average wheat harvest date corresponds to a beta value starting at 1 for any date before September 1 (*Bw* =134) with a 0.01 decrease per day after that.

$$Average\ canola\ harvest\ date(\beta c)$$

$$= \frac{\left(\left(10^i + 110^i\,\frac{\left(\frac{.5x}{443}\right)}{.67^i}\right) + \left(\frac{\left(\frac{.5x}{271}\right)}{.59^i}\right)\right) + \left(\left(10^i + 110^i\,\frac{\left(\frac{.5x}{443}\right)}{.67^i}\right)\right)}{2}$$

Where:

- Canola harvest start date is the wheat harvest end date $\left(10^i + 110^i\,\frac{\left(\frac{.5x}{443}\right)}{.67^i}\right)$. With the exception of the start date this calculation is the same as average wheat harvest date above.
- The average canola harvest date corresponds to a beta value starting at 1 for any date before September 15 (*Bw* =148) with a 0.01 decrease per day after that.

Figure 5.1 below is the distribution of wheat yield factors for wheat on a 6000ac farm size. This figure demonstrates the distribution is skewed more to the left as farm size increases.

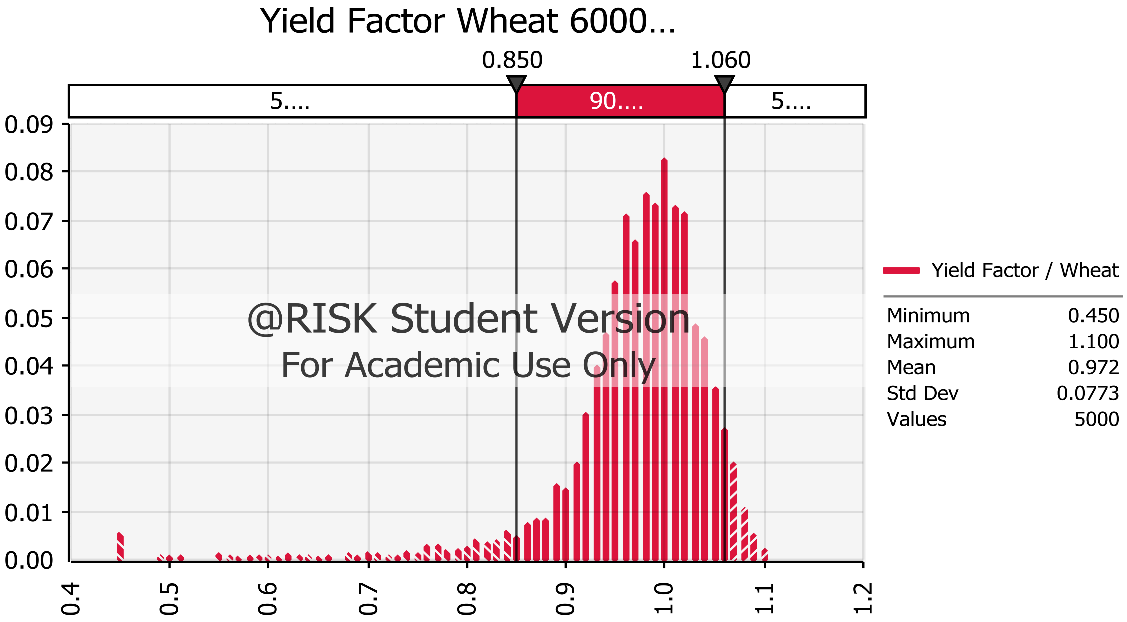


Figure 5.1 Yield Factor Distribution For 6,000 Acres.

5.2 500 Acre Increments

The simulation program @Risk© maximized total farm profit given 1,000 iterations of each of the distributions included within the objective function at varying farm sizes. The profit results from the iterations were averaged to give a mean profit at each different farm size.

Table 5.2 Mean Profit Simulation Results

Simulation Results					
Acres	**Mean Profit**	**Coefficient of Variation**	**Confidence Interval 5%**	**Confidence Interval 95%**	**Standard Deviation**
3000	$ 18,443	7.86	-$ 210,200	$ 265,436	$ 144,900
3500	$ 53,119	3.21	-$ 211,654	$ 339,732	$ 170,739
4000	$ 84,718	2.32	-$ 223,879	$ 417,100	$ 196,851
4500	$ 113,015	1.97	-$ 238,886	$ 482,864	$ 223,141
5000	$ 137,764	1.82	-$ 253,032	$ 546,098	$ 250,137
5500	$ 159,752	1.74	-$ 277,364	$ 619,067	$ 277,173
6000	$ 178,244	1.71	-$ 311,251	$ 676,233	$ 304,024
6500	$ 193,618	1.71	-$ 339,845	$ 738,965	$ 331,129
7000	$ 206,225	1.74	-$ 373,956	$ 802,514	$ 358,341
7500	$ 215,646	1.78	-$ 408,566	$ 857,274	$ 384,618
8000	$ 222,152	1.85	-$ 443,127	$ 901,175	$ 410,829
8500	$ 225,724	1.93	-$ 489,484	$ 939,791	$ 436,231
9000	$ 226,569	2.04	-$ 522,220	$ 977,496	$ 461,498
9500	$ 224,888	2.16	-$ 570,379	$ 1,032,213	$ 486,413
10000	$ 220,476	2.32	-$ 601,361	$ 1,067,601	$ 510,988
10500	$ 213,884	2.50	-$ 629,241	$ 1,088,115	$ 533,664
11000	$ 205,048	2.72	-$ 676,998	$ 1,133,246	$ 556,787
11500	$ 193,888	2.98	-$ 714,383	$ 1,137,132	$ 578,375
12000	$ 180,282	3.33	-$ 767,797	$ 1,174,898	$ 599,720
12500	$ 164,889	3.77	-$ 805,401	$ 1,192,071	$ 621,055

Table 5.2 above shows the gross mean profit, coefficient of variation, 90% confidence interval and standard deviation at each different farm size. Gross mean profit is the calculated average profit through 1000 model iterations. Standard deviation divided by mean, or coefficient of variation, is a measure of profit risk associated with farm size and as the coefficient of variation decreases so does variation in average profit. The 90% confidence interval is between the mean profit listed under the 5% and 95% column. That is, 900 of the 1000 iterations fell within this profit range. Standard

deviation is the amount of variation that can be reasonably expected given the associated mean profit.

