RURAL ECONOMY

A Comparison of Risk Between Continuous and Fallow Cropping Regimes

Leonard Bauer, Scott R. Jeffrey and Charles C. Orlick

Project Report 95-08

Alberta Agricultural Research Institute Project No. 04-0492

PROJECT REPORT

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Abstract

The focus of this study is to examine the risk and return trade-offs for various crop rotations and tillage systems. The geographic area represented in this study will be that contained within four soil, and five climatic zones with in the Province of Alberta. The predominant crops grown in these areas (i.e. spring wheat, barley, and canola) were used to derive cost estimates that reflect agronomic processes.

The results obtained from each of the areas indicate that several generalizations can be made about the interactions of crop rotations, tillage system and farm size. Firstly, the size of predicted net revenue increases and the probability of generating a negative net revenue decreases as one moves north from the Brown soil zone into the Dark Brown and Black soils. Secondly, as one moves from the Brown soil zone through to the Black soil zone, less significance can be placed on fallow crop rotations. Lastly, at the current price of the fallow herbicides, conventional tillage systems have a cost advantage over the alternatives tested here.

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Section 1: Introduction

1.1 Background

Cropping intensity is an important agricultural subject of inquiry directly related to soil conservation. Numerous reports have shown the high costs associated with summer fallow, and combined with the rising cost of land, has resulted in some producers utilizing high intensity cropping practices. The degree to which summer fallow is practiced seems to be dependant on the soil type/zone. For example in the brown soil zone, summer fallowing is a generally accepted practice, justified as a necessity. In the black soil zones the prevailing opinion is that summer fallow is not necessary, at least not on a regular basis. Agronomic evidence is suggesting that a reduction in the amount and/or proportion of summer fallow may be feasible.

Marv Anderson & Associates Limited (1981), in their report to the Environment Council of Alberta, trace the origins of summerfallow in North America to a grain farmer at Indian Head, Saskatchewan in 1885. During that summer this farmer had difficulty obtaining the labour and horses necessary to plant his wheat. He let the land lie idle, with only periodic tillage for weed control. The next year he was able to secure sufficient labour to plant his crop, and at harvest time, discovered that the land that had been left idle produced a wheat crop of 35 bushels per acre. This was contrasted with the adjacent property producing only 2 bushels of wheat per acre. Word of this discovery spread and soon it became known as the "miracle of summerfallow". Shortly after this discovery the Canadian Government, through the Department of Agriculture (now called Agriculture and Agri-Food Canada) began research on the practice of summerfallow in agriculture.

In 1950 a set of experimental plots was established at Lethbridge, Alberta, for the study of dryland farming practices. (Smith et al, 1994) Similar plots were established in 1957 at Melfort, Saskatchewan, 1958 at Indian Head, Saskatchewan (Zentner et al 1987), 1978 at Scott, Saskatchewan (Zentner et al 1990), and 1981 at Swift Current, Saskatchewan (Zentner et al, 1992) all for the same purpose, but on different soils and different climates. A short term study has also been conducted in central Alberta. The five year study was conducted through the Agriculture Canada research station at Lacombe. (Mahli et al, 1988) These experimental sites have provided a large body of literature not only for the agronomic study of various farming practices, but also for the economic aspects of them.

The research data collected from some of these on going experiments, were used by Zentner, Sonntag and Lee, to developed a model for simulating the cost structure, and decision making process used by dryland farmers on the Canadian prairies (Zentner et al, 1978). This decision making process was found to be very complex, and they found that breaking the model into two sub-systems of biological and economic processes was the simplest to manage. This model was used to generate cost structures for many studies.

Research in areas outside the region bounded by the previously noted research stations is limited, and research using production data obtained from farm level sources is rare. This gap in research seems to arise from three problems; first, the production cycles for grain farming are, at least, one year per cycle, which creates a situation where a great deal of time is required to collect data; secondly, cropping practices vary widely between individual farms; and finally, modelling the decision process of farmers, especially when uncertainty or risk is considered, can be complex.

McConnell (1983) and the reviewers of his model, Kiker and Lynne (1986), all agree that adoption of conservation practices is to some degree driven by risk and uncertainty considerations. Lerohl, Anderson and Robertson (1990) allude to the idea that policy packages available to producers may be contributing to continued use of practices that degrade the farmland by reducing risk and uncertainty of revenue. Van Kooten (1990) arrived at similar conclusions. Research by Bauer and McEvoy (1990) established that, for economic justification of adopting reduced or minimum tillage systems, gross revenue per cropped acre, under a crop fallow regime in the dark brown soil zones, must be in the neighbourhood of 20% to 25% greater than under continuous cropping assuming equal variability for the two regimes.

Of the studies cited, none have addressed the relative variability of yields and net incomes under the two cropping systems (i.e. continuous cropping versus a crop rotation that includes summerfallow). It is a widely held belief among producers, however, that variability of yield and income for continuous cropping exceeds that of crop fallow programs. Unfortunately, empirical evidence about the relative yield and income variability under various cropping programs is lacking.

Fox and Dickson (1988) conclude: "Farmers have been reluctant to adopt tillage systems which reduce farm income in the short and long runs." Seitz and Swanson (1980) suggest that "a farm decision process ... is much more complex than represented by the models we find in the literature." McConnell (1983) developed a model illustrating the private and social costs of soil erosion. In his conclusion he states: "if farmers know that the soil base affects farm ... values, they will conserve it. This result suggests that information about this be disseminated." (McConnell, 1983) The objective of this study is to compare the degree of risk faced by producers under various cropping regimes, including crop fallow and continuous cropping, and also to provide additional insights about the farm decision making process.

1.2 Study Objectives

The objective of this study is to examine the risk and return trade-offs for various crop rotations and tillage systems. The geographic area represented in this study will be that contained within the brown, dark brown, thin black, and black soil zones, in the Province of Alberta. The predominant crops grown in these areas (i.e. spring wheat, barley, and canola) will be used to derive cost estimates that reflect agronomic practices.

The objectives of this study are four-fold:

a) To measure the variability of crop yields under several crop rotations in several areas.

b) To estimate the gross revenues and costs associated with various tillage systems, and crop rotations.

c) To determine the expected net revenue for each of the crop rotations and tillage systems.

d) To estimate the degree of risk for each of the tillage systems and the crop rotations, which will allow for risk adjusted economic comparisons and estimation of the risk/return trade-off inherent in these types of agricultural production systems.

Section 2: Methodology

This section will describe the economic and agronomic models used, and the individual study areas. Section 3 is organized into three sections detailing the data used, and calculations performed to estimate the expected net revenue and its variability under three tillage systems and several crop rotations in the five study areas The first two sections describe the components of the economic model being employed for this study. That is to say, the first two sections of this section are describing the predictions (or estimates) and variances being used to arrive at an expected net revenue and a measure of how actual results may vary around that expected value. The theoretical background for these sections can be found in Orlick (1995). The last section will detail the individual areas being studied and the various tillage and crop rotations being simulated.

2.1 Economic Model

The objective of this study is to examine the level and variability of the net revenue generated under various tillage and crop rotation schemes. The economic model used in this study contains two parts; the first part describes how the net revenue and its variance for an individual crop are calculated. The second section builds on the first by expanding from one output or product to multiple outputs or products and describes how the net revenue and its variance for the whole farm are calculated. The exposition of this model will follow a format similar to that used in Section 2 to describe the net revenue function.

2.1.1 Predicted Crop Prices

This section describes the manner in which prices are predicted for the various crops. The production of grain crops involves growing several types of grains and oilseeds. In the study we use the three crops most commonly grown in Alberta: Hard red spring wheat, spring barley, and canola. Prices are quoted for each of the crops with adjustments made for regions and grades.

Boyda (1988) suggested that further differentiating the crop prices by grade in each area of production (in this study, by county or municipal district) will allow the effects of climatic differences between the areas to be demonstrated. The proportion of each grade in each area was obtained from the Alberta Wheat Pool. The grades included for wheat are #1, #2, and #3 CW and Feed. The grades included for barley are 2 Row, 6 Row Select, #1 and #2 CW Feed, and Non- Board Feed. Canola is not sold through the Canadian Wheat Board and prices are already weighted for grade in the published sources.

Grain crop prices were obtained from the Canadian Grains Council (various years), in nominal terms, to provide the time series. These prices are not those farmers ultimately receive, because there are usually additional deductions. Freight, elevation ,and dockage (FED) (i.e. charges for transporting to an export point and preparing the grain for export) are deducted from the price received by the farmer.

Freight rates vary according to the distance between the delivery point (country elevator) and the point of export.[1] In this study freight rates to the ports of Vancouver and Prince Rupert were used. Coincidentally, these two ports are considered to be of equal distance from all rail points in Alberta. In Alberta most grain is shipped by rail, and the railroads are regulated by law with respect to the charges a producer must pay.[2] These rates were obtained from an annual publication by Alberta Agriculture.

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[1] The Prairie farmers have four options available for the point of export of their grain crops. They are Prince Rupert and Vancouver, B.C., Churchill, Man., and Thunder Bay, Ont.

[2] The Canadian Government's budget for the year 1995- 1996 effectively discontinued the regulations and subsidies that were provided to the railroads serving prairie farmers. The freight rates are expected to change beginning with the 1995- 1996 crop year and costs are expected to rise, and reflect the full freight rate charges as levied by the railroads.

Nominal net grain prices were then converted, by use of the consumer price index (CPI), to their real equivalents in 1994 dollars. This conversion removes the effects of changes in the purchasing power of the dollar.

Since this study had objective of modelling the net revenue maximizing decisions of farmers, a method of using the historical information about grain price movements was developed. Mahli et al (1988, pg 161) approached the problem of how much history to use for the extraction of price information with the following rationale; "...economic processes are more transient than physical processes and that recent price and cost information is likely to be superior...". Pope and Just (1991) used an adaptive expectations approach to form price expectations for their model of potato production decision making in Idaho. They used a weighted average of the previous six years to obtain the historical base for their expectations formation model. Brorsen et al (1987, pg 734-735) used a similar approach to their examination of the acreage responses to the US. rice market. They used a three year lag structure to estimate the price deviations in their expectations model. Both of these groups of researchers chose their lag structures based on the attributes inherent to the markets being studied.

Govindasamy (1983, pg 129) reported survey results indicating that farmers in southern Alberta make their production choices using a short term or a year to year time horizon. He further suggested that production decisions hinge on perceptions of crop marketability, and the growing conditions that may be encountered in the upcoming growing season.

An adaptive expectations format is used in this study; an approach consistent with the advice given by governmental grain price forecasters. In this context, the best estimate of this year's price will be last year's price.[3] Consequently real net prices have been lagged one year to estimate the price, according to the following:

$$\hat{p}_{i,t} = p_{i,t-1}$$

Where:

$p_{i,t-1}$ represents the real price for the i^{th} crop lagged one year.

The nominal observed crop prices in this study have been converted to real prices through adjustment by the Consumer Price Index (CPI). The time series (i.e. 1976 to 1993) had annual CPI values ranging from 47.47 in 1976 to 130.33 in 1993. The base year was 1986 with index of 100.

The deviations of actual prices from the estimated price form the basis of the risk measurements used, and are defined as follows:

$$\hat{e}_{i,t} = (p_{i,t} - \hat{p}_{i,t}) = (p_{i,t} - p_{i,t-1})$$

Where:

$\hat{e}_{i,t}$ represents the error in estimating the price of the i^{th} crop in period t.

The mean squared error (MSE) statistic is calculated according to:

$$MSE = \hat{\sigma}^2_{p_t} = \frac{\sum_{t=1}^{T} (\hat{e}_t)^2}{T}$$

The MSE has a similar interpretation to the variance. A surrogate for standard deviation can therefore be developed from these measures by taking the square root of the MSE; this result is more formally termed as root mean squared error (RMSE). Table 2 in Appendices A to E details both the nominal price data as obtained from the various sources, the real prices that have been adjusted (as detailed previously), and the error of the price predictions.

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[3] At a policy analysis level, estimates are rarely projected ahead more than the next crop year due to the many factors that can come into play in estimating yields and then supply. The factors here also include some of the stochastic factors influencing a farmer's production decisions (e.g. moisture conditions, crops produced last year, etc.)

2.1.1.1 Estimated Crop Yields

The yields of each crop were obtained from Agriculture Financial Services (AFSC)[4]. AFSC was chosen as the data source because of its ability to provide a sufficiently long series of yields classified by both municipal division and whether the crop was grown on stubble (indicating that a continuous cropping pattern was being employed) or fallow (indicating the crop was grown on land that was summer fallowed the preceding year). Tables 1 in Appendices A to E contain the details of the yield histories for each area.

