

**AN ANALYSIS OF ISSUES RELATED TO ECONOMIES OF SIZE IN  
SASKATCHEWAN CROP FARMS**

A Thesis Submitted to the Faculty of  
Graduate Studies and Research  
In Partial Fulfillment of the Requirements  
For the Degree of Masters of Science  
In the  
Department of Agricultural Economics  
University of Saskatchewan  
Saskatoon, Saskatchewan

By  
Byambatseren Dashnyam

## **PERMISSION TO USE**

In presenting this thesis in partial fulfilment of the requirements for a Postgraduate degree from the University of Saskatchewan, I agree that the libraries of this University may make it freely available for inspection. I further agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purpose may be granted by the professor or professors who supervised my thesis work or, in their absence, by the Head of the Department or the Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition will be given to me and the University of Saskatchewan in any scholarly use that may be made of any material in this thesis.

Request for permission to copy or make use of material in this thesis in whole or part should be addressed to:

Head of the Department of Agricultural Economics  
University of Saskatchewan  
51 Campus drive  
Saskatoon, Saskatchewan

S7N 5A8

## **ABSTRACT**

Byambatseren Dashnyam., M.Sc. University of Saskatchewan, Saskatoon, May 2007. An Analysis of Issues Related to Economies of Size in Saskatchewan Crop Farms.

Supervisor. William J. Brown

Farm size economies size measure the relationship between the size of operation and the average cost of production. Along with increasing farm size, the average cost of production per unit may decline. One reason farms have been growing in size is that larger sized farms tend to have more recent and advanced machines capable of covering more land with less labor. However, it is still questionable how farm size affects on input costs and field operation costs in Saskatchewan.

The major objective of this study was to examine the issues related to size economies in larger crop farms in Saskatchewan. The project has taken a different approach than is traditionally done in economies of size research where various forms of statistical data are analyzed.

First, the study analyzed several different operating and investment costs to see whether they are decreasing or staying the same as a result of increasing farm size. Next the study determined the probabilities of available field workdays using conditional probability equations derived from the Markov Chain method. The analysis was carried out for the West central and East central Saskatchewan regions' to determine spring and fall field workability. Based on the field workdays estimation, the optimal area of combine for larger farms were analysed using a least-cost machinery size approach. The last part of this study analysed farm operational costs per unit for larger crop farms in order to

determine how machinery efficiency and farm size have an effect on the farm production costs.

The study found that however there were certain combine costs that increase with farm size in Saskatchewan. In addition, soil types, weather conditions and field efficiency can strongly affect combine cost per acre.

The results of this research provide a reference for policy makers in designing policy recommendations. In addition, the results may offer useful information for farmers in designing management plans to control farm operation costs.

## **ACKNOWLEDGEMENTS**

I wish to thank and acknowledge my supervisor, Prof. William, J. Brown. Without his expertise, guidance, and advice, the goals of this thesis would have been much more difficult to obtain. His efforts in providing me with constant feedback and encouragement are greatly appreciated. I also wish to thank my committee members Prof. Richard Gray and Jackson Clayton for their patience and help with various aspects of the farm analysis.

Special thanks are extended to the Department of Agricultural Economics for providing financial support throughout the study and Chokie Mengisteab for his valuable advice and help with the statistical analysis.

My sincere gratitude is extended to my wife, Tuyana, my daughters Egshiglen and Elizabeth for their love and encouragement to do my best during my entire life. This thesis is dedicated to them.

## TABLE OF CONTENTS

PERMISSION TO USE .....	i
ABSTRACT .....	ii
AKCNOWLEDGEMENTS .....	iv
TABLE OF CONTENTS .....	v
LIST OF TABLES .....	vi
LIST OF FIGURES .....	vii
CHAPTER 1. INTRODUCTION .....	1
1.1. Background .....	2
1.2. Problem Statement .....	4
1.3. Hypothesis .....	5
1.4. Objectives of the Study .....	5
1.5. Organization of the Thesis .....	6
CHAPTER 2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK .....	7
2.1 A Review of Related Research .....	7
2.1.1 Studies Dealing with Economies of Size .....	7
2.1.2 Studies Dealing with Least Cost Size of Farm Machinery .....	9
2.1.3 Studies Dealing with Field Workdays Estimation .....	10
2.2 Major Issues Involved in the Estimation of Least-Cost Size of Machinery .	15
2.2.1 Amount of Work Required for Spring and Fall .....	15
2.2.2 Available Time for Planting and Harvesting .....	16
2.2.3 Machinery Fixed and Variable Costs .....	18

2.2.4	Impact of Timeliness on Farm Operation .....	19
CHAPTER 3.	DATA AND PRELIMINARY ANALYSIS.....	21
3.1	Preliminary Survey .....	21
3.1.1	Survey Description.....	21
3.1.2	Summary of Survey.....	22
3.2	Data Sources.....	24
3.3	Analyzed Production Costs Results for Large Crop Farms in West and East central Saskatchewan.....	25
CHAPTER 4.	ANALYTICAL FRAMEWORK.....	32
4.1	Determination of Daily Field Workability.....	32
4.1.1	The Selection of the Field Workday Model.....	33
4.1.2	Major Criteria for Soil Tractability and Field Workdays.....	33
4.1.3	A Procedure for Determining Probabilities of Spring and Fall Field Workdays.....	34
4.2	The Least-Cost Approach to Estimate the Size of Agricultural Machinery...38	
4.2.1	Estimation of Machinery Fixed Costs.....	39
4.2.2	Estimation of Machinery Variable Costs.....	42
4.2.3	Estimation of Timeliness Costs.....	45
4.2.4	Estimation of the Least-Cost Size of Machinery.....	48
CHAPTER 5.	RESULTS OF COMBINE CAPACITY.....	51
5.1	Estimated Result for Fall Field Workdays.....	51
5.1.1	Estimated Result for Fall Field Workdays in West central Saskatchewan.....	52

5.1.2	Estimated Result for Fall Field Workdays in the East central Saskatchewan.....	53
5.2	Estimated Result for Optimal area Combined.....	54
5.2.1	Optimal Area Combined in the West central Saskatchewan.....	55
5.2.2	Optimal Area Combined in the East central Saskatchewan.....	58
5.2.3	Comparison Result for West central and East central Saskatchewan.....	61
5.3	Comparison Between the Two Regions of the Farms Interviewed.....	64
CHAPTER 6. SUMMARY AND CONCLUSION.....		69
6.1	Summary.....	69
6.2	Conclusion.....	70
6.3	Limitation of the Study.....	71
6.4	Suggestions for Further Study.....	72
REFERENCES.....		74
APPENDICES.....		79



## LIST OF TABLES

Table 1.1 Number and size of farms in Saskatchewan.....	2
Table 4.1 Timeliness Loss Factors.....	47
Table 5.1 Observed frequencies and probabilities, West central Saskatchewan.....	52
Table 5.2 Observed frequencies and probabilities, East central Saskatchewan.....	53
Table 5.3 Machinery cost per acre for 5000 acres to 25000 acres, West central Region (Field efficiency – 0.8).....	57
Table 5.4 Machinery cost per acre for 5000 acres to 25000 acres, East central (Field Efficiency – 0.80).....	60
Table 5.5 Least-cost acre for “class 7” combine.....	62
Table 5.6 Total combine cost for East central Saskatchewan (FE =0.8 vs 0.75).....	63
Table 5.7 Percentage change in fuel, West central Saskatchewan .....	67
Table 5.8 Percentage change in fuel, East central Saskatchewan.....	67
Table 5.9 Percentage change in labour cost, West central Saskatchewan.....	68

## LIST OF FIGURES

Figure 1.1 Distribution of Grain and Oilseed Farms.....	2
Figure 1.2 Concentration of Production, Grain and Oilseed Farms, 1998.....	3
Figure 3.1 Sales Income per Acre.....	26
Figure 3.2 Net Income per Acre.....	27
Figure 3.3 Total Expense per Acre.....	27
Figure 3.4 Total Wage per Acre.....	28
Figure 3.5 Fertilizer Expense per Acre.....	29
Figure 3.6 Herbicide Expense per Acre.....	29
Figure 3.7 Fuel Expense per Acre.....	30
Figure 3.8 Repair and Maintenance Expense per Acre.....	31
Figure 3.9 Machinery Assets per Acre.....	31
Figure 4.1 Yield of Wheat, Durum and Flax at Saskatoon.....	47
Figure 5.1 Machinery cost per acre, West central Region Saskatchewan.....	56
Figure 5.2 Minimum total combine cost for class 5, 7 and 8.....	56
Figure 5.3 Machinery cost per acre, East central Saskatchewan.....	61
Figure 5.4 Total Rotational Expense per Acre, West central Saskatchewan.....	65
Figure 5.5 Total Rotational Expense per Acre, East central Saskatchewan.....	66

# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 Background**

Crop production in Saskatchewan is vulnerable to unpredictable climatic conditions and variability in global market conditions. For these reasons, the farming sector in Saskatchewan faces numerous challenges. For instance, a lack of moisture combined with hot, dry and windy summers often lead to poor growing conditions and low yields. As well, a booming oil industry in the neighboring province of Alberta has caused a labour shortage, which adversely affects farm businesses in Saskatchewan.

The face of Saskatchewan agriculture continues to change. Since the 1940s, the number of farms in Saskatchewan and Canada has been declining (Statistic Canada, 2001). Although agriculture's share of the economy has declined steadily for the last few decades, Saskatchewan continues to represent an important element of Canadian agriculture. For example, in 2004, 20.5 percent of Canada's 246,923 farms were located in Saskatchewan. According to statistics from the 2001 Canadian Census of Agriculture, while the number of farms operating in Canada continues to decline, they are producing more output (Census Stat Fact, 2001).

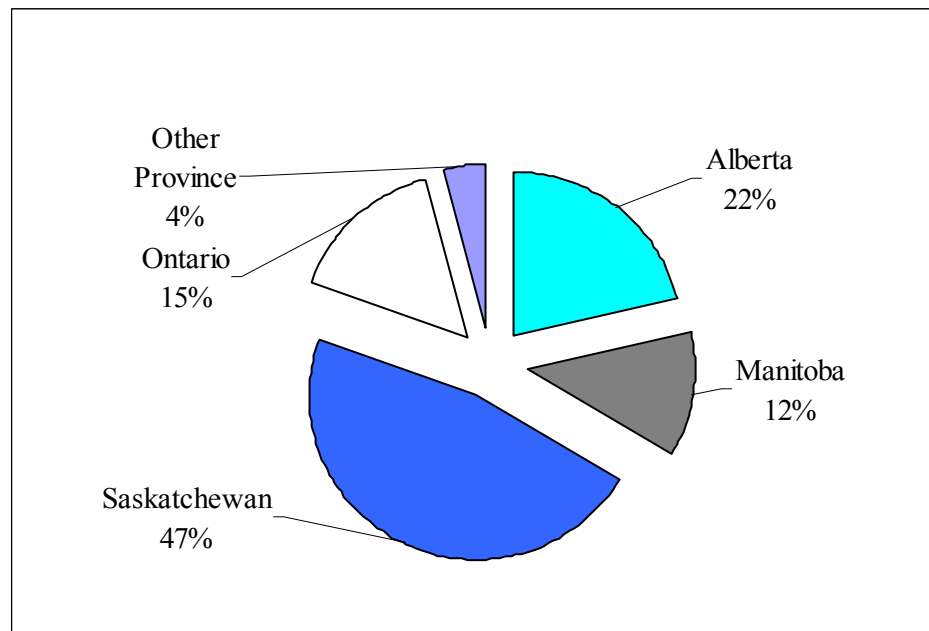
Grain and oilseed farms represent an important component of Saskatchewan agriculture. This can be seen from the number of farms in the province which produce grains and oilseeds (Census Stat Facts, 2001). Even as the number of the farms has been declining rapidly, Saskatchewan still has the highest concentration of grain and

oilseed farms of any province (Table 1.1). In 1998, about half of the grain and oilseed farms with revenue of \$10,000 or more were located in Saskatchewan, accounting for approximately 47% of total grain and oilseed farms nationally (Figure 1.1).

**Table 1.1** Number and size of farms in Saskatchewan

Year	1931	1941	1951	1961	1971	1981	1991	2001
Grain and oilseed farms	136,472	138,713	112,018	93,924	76,970	67,318	60,840	32,774
Average farm land (acres)	408	432	550	686	845	974	1,091	1,283

Source: Statistics Canada Census of Agriculture 2001.

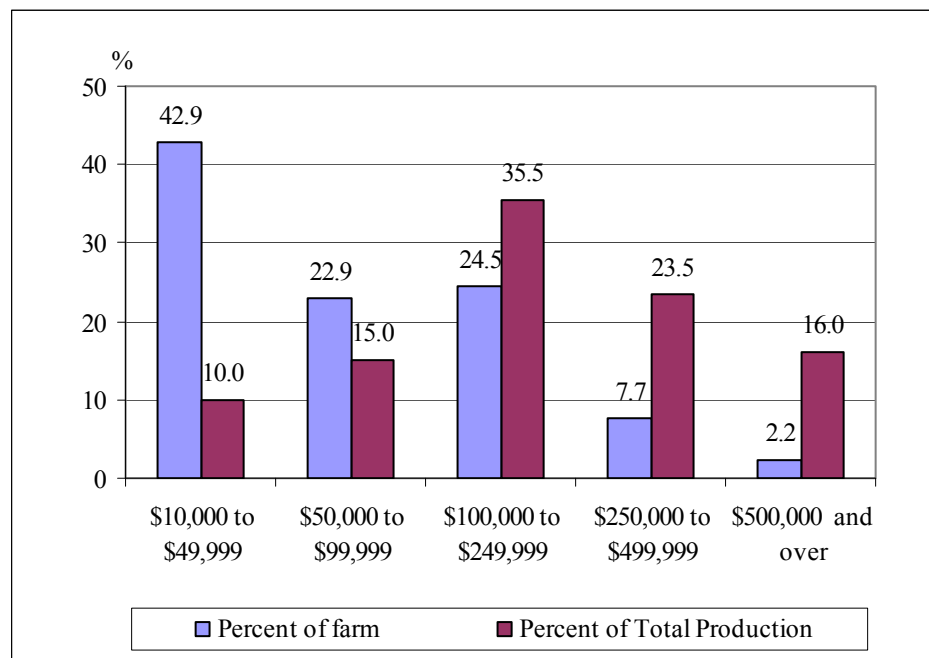


Source: Statistics Canada, Whole Farm Data Base, 2002

**Figure 1.1** Distribution of Grain and Oilseed Farms With Revenue of \$10,000 or

More

The size of farms in Saskatchewan increased during the second half of the 20th century (Table 1.1). For instance, in Saskatchewan, the average farm size has grown from 1,091 acres in 1991 to 1,283 acres in 2001, increasing by almost 212 acres in 5 years (Table 1.1). In addition, the share of large sized farms with revenues of \$100,000 to \$249,999 has remained relatively steady throughout the 1990s, accounting for around one third of total production by grain and oilseed farms (Agriculture and Agri-Food Canada, 2001). The share of production by very large farms with revenues of \$500,000 or more is 16.0% and only 2.2% of grain farms in Canada belong to the very large farm category in 1998 (Figure 1.2). Grain and Oilseed production is becoming heavily concentrated on farms with revenue of \$100,000 or more.



Source: Statistics Canada, Whole Farm Data Base, 2002

**Figure 1.2** Concentrations of Production, Grain and Oilseed Farms, Canada 1998

## **1.2 Problem Statement**

Grain and oilseed farm size has changed rapidly in recent years in Saskatchewan. With changing farm size, large grain and oilseed farms are acquiring larger more complex machines in their operations. Related to the size trend, there are comparatively few recent studies that address issues related to economies of size (EOS) and machine costs in farm production. Although some studies have been completed, they have usually studied all sizes of farm operations. In reality, farm production cost economies of large grain and oilseed farms has been a relatively unstudied topic in Saskatchewan.

Farm size is an important factor for production efficiency when it comes to commodity based agriculture. Theoretically, high profit crop farms are consistently bigger than low profit crop farms due to the bigger sized farms taking advantage of economies of size and spreading fixed costs over a larger farm area. Very large farms may also get discounts on the purchase price of machinery investments. As well these very large farms may also be able to capture discounts on variable costs like fuel, fertilizer, chemicals and transportation costs. Even within the group of very large farms, there are considerable differences in financial outcomes. The data from Statistic Canada demonstrates a significant difference in expenditures per dollar of sales for very large sized crop farms between the top 20% and bottom 20% (Statistics Canada, 2005).

As related above, the size of crop farms have been growing rapidly in Saskatchewan, not all of these larger farms have been successful and sometimes large farms get into financial problems or decide to exit agriculture. This increasing size trend raises an important question: does farm size matter for economic efficiency? In order to study economic efficiency connected with farm size, components of farm costs must be taken into account.

Issues related to size of economies deal with the relationship between production costs and size. There are several interrelated questions which relate to farm size and costs. These questions include: what operating and investment costs per acre are decreasing, increasing and staying the same as a result of growing farm size? Do large crop farms use machinery more efficiently? How does available field workday affect least-cost machinery size? This study will address these issues for Saskatchewan crop farms. Answering these questions would provide farm policy makers with useful information for the future development of farm policy.

### **1.3 Hypothesis**

The hypothesis of this study is that larger crop farms differ from smaller farms with respect to economies of size.

### **1.4 Objective of the Study**

The primary objective of this study is to analyse issues related to size economies in larger crop farms in Saskatchewan. More specifically, the objectives of this study are:

1. Examine several different farm operating and investment costs and state whether they are decreasing or staying the same as a result of increasing the farm size.
2. Estimate the probabilities of spring and fall field workdays for crop farms in the east central and west central areas of Saskatchewan.
3. Identify and compare optimal combine capacity for large crop farms in the west central and east central areas.
4. Calculate the effect of harvest machinery size and investment on large crop farm production costs.

### **1.5 Organization of the Thesis**

The study has six chapters. A review of the literature related to economies of size as well as the major issues involved in the estimation of least-cost size of machinery is presented in chapter two. Chapter 3 presents farm financial survey and data sources used. Also, the summary of managers of large crop farms interviewed is described in this chapter. Techniques for determining probabilities of field workdays, optimal size of machinery and the farm operation and investment costs is discussed in chapter 4. Chapter five presents the results for field workdays in the west central and the east central areas as well as results for machinery efficiency and comparison of large farms. The final chapter contains the summary and conclusion of the study. Possible further research areas and limitation of the study are provided in the final chapter.



## **CHAPTER 2**

### **LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK**

#### **2.1 A Review of Related Research**

This literature review focuses on three subjects related to the research questions. The first section reviews studies dealing with farm economies of size. Studies presenting analytical models for estimating the optimal size of farm machinery are reviewed next. Finally, studies providing methodological guidance on how to measure available field workdays at the farm level and provide methodological guidance are reviewed.