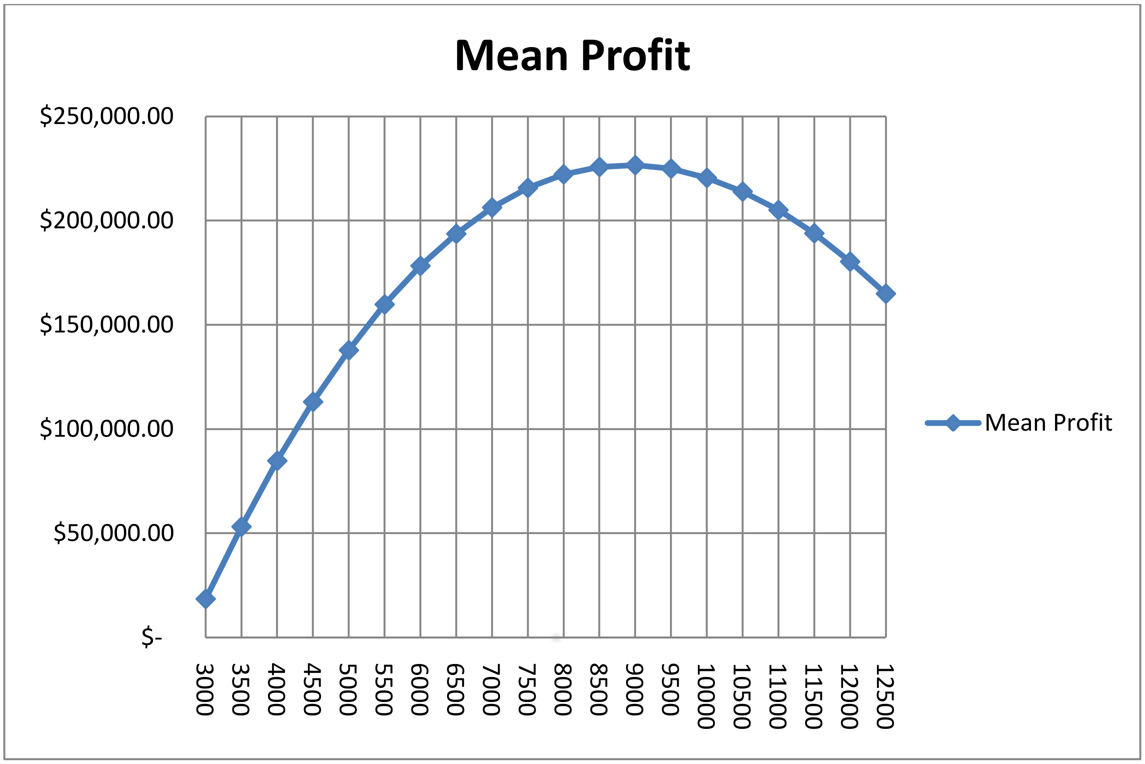


Figure 5.2 Mean Profit in Dollars

The results in Table 5.2 (illustrated in Figure 5.2 above) show that gross mean profit is maximized on the 9,000 acre farm at $226,570 with a standard deviation of $461,500.

5.3 Optimal Size Refined

Table 5.2 above was based on an original simulation that analyzed results of the 1,000 draws for 500 acre farm sizes. To further refine the optimal size it is reasonable to narrow farm size variation to 160 acres. A quarter section, or 160 acres, is generally the smallest amount of land a farmer can add to his/her farm size at once and therefore it is reasonable to increase size by that level. In Table 5.3, the highest mean profit of $225,938.05 occurs on a farm size of 8,840 acres with a standard deviation of $461,221.