2.1.1.2 Expected Gross Revenue and Variance of an Individual Crop

Expected gross revenue and its variance involve the product of price and yield, both of which are random variables. In general the expected value of a product of random variables, in this case gross revenue, is defined as follows:

$$E(\hat{\pi}_i) = E(\hat{p}_i)\,E(\hat{y}_i) + COV(p_i, y_i)$$

If the price and yield are statistically independent the covariance term is zero, and the expected gross revenue is the product of expected price and expected yield. Using the notation previously adopted in this report we have:

$$\hat{\pi}_i = \hat{p}_i \; \hat{y}_i$$

Bohrnstedt and Goldberger (1969) have shown that if two random variables are jointly distributed with expected values ($E(p_i)$ *and* $E(y_i)$; variances ($V(p_i)$ and $V(y_i)$, and a covariance ($COV(p_i,y_i)$) then, the variance of this product is:

$$V(p_i\, y_i) = E[p_i y_i - E(p_i y_i)]^2$$

They further demonstrated that if p_i and y_i are bivariately normally distributed, and are expectational and variance independent, then the above can be accurately calculated as:

$$V(p_i y_i) = E^2(p_i)V(y_i) + E^2(y_i)V(p_i) + V(p_i)V(y_i).$$

2.1.1.3 Crop Inputs

The crop inputs are defined as those expenses that can be directly attributed to the production of a specific crop using a specific tillage system, and crop rotation. These expenses are divided into two categories: crop input costs and machinery costs. These categories are discussed separately in the sections following.

2.1.1.3.1 Crop Input Costs

The crop inputs include: seed, fertiliser (N and P_2O_5), selective herbicides (weed control appropriate to the crop being grown and the weeds present), and non-selective herbicides (glyphosate). The costs for all of these (except the non-selective herbicides) were obtained from Alberta Agriculture survey results[5]. These survey results were published by area and summarize producers' reported use of these inputs.

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4 AFSC was formed as a merger of Alberta Hail and Crop Insurance Corporation and Agricultural Development Corporation. The information obtained here is not published or available except by special request.

5 The Production Economics Branch of Alberta Agriculture publishes, annually, Crop Projections by region. These are being produced to assist farmers with making application for various production related government sponsored programs. The information in these publications is based upon surveys of producers within each area. (Jetter, 1995, personal communication)

The non-selective herbicide used in this study is glyphosate. The costs for glyphosate were obtained from a manufacturer's advertisement[6] in a popular farm newspaper. (Western Producer, 1994). The application rates, and by extension costs are derived from the manufacturer's recommendation that this herbicide be applied at a rate of 1.0 *l* / ac.

2.1.1.4 Machinery Costs

Capital invested in equipment comprises major component of the costs of production. This section deals with the issues of correctly sizing the equipment complement and the capital costs associated with owning this equipment complement

Optimal equipment sizing has been discussed by several authors, but usually in an US. context. Woloshyn in 1990 took the findings of these US. studies and adapted them to a model that can be used for Alberta. (Woloshyn, 1990) Woloshyn determined that the cost of owning an asset can be divided into two distinct cost components: a) the capital costs, and b) the repair and maintenance costs. (Woloshyn, 1990, pg 9) The capital costs are those associated with the capital investment in equipment, and the assumption that the equipment investment is ongoing. The repair and maintenance costs include not only the costs associated with repairing and maintaining the equipment complement, but also the costs incurred due to field operations being delayed as a result of equipment repairs.

The equipment costs for both capital and operating expenses required are related to the particular crop rotation system, and the tillage system, used in each area. A table of the equipment complements, and the number of times the equipment is used within the tillage and crop rotation systems, is found at the end of this section.

2.1.2 Whole Farm Economic Model

To establish an expected net revenue for the whole farm, all the crop enterprises generating an income are summed according to the proportion they represent of the whole farm income (including the proportion of the farm in fallow and generating zero income). Previously the expected net revenue attributable to a particular crop was defined as $\hat{\pi}_i$. The expected net revenue for the whole farm will be defined as:

$$\hat{\pi} = \sum_{i=1}^{m} a_i \hat{\pi}_i$$

Where:

a_i represents the proportion that the i^{th} crop represents of the total crop acreage (including fallow acreage).

This methodology facilitates the comparison of various crop rotations on a per crop rotation acre.

The level of risk is calculated as the RMSE of expected net revenues. In this study the prices and quantities of the crop inputs are known with certainty. It follows that the RMSE of the expected net revenue will equal the RMSE of the gross revenue.

Farmers, for agronomic purposes, rotate their crops. If this rotation includes more than one kind of crop (for example grains and oilseeds) then the rotation can be considered a portfolio of revenue streams. The variance of the aggregate revenue stream should then be calculated in the same manner as an investment analysts would calculate variance for a portfolio of stocks or bonds.

Brealy et al (1992) cite an article written by H. M. Markowitz as the start of the formal study of the potential for risk effects. Brealy et al (1992) provide a description of how to calculate the variability of a portfolio of income streams. They state that a weighed average of the variabilities is not a complete measure of a portfolio's variability, and describe why the covariance is a necessary component. The methodology, as applied to crops within a crop rotation, is summarised as follows:

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[6] Glyphosate is the significant chemical ingredient in Monsanto Roundup, a popular herbicide used for chemical fallow. The use of this herbicide in this study is not to be construed as an endorsement for a particular product. It should be noted that there are other products registered for chemical fallow use.

$$\hat{\sigma}^2 = \sum_{i=1}^{n} \hat{\sigma}_i^2 a_i^2 + 2 \sum_{i<g}^{n} \sum_{g=1}^{n} \hat{\rho}_{ig} \hat{\sigma}_i \hat{\sigma}_g a_i a_g$$

Where:

$\hat{\rho}_{ig}$ is the coefficient of correlation between the i^{th} and g^{th} crop net revenue per acre,

a_i represents the proportion the ith crop devoted to the whole portfolio.

2.1.3 Risk Comparisons of Alternative Systems

An investor in the stock market desires information about the changes in the risk level of his stock portfolio that may occur as a result of adding or removing a particular stock. By analogy, a farmer would also desire information about the changes in his risk exposure as a result of adding or deleting a crop from his rotation.

The methodology described previously was used to calculate and interpret the probability of an expected net revenue being less than zero.

2.2 Agronomic Model

The economic model, previously described, relies on the interaction of the various inputs to produce and market the various crops. This section details the interactions that have been previously described as the production function. The specific interactions and assumptions being detailed here are the crop rotations and tillage systems.

2.2.1 Crop Rotations

The crop rotations (i.e. the sequence of crops within the rotation) used in this study have been either extracted directly or adapted from other published studies. Most studies of cropping practices caution that they reflect the actions or behaviours of farmers "on average." The term "on average" indicates that some farmers may actually be using these crop rotations. And if enough of the farmers are doing this then the term "typical" may be used to describe these crop rotations.[7] This study carries the same caveat.

A definition of the nomenclature used to describe the crop rotations is as follows:

WW, continuous cropping of wheat on stubble,

WF, 1/2 of the acreage is seeded to wheat on fallow, and the remaining 1/2 of the acreage is left to summerfallow

WWF, 1/3 of the acreage is seeded to wheat on fallow, 1/3 of the acreage is seeded to wheat on stubble, and the remaining 1/3 of the acreage is left to summerfallow,

WB, continuous cropping, 1/2 of the acreage is seeded to wheat on stubble, and the remaining 1/2 of the acreage is seeded to barley on stubble,

WBF, 1/3 of the acreage is seeded to wheat on fallow, 1/3 of the acreage is seeded to barley on stubble, and the remaining 1/3 of the acreage is left to summerfallow,

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7 These crop rotations were chosen after consultation with the researchers at the Production Economics Branch of Alberta Agriculture and Rural Development. They regularly conduct surveys of farmers to gather information about their farming practices, including the crop rotations used.

WWB, continuous cropping, 2/3 of the acreage is seeded to wheat on stubble, and the remaining 1/3 is seeded to barley on stubble,

WWBF, 1/4 of the acreage is seeded to wheat on fallow, 1/4 of the acreage is seeded to wheat on stubble, 1/4 of the acreage is seeded to barley on stubble, and the remaining 1/4 of the acreage is left to summerfallow,

CW, continuous cropping, 1/2 of the acreage is seeded to canola on stubble, and the remaining 1/2 of the acreage is seeded to wheat on stubble,

CWF, 1/3 of the acreage is seeded to canola on fallow, 1/3 of the acreage is seeded to wheat on stubble, and the remaining 1/3 of the acreage is left to summerfallow,

CWB, continuous cropping, 1/3 of the acreage is seeded to canola on stubble, 1/3 of the acreage is seeded to wheat on stubble, and the remaining 1/3 of the acreage is seeded to barley on stubble,

CWBB, continuous cropping, 1/4 of the acreage is seeded to canola on stubble, 1/4 of the acreage is seeded to wheat on stubble, and the remaining 1/2 of the acreage is seeded to barley on stubble,

CWBF, 1/4 of the acreage is seeded to canola on fallow, 1/4 of the acreage is seeded to wheat on stubble, 1/4 of the acreage is seeded to barley on stubble, and the remaining 1/4 of the acreage is being left to summerfallow.

2.2.2 Tillage Systems

Selecting the tillage systems used for crop production has been a much debated issue for as long as tillage has been studied for its agronomic and economic impacts. The definitions developed by Bauer and McEvoy (1990) for the Dark Brown soil zone in the Drumheller/Three Hills region will form the starting point for the definitions used in this study. These definitions are applied directly to the discussion of the Trochu area and are modified for the other regions. The study areas cover four soil zones (Black, Thin Black, Dark Brown, and Brown soils). Each area requires modification of the base tillage systems definition. The modifications are outlined in the individual study area descriptions.

Stonehouse (1991, pg 336) indicates that the intensity of different tillage systems can be measured "by the degree of soil inversion or disturbance ". Increased intensity results in larger labour and machinery inputs and can also result in a higher rate of soil degradation. In this research three levels of tillage intensity are being studied: conventional, minimum, and zero tillage. The most intensive system is conventional tillage, and the least intensive will be zero tillage. The specific definitions for this study are detailed in the following sections.

2.2.2.1 Conventional Tillage System (CT)

Conventional tillage is typified by several passes over the soil with soil disturbing implements. These passes are conducted with the intent of either, preparing a seed bed, or for the control of weeds.

Fall cultivation is often performed to incorporate some of the crop residues, and in some situations also to incorporate certain fall applied herbicides and/or fertilizers. The equipment used can vary from a mouldboard plow, to a discer, to a cultivator (either of the heavy duty, or the lighter field variety). The mouldboard plow is the most intensive because of the near total inversion of the soil. The difference in the use of tillage equipment has been attributed to producers cultural preferences and production objectives.

Here conventional tillage is assumed to include generally one fall cultivation, and at least one spring cultivation. A seeding operation will including harrowing, and incrop weed control performed, as needed, by tractor drawn spraying equipment. During the fallow portion of the crop rotation (if used) weed control is accomplished by cultivation several times during the growing season.

2.2.2.2 Minimum Tillage System (MT)

The objectives of minimum tillage are to reduce the producer's reliance on soil disturbance to prepare the seed bed and control weeds. This is accomplished by increasing the use of chemical weed control.

Minimum tillage is assumed to include one fall pass with a cultivator equipped to apply fertilizers and herbicides. The spring cultivation for seedbed preparation is eliminated. Seeding and incrop weed control is performed similarly to conventional tillage. During the fallow portion of the cropping rotation (if used), at least one of the cultivation passes is replaced by the application of herbicides.

2.2.2.3 Zero Tillage System (ZT)

Zero tillage is the simplest system to define because cultivation is all but eliminated. The only disturbance of the soil occurs when the seed is placed in the soil. Weed control is performed entirely by spraying herbicides.

2.3 Study Area

Alberta Agriculture reports that the area used for crop production including land set aside for summer fallow totals 27,228,354 acres. (Alberta Agriculture, 1994b) This area contains several broad classes of soils and even more climatic subdivisions. Both soil and climate have significant importance in the production of grain crops.

Soil classes can vary locally. This study is limited to the soils classified as Chernozemic, which is typified by a thick, humus rich surface horizon. This order of soil can be further differentiated and described by the colour of the surface horizon. (Toogood, 1989, pg 7). This study examines the Brown, Dark Brown, Thin Black, and Black soils in Alberta.