##### **2.1.1 Studies Dealing with Farm Size and Economies of Size**

Numerous studies employing a variety of techniques and methods have been undertaken to obtain information on size and scale economies for various industries. In general, several methods are commonly cited: descriptive analysis, economic engineering, average function analysis and frontier function analysis (Ker and Howard, 1993). For the agricultural sector, there are several studies on farm economies of size carried out in the 1990s mostly using an average functional approach or frontier function approach to model economies of size and scale. Although most of the early studies deal with general farming, with regard to the relationship between economic efficiency and crop farm sizes, a review of these studies is still important in order to provide a framework for establishing appropriate methodology and concepts.

Kumbhakar (1993) studied the effects of returns to scale, farm-size and economic efficiency of Utah dairy farms using a generalized production function and concluded that large farms are relatively more efficient than small and medium-sized farms. He argued that the growth of large farms may be explained in terms of economic efficiency. In addition, small farms are less efficient than medium and large-sized farms and large farms can deal with a decrease in output price or an increase in input price better than smaller-sized farms. This is consistent with early research work that demonstrated that optimum size differs between farms depending on the stock of labour, capital and management possessed in each farm (Heady, 1958), and existing family farms economies of size soon give away to diseconomies (Hall and Leveen, 1978).

Aly et al. (1987) estimated a deterministic statistical production frontier function for a sample of Illinois crop farms. They found that larger farms tend to be more technically efficient than smaller farms, Conversely Byrnes et al. (1987) examined grain farm efficiency in the same region and revealed larger farms in the sample to be slightly less technically efficient than smaller grain farms. Finally, Garcia et al. (1982) studied the relationship between technical efficiency in the same region and farm size. They found that smaller farms in their sample were as economically efficient as large farms. The major conclusion that can be carried out from reviewing these studies is the lack of clear evidence on both the level of average technical efficiency of crop farms and the relationship between technical efficiency and farm

size. This mixed empirical result can be the result of temporal events such as weather, which could significantly change the estimated efficiency from one year to another.

Kalaitzandonakes et al., (1992) analyzed the efficiency levels of a sample of Missouri grain farms by applying alternative frontier estimation procedures. In this study, the three different estimation approaches are found to significantly alter the levels of technical efficiency for each individual farm in the sample. They suggested that “mixed empirical evidence on the relationship between farm size and technical efficiency of grain farms found in recent literature is the result of variation in the estimation procedures employed” (p. 439). As well, their evidence supports that there is a positive relationship between farm size and technical efficiency, and an average larger farm can harvest more yield than smaller farms from a given amount of input.

### **2.1.2 Studies Dealing with Least-Cost Size of Farm Machinery**

Various studies have linked determining optimal size of machinery and how this optimal size of machinery is an essential contributor to farm efficiency. Some of this research has been recognized as vitally important to the current study. There are two significant studies on least-cost size of farm machinery referred to here, namely Brown and Schoney (1985) and Henning and Claus (2004).

Brown and Schoney studied proper machinery sizing for a given farm and found the least-cost combination of machinery taking into account fixed, variable and timeliness costs. In the study, they reviewed three different machinery size models and recommended the least-cost model can be a relatively simple model that

calculates the least-cost combination of machines for a given farm situation. They selected an 1800 acre grain farm in Saskatchewan and minimized the sum of fixed, variable and timeliness costs for the entire farm machinery complement.

Henning and Claus (2004) developed a system model to support the process of choosing the optimal level of farm mechanisation in terms of technical capability. “The optimisation model is a non-linear programming model implemented by using the programming software suite General Algebraic Modelling System”(p. 13). The model is based upon a least-cost concept involving all expected fixed and variable costs (including timeliness costs) for a particular farm size and crop plan. The output from the model is the sizing of each machine, and also the tractor power and number of tractors required. They have shown the effective work rates of the machinery sets and the duration in nominal time for performing each operation. The selection is based upon a farm-oriented matrix involving various types of constraints, such as available man-hours, available machine- and tractor-hours, timeliness and workability of operations, agronomic window of operations, and sequence of operations. The model was tested and verified for its operational behaviour using real farm data. They stated that although there are a variety of factors that can affect minimum machinery costs, operators always optimize farm machinery connected to these aspects. In real life, some of the actual machines are not optimally sized.

### **2.1.3 Studies Dealing with Field Workdays Estimation**

Field workdays are based on soil and weather conditions that indicate suitability of completing field work on a given day. The concept of a field workday has been an

important part of field work and machinery needs on an individual farm basis. There have been a number of significant studies on the field workability and tractability carried out in the last few decades. These studies mostly discuss the importance of soil workability for crop production, and review the limitations of a variety of models, especially their applicability for predicting the effects of climate change.

These field workability models can be classified into two different groups. Most researchers employ models that can calculate the number of spring or autumn workdays by combining meteorological and soil related factors. During the late 1960s and early 1970s several work-day models were formulated, which differ in their interpretation of workability from climatic variables and rely on various model inputs. Rounsevell (1993) concludes these were similar studies because precipitation was the overall controlling influence. The work of Amir et al. (1976) and Smith (1970, 1977) demonstrate the simplest of this category of models.

Amir et al. studied the probabilities of available field workdays using 40 years of recorded climatological data. First, they determined various types of calculated probabilities using observed data. Then results were tested by paired t-statistic tests to determine whether or not the observed and the calculated probabilities have the same mean. The result found that at the  $\alpha = 0.05$  level of significance that the two sets have the same mean for every month. The procedure described in this paper uses conditional probability equations derived from the Markov Chain method. However, this procedure is only as precise as the model from which it derives. Soil type and the model's suitability were completely ignored in this approach because only

precipitation data was used to determine field workdays. Therefore, the value of this model for estimating workability for a range of climates and soils is in doubt.

In Smith's (1977) model, land was divided into light medium and heavy soil textural classes, and for each class a set of empirical criteria were employed which determined the suitability of a spring day for working. The criteria considered only the amount of precipitation and occurrence of rainfall though different limits were imposed for each soil group. Although large errors were found in the prediction of field workdays, he attributed this result to soil variability within the simplified soil groupings and accepted that land at the boundary of a textural class would inevitably be subject to error.

Ruthledge and McHardy (1968) used a simplified version of the Versatile Soil Moisture Budget (VSMB) for estimating work and non-workday probabilities for seven stations in Alberta with light to heavy soils. They assumed a four inch soil moisture storage capacity distributed over the six zones of the VSMB. They recommended as criteria for non-workdays estimated soil moisture content in excess of 95% of field capacity in any of the three upper zones. However, the inclusion of three zones was justified only in medium or heavy soils. In sandy soils, only two zones warranted consideration.

Rounsevell (1993) presented a detailed review of previous work on soil workability and estimation of numbers of workdays for cultivation/tillage-type operations. The simplest models are based on precipitation alone, but most include some

consideration of soil, either as simple soil categories or as a complex consideration of soil strength. He revealed that some studies looked only at long-term average workability for broad soil categories or land types. Also, Rounsevell concluded that there is a reasonable consensus in favour of estimating workdays from some sort of soil water balance model, with the limiting water content for workability at or near field capacity.

Rounsevell and Jones (1993) discuss the distinction between workability and tractability. They define tractability as the capacity of soil to support and withstand traffic with negligible soil structural damage and no adverse effects on crop yield. They define workability as the condition in which soil tillage operations such as ploughing and seedbed preparation can be performed. In the case of seed-bed preparation conditions need to be suitable for the production of a friable land without smearing or compaction. They note that workability does not define a precise soil condition because this depends on the operation, operator, type and size of machine. Also soil type has a strong influence on the production of a friable tilth in seed-bed preparation.

McGechan and Cooper (1997) have presented an exploratory study of the role of a soil-water simulation model for the study of workdays for winter field operations in the current climate, particularly for the operation of field spreading of animal waste (slurry) in connection with waste management plans. In this case, as well as soil water content constraints, the incidences of snow and frozen soil were considered to avoid runoff pollutants to watercourses, either at the time or later when the thaw

occurred. This approach to modeling transport processes of water through the soil is more mechanistic than the simple soil-independent water balance with empirical adjustments for soils adopted by Rounsevell and Jones (1993).

Toro and Hansson (2004) studied an assessment of field machinery performance in variable weather conditions using discrete event simulation. A simulation model for field machinery operations was developed using a discrete event simulation technique in order to determine annual timeliness costs in a long-term assessment on cereal farms, with the results compared with a simpler approach. The experiment on spring seedbed preparation on a clay soil showed that “the date had only a minor effect on soil compaction but the fraction of fine aggregates increased with time” (p. 41). The fine aggregate is defined as containing a high proportion of particles passing a 5mm sieve. Thus, the optimal time for seedbed preparation depended more on soil friability than on the risks of compaction.

Although there have been numerous efforts to develop a methodology to determine available field workdays, there is still not a generally accepted method. The simulation model for field machinery operations developed using a discrete event simulation technique enabled timeliness costs and their annual variability to be estimated in a long-term assessment. In addition, the Toro and Hansson’s study revealed that the model is particularly appropriate for estimating timeliness costs for the harvesting operation in conditions of scattered field maturation times and probable overlapping of their ‘single harvesting periods’, where simpler approaches are difficult to apply.



From the Toro and Hansson's research, machinery sets with high daily effective field capacity not only resulted lower timeliness costs but also lower annual variation. Timeliness costs were more affected by a stepwise reduction in daily effective field capacity than a stepwise increase of the same magnitude. For given farming conditions and within certain limits of machinery capacity, there was not just one set identified as the 'least-cost' option. Instead, several sets performed at a similar low cost level. Higher specific machinery costs for the larger sets were offset by lower timeliness and labour costs, and the converse was equally true. The machinery set to be selected should be the largest set among those with a similar 'least-cost' on account of its lower annual variation, which usually implies lower risks.

## **2.2 Major Issues Involved in the Estimation of the Least-Cost Size of Machinery**

### **2.2.1 Amount of Work Required for Spring and Fall**

An important aspect of purchasing a new machine or tractor is making the decision on what size of a machine is needed. In order to optimise machinery selection, one needs to determine the amount of work required in spring and fall. This is one of the important parts of farm machinery planning. If the amount of work required for spring seeding and fall harvest could be determined with a reasonable degree of certainty, machinery selection would be much easier.

The amount of work required for the operation period can be approximated by using several key factors such as crop acres and yields. Crop acres to be planted are the main determining elements for amount of work required for spring. However,

combinations of crop yield and acres determine how much work has to be done for fall field work.

The number of acres that can be completed each day is more dependent on the measure of machinery capacity than machine width or acres completed per hour. In some cases, increasing the labour supply by hiring extra operators or by working longer hours during critical periods may be a relatively inexpensive way of extending machinery capacity. When the amount of work required for harvest can be anticipated to require more machinery and labour than the farm's capacity, farm operators have to decide whether or not to extend machine power capacity and to hire more labor or to hire custom work. The cost of additional labour or custom work only needs to be incurred in those years in which it is actually used, while the cost of investing in larger machinery becomes "locked in" (Edward and Hanna, 2001(a), pp. 2) as soon as the investment is made. On the other hand, extra labour and custom work may not always be available when needed, and working long hours over several days may reduce labour productivity.

### **2.2.2 Available Time of Field Operations**

Weather patterns partially determine the number of days suitable for field work in a given time period each year. Although actual weather conditions cannot be predicted far enough in advance to be used as an aid to machinery selection, past weather records can be used as a guide. Field workdays are usually expressed on a probability basis because of the randomness of weather. A 90% probability of a field workday can be interpreted as meaning that suitable field workdays could be expected in 9 out

of 10 days. Thus, machinery selection should be based on long-run weather patterns even though it results in excess machinery capacity in some years and insufficient capacity in others.

In addition, total time required for a field operation depends on the capacity of the machine and the number of available field workdays. Duration of field workdays can be different depending on the region's soil type and climate condition. For instance, wet soil and wet crop conditions require a special kind of field operation which may result in a delay of harvesting or an increase in operation cost.

The weather data of past years is obviously relevant, on the assumption that past weather statistics represent a population from which future years will show no significant deviation (Smith, 1970, p.18). But in some years weather can be unpredictable. For example, a rainy and cold summer could cause a delayed harvest. There are some options to deal with a shorten duration of field operations. Working over time can be one of these options if several operators are available. In addition, night-time operations have always been done when weather, soil and crop condition are favorable (Bowers, 1987, p. 121). Modern farm machinery equipped with GPS helps to facilitate the farm operator's duties. For instance wide tillage and seeding machines can be accurately steered without the sighting problems associated with darkness (Hunt, 2001, p. 276).

Profitable farming operations require strict control of production costs. One approach to production cost control is purchasing replacement machinery just large enough to

complete the required work in the time available. Owning extra machinery capacity is an added expense, but planting and harvesting delays can also be costly. Presently, farmers who can produce their product with lower cost survive in the competitive market. Cost conscious farmers will choose the size of their farm machinery based on the number of acres to be covered and the number of suitable days to do the required work. Unfortunately there are large fluctuations in the number of suitable field workdays from year to year. Thus, farmers must be aware to determine field workdays and use an appropriate method for a certain region to evaluate available field workdays.

### **2.2.3 Machinery Fixed and Variable Costs**

Owning and operating machinery remains one of the largest costs in crop production. Since the price received for agricultural produce has been stable or declining for a number of years at least in real terms, producers continue to pursue lower cost and more efficient production systems (Kay et al., 2004, p.398). The development or selection of optimal machinery systems can help reduce costs while providing timely field operations that optimize the yield and quality of crops produced. Machinery is costly to own and operate. Today, a single farm machine may cost several hundred thousand dollars. Farmers must be cautious of making decisions connected with owning machinery.

Machinery costs include costs of ownership and operation as well as penalties for lack of timeliness. Ownership costs tend to be independent of the amount a machine is used and are often called fixed or overhead costs. Per hectare ownership costs vary

inversely with the amount of annual use of a machine. Therefore, a certain minimum amount of work must be available to justify purchase of a machine and, the more work available, the larger the ownership costs that can be economically justified. Conversely, operating costs or variable cost increase by the amount the machine is used. Total machine costs are the sum of the fixed and variable costs. Total machine costs can be calculated on an annual, hourly, or per acre basis (Hunt, 1987, p.63). Total per acre cost is calculated by dividing the total annual cost by the area covered by the machine during the year.

A custom cost is the price paid for hiring an operator and equipment to perform a given task. A farm operator can compare total per acre costs to custom costs to determine whether it would be better to purchase a machine or to hire the equipment and an operator to accomplish a given task.

#### **2.2.4 Impact of Timeliness on the Farm Operation**

There is an optimum time of the year to perform some field operations and economic penalties are incurred if the operations are performed too early or too late. When harvesting a crop, for example, increasing fractions of the yield may be lost and/or the crop quality may be reduced if the harvest is started too early or delayed beyond the optimum time.

Timeliness costs include lower yields due to delayed planting and harvest date. In addition, fluctuations in the number and sequence of suitable field workdays from year to year cause timeliness costs to vary even when the machinery set, number of

crop acres and labour supply do not change (Hunt, 2001, p. 274). Investing in larger machinery can reduce the variability of timeliness costs by ensuring that crops are planted and harvested on time even in years in which there are few good working days. However, machinery fixed costs would be higher with larger machinery. Some farmers may be willing to pay more (in higher fixed machinery costs) than other operators for the insurance of not suffering substantial yield losses due to late planting and harvesting in certain years.

## **CHAPTER 3**

### **FARM FINANCIAL SURVEY AND DATA SOURCES**

This chapter presents results of the preliminary survey and analysis of production costs for crop farms in Saskatchewan. The first section presents a description of the preliminary survey including major results. This is followed by the graphical analysis of production costs for crop farms in Saskatchewan.

#### **3.1 Preliminary Survey**

##### **3.1.1 Survey Description**

Saskatchewan crop farms have been getting larger for several decades. There have always been outliers of a few extremely large farms. Given current profit margins, crop farms are becoming significantly larger. The traditional notion of the benefits of increased size is the reduction of machinery fixed costs. Very large farms may also get volume discounts on the purchase price of machinery. In addition these very large farms may also be able to capture discounts on variable costs like fuel, fertilizer, chemicals and trucking fees. Not all of these very large farms have been successful and the media have made it a major event when one or two get into financial problems or decide to exit agriculture (Maynard, April 13, 2006).

As part of this research, 13 large crop farms were visited in the west and east central regions of Saskatchewan. The purpose was to discuss economies of size issues with the owners of these businesses and to discover the major challenges facing very large crop farms in Saskatchewan. The producers interviewed were selected by soliciting their names from various sources known with the Department of Agricultural

Economics at the University of Saskatchewan and therefore the sample was not random. The questions asked dealt with machinery, building investments and purchases of fuel, fertilizer, and chemicals.

### **3.1.2 Summary of Survey Results**

The discussion indicated that most farmers interviewed felt that their yield per acre was higher than smaller farms in the area. Factors mentioned that influenced these higher yields were soil type and input use. Except for one, all farms interviewed had soil types of clay or clay loam.

Another important factor was the availability of the good quality land to rent. On average 70% of the land farmed by the interviewees was rented and all on cash rent basis. The farmers interviewed frequently receive land renting and selling requests from small and medium sized farms which help them to make better land selection and to settle the rental rate efficiently. Renting better quality land gives them a better chance for higher yields. Moreover, the amount and types of inputs per production unit for those interviewed appears to be significantly higher than typical farms as shown in SAF's crop planning guide (SAF, 2006).

Those interviewed generally felt that their yields were higher than others because of more efficient use of equipment and inputs. In addition, those interviewed felt they get more discounts on input purchases and more services from input dealers. The participants farmed between 12,000 and 23,000 acres, and an average combine's capacity was between 4,000 and 5,000 acres annually. Most of those interviewed



stated that they decide how many acres to rent on the capacity of their machinery. That is to say, first the farmers make a decision related to machinery sizing, and then they rent the necessary land. This planning strategy assists those interviewed to use their machinery more efficiently.

The farmers in the survey generally agreed that they receive some discounts on certain input purchases because of their size of operation. These discounts ranged from 5 to 20% for fuel and 1 to 5% for fertilizer and chemicals. Those interviewed also said they save on delivery costs and time and labour costs related to the purchasing activity. In addition, there are some consulting services that come with large chemical purchases that help to determine the optimal use of chemicals.

All but one of those interviewed used the same brand of farm machinery. Only three leased most of their machinery, the rest purchased it. Most traded in by three years, thereby most of the machines on the farms were under warranty. All those interviewed stated that timeliness of operations is crucial and reducing down time due to equipment repairs was important. Most of those interviewed said that typically a combine could harvest 4,000 to 5,000 acres per year in the west central region and 2000 to 4000 acres in the east central region. In addition, some of those interviewed use custom hired combines during the harvest time if it becomes necessary.

The biggest issue is the shortage of available and affordable labour. In the west central region, most young people go to Alberta and work in the oil and gas industry. Also, farmers usually prefer seasonal workers to permanent positions which provides

a problem for young people who look for permanent work. Those interviewed pay \$12 to \$18 an hour compared to the oil industry which pays a minimum \$20 an hour. The main source of labour in the west central region is retired farmers, above 50 years old. Benefits of hiring these types of people are that they are more experienced and skilled but usually do not want to work long hours. However, in the east central region, the farmers can still employ relatively younger workers.