Table 5.3 160 Acre Refined Simulation Results

Mean Profit/Acre 160 Acre Increments

Acres	Mean Profit	Coefficient of Variation	Confidence Interval 5%	Confidence Interval 95%	Standard Deviation
5000	$ 138,562	1.79	-$ 260,997	$ 543,199	$ 248,534
5160	$ 145,977	1.76	-$ 271,997	$ 564,965	$ 257,162
5320	$ 153,131	1.74	-$ 274,028	$ 586,100	$ 265,875
5480	$ 159,816	1.71	-$ 287,859	$ 606,057	$ 274,038
5640	$ 166,407	1.70	-$ 296,477	$ 630,470	$ 283,016
5800	$ 172,474	1.69	-$ 306,449	$ 648,208	$ 291,476
5960	$ 178,323	1.68	-$ 309,576	$ 667,501	$ 300,205
6120	$ 183,778	1.68	-$ 320,809	$ 684,777	$ 308,835
6280	**$ 188,674**	**1.68**	**-$ 330,731**	**$ 709,200**	**$ 317,642**
6440	$ 193,298	1.69	-$ 334,196	$ 722,925	$ 325,868
6600	$ 197,659	1.69	-$ 341,020	$ 738,239	$ 334,606
6760	$ 201,764	1.70	-$ 362,903	$ 756,231	$ 343,133
6920	$ 205,596	1.71	-$ 365,590	$ 776,100	$ 351,648
7080	$ 209,065	1.72	-$ 380,501	$ 791,211	$ 360,053
7240	$ 212,143	1.74	-$ 384,578	$ 802,100	$ 368,873
7400	$ 215,015	1.76	-$ 407,015	$ 819,242	$ 377,754
7560	$ 217,516	1.77	-$ 415,757	$ 830,525	$ 386,007
7720	$ 219,616	1.80	-$ 420,272	$ 845,945	$ 394,391
7880	$ 221,600	1.82	-$ 433,418	$ 868,646	$ 402,956
8040	$ 223,140	1.84	-$ 457,080	$ 886,007	$ 410,999
8200	$ 223,343	1.92	-$ 482,659	$ 931,338	$ 428,273
8360	$ 224,363	1.95	-$ 496,102	$ 953,106	$ 436,682
8520	$ 225,262	1.98	-$ 510,338	$ 970,231	$ 445,009
8680	$ 225,747	2.01	-$ 518,612	$ 983,557	$ 452,985
8840	**$ 225,938**	**2.04**	**-$ 529,071**	**$ 996,585**	**$ 461,221**
9000	$ 225,832	2.08	-$ 544,107	$ 1,007,937	$ 469,978
9160	$ 225,667	2.12	-$ 558,679	$ 1,021,429	$ 477,839
9320	$ 224,865	2.16	-$ 573,514	$ 1,043,090	$ 485,637
9480	$ 224,040	2.21	-$ 588,721	$ 1,065,278	$ 494,040
9640	$ 222,954	2.25	-$ 595,008	$ 1,069,486	$ 501,363
9800	$ 221,304	2.30	-$ 611,557	$ 1,091,011	$ 509,253
9960	$ 220,014	2.35	-$ 619,914	$ 1,094,409	$ 517,704
10120	$ 217,804	2.41	-$ 635,646	$ 1,098,311	$ 524,815
10280	$ 215,791	2.47	-$ 651,200	$ 1,119,618	$ 533,249
10440	$ 213,487	2.53	-$ 662,948	$ 1,122,734	$ 541,070
10600	$ 210,903	2.60	-$ 679,123	$ 1,140,013	$ 548,494
10760	$ 208,117	2.67	-$ 690,052	$ 1,160,984	$ 555,810

Chapter 6 - Conclusions

The objective of this study as stated in Section 1.1 was to determine the optimal grain farm size for an area of west central Manitoba commonly referred to as the Parkland Region, specifically Crop Insurance Risk Area 6. This study's objective function was designed to maximize expected farm profit. Given a fixed line of equipment, a 50/50 wheat/canola rotation and a risk neutral operator the optimal farm size to maximize expected profit in Risk Area 6 is 8,840 acres. Mean profit decreased as acres increased from 8,840 due to lack of timeliness of operations, yield and quality effects. The fixed line of equipment is not able to complete field operations within the optimal time frame and yield penalties outweigh the benefit of farming extra acres.

6.1 Discussion

Census Agricultural Region 3 is a good proxy for Crop Insurance Risk Area 6 as it is in much the same area. In the 2006 Census of Agriculture total acres in this region were calculated at approximately 1.16 million. If every producer in the region farmed only grain and his/her goal was to maximize expected profit as described in the model there would be a total of 128 farms. This would be a vast reduction from 1,764 which was the number of farms calculated in the 2006 Census of Agriculture. If we assume each of these farms employees two generations and that each generation consists of one couple, Risk Area 6 would employ 512 farmers. Again, this is a much lower farm population than 2,465 as counted in the 2006 Census of Agriculture. Referring back to Table 1 in Section 1.3 each of these farms would be in the highest revenue class of > $2,000,000 where in 2006 there were only 16 farms in this category.

A population decline of this magnitude would have both economic and social implications for communities in Risk Area 6. A drop in the number of farmers means fewer people to patronize local business and therefore fewer services available. For the farm families remaining, farm related service centers may be located at a distance. Other essential services such as health, education and retail may no longer be available in the area due to lack of support available from local residents. Policy makers would need to adjust not only farm policies but also essential services policies to accommodate a very sparse rural population. Or, a very sparse rural population may be forced to adjust their lifestyle in order to have access to essential services. This possibility has very negative consequences in that property and infrastructure value would essentially be zero if it has no use to the rural industries that remain.

As grain farms grow and amalgamate policy makers need to understand how the risk management tools these farms need may also change. For example the cash advance program is capped at $400,000, however, on an 8,000 acre farm this would cover less than 25% of operating costs. Large farms face more extreme fluctuations in profit and larger cash flow needs. Programs may need to be revamped or more funds focused on fewer programs to meet the needs of farmers as they size their farms most profitably.

6.2 Limitations

6.2.1 Risk Considerations

6.2.1.1 Diminishing Returns and Standard Deviation

The model's objective function is written to maximize whole farm profit and in theory a risk neutral firm would ultimately want to make the most profit as possible. However, due to diminishing returns to scale, increasing standard deviation and individual risk tolerances, this may not be true.

In the model, diminishing returns to scale occur when adding one acre to a farm's size yields less mean profit than adding the acre before. Each additional acre may increase mean profit but it also increases the risk of negative profit as demonstrated by a steadily increasing standard deviation. Once farm size reaches diminishing returns mean profit increases with each additional acre at a slower rate than the risk of negative returns. Once this point is reached, individual risk preferences will dictate individual optimal farm size. A risk seeking producer is willing to take the risk associated with each additional acre in order to gain mean profit. A risk averse producer may not be willing to take this risk and therefore his/her individual optimal farm size will be smaller than the risk seeking producer.