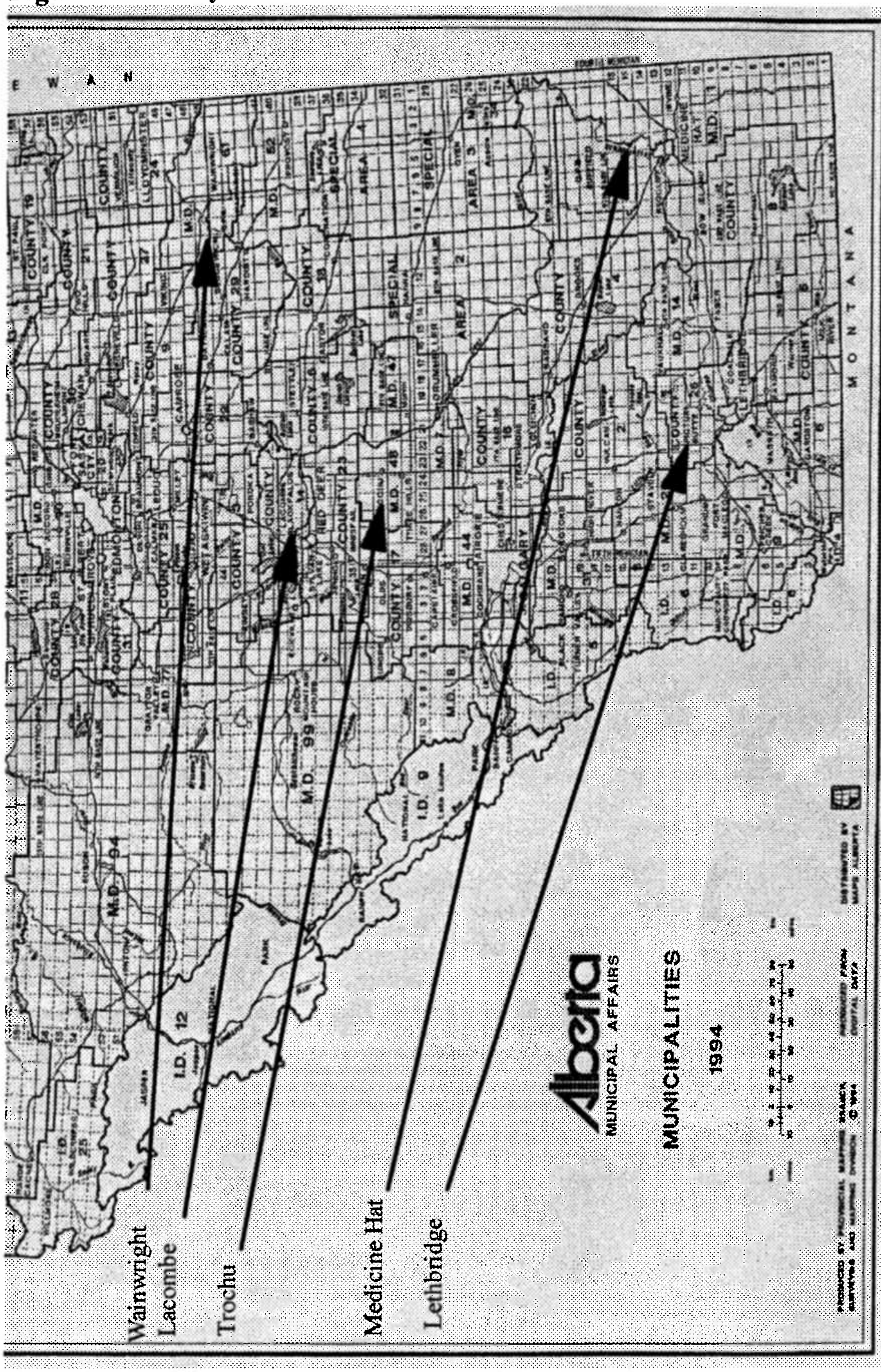
The Canadian Land Inventory (CLI) was developed to combine the effects of the climate and the type of soil to provide an indication of the capabilities (or conversely limitations for use) for areas deemed to have agricultural potential. The CLI system has seven broad groups, ranging from 1 which is described as having no limitations for agricultural production, to 7 which describes land that has no capability for arable agriculture or permanent pasture. (Alberta Energy and Natural Resources, 1983) To illustrate the climatic factors facing an agricultural producer in the study areas agroclimatic descriptors were used. These broadly define the growing conditions in an area, and are based upon precipitation and number of frost free days during the grain growing season. To better illustrate these differences, county and M.D. divisions were chosen as the gross area descriptors (see Figure 3.1). The five areas chosen represent four soil zones and four agro-climatic areas found in the major portion of Alberta's cropping region.

2.3.1 Medicine Hat Area

This study area is comprised of a portion of M.D. 1, a municipal district in south eastern Alberta. The region being studied is described as the area east and south of the South Saskatchewan river and having a southern boundary of approximately the Trans- Canada Highway. The 1991 census reports that there were 1004 farms with an average size of approximately 2396 acres in this area.

The soil is described as Brown Chernozemic. The CLI classification is 3A, which is described as having rainfall as a limiting factor for plant growth and a frost free period of greater than 100 days. The Agroclimatic Atlas of Alberta lists the annual precipitation for this area as 300-350 mm., and growing season (May 1 to August 31) precipitation of 200 mm.. The Atlas further reports a frost free period of 100 to 115 days, and total degree days above 5^0 C as 1700-1800. (Dzikowski and Heywood, 1990)

Figure 2.1: Study Areas



The agricultural practices in this area are described as "dryland farming", due to the limited amounts of precipitation. The predominant cropping pattern in this area is one year of cropping followed by one year of summerfallow. Summerfallowing is used to accomplish two objectives: moisture conservation and weed control. Because of the moisture limitations it is unusual to observe crops other that cereal grains being grown in this area.

2.3.1.1 Crop Rotations

For the Medicine Hat area four crop rotations were simulated: wheat/fallow (WF), wheat/barley/fallow (WBF), continuous wheat (WW), and wheat/wheat/barley (WWB). The wheat/fallow and continuous wheat crop rotations have been adapted from a study of flexible cropping decision rules by Bauer, Novak, Armstrong and Staples, (1992). The remaining two crop rotations were adapted from a study by Zentner et al (1992).

2.3.1.2 Tillage Systems and Equipment Complements

This area is typified by "dryland farming" practices because soil moisture is the limiting factor in grain production. Certain pieces of equipment are common to all tillage systems, and cropping rotations. These are the spraying equipment, harvesting equipment, and the fixed capacity tractor. For the machinery costing model a 60 foot wide field sprayer was used. The harvesting equipment consisted of a 22 foot pull type swather and a Class 4 combine which has a capacity compatible with the swather. The fixed capacity tractor is an 80 horsepower, two wheel drive type.

Under a continuous cropping rotational system, it is assumed that in conventional tillage and minimum tillage systems, some of the tillage operations are performed during the seeding operation. The conventional tillage system assumed two tillage passes and two harrowing passes, in addition to the seeding operation. The minimum tillage system assumed one tillage pass and the seeding operation. The zero tillage system assumed seeding would be the only ground-disturbing operation. The conventional tillage and minimum tillage systems assumed that there would be one tillage operation performed post harvest. Table 3.3, at the end of this section, provides the details of the equipment use and scheduling for the continuous crop rotation system.

The fallow crop rotational systems assume that the land left to fallow would require some weed control treatment. The conventional tillage system assumed that there would still be two tillage passes during the seeding and harvest periods, but two types of tillage equipment would be used once each. The minimum tillage and zero tillage systems use the same equipment, during the seeding and post harvest periods, as was assumed for the continuous cropping system. The fallow treatments for the conventional tillage system comprise two passes with a lighter piece of tillage equipment. The minimum tillage system substituted a tillage pass with one herbicide treatment. The zero tillage system assumed that all fallow tillage could be replaced by two herbicide treatments. Table 3.3, at the end of this section, provides the details of the equipment use and scheduling for the fallow crop rotation systems.

2.3.2 Lethbridge Area

The entire County of Lethbridge (not including areas farmed under irrigation) was used in this study. The county includes the City of Lethbridge and the communities of Picture Butte and Coaldale, and it is located approximately 60 miles north of the Canada- United States border. The 1991 census reports that there were 1188 farms with an average size of approximately 639 acres in this area. Since this average acreage figure includes irrigation as well as dryland farms, the average size of dryland farms would be larger.

The soil in this area is classified as Dark Brown Chernozemic and the CLI classification is 2A, which is described as having rainfall being a limiting factor for plant growth over 50% of the time, and a frost free period of greater than 100 days. The Agroclimatic Atlas of Alberta reports the annual precipitation for this area as 400- 450 mm., and growing season (May 1 to August 31) precipitation of 200 to 250 mm. The Atlas further reports a frost free period of 115+ days, and annual degree days above 5^0 C as 1600- 1800. (Dzikowski and Heywood, 1990) Again, because of limited amounts of precipitation in this area, it is also referred to as an area of "dryland farming".

The predominant cropping pattern in this area is one or two years of cropping followed by one year of summerfallow. Summerfallowing accomplishes two objectives: moisture conservation and weed control. Due to moisture limitations and high growing season heat values, cropping is usually limited to cereal crops, but due to new varieties becoming available there is an increase in the acreage of oilseeds being included in the rotations. (Jetter, 1995)

2.3.2.1 Crop Rotations

Four crop rotations were studied for the Lethbridge area: wheat/fallow (WF), wheat/wheat/ barley/fallow (WWBF), continuous wheat (WW), and wheat/wheat/ barley (WWB). The wheat/fallow and continuous wheat crop rotations have been adapted from a study of flexible cropping decision rules by Bauer, Novak, Armstrong and Staples, (1992). The remaining two crop rotations were adapted from a study by Zentner et al (1992).

2.3.2.2 Tillage Systems and Equipment Complements

This area is similar to Medicine Hat because soil moisture is a limiting factor for grain production. There are certain pieces of equipment that are common to all tillage systems, and cropping rotations. They are the spraying equipment, harvesting equipment, and the fixed capacity tractor. For the machinery costing model a 60 foot wide field sprayer was used. The harvesting equipment consists of a 22 foot pull type swather and a Class 4 combine which has a capacity compatible with the swather. The fixed capacity tractor is an 80 horsepower, two wheel drive type.

Under a continuous cropping rotational system, it is assumed that in conventional tillage and minimum tillage systems, some of the tillage operations will be performed during seeding. The conventional tillage system is assumed to include two tillage passes and two harrowing passes, in addition to the seeding operation. The minimum tillage system is assumed to include one tillage pass and the seeding operation. In the zero tillage system it is assumed that seeding would be the only ground disturbing operation. The conventional tillage and minimum tillage systems assumed that there would be one tillage operation performed post harvest. Table 3.4, at the end of this section, provides the details of the equipment use and scheduling for the continuous crop rotation system.

The fallow-crop rotational systems assume that the land left to fallow would require some weed control treatment. The conventional tillage system assumed that there would still be two tillage passes during the seeding time period and post harvest time periods, but two types of tillage equipment would be used once each. The minimum tillage and zero tillage systems use the same equipment, during the seeding and post harvest time periods, as was assumed for the continuous cropping system. The fallow treatments for the conventional tillage system comprised two passes with a lighter piece of tillage equipment. The minimum tillage system substituted a tillage pass with one herbicide treatment. The zero tillage system assumed that all fallow tillage could be replaced by two herbicide treatments. Table 3.4, at the end of this section, provides the details of the equipment used and scheduling for the fallow crop rotation systems.

2.3.3 Trochu Area

The area identified as Trochu is comprised of the M.D. 48. The area includes the communities of Acme, Trochu, and Three Hills. This area is located approximately 50 miles north east of the City of Calgary. The 1991 census reports that there were 989 farms with an average size of approximately 886 acres in this area

The soils of this area are also classified as Dark Brown Chernozemic and the CLI classification 1, which has adequate rainfall and a frost free period of greater than 90 days. Climate is the feature that differentiates this area from the Lethbridge area. The Agroclimatic Atlas of Alberta lists the annual precipitation for this area as 400- 450 mm., and growing season (May 1 to August 31) of 200-250 mm..

The Atlas further reports a frost free period of 100 to 115 days, and total degree days above 5° C as 1300-1500. (Dzikowski and Heywood, 1990)

The predominant cropping practices followed here are several years of cropping followed by one year of summerfallow. The inclusion of summerfallow in this area is not so much for moisture conservation but to provide for weed control and to facilitate the decomposition of the residues of the previous crops. Due to the reduction of climatic limitations both cereal and oilseed crops can be grown.

2.3.3.1 Crop Rotations

Three crop rotations were studied in the Trochu area: continuous canola/wheat/barley, continuous canola/wheat, and canola/wheat/fallow. The continuous canola/wheat and canola/wheat/fallow rotations were adapted from a study by Bauer and McEvoy (1990), which examined similar issues to those being studied here. The continuous canola/wheat/barley rotation was included as a third alternative for study in this area. (Jetter, pers. comm., March 1995)

2.3.3.2 Tillage Systems and Equipment Complements

This area is area is similar to Lethbridge, but cropping is less limited by moisture. There are certain pieces of equipment common to all tillage systems, and cropping rotations. These are the spraying equipment, harvesting equipment, and the fixed capacity tractor. For the machinery costing model a 60 foot wide field sprayer is used. The harvesting equipment consists of a 22 foot pull type swather and a Class 4 combine which has a capacity compatible with the swather. The fixed capacity tractor is an 80 horsepower, of the two wheel drive type.