Lastly, there are some common facts observed during the survey. In order to mitigate time constraints, the farmers interviewed work long hours, use grain dryers and more equipment and new technology. Especially during the spring seeding period, all those interviewed stated that it is very common to operate 20 to 24 hours per day. In the east central region all those interviewed farmers had a grain dryer. In addition, those interviewed stated that blending crops helps to increase prices.

According to those interviewees, when farms get bigger, they operate larger land and harvest bigger amount of crops than smaller farms and due to weather condition and soil types, sometimes quality of crops can be different. In this case, it is better to mix high grade crop with lower grade same crop in order to obtain higher average price per production unit.

### **3.2 Data Sources**

Three different sources of data were used in this study. The data used in the field work estimations were obtained from the National Climate Data and Information Archive, operated by Environmental Canada. Direct access to climate and weather

values in various locations in Canada is available at climate data online. For crop production, seeding operations are usually in April and May and harvest is usually August through October. Thus, the weather data includes the daily mean temperature and precipitation records for April to May and August through September for the period of 1980 to 2005 for east and west central Saskatchewan.

Secondly, the data used in the machinery costs was taken from the Saskatchewan Custom Rate Guide and Crop Planning Guide, 2005 (SAF, 2006). The information from the interviewees helped to set the average time period for spring seeding and fall harvesting, combine annual hours and the hourly wage rate.

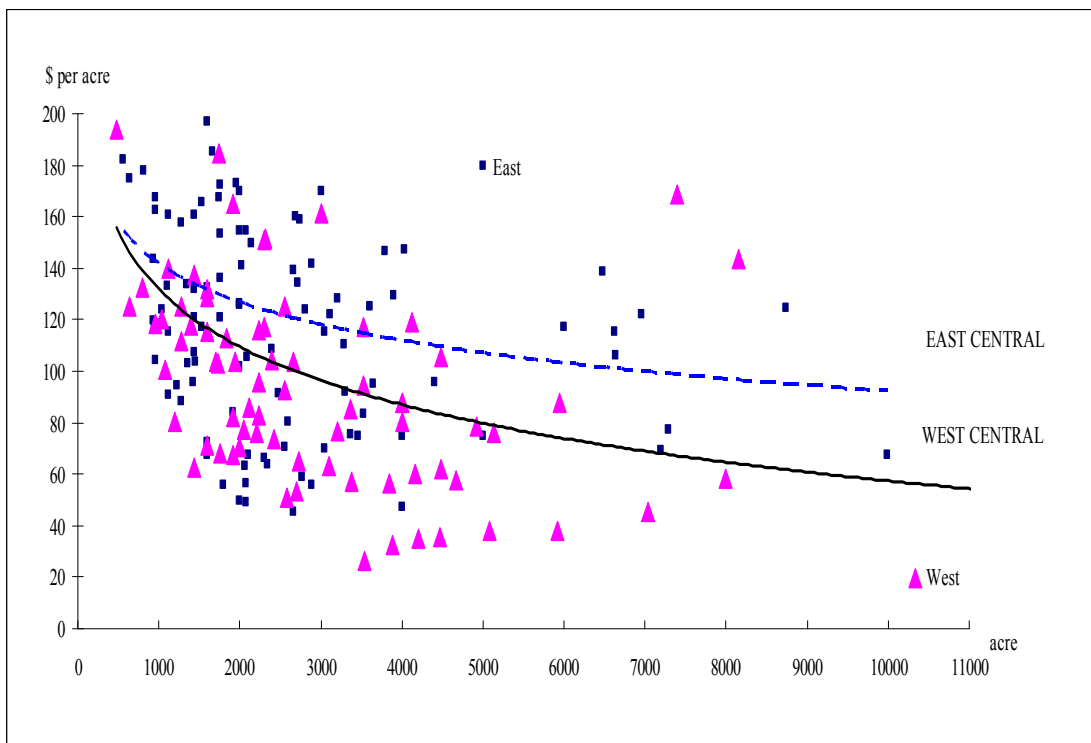
### **3.3 An Analysis of Production Costs for Crop Farms in West and East Central Saskatchewan**

This section examined how the components of production costs react with the increasing size of crop farms. The relationship between farm size and total expense per acre is displayed by a scatter plot in Figure 3.1. The farm size was measured by cropped acres. The farm financial survey data did not distinguish what type of crops each farm grows. Therefore, results explained in this section only shows the general trend of farm cost by size.

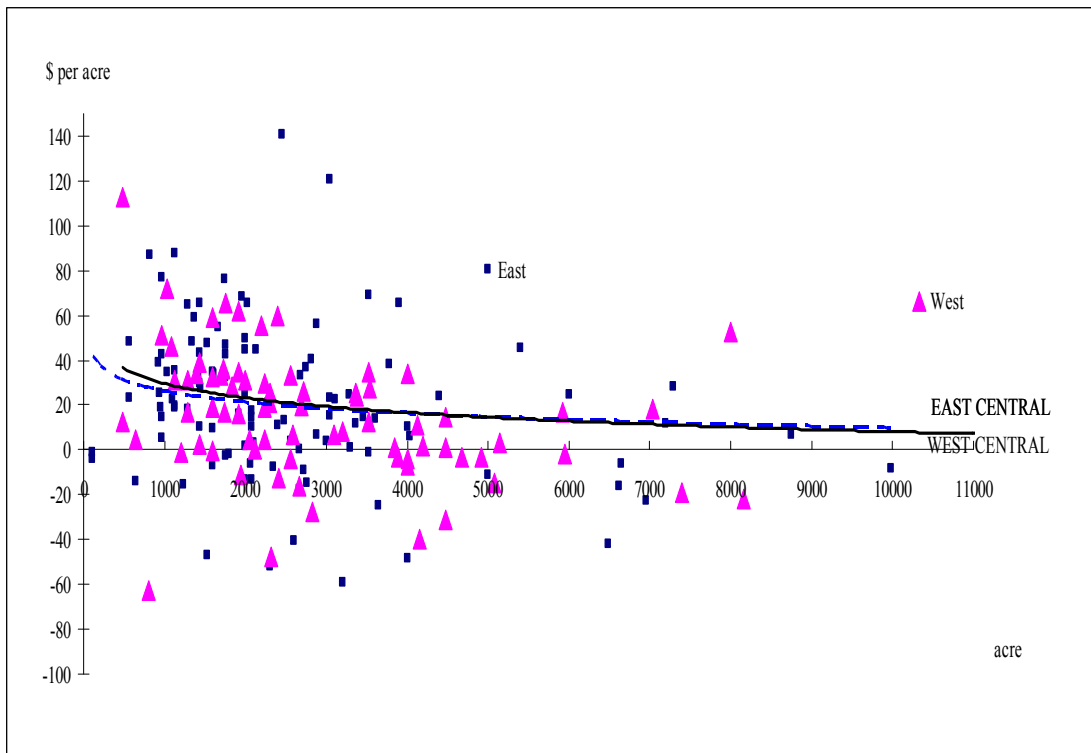
In the analysis, farms with over \$100,000 annual sales were examined. To see a better picture of farm economies of size, major components of farm production cost were evaluated separately for the both areas (Appendix 1 - 2).

Sales income per acre for both areas were decreasing with the increasing size of farm (Figure 3.1). However, sales income per acre in west central Saskatchewan was relatively lower than crop farms in the east central Saskatchewan, farm net income per acre for both areas were the same (Figure 3.2) due to yield differences.

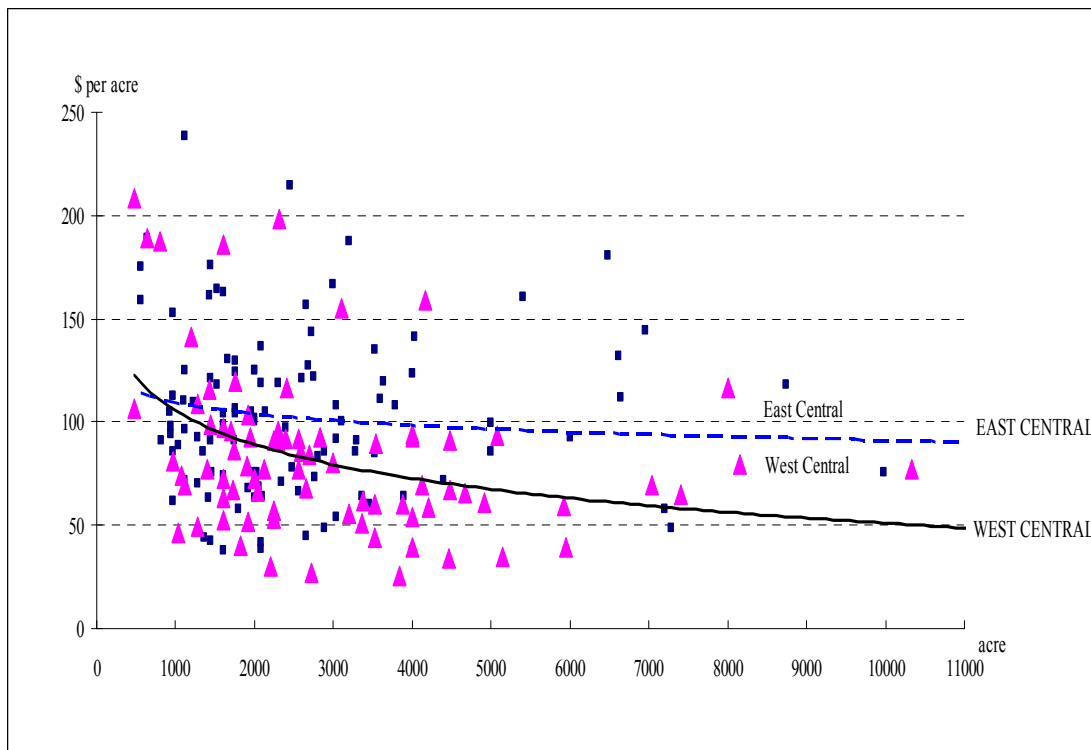
With the increasing farm size the total expense per acre decreases slightly for both regions. From Figure 3.3, the reduction of total cost per acre is comparatively higher for the farms with crop acres up to 6,000 acres and shows constant minor decline farms operate above 6,000 acres for the west central area. On the other side, the increasing farm size reduces total expense per acre slightly lower for the east central area than the west (Figure 3.3).



**Figure 3.1** Sales Income per Acre

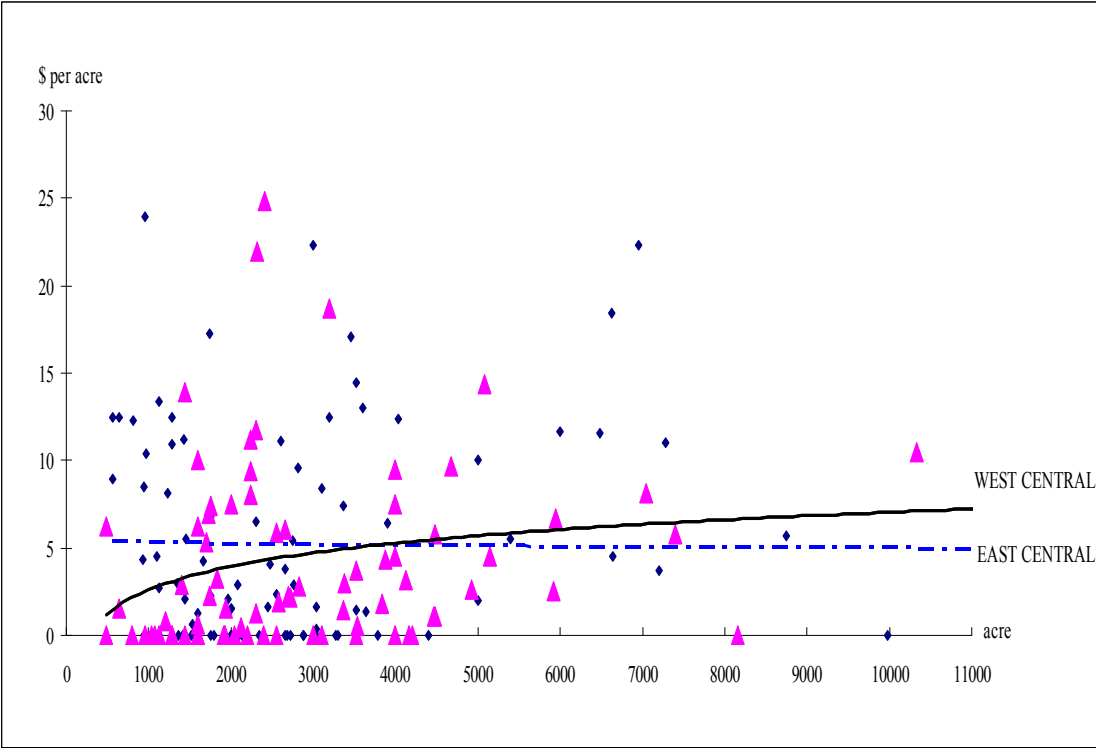


**Figure 3.2** Net Income per Acre

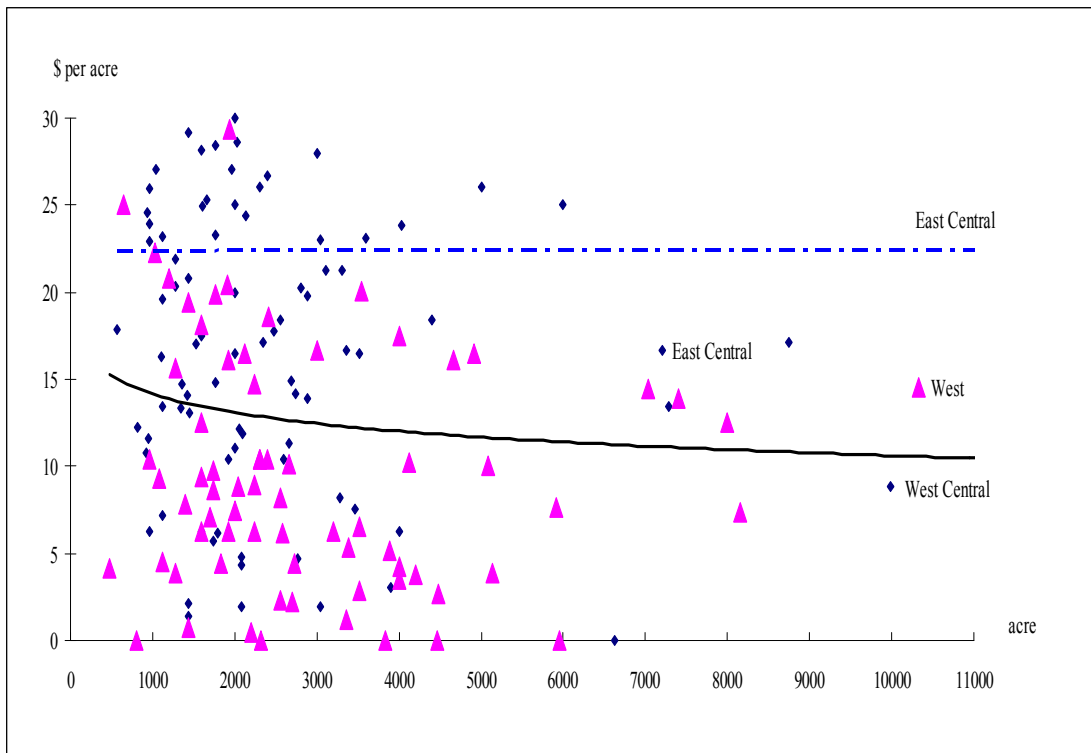


**Figure 3.3** Total expenses per acre

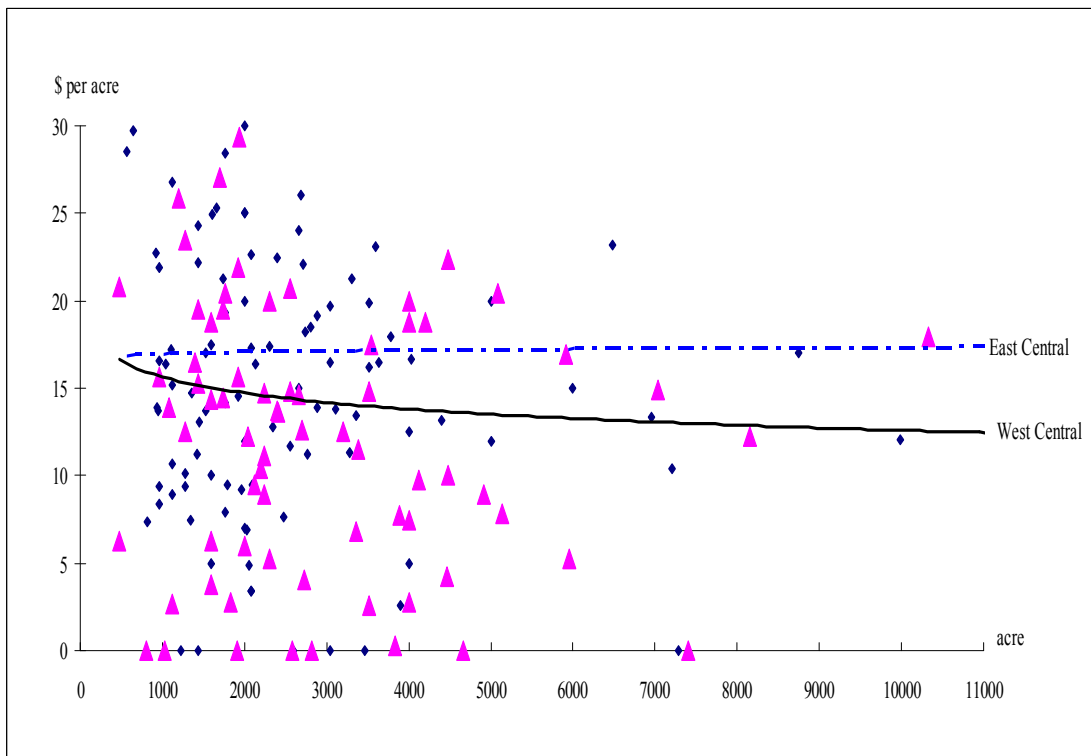
In addition, farm production cost components are showing a certain tendency such as increasing, decreasing and constant trends as a result of increasing farm size. For instance, total wage expense per acre increases as crop area increases for farms in the west and shows relatively constant trend for farms in the east central Saskatchewan (Figure 3.4). For herbicide and fertilizer, there are some decreasing trend for farms in the west central Saskatchewan and shows constant trend for the east central because of weather condition and soil texture (Figure 3.5 and 3.6). There is no change in fertilizer expense per dollar sale for the east central area.