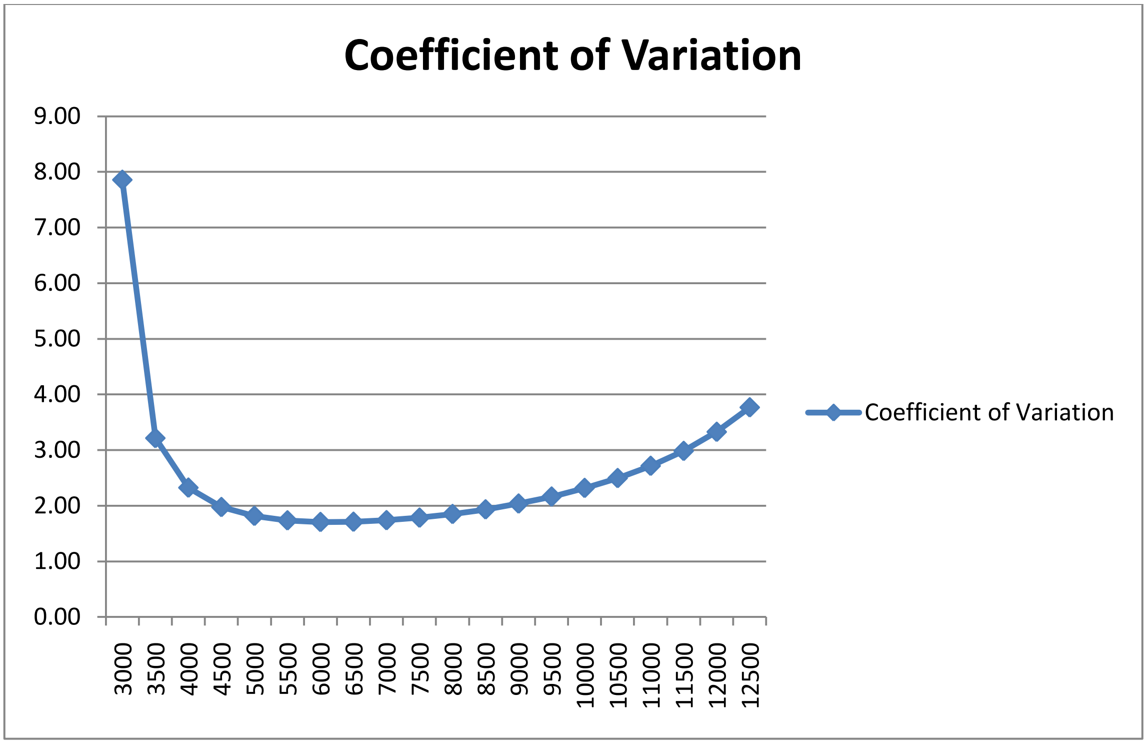


Figure 6.1 Coefficient of Variation for Profit as a Function of Farm Size

Figure 6.1 illustrates that as farm size increases from 6,500 to 9,000 acres the gross profit gain comes at the cost of additional risk or variability in that profit. For a risk averse individual, sizes above 6,500 may not be desirable because they are less profitable per acre and more risky. For an extremely risk averse person who's goal is to minimize risk rather than maximize expected profit may actually choose a farm size less than 6,500 acres.

6.2.1.2 Utility

Another factor specific to individuals is the additional time and effort associated with each additional acre. Farmers must consider this when increasing the size of their farm even when returns are not yet diminishing. This factor refers to the farmer's overall satisfaction with working harder or utility. A farmer may be increasing his/her mean profit by adding acres to his/her farm but by doing so he/she has to spend more time completing field operations and less time participating in leisure activities. Even though he/she is gaining mean profit the time spent away from leisure activities may actually decrease the farmer's utility and he/she may actually be less satisfied by farming more acres. Depending on an individual's preference for how they value their time spent working vs. leisure individuals may conclude different sizes of farm as optimal.

6.2.1.3 Safety First

"Safety First" is a risk management strategy originally developed by A.D. Roy (1952.) When applied in the context of choosing the optimal farm size the safety-first technique would select farm size based on the criteria that the probability of mean profit falling below a minimum desired threshold is minimized. If we apply the safety-first criterion with a threshold of $0 mean profit the following figures illustrate which farm size would be chosen.