Under a continuous cropping rotational system, it is assumed that in conventional tillage and minimum tillage systems, some of the tillage operations will be performed during the seeding time. The conventional tillage system assumed two tillage passes and two harrowing passes, in addition to the seeding operation. The minimum tillage system is assumed to be one tillage pass and the seeding operation. For the zero tillage system it is assumed that seeding would be the only ground disturbing operation. The conventional tillage and minimum tillage systems assumed that there would be one tillage operation performed post harvest. Table 3.5, at the end of this section, provides the details of the equipment usage and scheduling for the continuous crop rotation system.

The fallow crop rotational systems assume that the land left to fallow would require some weed control treatment. The conventional tillage system assumed that there would still be two tillage passes during the seeding time period and post harvest time periods, but two types of tillage equipment would be used once each. The minimum tillage and zero tillage systems use the same equipment, during the seeding and post harvest time periods, as was assumed for the continuous cropping system. The fallow treatments for the conventional tillage system comprised two passes with a lighter piece of tillage equipment. The minimum tillage system substituted a tillage pass with one herbicide treatment. The zero tillage system assumed that all fallow tillage could be replaced by two herbicide treatments. Table 3.5, at the end of this section, provides the details of the equipment used and scheduling for the fallow crop rotation systems.

2.3.4 Lacombe Area

The County of Lacombe in central Alberta was used for this study; the community of Lacombe is in the center this area. The 1991 census reports that there were 1327 farms with an average size of approximately 505 acres in this area.

The soils of this area are classified as Black Chernozemic. The County of Lacombe has a CLI classification of 2H, which is described as having adequate rainfall but a frost free period of 75 to 90 days. The Agroclimatic Atlas of Alberta lists the annual precipitation for this area as 450-500 mm., and growing season (May 1 to August 31) precipitation of 300 mm.. The Atlas further reports a frost free period of 85 to 115 days, and total degree days above 5° C as 1200-1300. (Dzikowski and Heywood, 1990)

The predominant cropping practices followed here are three years of cropping followed by one year of summerfallow. The inclusion of summerfallow in this area is not so much for moisture conservation but again to provide for weed control and to facilitate the decomposition of the residues of the previous crops. Although there is a growing season limitation in this region, both cereal and oilseed crops are grown. The typical crop rotation is two years of cereal crops followed by one year of an oilseed, and the fourth year is set aside for summerfallow.

2.3.4.1 Crop Rotations

In the Lacombe area two crop rotations were simulated: canola/wheat/barley, and canola/wheat/barley/barley. The canola/wheat/barley/barley rotation was adapted from a study by Mahli et al (1988) examining similar issues to those being studied here. The canola/wheat/barley rotation was suggested as a second alternative. (Jetter, pers. comm., March 1995)

2.3.4.2 Tillage Systems and Equipment Complements

This area is not limited because of soil moisture, but rather because of a shorter growing season and topography. There are certain pieces of equipment that are common to all tillage systems, and cropping rotations. They are the spraying equipment, harvesting equipment, and the fixed capacity tractor. For the machinery costing model a 60 foot wide field sprayer used. The harvesting equipment consists of a 22 foot pull type swather and a Class 4 combine which has a capacity compatible with the swather. The fixed capacity tractor is an 80 horsepower, two wheel drive type.

Under a continuous cropping rotational system, it is assumed that in conventional tillage and minimum tillage systems, some of the tillage operations will be performed during seeding time. The conventional tillage system assumed two tillage passes and two harrowing passes, in addition to the seeding operation. The minimum tillage system assumed one tillage pass and the seeding operation. The zero tillage system assumed seeding would be the only ground disturbing operation. The conventional tillage and minimum tillage systems assumed that there would be one tillage operation performed post harvest. Table 3.6, at the end of this section, provides the details of the equipment usage and scheduling for the continuous crop rotation system.

2.3.5 Wainwright Area

The area identified as Wainwright comprises the M.D. 61; the town of Wainwright is in the center of this area. The area is located south east of the City of Edmonton, on the eastern boundary of Alberta. In the 1991 census 650 farms with an average size of approximately 1290 acres were reported for this area.

The soils of this area are classified as Thin Black Chernozemic. The area of Wainwright has a CLI classification of 2A, which is described as having rainfall which limits plant growth over 50% of the time, and a frost free period of less than 100 days. The Agroclimatic Atlas of Alberta lists the annual precipitation for this area as 400-450 mm., and growing season (May 1 to August 31) precipitation of 200-250 mm.. The Atlas further reports a frost free period of approximately 100 days, and total degree days above 5^0 C of 1400-1500. (Dzikowski and Heywood, 1990)

The predominant cropping pattern in this area is two years of cropping followed by one year of summerfallow. The process of summer fallowing is followed in order to accomplish two objectives: moisture conservation and weed control. Due to the moisture limitations and high growing season heat values cropping is usually limited to cereal crops, but as new varieties of oilseed crops become available there is an increase in their acreage.

2.3.5.1 Crop Rotations

In the Wainwright area three crop rotations were simulated: continuous canola/wheat/barley, continuous canola/wheat/barley/barley, and canola/wheat/barley/ fallow. The continuous canola/wheat/barley/barley and canola/wheat/barley/fallow rotations were adapted from a study by Zentner et al (unpublished), who were examining similar issues to those being studied here. The continuous canola/wheat/barley rotation was suggested as a third alternative for study in this area. (Jetter, pers. comm., March 1995)

2.3.5.2 Tillage Systems and Equipment Complements

This area is similar to the Lethbridge and Trochu areas climatically; the differences arise from the soil being Thin Black. There are certain pieces of equipment that are common to all tillage systems, and cropping rotations. They are the spraying equipment, harvesting equipment, and the fixed capacity tractor. For the machinery costing model a 60 foot wide field sprayer is being used. The harvesting equipment consists of a 22 foot pull type swather and a Class 4 combine which has a capacity compatible with the swather. The fixed capacity tractor is an 80 horsepower, two wheel drive type.

Under a continuous cropping rotational system, it is assumed that in conventional tillage and minimum tillage systems, some of the tillage operations will be performed during seeding. The conventional tillage system assumed two tillage passes and two harrowing passes, in addition to the seeding operation. The minimum tillage system assumed one tillage pass and the seeding operation. The zero tillage system assumed seeding would be the only ground disturbing operation. The conventional tillage and minimum tillage systems assumed that there would be one tillage operation performed post harvest. Table 3.7, at the end of this section, provides the details of the equipment usage and scheduling for the continuous crop rotation system.

The fallow crop rotational systems assume that the land left to fallow would require some weed control treatment. The conventional tillage system assumed that there would still be two tillage passes during the seeding time period and post harvest time periods, but two types of tillage equipment would be used once each. The minimum tillage and zero tillage system use the same equipment, during the seeding and post harvest time periods, as was assumed for the conventional cropping system. The fallow treatments for the conventional tillage system comprised of two passes with a lighter piece of tillage equipment. The minimum tillage system substituted a tillage pass with one herbicide treatment. The zero tillage system assumed that all fallow tillage could be replaced by two herbicide treatments. Table 3.7, at the end of this section, provides the details of the equipment usage and scheduling for the fallow crop rotation systems.

2.4 Farm Size

To test the impact of farm size on the crop rotation and tillage system, three categories were selected. These size categories are consistent with those used by Bauer, Novak, Armstrong and Staples, (1992), and include small farms with 960 acres, medium farms with 1280 acres, and large farms with 1600 acres. These same size categories were used for all areas.

Table 2.1 Equipment Complements and Scheduling for the Medicine Hat Area

Continuous Cropping

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	0	0
DOUBLE PRESS DRILL	1	0	0	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HARROWS SM T 55'	2	0	0	0	0
HD FIELD CULT	2	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HD FIELD CULT	1	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	2	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Fallow Included in Crop Rotation

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	1	0
DOUBLE PRESS DRILL	1	1	0	0	0
FIELD CULT 24'	0	0	0	0	2
FIELD SPRAYER 60'	0	0	1	1	0
HARROWS SM T 55'	1	1	0	0	0
HD FIELD CULT	1	1	1	1	0
P.T.O. SWATHER 22'	0	0	1	1	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD CULT 24'	0	0	0	0	1
FIELD SPRAYER 60'	0	0	1	1	1
HD FIELD CULT	1	1	0	0	0
P.T.O. SWATHER 22'	0	0	1	1	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD SPRAYER 60'	0	0	2	2	2
P.T.O. SWATHER 22'	0	0	1	1	0

Note: ST indicates that the equipment is being operated on a stubble field, and SF indicates that the equipment is being operated on a summerfallowed field.
Seeding indicates that the equipment is being used during seeding time, and Other indicates the equipment is being used at a time other than Seeding.
Fallow indicates the equipment is being used for the summerfallow operation.

Table 2.2 Equipment Complements and Scheduling for the Lethbridge Area

Continuous Cropping

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	0	0
DOUBLE PRESS DRILL	1	0	0	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HARROWS SM T 55'	2	0	0	0	0
HD FIELD CULT	2	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HD FIELD CULT	1	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	2	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Fallow Included in Crop Rotation

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	1	0
DOUBLE PRESS DRILL	1	1	0	0	0
FIELD CULT 24'	0	0	0	0	2
FIELD SPRAYER 60'	0	0	1	1	0
HARROWS SM T 55'	1	1	0	0	0
HD FIELD CULT	1	1	1	1	0
P.T.O. SWATHER 22'	0	0	1	1	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD CULT 24'	0	0	0	0	1
FIELD SPRAYER 60'	0	0	1	1	1
HD FIELD CULT	1	1	0	0	0
P.T.O. SWATHER 22'	0	0	1	1	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD SPRAYER 60'	0	0	2	2	2
P.T.O. SWATHER 22'	0	0	1	1	0

Note: ST indicates that the equipment is being operated on a stubble field, and SF indicates that the equipment is being operated on a summerfallowed field. Seeding indicates that the equipment is being used during seeding time, and Other indicates the equipment is being used at a time other than Seeding. Fallow indicates the equipment is being used for the summerfallow operation.

Table 2.3 Equipment Complements and Scheduling for the Trochu Area

Continuous Cropping

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	0	0
DOUBLE PRESS DRILL	1	0	0	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HARROWS SM T 55'	2	0	0	0	0
HD FIELD CULT	2	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HD FIELD CULT	1	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	2	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Fallow Included in Crop Rotation

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	1	0
DOUBLE PRESS DRILL	1	1	0	0	0
FIELD CULT 24'	0	0	0	0	2
FIELD SPRAYER 60'	0	0	1	1	0
HARROWS SM T 55'	1	1	0	0	0
HD FIELD CULT	2	2	0	0	0
P.T.O. SWATHER 22'	0	0	1	1	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD CULT 24'	0	0	0	0	1
FIELD SPRAYER 60'	0	0	1	1	1
HD FIELD CULT	1	1	0	0	0
P.T.O. SWATHER 22'	0	0	1	1	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD SPRAYER 60'	0	0	2	2	2
P.T.O. SWATHER 22'	0	0	1	1	0

Note: ST indicates that the equipment is being operated on a stubble field, and SF indicates that the equipment is being operated on a summerfallowed field.
Seeding indicates that the equipment is being used during seeding time, and Other indicates the equipment is being used at a time other than Seeding.
Fallow indicates the equipment is being used for the summerfallow operation.

Table 2.4 Equipment Complements and Scheduling for the Lacombe Area

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	0	0
DOUBLE PRESS DRILL	1	0	0	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HARROWS SM T 55'	2	0	1	0	0
HD FIELD CULT	2	0	0	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HD FIELD CULT	1	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	2	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Note: ST indicates that the equipment is being operated on a stubble field, and SF indicates that the equipment is being operated on a summerfallowed field. Seeding indicates that the equipment is being used during seeding time, and Other indicates the equipment is being used at a time other than Seeding. Fallow indicates the equipment is being used for the summerfallow operation.