**Figure 3.4** Total wage per acre



**Figure 3.5** Fertilizer expense per acre

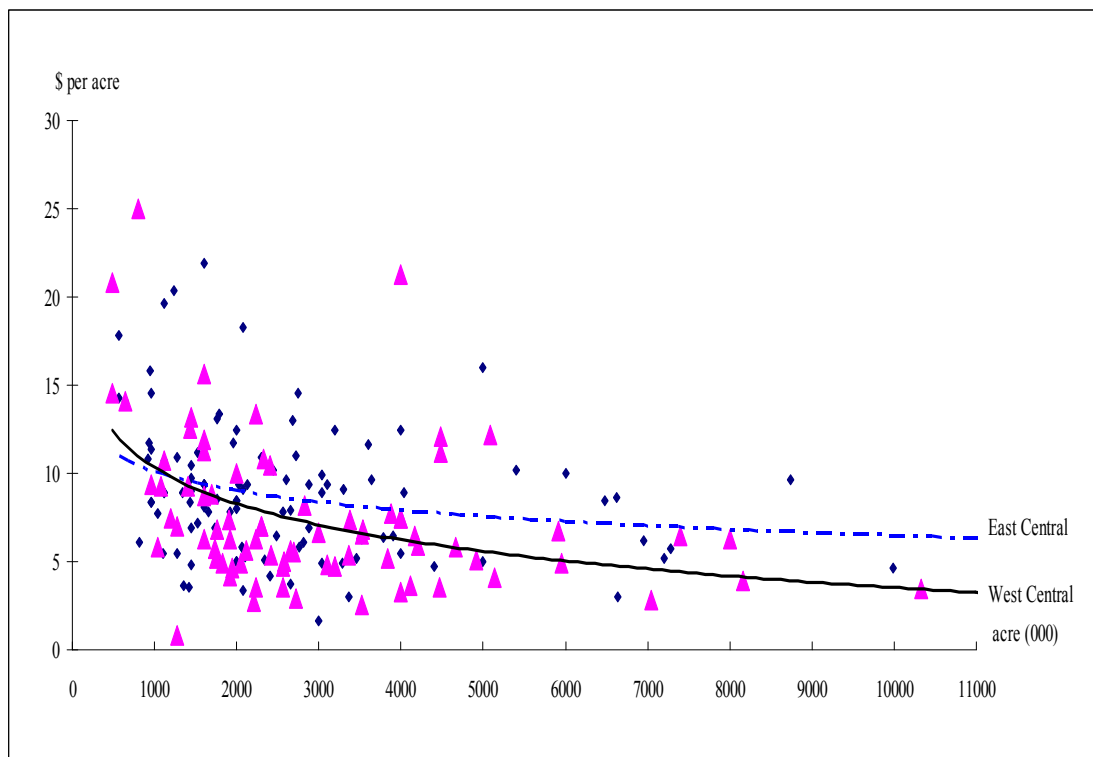


**Figure 3.6** Herbicide expense per acre

Although some expenses have direct relationships with crop acres, there are some expenses which decrease with the increase of crop acres for the selected areas.

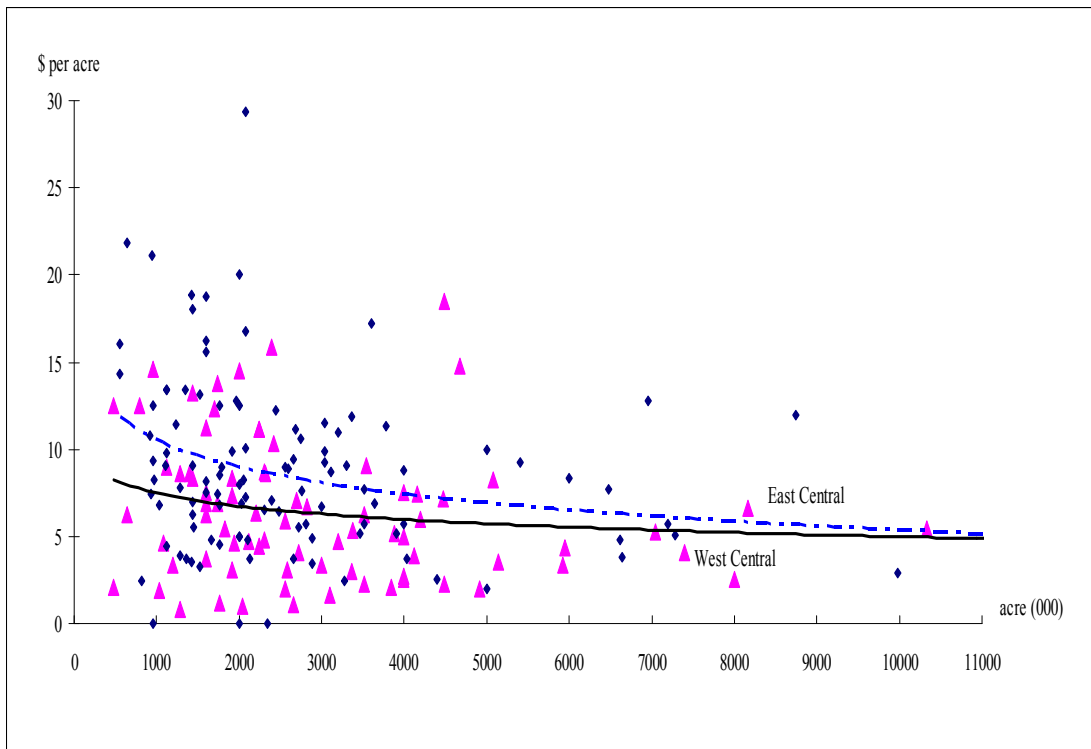
Because of large percentage share of fuel and repair expenses on total cost, overall expenses per acre decrease slightly when farms grow larger. Figure 3.7 and 3.8 show east and west central's fuel and repair costs. For the selected areas, shares of repair and fuel expenses on per acre show same trend. The reduction of fuel expense is much higher for farms with up to 6,000 crop acres.

Figure 3.9 shows the relationship between farm size and machinery assets. For the regions' machinery assets on a per acre basis show relatively constant trend as crop acres increase.

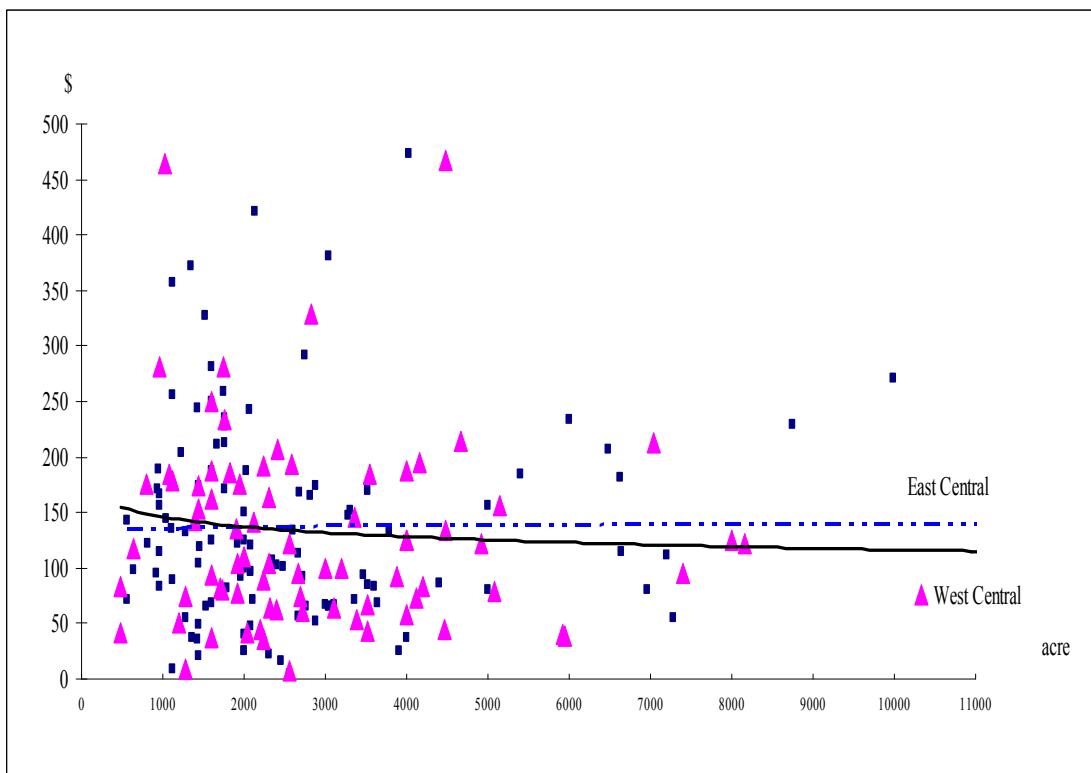


**Figure 3.7** Fuel expense per acre





**Figure 3.8** Repair expense per acre



**Figure 3.9** Machinery assets per acre

## **CHAPTER 4.**

### **ANALYTICAL FRAMEWORK**

This chapter presents the framework for the analysis of the crop farms in Saskatchewan. The first section presents a description of the field workday model including major criteria and general procedure of suitable workdays. This is followed by the discussion of the Least-Cost approach to determine optimal size of farm machinery.

#### **4.1 Determination of Daily Field Workability**

Machinery selection would be much easier if the number of available workdays could be estimated with a reasonable degree of certainty. In many areas of Canada the most critical limiting factor is the lack of field tractability at the time when either spring planting and harvesting must be done (Dyer, 1980). The limited numbers of field workdays can make the effective growing season shorter than the frost free period would indicate. The expected number of workdays during a critical period, such as harvest time, largely may determine the size of machinery needed for a given size farm. For instance, larger or more efficient combines may be needed to complete a harvest when work time is limited.

In spring and fall poor field work conditions occur immediately after a heavy rain and a temperature below 0 degrees Celsius. The number of non-workdays following rain varies with the amount of rainfall and the type of soil, since both factors influence the time for excess soil water to drain through the top layer of soil. These two factors are

important for determining a field workday. In general, a field workday can be defined as a day with no snow cover or amount of daily evaporation is more than daily rainfall. This definition assumes that different criteria apply to different field operations.

#### **4.1.1 The Selection of the Field Workday Model**

A variety of models have been previously developed to evaluate a suitable field workday. After reviewing soil workability models, transitional probability equations derived from the Markov Chain method has been selected to estimate expected field workdays. Although, the Markov Chain method oversimplifies the real conditions in the field in this procedure, it can be useful to approximate the probability of the field days. For most of the cases, some additional factors, operator time and machinery availability, affect the decision of whether or not to operate machinery in a particular field. Unfortunately, accurate information is currently not available for describing the effects of these factors on field workdays in the study areas. Thus the only factors used for this thesis is the tractability of soil with regard to its moisture level and soil type.

#### **4.1.2 Major Criteria for Soil Tractability and Field Workdays**

The interaction between rainfall, evapotranspiration and soil moisture influences soil tractability and determines the number of workdays for a specific soil, limiting time for seeding and harvesting (Pote et al., 1997). In order to determine available field work time, one needs to know which day is suitable for field work and what criteria is used to determine a day is workable. This estimation only takes into account daily precipitation and temperature due to lack of important soil moisture data.

For this paper, a day is assumed to be suitable for fall and spring field work if one of the following criteria is met:

- 1) Daily precipitation is less than 2.5 mm

Such criterion is justified in areas where the average rate of evaporation exceeds 2.5 mm. When a daily rainfall of less than 2.5 mm occurs, it generally evaporates during the day and thus can be defined as a suitable field workday (Amir et al., 1976).

- 2) Max air temperature was above 0 degrees Centigrade

A soil is assumed to be intractable, when temperature falls below 0 degrees Centigrade. Above 0 degrees Centigrade, farm machines can work on soil to satisfactorily perform the function of the machine, without causing significant damage to the crop yield or quality.

3. A day is suitable for field work if the previous two or more consecutive rainy days' daily precipitation does not exceed 2.5 mm (Ayres, 1975)

When two or more consecutive rainy days' daily precipitation is greater than or equal to 2.5 mm, then these rainy days including the next non rainy day are counted as unsuitable for field operations.

### **4.1.3 A Procedure for Determining Probabilities of Spring and Fall Field Workdays**

The procedure described in this part uses conditional probability equations derived from the Markov Chain method. In mathematics, a Markov chain is a discrete-time stochastic process with Markov property (Shiryayev, 1996). A Markov chain is a series of states of a system that has the Markov property. At each time the system may have changed from the state it was in the moment before, or may have stayed in the same state. The changes of state are called transitions. The series with the Markov property is such that the conditional probability distribution of the state in the future, given the state of the process currently and in the past, is the same distribution as one given only in the current state (Shiryayev, 1996). Markov Chain principles previously had been applied for determining field workday and non workday probabilities using observed data for many locations in North America (Ayres, 1975).

The purpose of this section is to provide an applicable procedure for determining the probabilities of field workdays when only observed data is available and verify the resulting calculated probabilities for two locations in Saskatchewan, namely the Kindersley and Yorkton. When daily weather data is available, the observed probabilities of “n” ( $n = 1, \dots, i$ ) consecutive field workdays can be estimated by using a simple probability equation. Then based on the observed probabilities, it is possible to come up with the calculated field workday probabilities.

The basic probability equation for determining “n” consecutive field workdays or non-workdays is:

$$P [ nS ] = P [ S ] P [ S / S ]( n - 1 ) \dots\dots\dots(4.1)$$

where:

$P[nS]$  - probability of “ $n$ ” consecutive  $S$  days;

$n$  - integer, express number of consecutive days,  $n \geq 1$ ;

$S$  - a field workday;

$P[S]$  - probability of a single  $S$  day;

$P[S/S]$  - conditional probability of a single  $S$  day given the previous day was also  $S$ .

In probability theory and statistics, the exponential distributions are a class of continuous probability distributions. They are often used to model the time between independent events that happen at a constant average rate (Shiryayev 1996). For practical purposes, equation 4.1 has been converted into following equation (Amir, 1977).

$$P_i [ nS ] = \alpha e^{-\beta n}; n \geq 1 \dots\dots\dots (4.2)$$

where  $\alpha$  and  $\beta$  are constants to be determined for local data.

The conversion of equation (4.1) to equation (4.2) can be accomplished by (Hastie et al., 2001):

$$P_i [ S ] = \alpha e^{-\beta} \dots\dots\dots (4.3)$$

$$P_i [ S / S ] = e^{-\beta} \dots\dots\dots (4.4)$$

Probability of one consecutive field (n = 1) day can be found by equation 4.3. Since the main model is given by the equation (4.2), sum of squares of deviations between the observed probability (p<sub>i</sub>) and the predicted probability (P<sub>i</sub>) given by the equation (4.2) is:

$$R = \sum (p_i - P_i)^2 = \sum (p_i - \alpha e^{\beta n})^2 \dots\dots\dots (4.5)$$

Differentiating this with respect to α and β and equating to zero gives

$$\frac{\partial R}{\partial \alpha} = -2 \sum p_i e^{\beta n} + 2 \alpha \sum e^{2\beta n} = 0 \dots\dots\dots (4.6)$$

$$\frac{\partial R}{\partial \beta} = -2 \alpha \sum n_i p_i e^{\beta n_i} + 2 \alpha^2 \sum n_i e^{2\beta n_i} = 0 \dots\dots\dots (4.7)$$

whence there are the two simultaneous equations in the unknowns α and β.

$$\sum p_i e^{\beta n_i} = \sum \alpha e^{2\beta n_i} \dots\dots\dots (4.8)$$

$$\sum n_i p_i e^{\beta n_i} = \sum 2 \alpha^2 n_i e^{2\beta n_i} \dots\dots\dots (4.9)$$

An exact solution can only be approximated by a tedious iterative procedure. An alternative approach is to take logarithms of the equation (4.2):

$$\log P_i [nS] = \log \alpha + \beta n_i \dots\dots\dots (4.10)$$

and obtain a least square solution for log α and β by minimizing in the usual way.

$$R = \sum \log p_i - \log P_i \dots\dots\dots (4.11)$$

In addition,  $n$  consecutive field workdays observed probabilities ( $p_i(nS)$ ) can be estimated by dividing the frequencies of  $n$  consecutive field workdays for  $i^{\text{th}}$  month by total number of days available follows:

$$p_i[nD] = \frac{F_i[nD]}{M_i \cdot \frac{y}{n}} \dots\dots\dots(4.12)$$

where

$p_i[nD]$  – probability of  $n$  consecutive field workdays for  $i^{\text{th}}$  month;

$F_i[nD]$  – frequencies of  $n$  consecutive field days for the  $i^{\text{th}}$  month;

$M_i$  - number of days in the  $i^{\text{th}}$  month;

$y$  - number of observed years.

#### **4.2 The Least-Cost Approach to Estimate the Optimal Size of Agricultural Machinery**

On today’s commercial farm, economic pressures are motivating operators to concentrate on managing their machinery resources. The long-standing trend of replacing capital for labour by adding higher capacity and more efficient machinery has resulted in large amounts of capital being used annually to acquire more machinery (Dalsted and Guitierrez, 2001). Increasing capital investment has had a dramatic effect on production costs, labour requirements, productivity and product quality. For instance, the increase in machinery investment can ease workers tasks and improve labour efficiency. In addition, the use of bigger machinery has contributed to higher machinery investment per farm and has made it possible for an



individual operator to farm many acres (Kay et al., 2004, pp. 402). Therefore, effectively managing machinery investment cost is essential to minimize total production cost.

The average annual machine costs fall in three basic categories: (1) fixed costs, (2) variable costs, and (3) timeliness costs. The specific machinery resources of these categories are identified briefly and characterized below.

#### **4.2.1 Estimation of Machinery Fixed Cost**

Fixed costs (FC) are those outlays that do not vary depending on machine use. There are some terminologies commonly used interchangeably with fixed costs such as ownership and overhead costs.

Regardless of the terminology used, fixed costs include the following items:

- 1. Interest expense:* Investment in machinery ties up capital and should be assigned a capital cost (Kay et al., 2004). The rate will depend on the opportunity cost for that capital elsewhere in the farm business if the operator uses his or her own capital. If capital is borrowed to finance the machinery investment, that cost should be at least large enough to cover the interest paid on the loan. When operators borrow money to invest in machinery, lenders determine how much interest is charged. Interest rates can fluctuate depending on the amount of money borrowed. If only part of the money is borrowed, an average of the two rates should be used. Choosing the interest rate is vital to calculate accurate machinery estimates.

2. *Depreciation* - is a way of representing, how capital assets decline in value over time because of wear and obsolescence. Hard assets, such as machinery, depreciate over time and must eventually be replaced. Depreciation costs need to be calculated over the estimated useful life of the asset. In this way, the farm's cost of capital equipment is reflected more appropriately in the unit costs of goods produced by that farm equipment.

The joint costs of depreciation and interest can be calculated by using a capital recovery factor (CRF) (Hunt, 1987). Capital recovery is the number of dollars that would have to be set aside each year to repay the value lost due to depreciation and pay interest costs. CFR can be used to combine the total depreciation and interest charges into a series of equal annual payments at compound interest. These payments plus the interest on the undepreciated amount,  $S$ , can be used to estimate the capital consumption (CC) of farm machinery (Hunt, 1987).

$$CC = (P_p - S_v) CRF + iS_v \dots\dots\dots(4.13)$$

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1}$$

where:

$S_v$  - salvage value percentage,

$L$  - years of life.