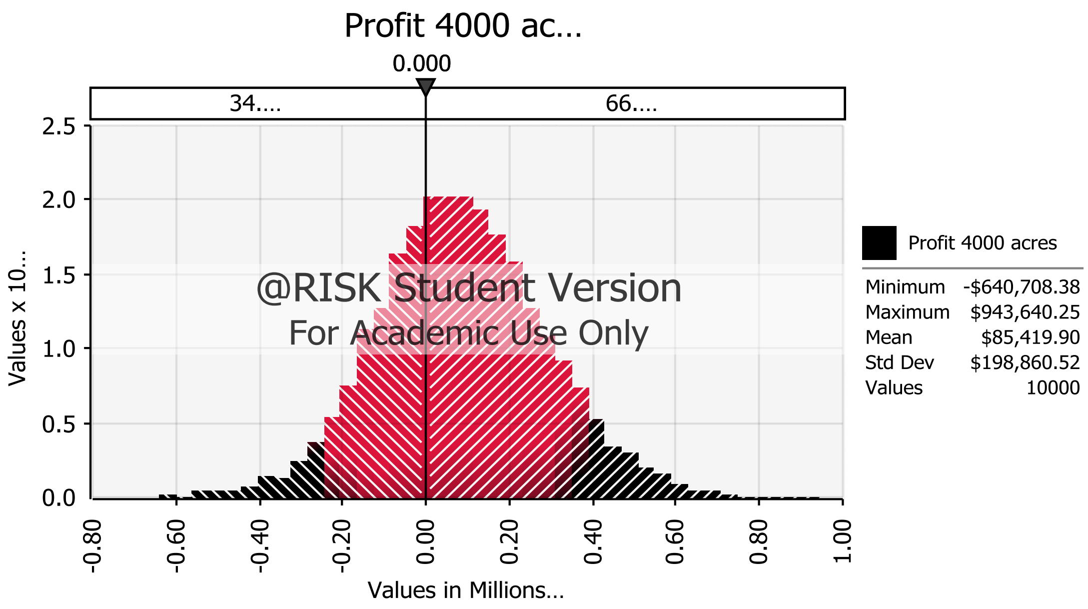


Figure 6.2 Distribution of Net Profit at 4,000 acres

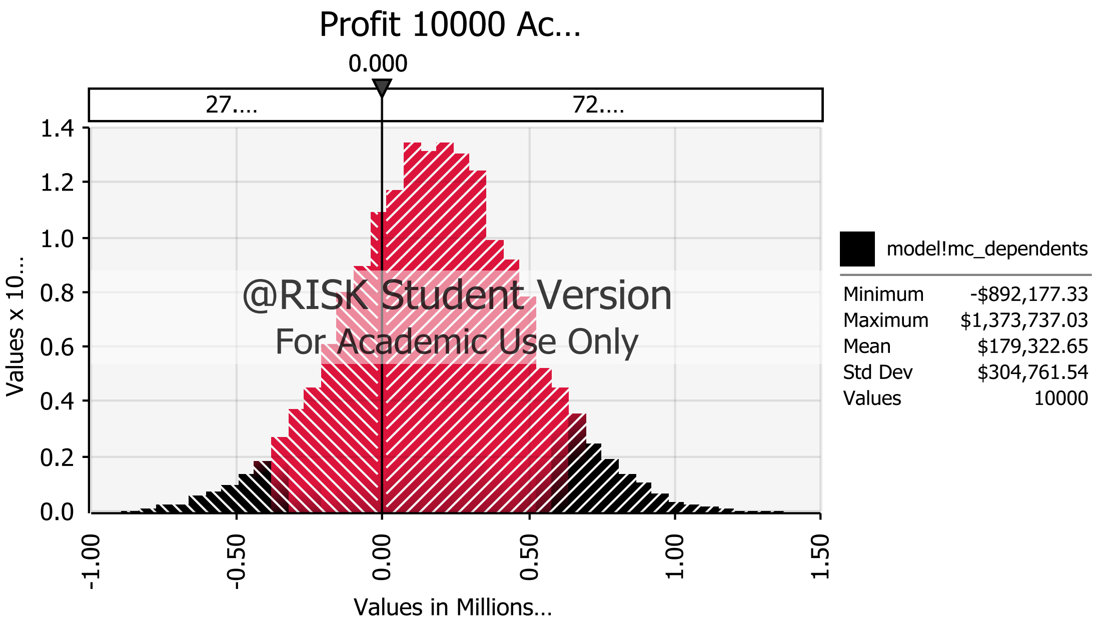


Figure 6.3 Distribution of Net Profit at 6,000 acres

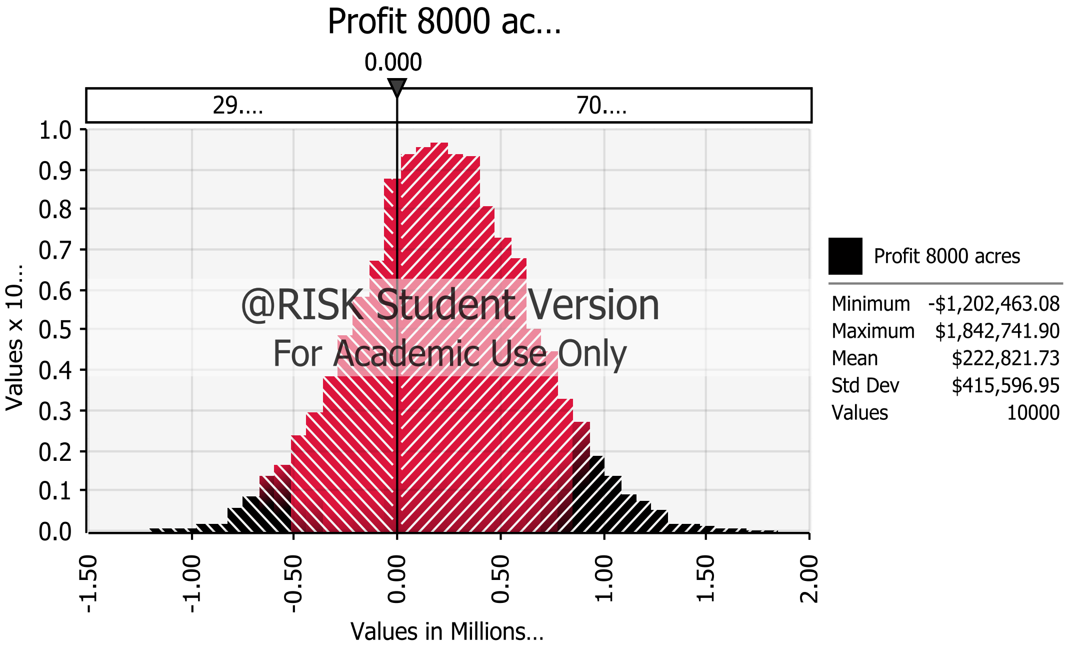


Figure 6.4 Distribution of Net Profit at 8,000 acres

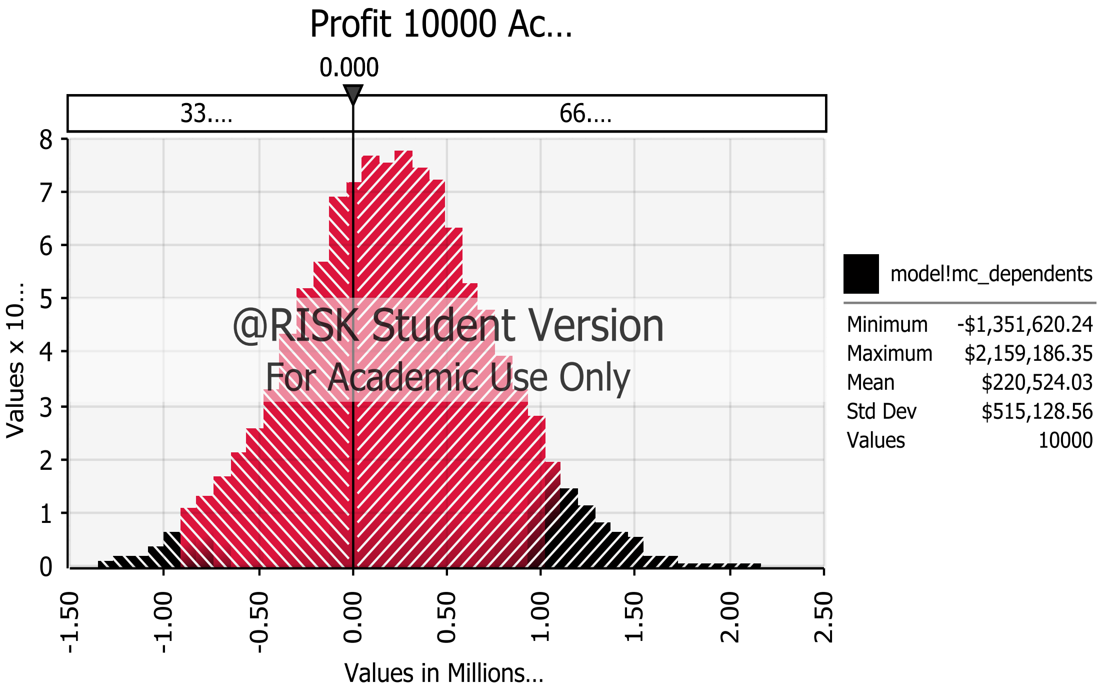


Figure 6.5 Distribution of Net Profit at 10,000 acres

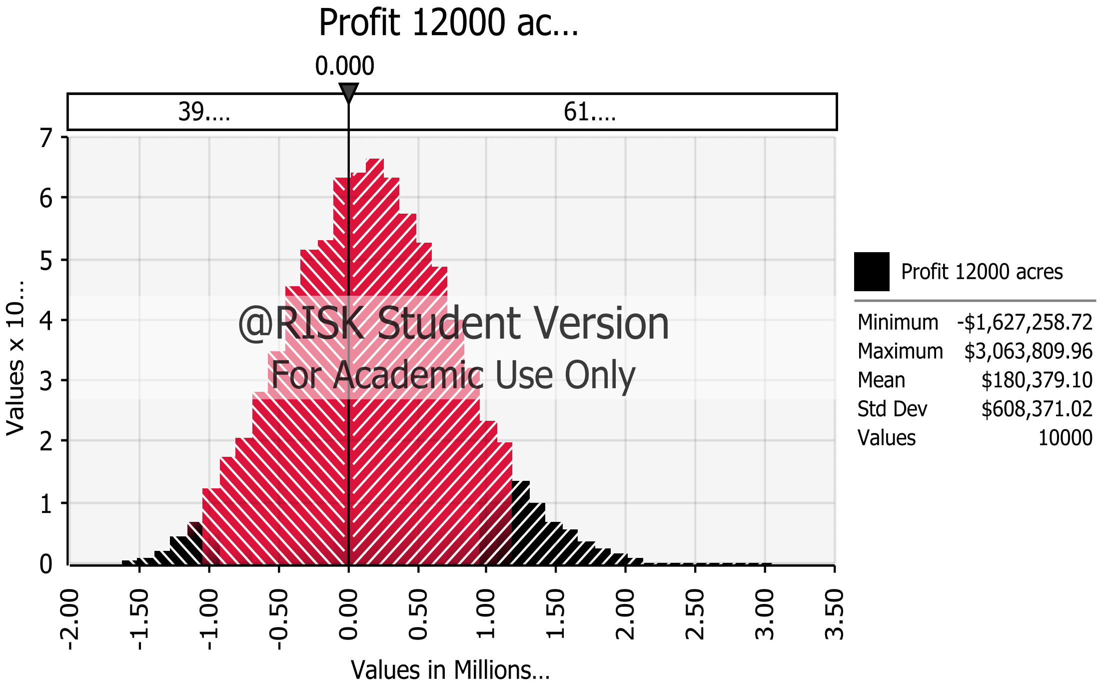


Figure 6.6 Distribution of Net Profit at 12,000 acres

Figures 6.2 through 6.6 above illustrate the difference in profit variability on a 4,000 to 12,000 acre farm. Each graph shows 10,000 model iterations at the respective farm size. On the X axis is mean profit and on the Y axis is the number of times that profit occurs during the 10,000 iterations. Each graph has a vertical line at $0 profit to illustrate how often a producer could expect to make a positive versus negative profit. The graphs quantify the risk of negative profit in that a producer could expect to lose money 34%, 28%, 29%, 34% and 39% of the time at 4,000, 6,000, 8,000, 10,000 and 12,000 acres respectively. This analysis indicates that a farm between 6,000 and 8,000 acres is the most desired farm size using the safety-first criterion.

Figure 6.7 below demonstrates the risk vs. return trade-off a farmer considering expansion faces. As farm size increases the risk of negative returns also increases.