Table 2.5 Equipment Complements and Scheduling for the Wainwright Area

Continuous Cropping

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	0	0
DOUBLE PRESS DRILL	1	0	0	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HARROWS SM T 55'	2	0	0	0	0
HD FIELD CULT	2	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	1	0	0
HD FIELD CULT	1	0	1	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	0	0	0	0
COMBINE SP (class 4)	0	0	1	0	0
FIELD SPRAYER 60'	0	0	2	0	0
P.T.O. SWATHER 22'	0	0	1	0	0

Fallow Included in Crop Rotation

Conventional Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
COMBINE SP (class 4)	0	0	1	1	0
DOUBLE PRESS DRILL	1	1	0	0	0
FIELD CULT 24'	0	0	0	0	2
FIELD SPRAYER 60'	0	0	1	1	0
HARROWS SM T 55'	1	1	0	0	0
HD FIELD CULT	1	1	1	1	0
P.T.O. SWATHER 22'	0	0	1	1	0

Minimum Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD CULT 24'	0	0	0	0	1
FIELD SPRAYER 60'	0	0	1	1	1
HD FIELD CULT	1	1	0	0	0
P.T.O. SWATHER 22'	0	0	1	1	0

Zero Tillage System

MACHINERY	Seeding ST	Seeding SF	Other ST	Other SF	Fallow
AIR SEEDER W/CHISE	1	1	0	0	0
COMBINE SP (class 4)	0	0	1	1	0
FIELD SPRAYER 60'	0	0	2	2	2
P.T.O. SWATHER 22'	0	0	1	1	0

Note: ST indicates that the equipment is being operated on a stubble field, and SF indicates that the equipment is being operated on a summerfallowed field.
Seeding indicates that the equipment is being used during seeding time, and Other indicates the equipment is being used at a time other than Seeding.
Fallow indicates the equipment is being used for the summerfallow operation.

Section 3: Results

This section presents the results for the study areas described previously. Each study area was tested for the interaction of crop rotation, tillage system and farm size on expected net revenue and variance resulting for selected grain and oilseed crops. Each study area will be discussed independently with respect to the crop input costs and revenue and the variance of revenue. This is in keeping with the previous discussions of the differences between the areas, and how the differences impact the costs and revenues. The machinery costs will be discussed in a section by itself.

3.1 Crop Input Costs

The previous section detailed how and what would be considered crop inputs for this study. This section will discuss the costs associated with these crop inputs. All costs will be discussed on a per acre basis, and represent a weighted average for a rotation acre on the farm. Areas are discussed individually in this section.

3.1.1 Crop Input Costs for the Medicine Hat Area

In this area four crop rotations were tested. Crop input costs varied with the rotation. The lowest input costs are associated with the crop rotations which include fallow. The rotation where wheat and fallow are divided equally had crop input costs of $11.48/acre for conventional tillage, $16.45/acre for minimum tillage, and $26.40/acre for zero tillage. These differences arise from the increasing use of glyphosate for chemical fallow control. Zero tillage used $14.93/acre of gylphosphate where as minimum tillage used $4.98/acre for the method of fallow weed control.

When barley was added to the crop/ fallow rotation revenues increased by $0.32/acre but the crop input costs also increased. This input cost increase arises from the increased costs associated to the production of an increased number of acres of crop. In this case the acreage was initially 1/2 cropped, the WBF rotation increases the cropped acreage to 2/3 of the total.. Under a conventional tillage system the crop inputs cost increased $4.74/acre over the wheat/fallow rotation. The crop input costs increased for the minimum and zero tillage systems, but by a smaller amount because a smaller acreage is being chemically treated for summer fallow. The crop input cost increases under the minimum and zero tillage systems were $3.09/acre each. Refer to tables A1and A2 in Appendix A for the detailed crop input cost breakdowns for the fallow crop rotations.

The crop input costs were higher for the continuous cropping rotations, when compare to the fallow rotations. The continuous wheat rotation was the most expensive at $33.71/acre for both conventional and minimum tillage systems. The zero tillage system crop input costs were $9.95/acre higher than the conventional and minimum tillage systems, because of the application of gylphosphate to replace mechanical tillage operations.

The continuous cropping rotation of wheat/wheat/barley had lower crop input costs. Conventional and minimum tillage systems had crop input costs of $31.05/acre the zero tillage system was again $9.95/acre higher as a result of the application of glyphosate to replace pre-seeding and post harvest tillage operations. Refer to tables A3 and A4 in Appendix A for detailed breakdowns of the crop input costs for the continuous cropping rotations.

3.1.2 Crop Input Costs for the Lethbridge Area

Lethbridge is also considered a dryland farming area and consequently the crop rotations are similar to those tested in Medicine Hat. The wheat/fallow rotation was used, as well as a lengthened multi-crop fallow rotation.

The crop input costs vary with the crop rotation. The least expensive input costs are associated with the crop rotations which include fallow. The rotation where wheat and fallow (WF) are divided equally had input costs of $11.48/acre for conventional tillage, $16.45/acre for minimum tillage, and $26.40acre for zero tillage. These differences arise from the increasing usage of glyphosate for chemical fallow control. Zero tillage used $14.93/acre of gylphosphate and minimum tillage used $9.95/acre for fallow weed control.

When the crop rotation was changed to 50% wheat, 25% barley and 25% fallow (WWBF), revenues increased by $7.77/acre but the crop input costs also increased. This increase arose from the increased costs associated to the production of barley on land that was not cropped in the WF rotation. Under a conventional tillage system the crop inputs cost increased $4.74/acre (41.3%) over WF. While the total crop input costs also increased for the minimum and zero tillage systems, the increase was because a smaller acreage is being chemically treated for summerfallow. The crop input cost increases under the minimum and zero tillage systems were $3.09/acre. Refer to tables B1 and B2 in Appendix B for the detailed crop input cost breakdowns.

The crop input costs were higher for the continuous cropping rotations than crop rotations with fallow. The continuous wheat/wheat/barley (WWB) rotation was the most expensive at $23.55/acre for both conventional and minimum tillage systems. The zero tillage system crop input costs were $9.95/acre higher because of the application of gylphosphate to replace pre-seeding and post harvest tillage operations.

The continuous wheat crop rotation had $0.60/acre lower crop input costs due to the reduced fertilizer and selective herbicide costs. Conventional and minimum tillage systems had crop input costs of $23.55/acre and the zero tillage system was again $9.95/acre higher resulting from the application of glyphosate to replace pre-seeding and post harvest tillage operations. Refer to tables B3 and B4 in Appendix B for detailed breakdowns of the crop input costs.

3.1.3 Crop Input Costs for the Trochu Area

The Trochu area has the same soil classification as Lethbridge, but a climate that provides fewer limitations for crop production. The climate here allows for the inclusion of oilseeds in crop rotations. As described earlier the inclusion of summerfallow in crop rotations is for the control of weeds or to facilitate the decomposition of crop residues, rather than the conservation of soil moisture and continues to be used in this area but to a lesser extent.

The least expensive crop input costs are associated with the canola/wheat/fallow crop rotation. This rotation, where fallow represented 1/3 of the cultivated acres, had input costs of $21.03/acre for conventional tillage, and $24.35/acre for minimum tillage, and $34.30/acre for zero tillage. These differences arise from the increasing use of glyphosate for chemical fallow control. Zero tillage used $13.27/acre of gylphosphate, and minimum tillage used $3.32/acre of glyphosate for fallow weed control. Refer to table C3 in Appendix C for the detailed crop input cost breakdowns.

The crop input costs were higher for the continuous cropping rotations. The continuous canola/wheat (CW) rotation was the most expensive at $31.84/acre for both conventional and minimum tillage systems. The zero tillage system crop input costs were $9.95/acre higher because of the application of gylphosphate to replace pre-seeding and post harvest tillage operations.

The continuous canola/wheat/barley (CWB) crop rotation had $1.29/acre lower crop input costs due to the reduced fertilizer, and selective herbicide costs. Conventional and minimum tillage systems had crop input costs of $33.13/acre The zero tillage system was again $9.95/acre higher resulting from the application of glyphosate to replace pre-seeding and post harvest tillage operations. Refer to tables C1 and C2 in Appendix C for detailed breakdowns of the crop input costs.

3.1.4 Crop Input Costs for the Lacombe Area

The Lacombe area represents the black soil zone and consequently has different soil fertility requirements together with a cooler and wetter climate. In this area two crop rotations were tested using three tillage systems. Both the crop rotations were variations of continuous cropping. Fallow was not considered here for the reasons discussed in the previous section.

The canola/wheat/barley (CWB) crop rotation had crop input costs of $44.87/acre, the canola/wheat/barley/barley (CWBB) crop rotation had crop input cost that were $0.16/acre less. This reduction in costs appears to be a result of a series of small increases and decreases in the individual input costs. The zero tillage system crop input costs were $9.95/acre higher again a result of the use of herbicides rather than mechanical tillage. Refer to tables D1 and D2 in Appendix D for detailed breakdowns of the crop input costs.

3.1.5 Crop Input Costs for the Wainwright Area

The Wainwright area represents a transition zone between the Dark Brown and Black soils. The soil here is termed Thin Black. Because of the transitional characteristics of this area, the crop rotations of Lacombe were used and a rotation with fallow was added. Three crop rotations using the three tillage systems were simulated in this area.

One crop rotation containing a fallow period was simulated. This rotation was comprised of equal proportions of canola, wheat, barley, and fallow (CWBF). The crop input costs were $24.39/acre, $26.87/acre, and $36.82/acre for conventional, minimum, and zero tillage systems respectively. The increasing crop input costs reflect the increased usage of glyphosate for fallow weed control. Table E3 in Appendix E provide details of the crop inputs.

The crop input costs were higher for the continuous cropping rotations. The continuous canola/wheat/barley rotation (CWB) was the most expensive at $34.49/acre for both conventional and minimum tillage systems. The zero tillage system crop input costs were $9.95/acre higher because of the application of gylphosphate to replace pre-seeding and post harvest tillage operations.

The continuous cropping rotation of canola/wheat/barley/barley (CWBB) had lower crop input costs due to the reduced fertilizer, selective herbicide, and crop insurance costs resulting from the inclusion of one additional barley crop in the rotation. Conventional and minimum tillage systems had crop input costs of $33.16/acre the zero tillage system was again $9.95/acre higher resulting from the application of glyphosate to replace pre-seeding and post harvest tillage operations. Refer to tables E1 and E2 in Appendix E for detailed breakdowns of the crop input costs.

3.2 Machinery Cost Differences

Machinery costs for this study were estimated in three categories: annual capital costs, annual repair costs and annual fuel costs. Each of these three costs are expressed on a per acre basis. The capital costs are the annuitized costs of owning an equipment complement that is replaced by an equivalent complement at the optimal age, in perpetuity. The annual repair and fuel costs are calculated as described previously. Combined, these three costs are considered the annual costs of owning an equipment complement, or the annual ownership costs.

The annual ownership costs in relation to changes in three factors: soil zone, the tillage system employed, and/or the size of the farm. This section describes how total machinery costs are affected as these three factors are changed.

Equipment costs display an increasing relationship with soil colour; that is as the soil becomes darker in colour the equipment costs rise. This is a result of the soil composition changing because of various geographic factors present in each area that affect the soil colour (i.e. climate, parent material, etc.).

The choice of tillage system also plays a role in the changes in costs. The minimum tillage systems consistently had the largest equipment costs as a result of combining some of the conventional tillage techniques with the use of zero tillage seeding equipment. The air seeder is more expensive to own and use than a double disc drill. The reduction in tillage passes and the accompanying reduction in costs associated in owning this part of an equipment complement is not sufficient to overcome the increased costs of the air seeder. The air seeder is a larger piece of equipment than the double disc drill and therefore requires a larger tractor (i.e. higher horsepower) to draw it through the soil.

Generally the cost difference between conventional tillage systems and zero tillage systems was less than $5.00/acre, with the zero tillage systems being the more expensive. The minimum tillage system was up to approximately $10.00/acre more expensive to own and operate than a conventional tillage system, because of the combination of some conventional tillage equipment and zero tillage equipment (i.e. air seeder and cultivators).

The size (in cultivated acres) of the farm provided the greatest changes in total machinery costs. In all areas and crop rotations, as the size of the farm is increased the machinery costs associated with a particular equipment complement declined. The cost reductions achieved were about 20% when farm size was increased from 960 cultivated acres to 1600 cultivated acres. An increase in size from 960 acres to

1280 acres resulted in total machinery cost reductions of about 15%. The exact magnitude of the total machinery cost reductions resulting from farm size increases is also a function of the amount of equipment used for the particular equipment complement. These cost reductions represent economies of size. The economies of size displayed appear to be lumpy because the cost reductions are not constant between the areas and between the tillage systems used. Table d, in each section of the appendices in Orlick (1995), details the changes in total machinery costs from increasing the farm size.

3.3 Revenue and Variance Comparisons

This section discusses revenue and variance results for each area separately. The separate discussions are necessary because the crop rotations, which determine the revenues and variances, are not the same in each area for agronomic and cultural reasons. The discussion begins with the differences observed between gross revenues and their variances. The discussion of the net revenues and why they do not differ in the same proportion as gross revenues follows. And this section concludes with a discussion of the relative riskiness of the crop rotations.