3. *Housing and insurance (HI)*: Most machinery cost estimates include an annual cost for housing the machine and insuring it. These costs generally are much smaller than depreciation and interest expense however; they have to be considered carefully.

Insurance should be carried on farm machinery to allow for replacement in case of a disaster such as a fire, collision and theft. For charge insurance needs to be included in fixed costs because some losses can be expected over time. If the owner decides not to purchase insurance for machinery, the risk is assumed by the rest of the farm business (Kay et al., 2004).

There is a variety of housing for farm machinery. Basically, providing shelter and maintenance equipment for machinery may result in less deterioration of mechanical parts and appearance from weathering and fewer repairs in the field. On the other hand, fewer repairs and less deterioration can reduce machinery repair and maintenance costs significantly (James and Eberle, 2000). That should produce greater reliability in the field and a higher trade-in value. The HI costs are usually expressed as percentage of the average investment. In this study, insurance and housing cost per year is determined as one percent of the original cost of the machinery (SAF, A Rental and Custom Rate Guide, 2006).

After determining all the costs mentioned above, the estimation of the total fixed costs can be expressed as a percent of the purchase price. The FC percentage is the sum of capital consumption (CC from Eq 4.2) and percentage for housing and insurance.

$$FC \% = (1 - S_v) \cdot \left( \frac{i(1+i)^L}{(1+i)^L - 1} \right) + i \cdot S_v + HI \quad \dots(4.14)$$

#### 4.2.2 Estimation of Machinery Variable Costs

Variable costs are defined as those costs that change relative to a change in an operational activity or business. In regards to everyday operations these are the costs associated with inputs and services required to operate the machine. The variable costs are also called operating costs and are measured on a per unit of production basis such as per acre or hours of use.

The variable costs for machinery include fuel, lubrication, maintenance repairs and operator's labour. The correct estimation of these costs is important because some machines will use these inputs more efficiently than others. Better technology and quality can bring the efficiency that cuts repair requirements and energy waste.

*Fuel and lubrication:* The fuel cost estimation is based on the engine consumption rate. The consumption rate can come from either performance records or engineering equations and is based on engine size (American Society of Agricultural Engineers, 2001). Fuel cost is a function of the percent loading, fuel price and total hours of machinery use (Brown and Schoney, 1985). Fuel cost is calculated as follows:

$$f_i = \frac{(MaxPTOHP) \cdot (PL_i) / 100}{1.20 \cdot (2.23 + 0.20 \cdot PL_i - 0.0098 \cdot (PL_i^2))} \cdot (HRST) \cdot (P_D) \quad (4.15)$$

where:

$f_i$  – tractor fuel cost,

$Max PTOHP$  – the size of machinery that will pull or carry all implements within load factor of no more than 80 percent,

$PL$  – percent load used by the  $i^{th}$  implement,

$HRST$  – total tractor hours,

$P_D$  – price of diesel fuel per litre.

*Repair and maintenance (RM):* Expenditures for parts and labour installing replacement parts are a part of RM costs. Repair costs for farm machinery normally go up as the use of machinery increases. Depending on field working conditions, the repair costs required for identical machines used the same hours can be different. Precise predictions of machinery RM costs are not easy to obtain. Thus repair and maintenance costs are normally estimated as a constant percentage of purchase price per hour and depend on machine type (SAF, Custom Rate Guide, 2005).

*Labour cost:* In the estimation of machinery variable costs, labour cost is an important variable cost. Although labour costs are usually estimated separately from machinery costs, it is better to be included in the given machinery variable costs.

When the machine operator is a hired worker, these costs also should be included in

the machinery variable costs for the farm. Labour costs are usually quoted by hours that include time spent fuelling, lubricating, repairing, adjusting and moving machinery between fields and working in the field.

Annual variable costs (VC) include repairs and maintenance, oil, fuel and labour are a function of the area covered, speed of operation, field efficiency and width of the machine (Brown and Schoney, 1985).

In the estimation of timeliness cost, area covered, speed of operation, width of machine, field efficiency and the timeliness loss factor must be considered.

*Field efficiency:* In farm machinery cost estimation, one needs to obtain the effective field capacity of the machine. The capacity of a machine is the number of units which it can process or cover in a specific time. Capacity is expressed as the area covered or volume harvested per unit of time. The effective field capacity is the measure of a machine's ability to do a job under actual field conditions. To estimate effective field capacity, calculate the theoretical field capacity and multiply by the field efficiency. Field efficiency is defined as the percentage of time the machine operates at its full rated speed and width while in the field.

*Effective Capacity = Theoretical Field Capacity x Field efficiency*

The machine cannot operate at its theoretical capacity at all times while it is in the field due to the following factors (Hunt, 2001):

- Turning and idle travel
- Land topography
- Operating at less than full width
- Operator's personal time
- Handling seed, fertilizer, chemicals, water or harvested materials
- Cleaning clogged equipment
- Machine adjustment
- Lubrication and refuelling during the day
- Waiting for other machines
- Waiting for repairs to be made.

As a result of these factors, the field efficiency is always less than 100 percent.

The VC is estimated as follows:

$$VC_i = \frac{c \cdot A}{S \cdot w \cdot e} \cdot [(RM_i + O_i + f_i) \cdot w + L_i] \dots\dots\dots(4.16)$$

VC<sub>i</sub> – annual variable cost implement i,

C – constant (8.25 english system),

A – area covered (acre),

S – speed of operation (mph),

e – field efficiency (%),

w – width of machine (ft),

RM – repair and maintenance cost (\$/hr),

o – oil cost (\$/hr),

f – fuel cost (\$/hr) and

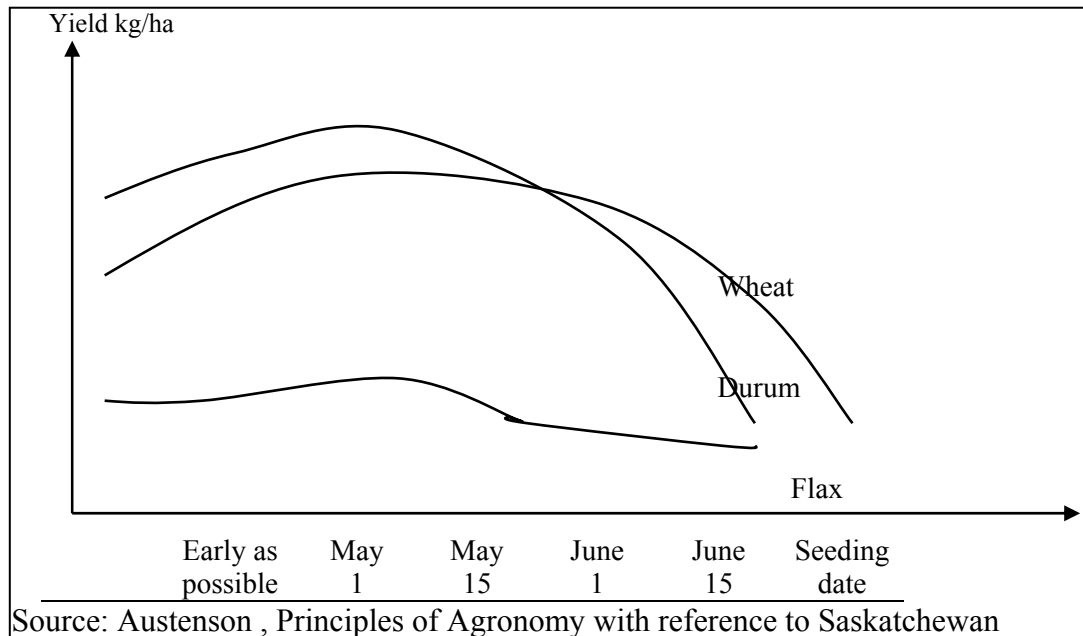
L – labour cost (\$/hr).

### **4.2.3 Estimation of Timeliness costs**

Timeliness costs are closely connected to machine size and do not belong to either the fixed or variable costs. Timeliness costs increase due to the inability to complete field tasks in a certain time period (Gunnarsson and Hansson, 2003). In some years, farm operators could not harvest during the most appropriate period because of weather delay. In this case, delaying harvest can cause reduction in crop quality and potential yield (Figure.4.1). For instance, “wheat has been reported to suffer a 46% reduction in yield for each week of delay in planting” (Hunt, 2001, p. 391). Timeliness cost is very important when farmers compare and select different sizes and capacity of machinery.

Timeliness costs associated with undersized farm machinery can be difficult to measure. This cost varies not only between crops but also depends on operations completed on that crop. Timeliness costs are often identified as money value of amount of yield reduction per day of delay.





Conditions, 1974.

**Figure 4.1** Yield of Wheat, Durum and Flax at Saskatoon

*Timeliness loss factor (K):* is a constant that expresses the amount of yield loss per day of delay in harvest and planting. Table 4.1 shows some typical timeliness factors (ASAE Standard, 2001).

**Table 4.1** Timeliness Loss Factors

Operation	K
Tillage	0.001- 0.002
Seeding	0.002-0.006
Cultivation, spraying	0.01
Harvesting: Green forage	0.001
Cotton	0.008
Small grain	0.004
Soybeans	0.005

Source: ASAE, 2001

Total timeliness costs can be defined as follow:

$$T_i = \frac{c \cdot A^2}{S \cdot w \cdot e} \cdot \frac{K \cdot Y \cdot V}{(P [ D ]) \cdot h} \dots\dots\dots(4.17)$$

where:

$T_i$  –timeliness cost of implement I (\$/yr),

$K$  – timeliness loss factor ( $K=0.004$  for small grain),

$Y$  – potential crop yield,

$A$  – crop area (acre),

$W$  – width of machine,

$e$  – field efficiency,

$V$  – value of crop,

$P[D]$  – probability of a given operation’s field workday,

$h$  – total work hours available per day.

#### **4.2.4 Estimation of the Least-Cost Size of Machinery**

An optimal machinery system is important for farming to be economically competitive. For crop farming in Saskatchewan, the combine harvester is the most important machine. Although the farm machinery used in spring planting is also very important, seeding capacity of machinery is usually much higher than combine capacity. In addition, the combining is the most expensive and time consuming operation on the farm. Therefore, minimizing the total cost for the harvest operation can be one of the key elements for crop production to improve efficiency.

To attain high yields of good quality there are optimal times for performing field operations for crop production (Witney, 1996). Related to optimal times for field operations, optimizing machinery size is one of the important factors for farm profitability. The optimizing machinery size can be achieved by minimizing machinery costs for a given farm operation. The minimizing machinery cost procedure described in the following section is based on Brown and Schoney's (1985) paper.

The least-cost procedure is divided into two stages. In stage 1, total combine costs are defined. for variety types of combines.

$$TC_i = \frac{(FC\%) \cdot p_i \cdot w}{100} + \frac{c \cdot A}{S \cdot w_i \cdot e} \cdot [(RM_i + O_i + f_i) \cdot w_i + L_i] \tag{4.18}$$

where  $i$  implies  $i^{\text{th}}$  type of machinery.

Calculating the least cost size of combine, one needs to consider a variety of factors such as soil textures, weather condition, crop types and yield.

Minimizing machinery total cost with respect to width of machinery defines minimum cost represented by Equation 4.18,

$$w = \sqrt{\frac{100 \cdot c \cdot A \cdot L}{(FC\%) \cdot p \cdot S \cdot e}} \tag{4.19}$$

Including the charge for timeliness, Equation 4.19 can be modified;

$$w_1 = \sqrt{\frac{100 \cdot c \cdot A}{(FC\%) \cdot p \cdot S \cdot e} \cdot \left( L + \frac{K \cdot Y \cdot V \cdot A}{(P[D]) \cdot h} \right)}, \dots\dots\dots(4.20)$$

where:

p – purchase price of machinery,

w<sub>1</sub> – the least cost width of machinery.

The machine width, w<sub>1</sub>, found by this procedure, represents the width consistent with a least cost combine. The total least cost machinery width for combines depends on what class of combine is employed for a given farm. If an operator uses larger size and big capacity combine, the least cost size of combine can be shorter than small combines if the farmer uses in his or her operation. On the other hand, the least-cost estimation can be based on size of crop acres. It can give an opportunity to determine combine's the most efficient use of crop acres. Therefore, the estimation of least cost size of combine requires careful consideration.

On the other hand, farm operators usually use the same types of combine with the same width. In this case, the least cost acre a combine can be derived from Equation 4.20 with respect to crop area (Appendix 4).

## **CHAPTER 5.**

### **RESULTS OF COMBINE CAPACITY**

This chapter reports and interprets the result of the analysis that were undertaken to examine the amount of crop area combine per year and the effect of combine cost on production cost for the selected areas. In the estimation of the combine capacity, fall field workdays and optimal acre per combine were determined. It is followed by the comparison results between farms in the west and east central regions.

#### **5.1 Estimated Result for Fall Field Workdays**

In farm machinery planning, knowledge of suitable field work time is one of the important factors to consider both for spring planting and fall harvesting. Based on the estimation of available field work time, one can determine how much time is available for harvesting and can make decisions on sizes of machines or systems of machines needed for the farm operation or calculate the amount of area that can be done by a particular size of machine. The determination of available total time during the harvest period followed the certain steps which were explained in Chapter 4.

The model described in Chapter 4 was used to determine the probability of spring and fall field workdays on a monthly basis, August and September, using the previous 25 years of weather records in the both west and east central Saskatchewan. Due to weather dissimilarity between these areas, the probabilities of field workdays in the west central Saskatchewan are higher than the east central Saskatchewan. The results will be explained in the following sections. The results of the calculated probabilities

of field workdays were used in the combine area capacity estimation for the both areas.

### 5.1.1 Estimated Result for Fall Field Workdays in West central Saskatchewan

For planning and operating purposes various types of dry and wet day probabilities are required. In west central Saskatchewan, the observed probability of single field workday in May is 0.78 which is relatively close to probability of field day in August, 0.77 and September, 0.80. Table 5.1 lists the observed frequencies (*F*) and probabilities (*P*).

**Table 5.1.** Observed frequencies and probabilities, west central (25 years of observation)

Consecutive field workdays	May		August		September	
	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
1	280	0.784	226	0.769	515	0.804

Source: Estimated

Potential monthly field workdays were assumed 15 days in May (May 13 – 18), 14 days in August (August 17 - 31) and 28 days in September for the West central Saskatchewan. These days are based on the preliminary survey responses and average dates of last spring frost dates for the selected region.

Spring wheat and durum are the major crops in the region (Saskatchewan Agriculture and Food, 2006), and 90 to 100 days are required for wheat to reach maturity. Spring seeding date and crop maturity days are included to obtain the beginning of harvest

date. In the estimation, August 17 was assumed to be the beginning of harvest date due to crop maturity period for the west central Saskatchewan. In addition, analysing the previous 25 years weather data shows that daily temperature usually drops below 0 degrees Centigrade after September 28 which reduces the time available for harvesting.

### **5.1.2 Estimated Result for Fall Field Workdays in East central Saskatchewan**

In the east central region of Saskatchewan, the observed probability of single field workday in May is 0.80 which is relatively higher than probability of field day in August, 0.72 and September, 0.77. Thus, the observed probability of 1 consecutive dry day is 0.72. Table 5.2 lists the observed frequencies (*F*) and probabilities (*P*).

**Table 5.2** Observed frequencies and probabilities, East central (24 years of observation)

Consecutive field workdays	May		August		September	
	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
1	601	0.808	209	0.726	576	0.773

Source: Estimated

The potential monthly field workdays were assumed to be the same as the west central Saskatchewan, 15 days in May (May 13 – 18), 14 days in August (August 17 - 31) and 28 days in September for the east central Saskatchewan. The first killing frost occurs after September 10<sup>th</sup> in east central and the average frost-free period is around 109 days. Thus, there is enough time for crops to reach maturity for the east central

Saskatchewan. Canola and spring wheat are the major crops in the region (Saskatchewan Agriculture and Food, 2006). The same procedure followed for west central Saskatchewan part was used in the estimation of field workdays in this region.

## **5.2 Estimated Result for the Optimal Area Combined**

The cost of every class of combine is different because the price of combine, power, energy consumption and size of header are different. Since a different combine uses a different size of header, determining the optimal size of combine is difficult to estimate. To simplify this, in the machinery cost estimation, cost of a “class 7” combine was determined separately for both regions and compared to each other. In addition, the preliminary survey found that larger farms in both areas mainly use “class 7” combines with 40 ft header. The total cost of a “class 7” combine was estimated with or without custom work for 5,000 acres to 25,000 acres.

### **5.2.1 Optimal Area Combined in the West central Saskatchewan**

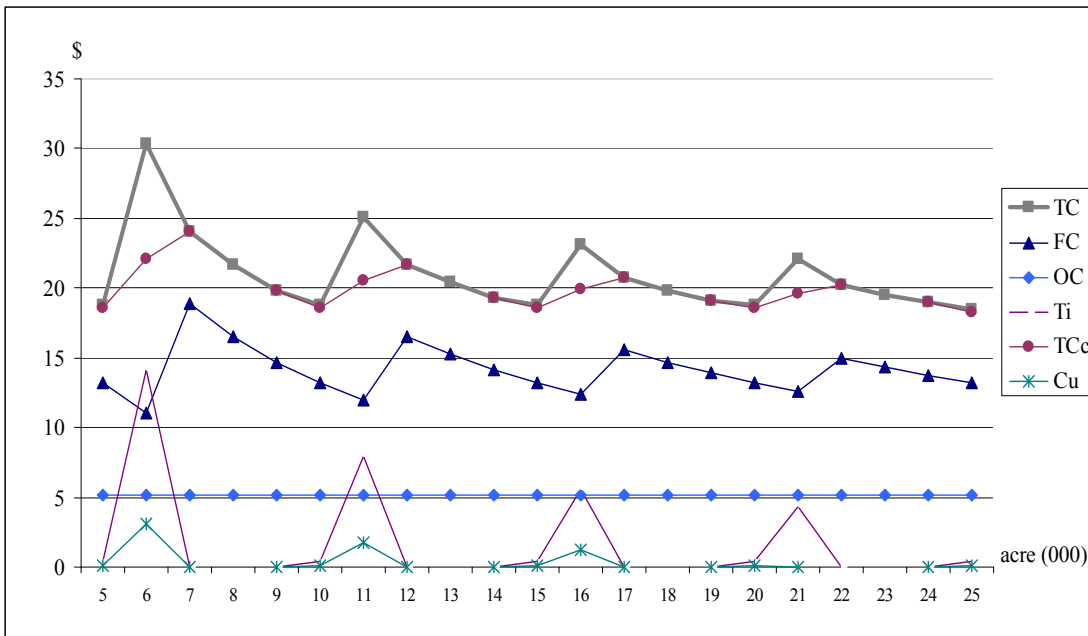
The estimated results of every thousand acres for fall harvest machinery costs with or without custom work for 5000 acres to 25000 acres assuming that operators use “class 7” combines with 40 ft header during the harvest period are shown in Figure 5.1. From the machinery costs estimation, a “class 7” combine can harvest around 4974 acres in the west central Saskatchewan during the giving period of August 17 to September 28 which was around 33 field workdays according to the field workday estimation. It suggests that when crop area increases every 4,974 acres for west central Region, a “class 7 “ combine costs are minimized. For instance, when an operator of farm uses only one “class 7” combine in his or her operation in this area,



least cost operational acres would be 4974 acres and costs \$18.47 per acre. For 2 combines, 9,948 acres would be the most optimal operational acres. Table 5.3 shows the estimation total combine costs.