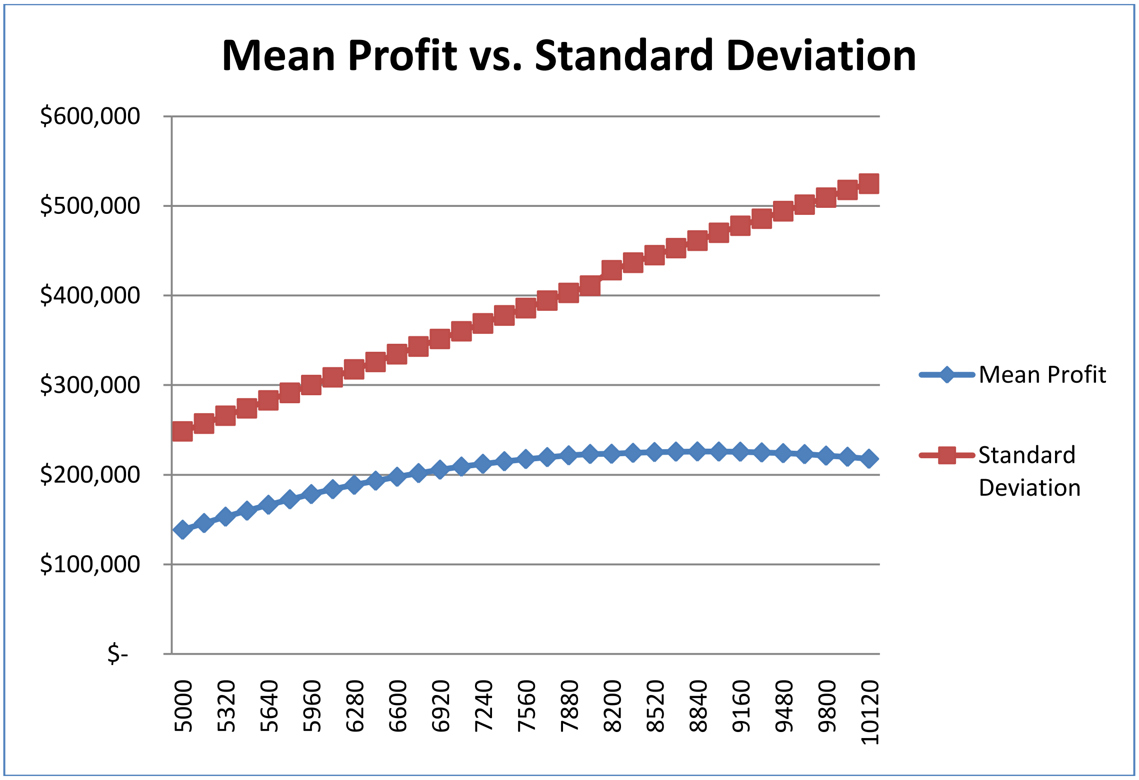
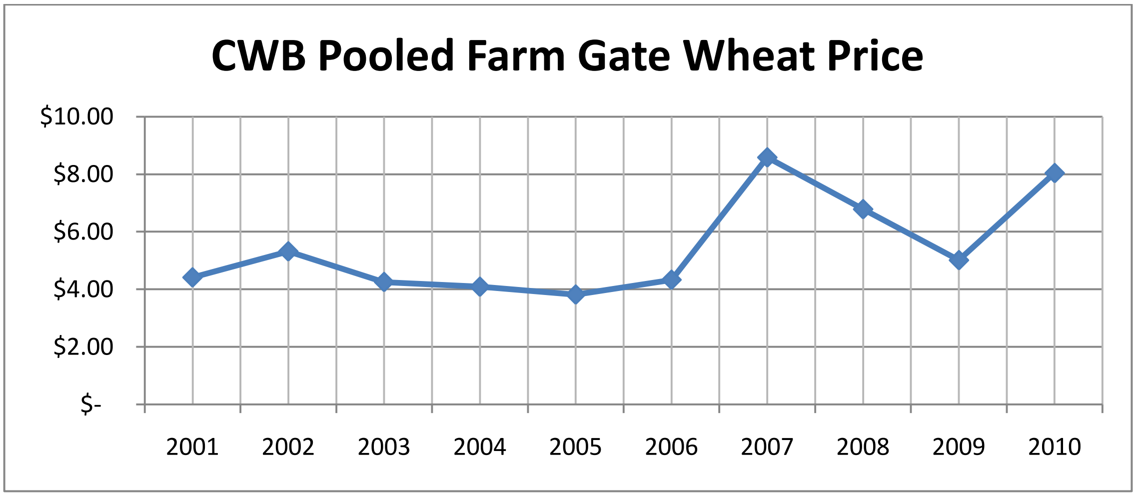


Figure 6.7 Mean Profit And Standard Deviation In Dollars

A farmer who is extremely risk averse may want to minimize the risk of incurring negative profit or losing money. This farmer may use the safety-first criterion to choose what size of farm he/she should operate and set his/her threshold at $0 mean profit. Under these stipulations, the safety-first criterion would choose an optimal farm size between 6,000 and 8,000 acres. By farming 6,000 – 8,000 acres, a farmer minimizes his/her risk of incurring negative profits.

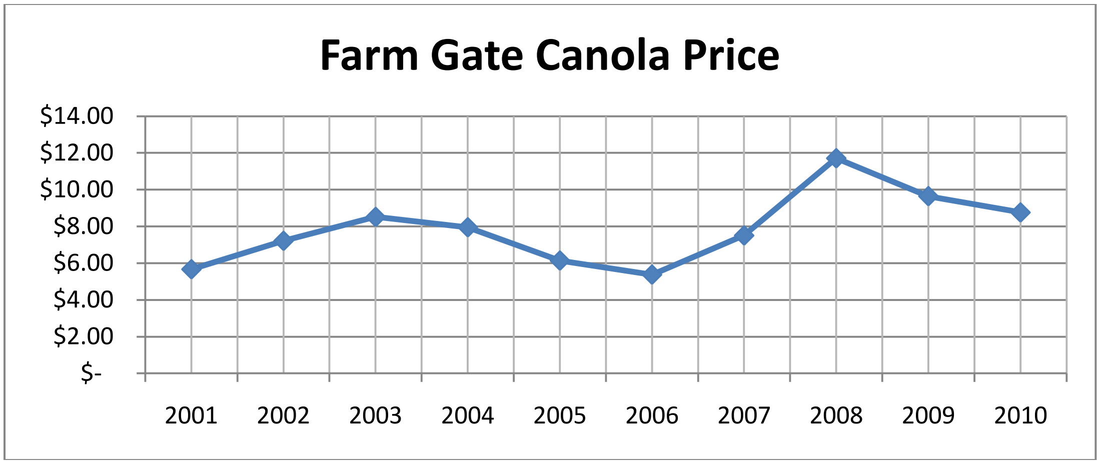
6.2.2 Current Costs vs. Historical Prices

Cost data built into the model was based on current estimations for 2011 production costs. Price data, however, was allowed to vary based on historical prices for the years 2001 through 2010. Figures 6.2 and 6.3 below illustrate the upward trend in crop prices over the ten year period.