3.3.1 Medicine Hat Area

Medicine Hat is the driest and warmest of the cropping areas being examined. In this area four crop rotations were examined; two with fallow included WF and WBF, and two using continuous crop rotations WW and WWB. This combination of crop rotations was, as previously indicated, to represent cropping choices that a "typical" grain farmer may use.

The wheat/fallow rotation had the lowest predicted gross revenue and continuous wheat had the highest . The relative ranking of the gross revenues (highest to lowest), by crop rotation are as follows: continuous wheat ($57.85/acre), wheat/wheat/barley ($54.90/acre), wheat/barley/fallow ($48.36/acre), and wheat/fallow ($48.04/acre).

The wheat/barley/fallow rotation had the lowest RMSE of gross revenue while the continuous wheat rotation had the highest. The relative magnitude of the RMSE for the crop rotations tested in this area can be observed in the tables within Appendix A.

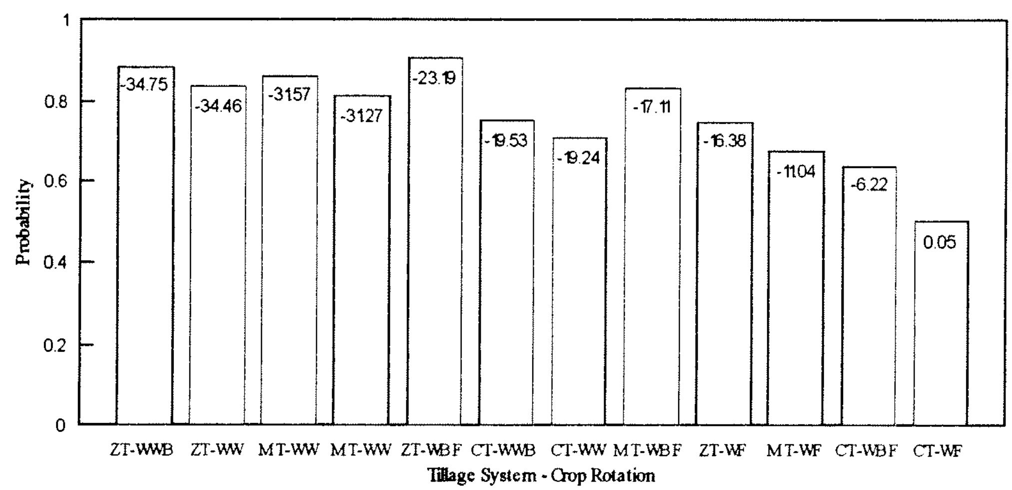
Thirty six combinations of crop rotation, tillage system and farm size were analyzed in this area. Of the 36, five resulted in positive net revenues. These five were for conventional tillage and either a proportion of 1/2 or 1/3 fallow in the rotations. Farms of the 960 acre size having the conventionally tilled wheat/fallow crop rotation resulted in a positive expected net revenue of $0.05/acre with a RMSE of $24.50. For farms with 1280 cultivated acres, conventional tillage and a wheat/fallw crop rotation the return was $6.79/acre with a RMSE of $24.50, and the wheat/barley/fallow crop rotation had an expected net return of $0.39/acre with a RMSE of $17.65. When the number of cultivated acres was increased to 1600 acres, conventional tillage systems using a wheat/barley/fallow and wheat fallow rotation returned $4.34/acre and $10.93/acre respectively. These returns are associated with RMSE of $17.65 and $24.50 respectively.

In each farm size category the lowest probability of generating a negative expected net revenue occured with the conventionally tilled wheat fallow crop rotation. The probabilities ranged from 49.9% on the 960 acre farm, to 32.8% on the 1600 acre farm. The wheat/fallow crop rotation had the lowest predicted gross revenue and the second lowest RMSE. The crop rotation with the highest gross revenue was continuous wheat, but it consistently ranked in the lower half of the choices when net revenues are sorted for relative size. Table 3.1 to 3.3 and Figures 3.1 to 3.3, show the expected net revenues and probability of negative expected net revenue results for this area.

Table 3.1: Probability of Negative Net Revenue for the 960 Cultivated Acre Farm in the Medicine Hat Area

Tillage System	Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	WWB	54.90	89.65	-34.75	29.11	-0.84	88.4%
ZT	WW	57.85	92.31	-34.46	35.32	-1.02	83.5%
MT	WWB	54.90	86.47	-31.57	29.11	-0.92	86.1%
MT	WW	57.85	89.12	-31.27	35.32	-1.13	81.2%
ZT	WBF	48.36	71.55	-23.19	17.65	-0.76	90.5%
CT	WWB	54.90	74.43	-19.53	29.11	-1.49	74.9%
CT	WW	57.85	77.09	-19.24	35.32	-1.84	70.7%
MT	WBF	48.36	65.47	-17.11	17.65	-1.03	83.4%
ZT	WF	48.04	64.42	-16.38	24.50	-1.50	74.8%
MT	WF	48.04	59.08	-11.04	24.50	-2.22	67.4%
CT	WBF	48.36	54.58	-6.22	17.65	-2.84	63.8%
CT	WF	48.04	47.99	0.05	24.50	490.00	49.9%

Figure 3.1: Probability of Negative Net Revenue for the 960 Cultivated Acre Farm in the Medicine Hat Area

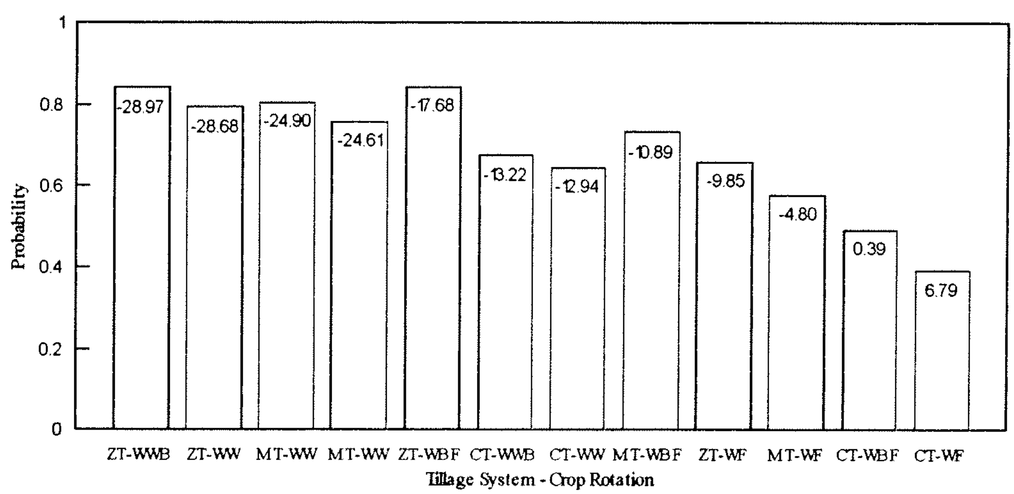


Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.2: Probability of Negative Net Revenue for the 1280 Cultivated Acre Farm in the Medicine Hat Area

Tillage System	Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	WWB	54.90	83.87	-28.97	29.11	-1.00	84.0%
ZT	WW	57.85	86.53	-28.68	35.32	-1.23	79.2%
MT	WWB	54.90	79.80	-24.90	29.11	-1.17	80.4%
MT	WW	57.85	82.46	-24.61	35.32	-1.44	75.7%
ZT	WBF	48.36	66.04	-17.68	17.65	-1.00	84.2%
CT	WWB	54.90	68.12	-13.22	29.11	-2.20	67.5%
CT	WW	57.85	70.79	-12.94	35.32	-2.73	64.3%
MT	WBF	48.36	59.25	-10.89	17.65	-1.62	73.2%
ZT	WF	48.04	57.89	-9.85	24.50	-2.49	65.6%
MT	WF	48.04	52.84	-4.80	24.50	-5.10	57.8%
CT	WBF	48.36	47.97	0.39	17.65	45.26	49.1%
CT	WF	48.04	41.25	6.79	24.50	3.61	39.1%

Figure 3.2: Probability of Negative Net Revenue for the 1280 Cultivated Acre Farm in the Medicine Hat Area

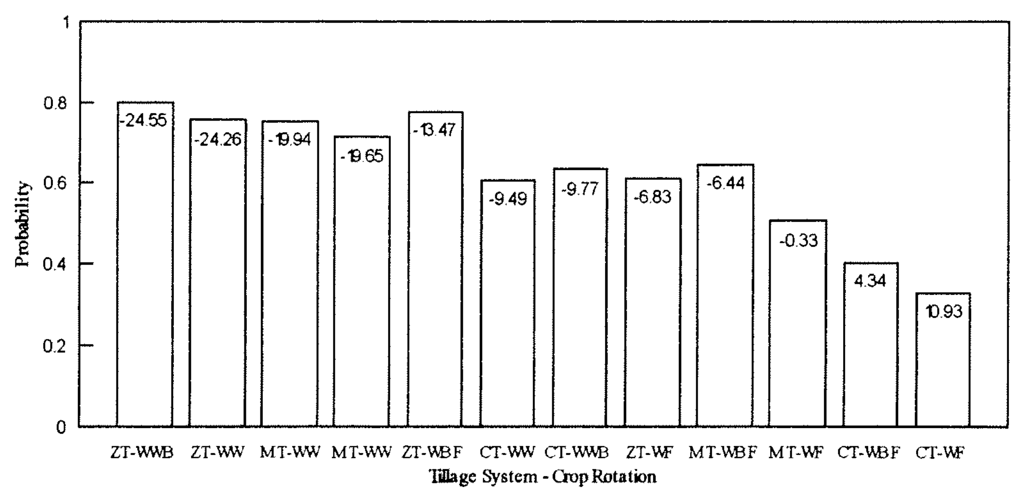


Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.3: Probability of Negative Net Revenue for the 1600 Cultivated Acre Farm in the Medicine Hat Area

Tillage System	Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	WWB	54.90	79.45	-24.55	29.11	-1.19	80.0%
ZT	WW	57.85	82.11	-24.26	35.32	-1.46	75.4%
MT	WWB	54.90	74.84	-19.94	29.11	-1.46	75.3%
MT	WW	57.85	77.50	-19.65	35.32	-1.80	71.1%
ZT	WBF	48.36	61.83	-13.47	17.65	-1.31	77.7%
CT	WW	57.85	67.34	-9.49	35.32	-3.72	60.6%
CT	WWB	54.90	64.67	-9.77	29.11	-2.98	63.2%
ZT	WF	48.04	54.87	-6.83	24.50	-3.59	61.0%
MT	WBF	48.36	54.80	-6.44	17.65	-2.74	64.3%
MT	WF	48.04	48.37	-0.33	24.50	-74.24	50.5%
CT	WBF	48.36	44.02	4.34	17.65	4.07	40.3%
CT	WF	48.04	37.11	10.93	24.50	2.24	32.8%

Figure 3.3: Probability of Negative Net Revenue for the 1600 Cultivated Acre Farm in the Medicine Hat Area



Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

3.3.2 Lethbridge Area

In this area four crop rotations were analyzed, using three tillage systems. The Lethbridge area, while still often referred to as being an area where dryland farming is practiced, represents a moderation of the climate found in the Medicine Hat area. Lethbridge has more precipitation and is a little cooler.

The wheat/fallow rotation had the lowest predicted gross revenue where as continuous wheat had the highest . The relative ranking of the gross revenues (highest to lowest), by crop rotation are as follows: continuous wheat ($67.17/acre), wheat/wheat/barley ($62.42/acre), wheat/wheat/barley/fallow ($52.29/acre), and wheat/fallow ($44.52/ac).

The wheat/fallow rotation had the lowest RMSE of predicted gross revenue and the continuous wheat rotation had the highest. The relative ranking of the RMSE (lowest to highest) is as follows: wheat/fallow ($20.66), wheat/wheat/barley/fallow ($29.30), wheat/wheat/barley ($39.84), and continuous wheat ($41.33). The tables in Appendix B illustrate the relative magnitude of the RMSE for the crop rotations tested in this area. The inclusion of fallow and/or barley to the crop rotations appears to reduce the RMSE. This reflects the risk reducing portfolio effects of adding a non-perfectly correlated revenue stream to the crop rotation income stream.