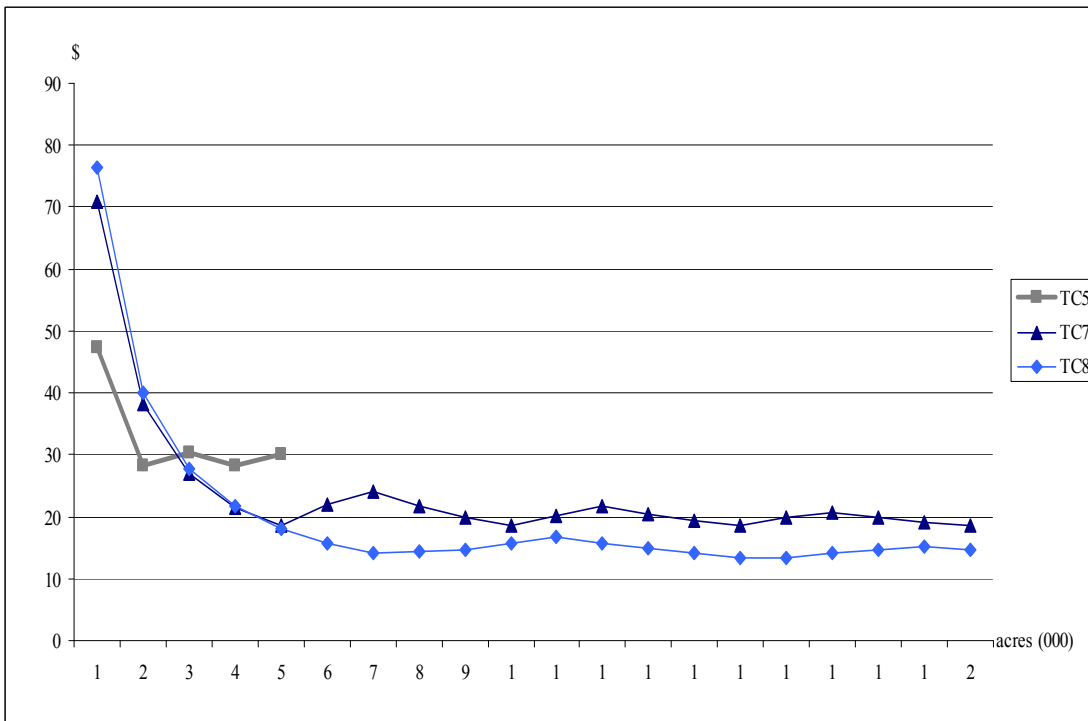
In addition, between combine units total costs may go up quickly as a result of rising timeliness costs. From the results, crop acres above combine capacity have caused quick increases in timeliness cost for example, 5,000 acres to 8,000 acres. When crop acres reach 7,000, the result suggests that it is the right decision to purchase a second combine. Two combines cost \$24.06 per acre for 7,000 acres which is much lower than using only one combine (Table 5.3). The trend can be seen graphically in Figure 5.1 which shows when a farm owner needs to purchase the next combine.

Figure 5.2 shows minimum total combine cost if farmers use different types of combines, such as class 5 combine with 20 ft header, class 7 combine with 40 ft header and class 8 combine with 42 ft header. In this estimation “class 8” combine was assumed to have a higher working speed, (6 mph) and 10 % higher purchase price and costs. In the west central Saskatchewan, the estimated optimal capacity of combine were 1866 acre for class 5 and 7832 acre for class 8 combine (Figure 5.2). The results showed that it is better to purchase a larger combine, when farmers operate above 3000 acres. As well, using a “class 8” combine can be more efficient above 4974 acres.



(TC – total cost, FC – fixed cost, OC – operation cost, Ti – timeliness cost, Cu custom cost and TCC – total costs with custom work)

**Figure 5.1** Machinery cost per acre, west central Region



**Figure 5.2** Minimum total combine cost for class 5, 7 and 8.

**Table 5.3** Machinery cost per acre for 5,000 acres to 25,000 acres, west central Region (Field efficiency – 0.8)

Number of combine	Crop acre	TC per acre no custom	FC per acre	VC per acre	Ti cost	TC per acre with custom	Custom cost	Number of combine	Crop acre	TC per acre no custom	FC per acre	VC per acre	Ti Cost	TC per acre with custom	Custom cost
1	4974	18.47	13.29	5.18	0.00	18.47	0.00	3	15000	18.83	13.22	5.18	0.43	18.58	0.09
2	5000	18.83	13.22	5.18	0.43	18.58	0.09	4	15000	22.80	17.62	5.18	0.00	22.80	0.00
1	6000	30.39	11.01	5.18	14.19	22.10	3.06	3	16000	23.16	12.39	5.18	5.59	19.90	1.21
2	6000	27.21	22.03	5.18	0.00	27.21	0.00	4	16000	21.70	16.52	5.18	0.00	21.70	0.00
1	7000	38.64	9.44	5.18	24.02	24.61	5.19	4	17000	20.73	15.55	5.18	0.00	20.73	0.00
2	7000	24.06	18.88	5.18	0.00	24.06	0.00	5	17000	24.62	19.43	5.18	0.00	24.62	0.00
1	8000	44.84	8.26	5.18	31.39	26.50	6.78	4	18000	19.87	14.68	5.18	0.00	19.87	0.00
2	8000	21.70	16.52	5.18	0.00	21.70	0.00	5	18000	23.52	18.35	5.18	0.00	23.52	0.00
3	8000	29.96	24.78	5.18	0.00	29.96	0.00	3	19000	33.43	10.43	5.18	17.81	23.02	3.85
1	9000	49.65	7.34	5.18	37.13	27.97	8.02	4	19000	19.09	13.91	5.18	0.00	19.09	0.00
2	9000	19.87	14.68	5.18	0.00	19.87	0.00	5	19000	22.57	17.39	5.18	0.00	22.57	0.00
3	9000	27.21	22.03	5.18	0.00	27.21	0.00	4	20000	18.83	13.22	5.18	0.43	18.58	0.09
1	10000	52.51	6.61	5.18	41.72	29.14	9.01	5	20000	21.70	16.52	5.18	0.00	21.70	0.00
2	10000	18.83	13.22	5.18	0.43	18.58	0.09	4	21000	22.13	12.59	5.18	4.36	19.58	0.94
3	10000	25.01	19.82	5.18	0.00	25.01	0.00	5	21000	20.92	15.73	5.18	0.00	20.92	0.00
2	11000	25.13	12.01	5.18	7.94	20.50	1.71	4	22000	25.13	12.01	5.18	7.94	20.50	1.71
3	11000	23.20	18.02	5.18	0.00	23.20	0.00	5	22000	20.20	15.02	5.18	0.00	20.20	0.00
3	12000	21.70	16.52	5.18	0.00	21.70	0.00	4	23000	27.87	11.49	5.18	11.20	21.33	2.42
4	12000	27.21	22.03	5.18	0.00	27.21	0.00	5	23000	19.55	14.36	5.18	0.00	19.55	0.00
3	13000	20.43	15.25	5.18	0.00	20.43	0.00	4	24000	30.39	11.01	5.18	14.19	22.10	3.06
4	13000	25.51	20.33	5.18	0.00	25.51	0.00	5	24000	18.95	13.77	5.18	0.00	18.95	0.00
3	14000	19.34	14.16	5.18	0.00	19.34	0.00	4	25000	32.39	10.57	5.18	16.94	22.50	3.66
4	14000	24.06	18.88	5.18	0.00	24.06	0.00	5	25000	18.52	13.22	5.18	0.43	18.27	0.09

Source: Estimation

A solution for keeping total combine cost lower will be to hire custom work and to expand combine capacity. For instance, the combination of owning one combine and hiring custom work is better for up to 7,000 acres. When crop acres exceed 8,000 acres, purchasing a second combine will keep the machinery cost lower than hiring custom work, as can be seen in Figure 5.1. However, combine fixed costs reach the lowest point in 6,000, 11,000, 16,000 and 21,000 acres based on the every 1,000 acres estimation, if a farm do not hire custom work, total machinery costs peak at the highest point due to high cost of timeliness. Conversely, hiring custom work can reduce total cost significantly.

### **5.2.2 Optimal Area Combined in the East central Saskatchewan**

The same procedure was followed in the estimation of combine costs for east central Saskatchewan. During the harvest period, a “class 7” combine can harvest around 4,529 acres in this area (Table 5.4). It suggests that when crop area increases every 4,529 acres for the East central, a regular new “class 7” combine will be needed. For instance, a “class 7” combine costs \$19.77 per acre for 4,529 acres. For 2 combines, 9,058 acres would be the most optimal operational acres. Table 5.4 shows the estimation total combine costs.

From the results, crop acres above combine capacity have caused a quick increase in timeliness costs 5,000 acres to 6,000 acres. When crop acres reach 7,000 acres, the result suggests that it is the right decision to purchase second “class 7” combine. Two combines cost \$24.8 per acre for 7,000 acres which is much lower than using only one class combine (Table 5.4). A similar trend can be seen in Figure 5.3. The regarding to machinery cost estimation on every 1,000 acres, when crop acres reach 12,000, 16,000

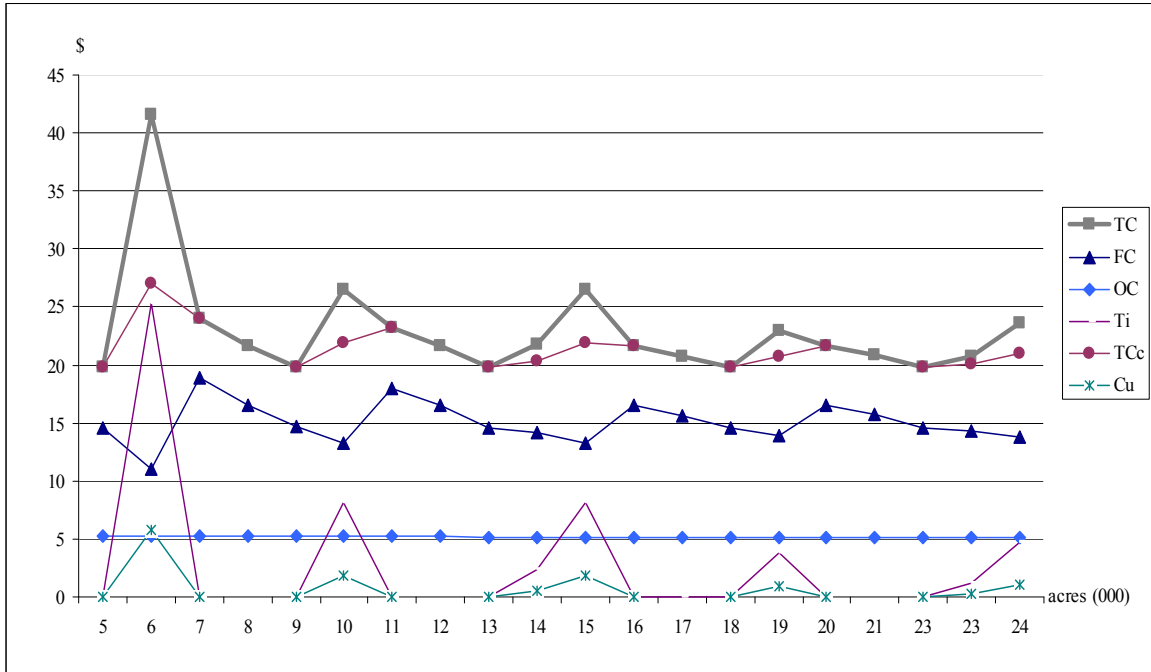
and 20,000 acres, a farm owner needs next combine to purchase. Detailed estimation of machinery cost is shown in Table 5.4.

In the east central region, keeping total machinery costs lower will be to hire custom work when crop acres are higher than combine capacity, especially crop acre ranges between 5,000 to 6,000 acres, 10,000 to 11,000 acres and 14,000 to 15,000 acres (Figure 5.3). In addition, when crop area varies between 7,000 to 9,000 acres, 12,000 acres and 16,000 to 18,000 acres, extending capacity costs relatively lower than hiring custom work. For example, the combination of owning one combine and hiring custom work is better for up to 7,000 acres. When crop acres exceed 7,000 acres, purchasing a second combine keeps machinery cost lower than hiring custom work, as can be seen in Figure 5.3. Although, machinery fixed costs reach the lowest point \$11.01 in 6,000, 11,000 and 15,000 acres, if a farm does not hire custom work, total machinery costs peak the highest point due to the high cost of timeliness. On the other hand, hiring custom work can reduce total machinery cost significantly such as from \$36.09 acre to \$25.16 acre at 6,000 acres, \$31.73 acre to \$23.86 acre in 11,000 acres and \$26.50 to \$22.30 in 15000 acres (Figure 5.3). Thus, the decision involved with custom hiring and purchasing new combine requires careful consideration for farmers.

**Table 5.4 Machinery cost per acre for 5000 acres to 25000 acres, east central (Field Efficiency – 0.80)**

Number of combine	Crop acre	TC per acre no custom	FC per acre	VC per acre	Ti cost	TC per acre with custom	Custom cost	Number of combine	Crop acre	TC per acre no custom	FC per acre	VC per acre	Ti Cost	TC per acre with custom	Custom cost
1	4529	19.77	14.59	5.18	0.00	19.77	0.00	3	15000	26.5.2	13.22	5.18	8.13	21.89	1.86
1	5000	26.52	13.22	5.18	8.13	21.89	1.86	4	15000	26.5.2	13.22	5.18	8.13	21.89	1.86
1	6000	41.57	11.01	5.18	25.37	27.09	5.82	3	16000	31.45	12.39	5.18	13.88	23.5.2	3.18
2	6000	27.21	22.03	5.18	0.00	0.00	0.00	4	16000	21.70	16.52	5.18	0.00	21.70	0.00
1	7000	57.25	9.44	5.18	42.62	32.92	9.78	3	17000	36.47	11.66	5.18	19.63	25.27	4.50
2	7000	24.06	18.88	5.18	0.00	24.06	0.00	4	17000	20.73	15.55	5.18	0.00	20.73	0.00
1	8000	73.31	8.26	5.18	59.87	39.15	13.73	4	18000	19.87	14.68	5.18	0.00	19.87	0.00
2	8000	21.70	16.52	5.18	0.00	21.70	0.00	4	18116	19.77	14.59	5.18	0.00	19.77	0.00
3	8000	29.96	24.78	5.18	0.00	29.96	0.00	4	19000	22.91	13.91	5.18	3.81	20.73	0.87
1	9000	89.64	7.34	5.18	77.12	45.64	17.69	5	19000	22.57	17.39	5.18	0.00	22.57	0.00
1	9058	19.77	14.59	5.18	0.00	19.87	0.00	5	19000	22.57	17.39	5.18	0.00	22.57	0.00
3	9000	27.21	22.03	5.18	0.00	27.21	0.00	4	20000	26.5.2	13.22	5.18	8.13	21.89	1.86
1	10000	106.16	6.61	5.18	94.37	52.31	21.65	5	20000	21.70	16.52	5.18	0.00	21.70	0.00
2	10000	26.5.2	13.22	5.18	8.13	21.89	1.86	4	21000	30.21	12.59	5.18	12.44	23.11	2.85
3	10000	25.01	19.82	5.18	0.00	25.01	0.00	5	21000	20.91	15.73	5.18	0.00	20.91	0.00
2	11000	33.95	12.01	5.18	16.75	24.39	3.84	4	22000	33.95	12.01	5.18	16.75	24.39	3.84
3	11000	23.20	18.02	5.18	0.00	23.20	0.00	5	22645	19.77	14.59	5.18	0.00	19.77	0.00
2	12000	41.57	11.01	5.18	25.27	27.09	5.82	4	23000	37.74	11.49	5.18	21.06	25.72	4.83
3	12000	21.70	16.52	5.18	0.00	21.70	0.00	5	23000	20.77	14.36	5.18	1.23	20.07	0.28
2	13000	49.35	10.17	5.18	34.00	29.95	7.80	4	24000	41.57	11.01	5.18	25.27	27.09	5.82
3	13587	19.77	14.59	5.18	0.00	19.77	0.00	5	24000	23.62	13.77	5.18	4.68	20.96	1.07
3	14000	57.25	9.44	5.18	42.62	32.92	9.78	4	25000	45.24	10.57	5.18	29.69	28.50	6.81
4	14000	21.72	14.16	5.18	2.38	20.36	0.55	5	25000	26.5.2	13.22	5.18	8.13	21.89	1.86

Source: Estimation



**Figure 5.3** Machinery cost per acre, east central Saskatchewan

### 5.2.3 Comparison of Results for West central and East central Saskatchewan

There are complicated relations between variables affecting machinery costs such as field efficiency, working hours and working speed. These factors, except field efficiency, were maintained at constant levels during the combine cost estimation. In the previous section, field efficiency was assumed to be 80% for both areas. In this case, the difference between total machinery costs associated with available field workdays can be seen clearly in Table 5.5. Table 5.5 contains the comparison results of the combine cost estimation based on per acre machinery cost for the selected areas.

The results show that combine total cost in the east central Saskatchewan is higher than the west central Saskatchewan due to the amount suitable harvest field workdays. During a given harvest period, the probability of a field workday in the east central Saskatchewan was estimated 0.726 or 10 suitable days in August and 0.755 or 21 suitable

days in September which were 2 field days lower than the west central Region. Total combine cost per acre differs significantly because of these differences. For instance, the estimated optimal total combine cost is \$21.89 per acre for 5,000 acres in the East central Saskatchewan which is \$3.31 higher than \$18.58 per acre in the West central Saskatchewan (Table 5.5). In addition, it has to be mentioned that due to excess capacity of combines for both areas, the estimated combine cost per acre is equal to each other (Table 5.5). Excess power of farm machinery can provide operators to complete field tasks reasonably short period of time. An increase in daily effective machinery capacity had a lower effect on timeliness costs. On the other side, very low daily effective field capacity also can lead to peculiar effects on timeliness costs.