Source: Canadian Wheat Board, 2011

Figure 6.8 Spring Wheat Farm Gate Price from 2001 to 2010



Source: Canola Council of Canada, 2011

Figure 6.9 Farm Gate Price of Canola From 2001 to 2010

Farm expenses have followed this trend. By subtracting current costs from gross revenue based on a lower than current price, the model underestimates profit potential. Theoretically, commodity prices could fall anywhere in the distribution for the current year. However, up to date market reports and the global nature of commodity trade allows for relatively certain approximation of current price for budgeting purposes. A more accurate estimation of current year profit potential would use current or estimated crop year prices.

However, the model was created to choose the optimal farm size in Risk Area 6 given a long term planning horizon. Farm costs could be varied using long term cost data and tied to the corresponding year's price data to improve mean profit results.

6.2.3 Government programs

This study did not take into account the income smoothing effects of government risk management programs such as AgriInsurance and Agristability. AgriInsurance averages a producer`s yield for each crop and insures either 50%, 70% or 80% of this yield. If a producer`s yield for an insured crop fall below the insured level they receive payment up to that level. This payment is based on a commodity price per bushel chosen by AgriInsurance at the beginning of the crop year. Any producer who is enrolled the program effectively has a yield minimum for each crop and this would reduce the downward variability of mean profit.

Agristability provides income insurance for producers. Insurance level is based on an Olympic average of their production margin (eligible income – eligible expenses) over the last five years. If current year production margin falls below the insured level payment is made. Again, inclusion of this program in the model would reduce the downward variability of mean profit. None of these insurance programs were factored into this farm income model.

6.2.4 Labour Availability & Variability

The availability of additional skilled labour to operate machinery was assumed to be unlimited for the purpose of this study. This in reality is not the case and may be a significant deterrent for producers to increase utilization of their current equipment and/or increase their acres.

The model also assumed that labour was perfectly variable with acres which in reality is certainly not the case. Farm labourers seek guaranteed hours and are not available incrementally with each acre but by job position.

6.2.5 Access to Land and Capital

For the purpose of this study it was assumed that land and capital availability were unlimited. Access to credit has been generally easy for grain farmers in the last few years even though historically access to capital has been a major limitation to farmers. The assumption that land availability is unlimited would be a major limitation of this study. In reality competition for farm land is high in most areas and land may not be readily available for farmers to expand.

6.2.6 Credit Availability and Cash Flow Needs

The study did not take into account changing credit and cash flow needs as farms get larger. In the model variable costs alone would be over $1.5 million for an 8,000 acre farm. The model assume that a farm could find credit to cash flow these costs, however, farms may not be able to secure this level of credit or credit may become prohibitively expensive as operating limits are pushed higher.

6.2.7 Depreciation

The model assumes a declining balance depreciation rate of 7.5% across all farm sizes. Depreciation would actually be variable as acres increase because equipment is operated for longer hours over more acres.

6.2.8 Volume Input and Grain Price Opportunities

The model budget did not take into account the volume input and grain price opportunities that large farms often enjoy. As volumes of grain increase from one producer he/she is better able to negotiate with buyers on price, grade, delivery time etc. for that grain. Large producers are also able to negotiate lower prices for inputs because they buy in large volumes. If included in the model these two factors would affect the farm budget and may make larger farms more profitable.

6.3 Further Study

Further study would be useful in the area of optimal farm size. The model could be adapted to different regions simply by changing yield potential and weather distributions to reflect the local conditions. Fixed equipment costs could also be changed to reflect different ages or combinations of equipment.

Spraying is another major farm operation and could be incorporated into the model. In Manitoba fungicide spraying of cereal and oilseed crops has only become a mainstream practice in the last ten years. Incorporation of this operation would require primary data collection as there is no concrete data available on the optimum timeliness of spraying and resulting yield effects.

The risk vs. return of farming additional acres could also be studied in more detail. It would be interesting to maximize producer utility given different levels of risk aversion.

In Western Canada climate is a major limiting factor to farm size and production. One could study the competitive disadvantages associated with farming in Canada’s prairie region vs. other parts of the world. Regions with longer growing seasons may have better machinery utilization and lower cost of production. The results of this study may shed light on where Canadian research resources should be targeted to mitigate our climatic competitive disadvantages.

6.4 Summary

The objective of this study was to determine the optimal grain farm size for an area of west central Manitoba commonly referred to as the Parkland Region, more specifically Crop Insurance Risk area 6. The study's criterion to choose optimal farm size was maximum long term profit.

The study's initial assumption was that the optimal farm size would use assets, specifically seeding and harvest machinery, as efficiently as possible. Here efficiency is measured through covering the most acres in the least amount of time. This assumption led to fixing machinery size at the largest seeding and harvest equipment size that is widely available from a number of common farm machinery manufacturers. After this start, tradeoffs between timeliness and productivity were introduced.

The study determined net profit by creating a model that multiplied price x yield x acres minus costs assuming a 50/50 wheat/canola rotation. Timeliness of operations is important because this region of Manitoba has a frost free growing period of only 95 – 105 days in which the majority of crop operations must occur. Timeliness is affected by weather and farm size. As farm size increases there is more risk that inclement weather will lengthen the time needed for crop operations. Previous studies have shown that both seeding and harvest operations have optimum time windows in which they should occur for best yield results. Within the profit function, weather factors were included that affected the timeliness of operations and ultimately the crop yield.

Farmers sell their commodities on the open world market and are price takers. Within the profit function price was varied according to historical price variation over the last 10 years. Costs were entered into the model at best estimates for the current crop year (2011).

The model returned some interesting results. Total mean profit was maximized on the 8,840 acre farm. For farm sizes above 8,840 acres, losses associated with lack of field operation timelines could not be compensated by cropping additional acres. Also, the risk, measured as Standard Deviation, associated with attaining additional mean profit increased as acreage increased. These additional results indicated that optimal farm size may actually be different for different individuals depending on their risk tolerance.

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