Thirty six combinations of crop rotation, tillage system and farm size were analyzed in this area. Of the 36, four resulted in positive expected net revenues. The 960 acre farm size resulted in no positive expected net revenue. For farms with 1280 cultivated acres conventional tillage and a wheat/wheat/barley/fallow crop rotation provided the largest expected net return at $1.45/acre with a RMSE of $29.30. And wheat/fallow provided an expected net revenue of $0.18/acre with a RMSE of $20.66. When the number of cultivated acres is increased to 1600 acres, similar results were obtained with conventionally tilled wheat/wheat/ barley/fallow providing expected net returns of $4.66/acre and wheat fallow providing expected net returns of $3.67/acre.

In each farm size category the lowest probability of generating a negative net revenue occured with conventionally tilled crop rotations that included fallow. The wheat fallow rotation had probabilities 49.7% on the 1280 acre farm, and 43.0% on the 1600 acre farm, where as the wheat/wheat/barley/fallow crop rotation had probabilities 48.0% on the 1280 acre farm, and 43.7% on the 1600 acre farm. These results are consistent with those observed in the Medicine Hat area, and continue to indicate that the inclusion of fallow reduces the risk of generating a negative expected net revenue. Tables 3.4 to 3.6 and Figures 3.4 to 3.6, provide a listing and illustrations of the net revenue and probability of negative net revenue results for this area.

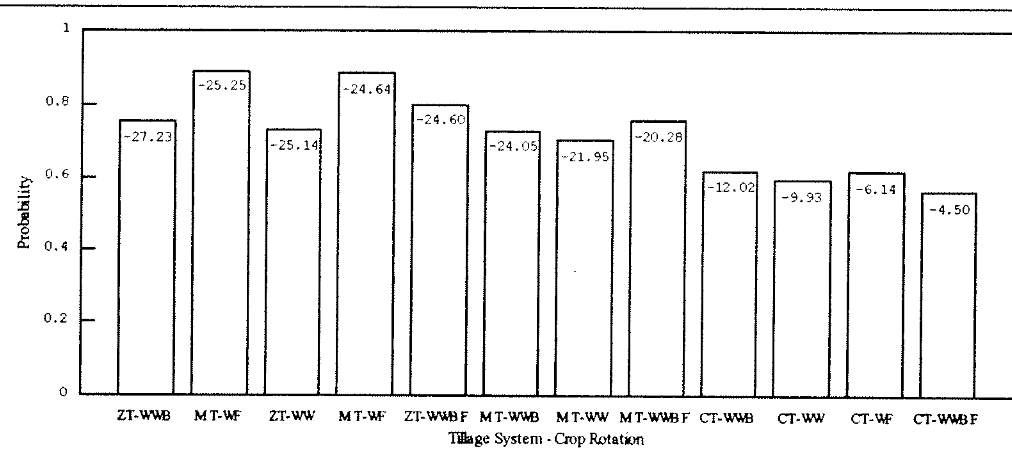
3.3.3 Trochu Area

In this area three crop rotations were analyzed, using three tillage systems. The Trochu area, while sharing the same soil zone classification as Lethbridge, has a cool enough climate that canola can be added to the crop rotations. The crop rotations in Trochu use less fallow. The canola/wheat/fallow (CWF) rotation had the lowest predicted gross revenue and continuous canola/wheat (CW) had the highest. The relative ranking of the gross revenues (highest to lowest), by crop rotation are as follows: CW ($132.69/acre), CWB ($128.39/acre), and CWF ($102.68/acre).

Table 3.4: Probability of Negative Net Revenue for the 960 Acre Farm in the Lethbridge Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	WWB	62.42	89.65	-27.23	39.84	-1.46	75.3%
ZT	WF	44.52	69.77	-25.25	20.66	-0.82	88.9%
ZT	WW	67.17	92.31	-25.14	41.33	-1.64	72.9%
MT	WF	44.52	69.16	-24.64	20.66	-0.84	88.3%
ZT	WWBF	52.29	76.89	-24.60	29.30	-1.19	79.9%
MT	WWB	62.42	86.47	-24.05	39.84	-1.66	72.7%
MT	WW	67.17	89.12	-21.95	41.33	-1.88	70.3%
MT	WWBF	52.29	72.57	-20.28	29.30	-1.44	75.6%
CT	WWB	62.42	74.44	-12.02	39.84	-3.31	61.9%
CT	WW	67.17	77.10	-9.93	41.33	-4.16	59.5%
CT	WF	44.52	50.66	-6.14	20.66	-3.36	61.7%
CT	WWBF	52.29	56.79	-4.50	29.30	-6.51	56.1%

Figure 3.4: Probability of Negative Net Revenue for the 960 Acre Farm in the Lethbridge Area



Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.5: Probability of Negative Net Revenue for the 1280 Acre Farm in the Lethbridge Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	WWB	62.42	83.87	-21.45	39.84	-1.86	70.5%
ZT	WW	67.17	86.53	-19.36	41.33	-2.13	68.0%
ZT	WF	44.52	63.25	-18.73	20.66	-1.10	81.8%
MT	WF	44.52	62.25	-17.73	20.66	-1.17	80.4%
MT	WWB	62.42	79.80	-17.38	39.84	-2.29	66.9%
ZT	WWBF	52.29	67.67	-15.38	29.30	-1.91	70.0%
MT	WW	67.17	82.46	-15.29	41.33	-2.70	64.4%
MT	WWBF	52.29	65.98	-13.69	29.30	-2.14	68.0%
CT	WWB	62.42	68.13	-5.71	39.84	-6.98	55.7%
CT	WW	67.17	70.79	-3.62	41.33	-11.42	53.5%
CT	WF	44.52	44.34	0.18	20.66	114.78	49.7%
CT	WWBF	52.29	50.84	1.45	29.30	20.21	48.0%

Figure 3.5: Probability of Negative Net Revenue for the 1280 Acre Farm in the Lethbridge Area

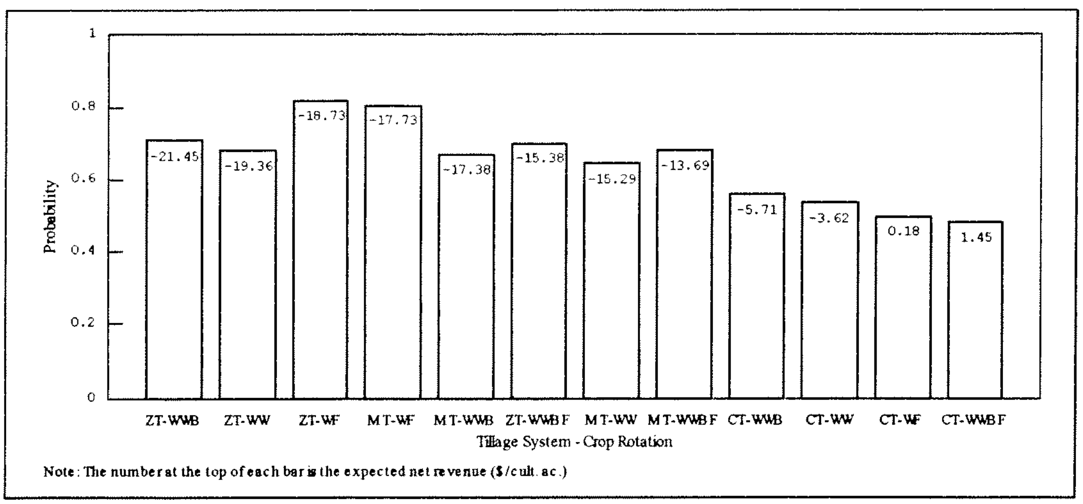
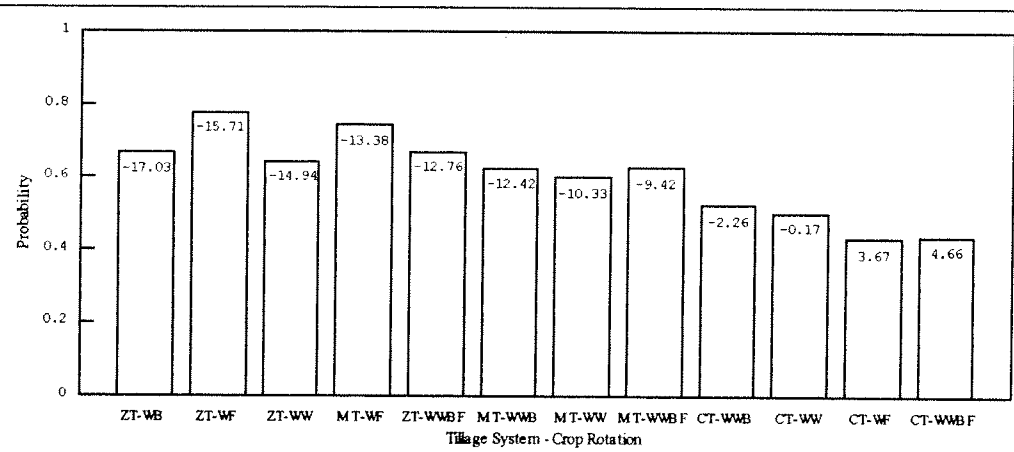


Table 3.6: Probability of Negative Net Revenue for the 1600 Acre Farm in the Lethbridge Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	WWB	62.42	79.45	-17.03	39.84	-2.34	66.6%
ZT	WF	44.52	60.23	-15.71	20.66	-1.32	77.6%
ZT	WW	67.17	82.11	-14.94	41.33	-2.77	64.1%
MT	WF	44.52	57.90	-13.38	20.66	-1.54	74.2%
ZT	WWBF	52.29	65.05	-12.76	29.30	-2.30	66.9%
MT	WWB	62.42	74.84	-12.42	39.84	-3.21	62.2%
MT	WW	67.17	77.50	-10.33	41.33	-4.00	59.9%
MT	WWBF	52.29	61.71	-9.42	29.30	-3.11	62.6%
CT	WWB	62.42	64.68	-2.26	39.84	-17.63	52.2%
CT	WW	67.17	67.34	-0.17	41.33	-243.12	50.2%
CT	WF	44.52	40.85	3.67	20.66	5.63	43.0%
CT	WWBF	52.29	47.63	4.66	29.30	6.29	43.7%

Figure 3.6: Probability of Negative Net Revenue for the 1600 Acre Farm in the Lethbridge Area



Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

The CWF rotation had the lowest RMSE of revenue and the CWB rotation had the highest. The relative ranking of the per acre RMSE (highest to lowest) is as follows: canola/wheat/barley ($50.05), canola/wheat ($48.28), and canola/wheat/fallow ($25.99). The tables in Appendix C illustrate the relative magnitude of the RMSE for the crop rotations tested in this area. The inclusion of fallow in the crop rotation appears to reduce the RMSE. This is consistent with diversifying a portfolio by adding a revenue stream that is not correlated to the rest of the portfolio or has no variability. In this case fallow has a RMSE of zero.

Twenty seven cases were evaluated in this area, and all of these resulted in positive expected net revenues. The conventional tillage system provided the largest net returns, and all cases displayed an increase in expected net return as the acreage was increased. The largest expected net return was $59.81/acre, and corresponded to the conventional tillage system and a canola/wheat rotation on 1600 cultivated acres. The lowest expected net return was $26.32/acre, and occurred with the zero tillage system and a canola/wheat/fallow crop rotation on 960 cultivated acres.

In each farm size category the lowest probability of generating a negative net revenue occured with the conventionally tilled cropping of canola/wheat/fallow. The probabilities of a negative expected net revenue ranged from 5.3% on the 960 acre farm, to 2.2% on the 1600 acre farm. In the Trochu area the continuous CW crop rotation has the highest expected net revenue and the highest RMSE, but again the results with the largest net revenue does not necessarily provide sufficient extra return to offset the additional variance resulting from that crop rotation (i.e. CW in this case). Tables 3.7 to 3.9 and Figures 3.7 to 3.9, display the net revenues and probabilities of generating a negative net revenue in this area.

3.3.4 Lacombe Area

The Lacombe area represents the darkest coloured soil zone, and has the coolest and wettest climate tested in this study. In this area fallow is seldom observed. Therefore only two continuous crop rotations were tested here.

The canola/wheat/barley/barley (CWBB) crop rotation had the lowest gross revenue at $142.15/acre. When the rotation is reduced to canola/wheat/barley (CWB) the gross revenue rises to $148.38/acre. This is a result of increasing proportion that canola represents in the crop rotation (i.e. canola proportion rising from 1/4 to 1/3).

The per acre RMSE rankings for the two crop rotations are: CWB ($34.07), and CWBB ($36.68). In this area the addition of a barley crop to the rotation adds variability to the revenue stream. It is unclear whether the increased variability attributed to barley is a result of price variability (which includes grade variability) or from yield variability. The tables in Appendix D provides the details of the gross revenue and RMSE components.

Eighteen cases were evaluated for this area. All the cases resulted in positive expected net revenues. The lowest expected net revenue occurred using a zero tillage canola/wheat/barley/barley crop rotation on 960 cultivated acres ($30.83/acre). The highest expected net revenue occurred using a conventional tillage system on 1600 cultivated acres and the canola/wheat/barley crop rotation ($60.65/acre).