**Table 5.5** Least-cost acre for “class 7” combine

Crop acre	Number of combine	Min cost per acre		Difference	Crop acre	Number of combine	Min cost per acre		Difference
		West	East				West	East	
5000	1	18.58	21.89	3.31	16000	4	21.70	21.7	0
6000	1	22.10	27.09	4.99	17000	4	20.73	20.73	0
7000	2	24.06	24.06	0	18000	4	19.87	19.87	0
8000	2	21.70	21.7	0	19000	4	19.09	20.73	1.64
9000	2	19.87	19.87	0	20000	4	18.58	21.7	3.12
10000	2	18.58	21.89	3.31	21000	5	19.58	20.91	1.33
11000	2	20.50	23.2	2.7	22000	5	20.02	20.2	0.18
12000	3	21.70	21.7	0	23000	5	19.55	20.07	0.5.2
13000	3	20.43	20.43	0	24000	5	18.95	20.96	1.12
14000	3	19.34	20.36	1.02	25000	5	18.27		
15000	4	18.5.2	21.89	3.35					

Source: Estimation

Besides that, the study found that field efficiency (FE) in East central Saskatchewan is expected to be lower than the West central Saskatchewan. In the West central Saskatchewan, the land surface is relatively smoother, flatter and with less trees than East central Saskatchewan. In order to find the effect of FE on combine costs in this region,



combine costs were estimated assuming the FE is 0.75 and 0.80. The results show that lower FE increases total combine cost. For instance, a 5 percent reduction of FE in the East central Saskatchewan increases machinery cost per acre by \$0.34 to \$2.81 (1.7% - 12.84%) (Table 5.6). With the reduction of FE, the farm requires more capacity to complete harvest. Thus field efficiency has an influence on machinery variable cost per acre and custom hired work to increase significantly. Appendix 3 contains complete results of combine costs estimation due to change in field efficiency.

**Table 5.6** Total combine cost for East central Saskatchewan (FE =0.8 vs 0.75)

Crop acre	Number of combine	Min cost per acre		Difference	Crop acre	Number of combine	Min cost per acre		Difference
		FE 0.80	FE 0.75				FE 0.8	FE 0.75	
5000	1	21.89	24.7	-2.81	15000	4	21.89	24.7	-2.81
6000	1	27.09	27.55	-0.46	16000	4	21.7	22.05	-0.35
7000	2	24.06	24.41	-0.35	17000	4	20.73	21.08	-0.35
8000	2	21.7	22.05	-0.35	18000	4	19.87	20.21	-0.34
9000	2	19.87	20.21	-0.34	19000	4	20.73	22.92	-2.19
10000	2	21.89	24.7	-2.81	20000	4	21.7	22.05	-0.35
11000	2	23.2	23.55	-0.35	21000	5	20.91	21.26	-0.35
12000	3	21.7	22.05	-0.35	22000	5	20.2	20.55	-0.35
13000	3	20.43	20.78	-0.35	23000	5	20.07	22.69	-2.62
14000	3	20.36	23.01	-2.65	24000	5	20.96	23.67	-2.71

Source: Estimation

When field efficiency is assumed to be 0.75 in the East central Saskatchewan, the least cost operation acre is 4,246 acres for one combine and costs \$18.75 per acre which is \$0.35 higher than when FE is 0.80 (Appendix 3). As can be seen from Table 5.6, change in field efficiency could affect the least cost acres. However, lowering FE increases total cost of machinery; the least-cost acres are still the same as 9,000 and 18,000 acres for the east central area.

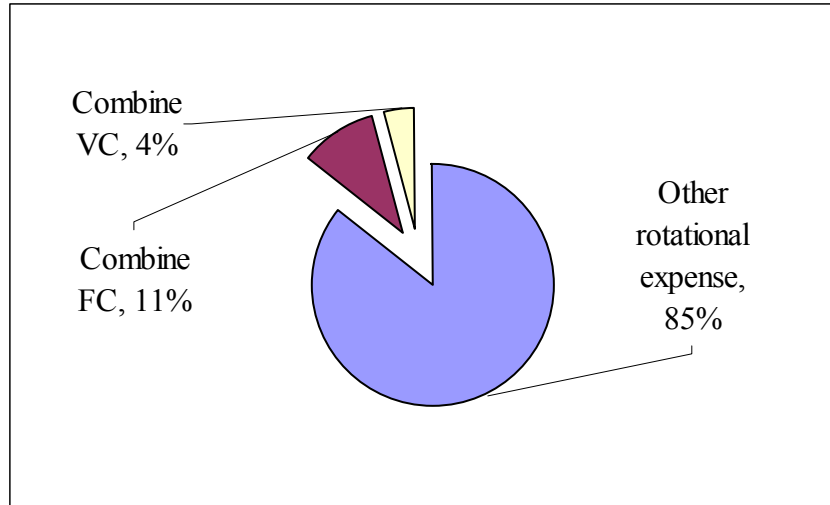
### **5.3 Comparison Between the Two Regions of the Farms Interviewed**

The purpose of this part was to evaluate the effect of variable expenses on combine costs and combine costs on farm production costs in both regions. The selected farms operate 14,000 acres in the West central area and 22,000 acres in the East central area were selected and both mainly produce direct seeded spring wheat. Production costs of these farms were estimated using the Saskatchewan Agriculture and Food, Crop Planning Guide, 2006 (SAF, 2006 a).

According to the combine cost estimation, owning 3 “class 7” combines minimize total fall harvest machinery costs for 14,000 crop acres in the West central region. The estimated total rotational expense for this farm is \$133.38 per acre (SAF, 2006 b).

Combining cost is \$19.34 per acre (Table 5.3) which is comparatively lower than other options of combine cost for this area. The percentage share of combine cost is equal to 15% of total production expense per acre (Figure 5.4). On the other side, 85% percent of total farm expenses are connected with spring and summer field operations, such as spring seeding, fertilizer, herbicide, interest and other costs.

For this farm, there can be some possibilities to decrease combine costs if the owner of farm decide to increase operation land. However, increasing the land base requires more machinery capacity; the cost of 3 combines can reached a minimum point when the farm operates 14934 acres and it may reduce combine cost by \$0.87 per acre.



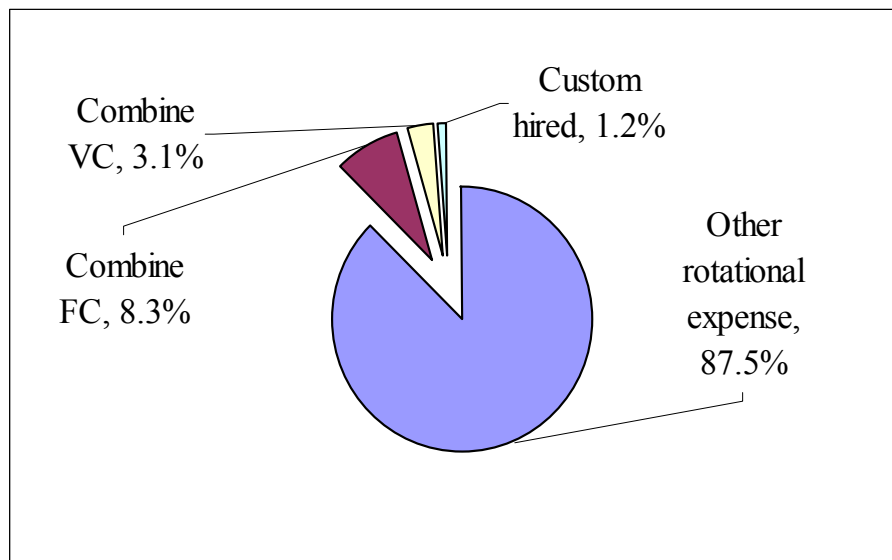
Source: Estimation

**Figure 5.4** Total rotational expenses per acre, west central Saskatchewan

In the east central area, the estimated total rotational expense is \$165.22 per acre for the selected farm (SAF, 2006). Combines cost is \$20.96 per acre when field efficiency is 0.80 and \$23.67 per acre when FE is 0.75 (Table 5.6). The higher FE means that the farm requires less “class 7” combines, such as 5 combines is appropriate for 24000 acres when FE is 0.80. Conversely, the lower FE means the farm needs more capacity to complete harvest within a given time period. In the given condition of FE is 0.80, the farm has excess capacity which causes production cost to rise. In this case, the farm operator can have two options to deal with optimizing combine capacity: decreasing the number of combines or enlarging crop area.

In this region, the percentage share of combine cost is approximately 12.3% of total production expense per acre when FE is 0.80 (Figure 5.5). On the other side, 87.3% percent of total farm expenses are connected with spring and summer field operations. In the east central region, rotational expense per acre is much higher than the west central due to high consumption of fertilizer, herbicides and use of grain dryer. For instance,

\$20.70 fertilizer cost per acre in brown soil is much lower than \$27.60 per acre in black soil (Crop Planning Guide, 2006). As well, the farmers interviewed said that it is very common to use a grain dryer in their operation in the East central due to weather conditions. According to the Crop Planning Guide, using a grain dryer increases production expense by \$0.70 per acre.



Source: Estimation

**Figure 5.5** Total rotational expenses per acre, East central Saskatchewan

Due to lack of data availability, the economies of size for crop farms were difficult to determine. Most participants, in the 2005, Farm Financial Survey operate less than 6,000 acres. Those farmers interviewed in the preliminary survey stated that larger farms are able to capture discounts on variable costs such as fuel, fertilizer and chemicals especially for fuel; discount on price may be up to 15 %.

In the combine cost estimation, major variable expenses include fuel, repair, oil and labour costs. According to the combine cost estimation, approximately 28% of total cost

per acre belongs to the variable cost for the West central (Table 5.7) and 26 % for the East central Saskatchewan farms (Table 5.8). In order to show how combine cost per acre affects as a result of change in variable costs, fuel and labour costs were selected based on the preliminary survey response and adjusted 5 to 20 percent for the both areas (Table 5.7 and 5.8). Fuel expense per acre were shown comparatively decreasing trend due to increasing crop acres (Figure 3.7). From Table 5.7, 5 to 20 percent discount on fuel can affect only -0.5 to -2.0 percent or \$0.9 to \$0.36 (Table 5.7) decrease in total combine cost per acre for the West central Saskatchewan and -0.46 to -1.84 percent or \$0.09 to \$0.36 for the East central Saskatchewan (Table 5.8).

Table 5.7 Percentage change in fuel, West central Saskatchewan

West /4974 acre/	Combine cost /4974 acre/		5% change in Fuel		10% change in Fuel		15% change in Fuel		20% change in Fuel	
	\$	%	\$	change	\$	change	\$	change	\$	change
TC	18.47	100.0%	18.37	-0.5%	18.28	-1.0%	18.19	-1.5%	18.09	-2.0%
FC	13.29	72.0%								
VC	5.18	28.1%								
Fuel	1.83	9.9%	1.74	-5.0%	1.65	-10.0%	1.56	-15.0%	1.46	-20.0%

Source: Estimation

Table 5.8 Percentage change in fuel, east central Saskatchewan

	Combine cost /4529 acre/		5% change in Fuel		10% change in Fuel		15% change in Fuel		20% change in Fuel	
	\$	%	\$	change	\$	change	\$	change	\$	change
TC	19.77	100.0%	19.68	-0.46%	19.59	-0.92%	19.50	-1.38%	19.40	-1.84%
FC	14.59	73.8%								
VC	5.18	26.2%								
Fuel	1.83	9.3%	1.74	-5.0%	1.64	-10.0%	1.55	-15.0%	1.46	-20.0%

Source: Estimation

For the West central Saskatchewan, a labour shortage is one of the major issues because of booming oil and gas industry in the neighbouring province Alberta. Thus farmers in this area are willing to increase hourly wage to keep workers and to recruit new people

which increases total combine costs. To show this increase in fall machinery costs, 5 to 20 percent increase in labour cost were estimated and shown in Table 5.9 for the West central Saskatchewan farms. From Table 5.9, 5 to 20 percent increase in labour can affect only 0.3 to 1.2 percent or \$0.06 to \$0.23 increase in total combine cost per acre for the West central Saskatchewan (Table 5.9).

Table 5.9 Percentage change in labour cost, west central Saskatchewan

West /4974 acre/	Combine cost /4974 acre/		5% change in Labour		10% change in Labour		15% change Labour		20% change in Labour	
	\$	%	\$	change	\$	Change	\$	change	\$	change
TC	18.47	100.0%	18.89	0.3%	18.95	0.6%	19.00	0.9%	19.06	1.2%
FC	13.29	72.0%	13.29	0.0%	13.29	0.0%	13.29	0.0%	13.29	0.0%
VC	5.18	28.1								
Labour	1.16	6.3%	1.22	5.0%	1.28	10.0%	1.33	15.0%	1.39	20.0%

Source: Estimation

However, there are some possible combine cost increasing or decreasing changes due to discount on fuel and labour issues, these changes do not impact combine cost significantly. In addition, increasing labour expense per acre can decrease the effect of decreasing fuel cost per acre on total combine cost.

## CHAPTER 6

### SUMMARY AND CONCLUSIONS

This chapter summarizes the findings of the research and provides conclusions that this research has drawn regarding the hypothesis and objectives set out in Chapter 1. In addition, it presents the limitations of this study and discusses potential areas for further research.

#### 6.1 Summary

The major objective of the study was to examine the nature of size economies in larger crop farms in Saskatchewan. More specifically, the major objectives of this study were:

1. Examine several different farms operating and investment costs and state whether they are decreasing or staying the same as a result of increasing farm size;
2. To identify and compare optimal combine capacity for large crop farms in the West central and East central areas;
3. To evaluate the effect of various expense items on combine costs and on farm production costs in the both regions.

Three different types of data were used in this study to meet these objectives. First, data calculated field work day estimation was obtained from the National Climate Data and Information Archive, operated by Environmental Canada. Secondly the data used in the machinery cost was estimated from the SAF Custom Rate Guide and Crop Planning Guide, 2006. Next, a small group of owners of large farms were interviewed to determine their perception of factors that contribute to the economies of large crop farm size.

Finally data from the 2005 Farm Financial Survey of Statistics Canada was used. This data included 391 crop farms in Saskatchewan.

The farmer survey was conducted in West and East central Saskatchewan in order to discuss economies of size issues with the owners of their businesses and to discover what major challenges are facing very large crop farms. Based on the survey, major inquiries of the study were determined such as farm machinery types, harvest dates, field efficiency, wage rate per hour and approximate discount rate on input prices.

The analysis of farm production costs in West and East central Saskatchewan revealed that large crop farms have an effect on expense per acre and how the components of production cost react along with increasing size. In addition, the optimal capacity for a combine was determined for selected acres and regions using the least-cost approach. The effect on variable costs per acre of changes in FE, fuel cost and labour were also measured.

## **6.2 Conclusions**

The Farm Financial Survey analysis showed that total farm expenses per acre decrease as farm size increases (Figure 3.1). However, the overall trend was decreasing costs per acre. It has to be mentioned that some costs increase with farm size, such as total wage for West central Saskatchewan (Figure 3.2). Increasing labour expenses in this region could be explained by a shortage of labour because of neighbouring Alberta. Also farm work is not full time work all year round. The percentage share of large crop farms' combine variable costs, such as fuel, repair and labour, in total combine cost were small and changing these costs up to 20% had little impact on total farm operation expenses.



Timeliness costs were an important component of total combine costs for field machinery in West and East central Saskatchewan. A lower capacity of combine could increase timeliness cost more. The use of custom work during harvest period might significantly reduce combine cost. Depending on crop land, excess machinery cost per acre and custom rate per acre, it is better to evaluate whether or not to hire custom work or purchase new combine.

The economically optimal combine capacity was found to be 4974 acres for west and 4,529 acres for the east central Saskatchewan in the absence of hiring custom work and renting a combine. The field workdays had a big effect on combine capacity for both regions. Especially for East central Saskatchewan, the estimated field workdays were shorter than West central Saskatchewan because of wet weather. In addition, the optimal combine capacity was more affected by field efficiency. Lower field efficiency tends to increase machinery cost per acre and decrease optimal acres for combining for both regions. Thus, optimal capacity of combine was determined to be smaller in the East than for the West central region.

Finally, the analysis determined that lower farm operation costs per acre for the West than the East central region due to soil type, weather condition, land topography and cropping technology.

### **6.3 Limitation of the Study**

A number of potential limitations to the research should be acknowledged. One limitation of this study is the data itself. In the Farm Financial Survey, most farmers operate less

than 6000 acres which was not enough representatives of larger crop farms in Saskatchewan.

Another limitation of the study lies with the probability of field workday estimation. There is still not a generally accepted and accurate methodology to estimate available workdays for field operations (Toro and Hansson, 2004) and many factors that influence determining field workdays such as soil type, soil moisture and weather condition. Due to the data requirements and the study period, the weather data used to determine field workdays is a major weakness of this study.

The preliminary survey used to establish basic criteria of the study may not fully represent larger crop farms in Saskatchewan because the producers who were interviewed were selected by soliciting their names from various sources known with the Department of Agricultural Economics at the University of Saskatchewan and therefore was not random.

#### **6.4 Suggestions for Further Study**

There are several areas of research that could be advanced by further study. It would be interesting to examine field efficiency and harvest dates. In addition, soil workability may vary from soil to soil, machine to machine and farm manager to farm manager and using soil workability models which consider factors that can influence soil workability such as soil moisture content and soil types might be useful to determine field workdays.

There are a variety of issues related to economies of size. One is the lack of available labour for agricultural businesses. Studying issues related to farm labour would help policy makers to develop and implement accurate farm policies.

The analysis performed in this thesis did not examine the exact relationship between farm size and operational costs. Employing empirical models of economies of size would improve interpretation of the results. Although the general picture of economies of size can be seen from studying farm size and examining seasonal farm operations separately, such as spring planting, summer and fall operations, would improve the results.

## REFERENCES

- Agriculture and Agri-Food Canada (2001). *Economic Overview of Farm Incomes* Economic and Policy Analysis Directorate 2. Available online at <http://www.agr.ca/spb/fiap>.
- Aly, H. Y., K, Belbase, R. Grabowski and S. Kraft (1987). *The Technical Efficiency of Illinois Grain Farms: An Application of a Ray Homothic Production Function*. Southern Journal of Agricultural Economics, Vol. 6, pp. 21-37.
- American Society of Agricultural Engineering Standards (2000). *Agricultural Machinery Management*. ASAE EP496.2 DEC99. 47th ed., ASAE, St. Joseph, Michigan, USA. pp 344-349.
- Amir, I., J. B. Arnold and Bilanski, W. K (1976). *A Procedure for Determining Probabilities of Dry and Wet Days*. Canadian Journal of Agricultural Engineering, Vol. 19. pp. 2-5.
- Audsley, E. and Boyce, D. S (1974). *A Method of Minimizing Cost of Harvesting and high Temperature Grain Drying*. Journal of Agricultural Engineering Research, Vol. 19(2), pp. 173-189.
- Austenson, H. M (1979). *Principles of Agronomy with Particular Reference to Saskatchewan Condition*. University of Saskatchewan, pp. 20-43.
- Ayres, G. E (1975). *A Simulation Model for Predicting Days Suitable for Corn Harvesting*. American Society of Agricultural Engineers, pp. 75.
- Bowers, W (1987). *Considering Future Capacity Needs. In Machinery management; Fundamentals of Machine Operation*, John DeereService Training Department, Illinois, pp. 115-126.
- Brown, D. M. and Van Die, P (1974). *Spring Work-Days in Ontario. Technical Monograph 74-1*, University of Guelph, Canada.
- Brown, W. J (1989). *A Review of the Economies of Farm Enterprise Size and Implication for Farm Diversification*. Discussion Paper 360, Ottawa, Ontario: economic Council of Canada.
- Brown, W. J. and Schoney, R. A. (1985). *Calculating Least- Cost Machinery Size for Grain Farms Using Electronic Spreadsheets and Microcomputers*. Canadian Journal of Agricultural Economics, Vol. 33, pp. 47- 65.
- Brownlee, K. A (1965). *Simple Linear Regression. In Statistical Theory and Methodology in Science and Engineerin.*, John Wiley & Sons Inc, New York, pp. 334-393.

- Byrnes, P., R. Fare, S. Grosskopf and S. Kraft (1987). *The Technical Efficiency and Size: The Case of Illinois Grain Farms*. *European Review of Agricultural Economics*, Vol. 14, pp. 367-381.
- Cooper, G. and McGechan, M. B (1997). *The Influence of a Changed Climate on Soil Workability and Available Workdays in Scotland*. *Journal of Agricultural Engineering Research*, Vol. 68 (3), pp. 253-269.
- Dalsted, N. and Guitierrez, P (2001). *The Cost of Owning and Operating Farm Machinery*. *Agriculture and business management Notes*, Colorado State University, pp. 1-5.
- Danok, A. B., McCarl, B. A and White, K. T (1980). *Machinery Selection Modeling: Incorporation of Weather Variability*. *American Journal of Agricultural Economics*, Vol. 62, pp. 700-708.
- Dyer, J. A (1980). *Fall Field Workdays in Canada*. Technical Bulletin 92. Agrometeorology Section, Land Resource Research Institute, Research Branch, Agriculture Canada, Ottawa.
- Dyer, J. A., Baier, W., and Sharp, W. R (1979) *The Versatile Soil Moisture Budget*. Tech. Bull. 87, Agrometeorology Section, Research Branch, Agriculture Canada, Ottawa, ON, Edinburgh.
- Edward, W (2001)a. *Machinery Management: Joint Machinery Ownership*. Iowa State University Extension Vol. PM1373, pp. 1-5.
- Edward, W (2001)b. *Machinery Management: Replacement Strategies for Farm Machinery*. Iowa State University Extension, Vol. PM1860, pp. 4.
- Edward, W. and Hanna, M (2001). *Machinery Management: Combine Ownership or Custom Hire*. Iowa State University Extension, Vol. PM 786, pp. 2.
- Environment Canada (2006). *Climate and Normal Averages*. Weather Office. Available online at <http://www.climate.weatheroffice.ec.gc.ca>.
- Feder, G (1985). *The Relation Between Farm Size and Farm Productivity*. *Journal of Development Economics*, Vol. 18, pp. 297-313.
- Garcia, P., S. Sonka and M. Yoo (1982). *Farm Size, Tenure and Economic efficiency in a Sample Illinois Grain Farms*. *American Journal of Agricultural Economics*, Vol. 64, pp. 119-123.
- Giannakas, K., Schoney, R and Tzouvelekas, V (1999). *Technical Efficiency, Technological Change of Wheat Farms in Saskatchewan*. *Canadian Journal of Agricultural Economics*, Vol. 49, pp. 135-152.

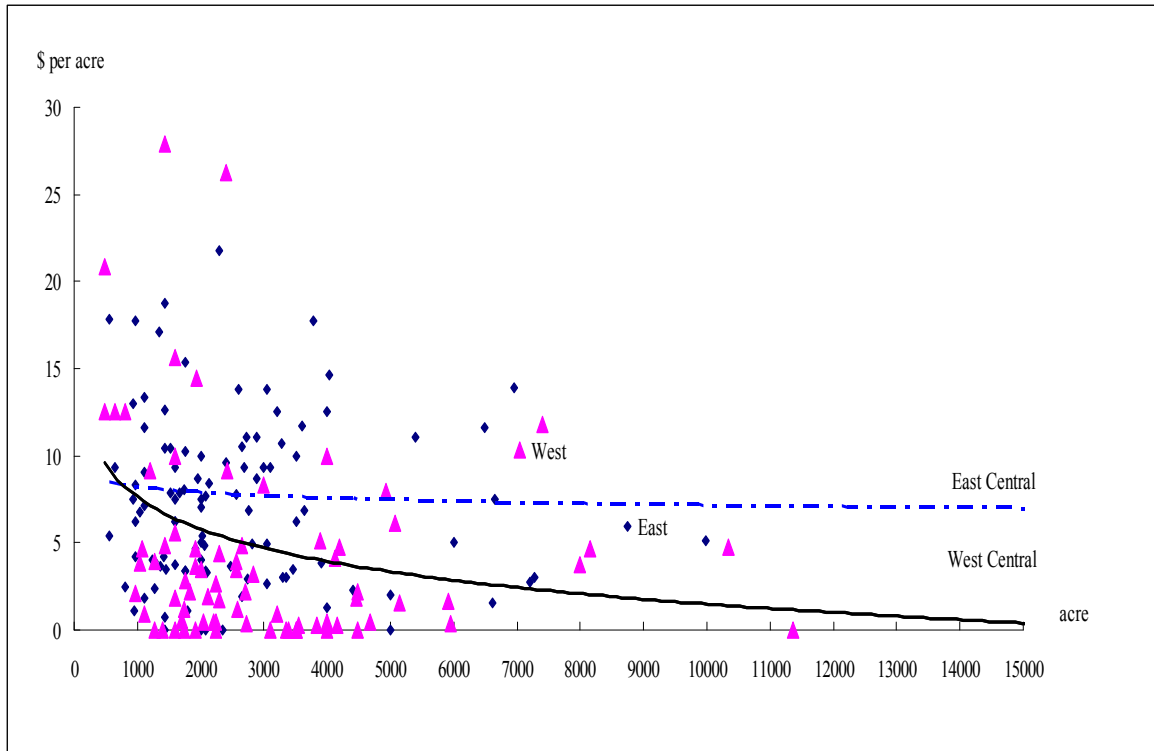
- Gunnarsson, C. and Hansson, P. A (2003). *Optimisation of Field Machinery for an Arable Farm Converting to Organic Farming*. Agricultural Systems, Vol. 80(1), pp. 85-103.
- Gunnarsson, C. and Hansson, P.A (2004). *Optimization of Field Machinery for an Arable Farm Converting to Organic Farming*. Agricultural Systems Vol. 80, pp. 85-103.
- Hall, B. F., and E. P. LeVeen (1978). *Farm Size and Economic Efficiency: The Case of California*. American Journal of Agricultural Economics, Vol. 60, pp. 589-599.
- Hallam, A (1991). *Economies of Size and Scale in Agriculture: An Interpretive Review of Empirical Measurement*. Review of Agricultural Economics, Vol. 60(4), pp. 589-599.
- Hastie, T., R. Tibshirani. and Friedman, J (2001). *The Elements of Statistical Learning*. Springer-Verlag, New York.
- Heady, E. O (1958). *Economics of Agricultural Production and Resource Use*. New York: Prentice-Hall, Inc.
- Henning, S. T. and Claus, S. G (2004). *A Model for Optimal Selection of Machinery Sizes within the Farm Machinery System*. Biosystems Engineering, vol. 89, pp. 13-28.
- Hunt, D (1987). *Cost Determination*. In *Farm Power and Machinery Management*. Iowa State University Press, pp. 63-83.
- Hunt, D (2001). *Equipment Selection*. In *Farm Power and Machinery Management*. Iowa State University Press, pp. 271-295.
- James, S. C. and Eberle, P. R (2000). *Acquisition of Farm Machinery Services*. In *Economic and Business Principles in Farm Planning and Production*. Iowa University Press, pp. 315-335.
- Jensen, K (1984). *An Economic View of the Debate on Farm Size in Saskatchewan*. Canadian Journal of Agricultural Economics, Vol. 32(1), pp. 187-200.
- Jones, R. J. A. and Thomasson, A. J (1986). *Land Suitability Classification for Temperate Arable Crops*. In: *Quantified Land Evaluation Procedures* (eds K. J. Beek, P. A. Burrough and D. E. McCormak), ITC Publication 6, pp. 29-35.
- Kalaitzandonakes, N. G., Wu, S. and Ma, J-C (1992). *The Relationship between Technical Efficiency and Firm Size Revisited*. Canadian Journal of Agricultural Economics, Vol. 40, pp. 113-119.

- Kay, R. D., Edwards, W. M. and Duffy, P. A (2004). *Machinery Management. In Farm Management*. McGraw-Hill Inc, New York, pp. 397-416.
- Ker, A. and W. H. Howard (1993). *Economies of Size in the Ontario Swine Industry*. Working Paper Series wp93/08. Department of Agricultural Economics, university of Guelph. Ontario.
- Konning, K (1973). *Measurement of Some Parameters of Different Spring Wheat Varieties Affecting Combine Harvesting Losses*. Journal of Agricultural Engineering Research, Vol. 18, pp. 107-115.
- Kumbhakar, S.C (1993). *Short Run Returns to Scale, Farm Size, and Economic Efficiency*. The Review of Economics and Statistics 75:2, pp. 336-341.
- Leung, C. Y (1991). *Economies of Size in Beef Production in Saskatchewan*. Masters Theses, Agricultural Economics Department, university of Saskatchewan.
- Maynard, H (2006). *Large Farms Profitable, but at What Costs?*. Special Report, Western Producer, April 13, 2006.
- McGechan M.B. and Cooper, G (1997). *The Influence of a Changed Climate on Soil Workability and Available Workdays in Scotland*. Journal of Agricultural Engineering Research, Vol. 68(17), pp. 253-269.
- Olson, K. D (2004). *Estimating the Annual Costs of Capital Assets. In farm Management, Principles and Stragies*. Iowa state University Press, pp. 371-378.
- Pote, J. W., Wax, C. L. and Karr, B. L (1997). *Available Workdays in Mississippi Forests Resulting from Climate and Soil Type Interactions*. Research Bulletin 86, Mississippi Water Resource Institute, pp.18.
- Rounsevell, M. D. A (1993). *Review of Soil Workability Models and Their Limitations in Temperate Regions*. Soil Use Management, Vol. 9, pp. 15-21.
- Rounsevell, M.D.A. and Jones, R.J.A. (1993). *A Soil and Agro Climatic Model for Estimating Machinery Workdays: the Basic Model and Climatic Sensitivity*. Soil and Tillage Research, Vol. 26(3), pp. 179-191.
- Ruthledge, P. L. and McHardy, F. V (1968). *The Influence of the Weather on Field Tractability in Alberta*. Canadian Agricultural Engineering, Vol. 10, pp. 70-73.
- Saskatchewan Agriculture and Food (2004). *Census Statistic Facts: Number of Census Farms*. [www.agr.gov.sk.ca](http://www.agr.gov.sk.ca). Regina, SK. Saskatchewan Agriculture and Food
- Saskatchewan Agriculture and Food (2005). *Historic crop Yields: Rural Municipality #281*. [www.agr.gov.sk.ca](http://www.agr.gov.sk.ca). Regina, Saskatchewan Agriculture and Food.

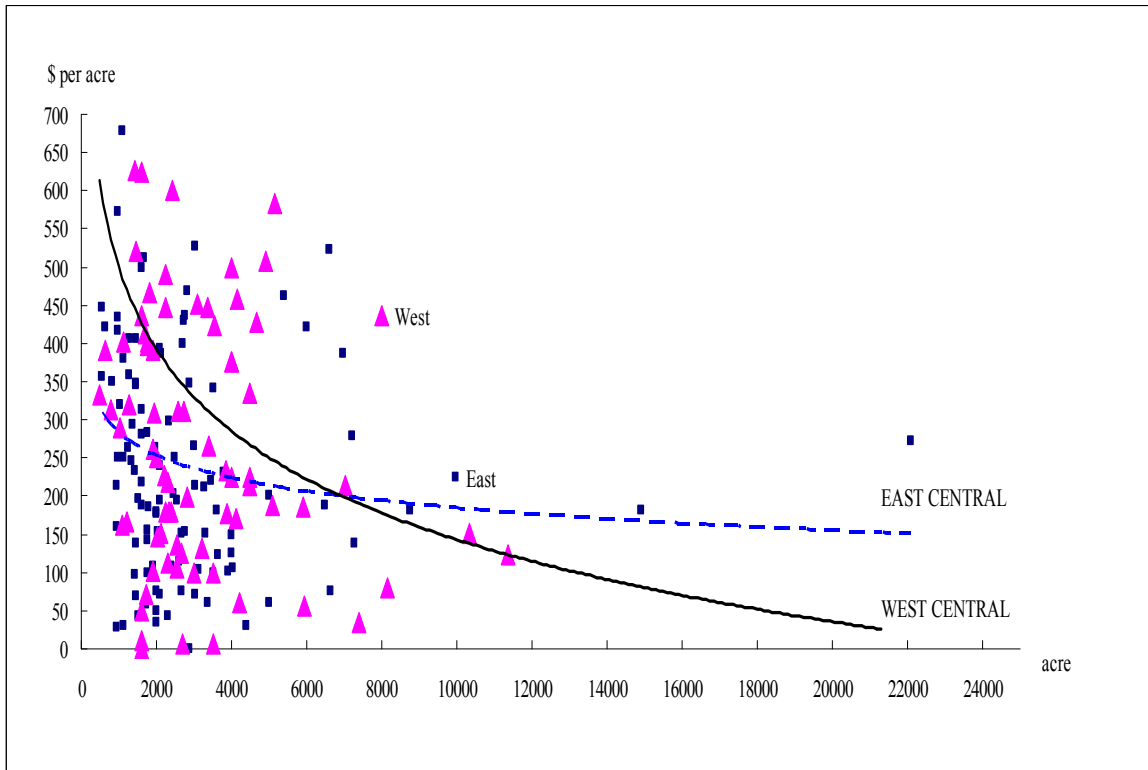
- Saskatchewan Agriculture and Food (2006)a. *Crop Production Guide; Dark and Brown Soil Zone (2006)*. Saskatchewan Agriculture and Food, Regina.
- Saskatchewan Agriculture and Food (2006)b. *Saskatchewan Custom Rate Guide, 2005*. Saskatchewan Agriculture and Food, Regina.
- Shiryayev, A. N (1996). *Sequences of Random Variables that Form Markov Chains*. In Probability, Graduate Texts in Mathematics, Springer-Verlag, New-York, pp. 564-587.
- Smith, C.V (1970). *Weather and Machinery Work Days*. In Weather Economics (ed. J. A. Taylor), Pergamon Press, Oxford, pp. 17-25.
- Smith, C.V (1977). Work-days and Spring Cultivation. *Agricultural Engineer*, Vol. 32, pp. 95-97.
- Statistic Canada (2001). *Census of Canada: Agriculture: Farm and Farm Operators*.
- Statistics Canada (2002). *Census of Canada: Whole Farm Data Base 2002*.
- Statistics Canada (2004). *Census of Canada: Agriculture: Farm and Farm Operators*.
- Statistics Canada (2005). *Farm Financial Survey*. Agricultural Division, Ottawa.
- Toro, A and Hansson, P. A (2004). *Analysis of Field Machinery Performance Based on Daily Soil Workability Status Using Discrete Event Simulation or on Average Workday Probability*. Masters Theses, Department of Agricultural Engineering, Swedish University of Agricultural Sciences.
- Witney, B. (1996). *Choosing and Using Farm Machines*. Land Technology Ltd, pp. 58-64.



**APPENDIX 1. Seed expense per acre**



**APPENDIX 2. Land and building assets per acre**



**APPENDIX 3.** Combine costs estimation due to change in field efficiency

Crop acre	TCmin		VC		FC		Ti		Custom	
	FE (0.80)	FE (0.75)	FE (0.80)	FE (0.75)	FE (0.80)	FE (0.75)	FE (0.80)	FE (0.75)	FE (0.80)	FE (0.75)
5000	21.89	24.7	5.18	5.52	13.22	13.21	8.13	13.87	1.86	3.18
6000	27.09	27.55	5.18	5.52	22.03	22.03	0	0	0	0
7000	24.06	24.41	5.18	5.52	18.88	18.88	0	0	0	0
8000	21.7	22.05	5.18	5.52	16.52	16.52	0	0	0	0
9000	19.87	20.21	5.18	5.52	14.68	14.68	0	0	0	0
10000	21.89	24.7	5.18	5.52	13.22	13.22	8.13	13.87	1.86	3.18
11000	23.2	23.55	5.18	5.52	18.02	18.02	0	0	0	0
12000	21.7	22.05	5.18	5.52	16.52	16.52	0	0	0	0
13000	20.43	20.78	5.18	5.52	15.25	15.25	0	0	0	0
14000	20.36	23.01	5.18	5.52	14.16	14.15	2.38	7.74	0.55	1.77
15000	21.89	24.7	5.18	5.52	13.22	17.62	8.13	0	1.86	0
16000	21.7	22.05	5.18	5.52	16.52	16.52	0	0	0	0
17000	20.73	21.08	5.18	5.52	15.55	15.55	0	0	0	0
18000	19.87	20.21	5.18	5.52	14.68	14.68	0	0	0	0
19000	20.73	22.92	5.18	5.52	13.91	17.39	3.81	0	0.87	0
20000	21.7	22.05	5.18	5.52	16.52	16.52	0	0	0	0
21000	20.91	21.26	5.18	5.52	15.73	15.73	0	0	0	0
22000	20.2	20.55	5.18	5.52	15.02	15.02	0	0	0	0
23000	20.07	22.69	5.18	5.52	13.77	14.36	4.68	6.51	1.07	1.49
24000	20.96	23.67	5.18	5.52	13.22	13.21	8.13	13.87	1.86	3.18

#### APPENDIX 4.

$$w_l = \sqrt{\frac{100 \cdot c \cdot A}{(FC \% ) \cdot p \cdot S \cdot e} \cdot \left( L + \frac{K \cdot Y \cdot V \cdot A}{(P [ D ]) \cdot h} \right)} \quad (1)$$

Solving equation (1) with respect to (A) gives the following quadratic equation (2):

$$100 \cdot c \cdot K \cdot Y \cdot V \cdot A^2 + 100 \cdot c \cdot L \cdot A - (FC \% ) \cdot p \cdot S \cdot e \cdot (P [ D ]) \cdot h \cdot w_l = 0 \quad (2)$$

From equation (2), optimal area combined (A) can be derived by equation (3);

$$A = \frac{-100 \cdot c \cdot L \pm \sqrt{(100 \cdot c \cdot L)^2 - 400 \cdot c \cdot K \cdot Y \cdot V \cdot (FC \% ) \cdot p \cdot S \cdot e \cdot (P [ D ]) \cdot h \cdot w_l}}{2 \cdot 100 \cdot c \cdot K \cdot Y \cdot V} \quad (3)$$