For all the farm sizes simulated the CWB crop rotation using a conventional tillage system resulted in the most risk efficient combination. This system resulted in a probability of net revenue being less than zero of 9.4%, 6.2%, and 4.9% for the 960, 1280, and 1600 acre farm sizes respectively. Table 3.10 to 3.12 and Figures 3.10 to 3.12 detail the expected net revenues and probabilities of generating a negative expected net revenue.

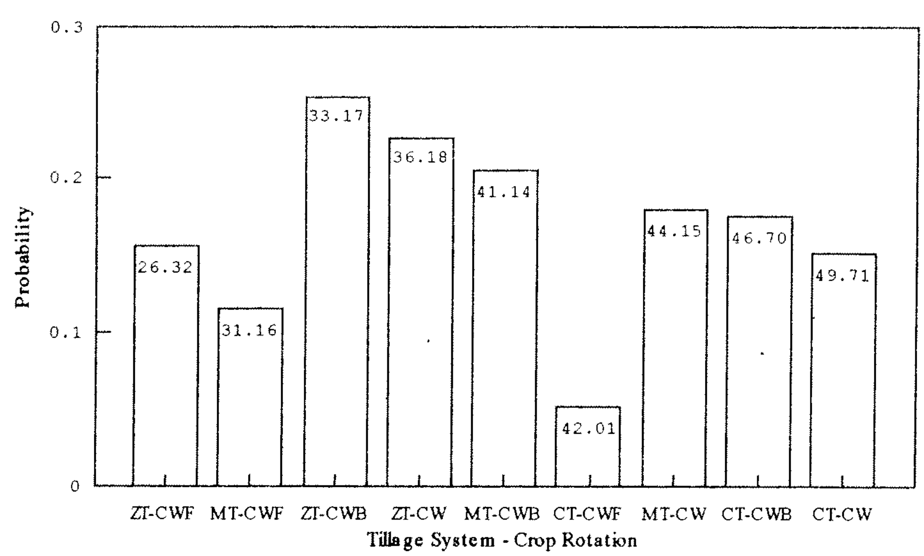
3.3.5 Wainwright Area

The Wainwright area is a transitional area between the Brown soils and the Black soils. It has a climate as well as soil characteristics that fall in between the two. Wainwright farmers still practise some fallow but are able to incorporate canola into the crop rotations.

Table 3.7: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Trochu Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWF	102.68	76.36	26.32	25.99	0.99	15.6%
MT	CWF	102.68	71.52	31.16	25.99	0.83	11.5%
ZT	CWB	128.39	95.22	33.17	50.05	1.51	25.4%
ZT	CW	132.69	96.51	36.18	48.28	1.33	22.7%
MT	CWB	128.39	87.25	41.14	50.05	1.22	20.6%
CT	CWF	102.68	60.67	42.01	25.99	0.62	5.3%
MT	CW	132.69	88.54	44.15	48.28	1.09	18.0%
CT	CWB	128.39	81.69	46.70	50.05	1.07	17.6%
CT	CW	132.69	82.98	49.71	48.28	0.97	15.2%

Figure 3.7: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Trochu Area

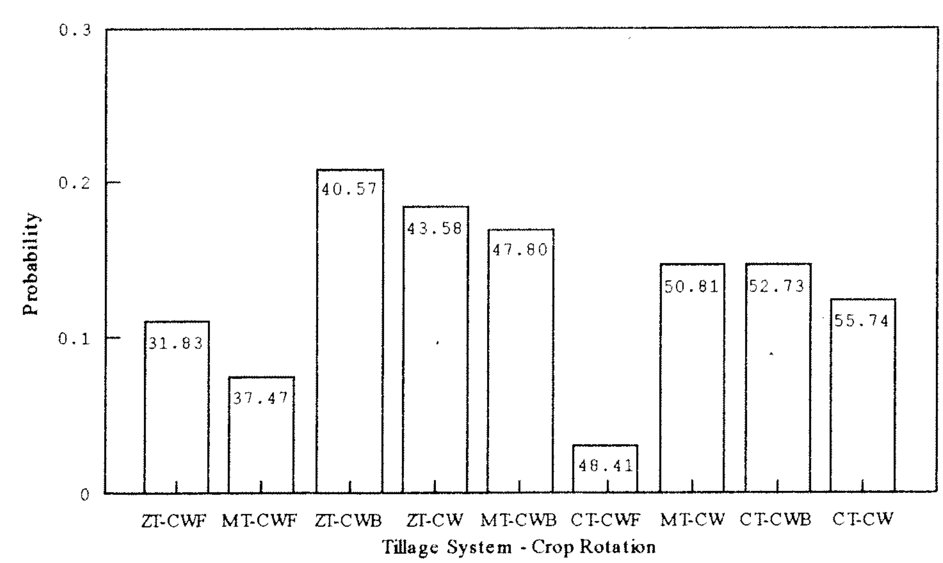


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.8: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Trochu Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWF	102.68	70.85	31.83	25.99	0.82	11.1%
MT	CWF	102.68	65.21	37.47	25.99	0.69	7.5%
ZT	CWB	128.39	87.82	40.57	50.05	1.23	20.9%
ZT	CW	132.69	89.11	43.58	48.28	1.11	18.4%
MT	CWB	128.39	80.59	47.80	50.05	1.05	17.0%
CT	CWF	102.68	54.27	48.41	25.99	0.54	3.1%
MT	CW	132.69	81.88	50.81	48.28	0.95	14.7%
CT	CWB	128.39	75.66	52.73	50.05	0.95	14.6%
CT	CW	132.69	76.95	55.74	48.28	0.87	12.4%

Figure 3.8: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Trochu Area

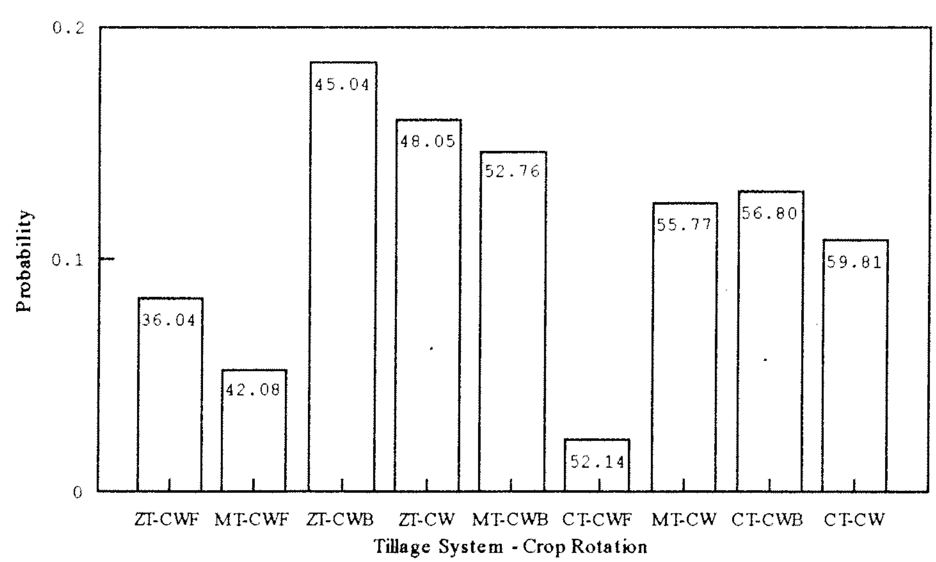


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.9: Probability of Negative Net Revenues for the 1600 Cultivated Acre Farm in the Trochu Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWF	102.68	66.64	36.04	25.99	0.72	8.3%
MT	CWF	102.68	60.60	42.08	25.99	0.62	5.3%
ZT	CWB	128.39	83.35	45.04	50.05	1.11	18.4%
ZT	CW	132.69	84.64	48.05	48.28	1.00	16.0%
MT	CWB	128.39	75.63	52.76	50.05	0.95	14.6%
CT	CWF	102.68	50.54	52.14	25.99	0.50	2.2%
MT	CW	132.69	76.92	55.77	48.28	0.87	12.4%
CT	CWB	128.39	71.59	56.80	50.05	0.88	12.8%
CT	CW	132.69	72.88	59.81	48.28	0.81	10.8%

Figure 3.9: Probability of Negative Net Revenues for the 1600 Cultivated Acre Farm in the Trochu Area



Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

The canola/wheat/barley/fallow (CWBF) rotation had the lowest expected gross revenue and continuous canola/wheat/barley (CWB) had the highest . The relative ranking of the gross revenues (lowest to highest), by crop rotation are as follows: CWBF ($99.99/acre), CWBB ($112.89/acre), and CWB ($116.33/acre).

The CWBF rotation had the lowest RMSE of predicted gross revenue and the continuous CWBB rotation had the highest RMSE of predicted gross revenue. The relative ranking of the RMSE (lowest to highest) is as follows: CWBF ($23.05), CWB ($35.95), and CWBB ($36.17). Once again it appears that adding one year of barley to the crop rotation increases the variance of gross revenue, but it is unclear whether the increased variability attributed to barley is a result of price variability (which includes grade variability) or from yield variability.. the tables in Appendix E illustrates the relative magnitude of the RMSE for the crop rotations tested in this area.

Twenty seven cases were evaluated in this area. All the cases displayed an increase in expected net return as the farm size was increased. The largest expected net return was $44.20/acre, and occurred with the conventional tillage system and a canola/wheat/barley/fallow rotation on 1600 cultivated acres. The lowest expected net return was $14.43/acre, and this occurred with the zero tillage system and a canola/wheat/barley/fallow crop rotation on 960 cultivated acres.

The lowest probability of generating a negative expected net return occured with the CT-CWBF system in all three sizes of farm. In all three farm sizes the second lowest probability of earning a negative expected net revenue is associated with the MT-CWBF system. Tables 3.13 to 3.15 and Figures 3.13 to 3.15 detail the expected net revenues and probabilities of generating a negative expected net revenue.

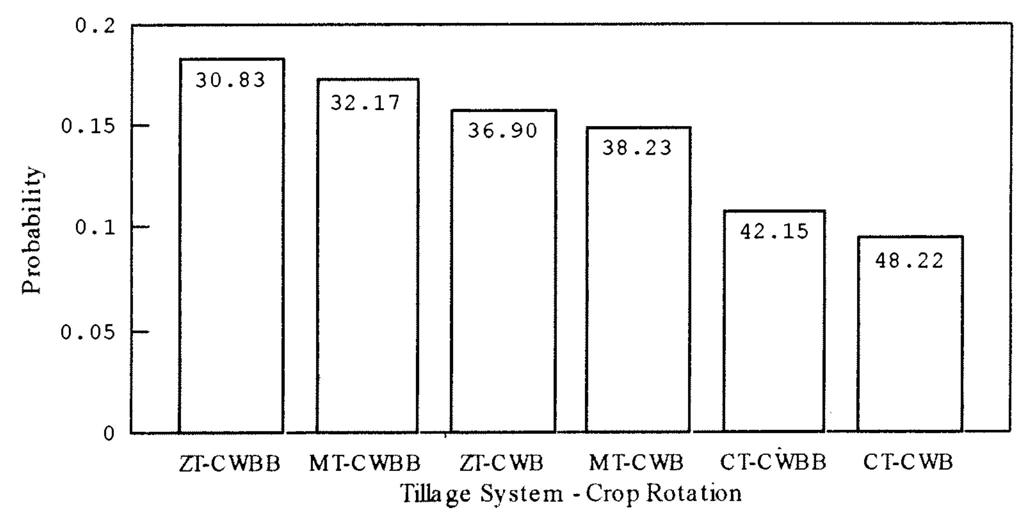
3.4 Generalizations From All Results

The results obtained from each of the areas indicate that several generalizations can be made about the interactions of crop rotations, tillage system and farm size. Firstly, the size of predicted net revenue increases and the probability of generating a negative net revenue decreases as one moves from the Brown soil zone to the Dark Brown and Black soil zones. Secondly, as one moves from the Black soil zone to the Thin Black and Brown soil zones the more significance can be place on the inclusion of fallow in the crop rotation from a risk reduction perspective. Lastly, at the current price of the fallow herbicides, conventional tillage systems have a cost advantage over the alternatives tested here.

Table 3.10: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Lacombe Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWBB	142.15	111.32	30.83	34.07	1.11	18.3%
MT	CWBB	142.15	109.98	32.17	34.07	1.06	17.3%
ZT	CWB	148.38	111.48	36.90	36.68	0.99	15.7%
MT	CWB	148.38	110.15	38.23	36.68	0.96	14.9%
CT	CWBB	142.15	100.00	42.15	34.07	0.81	10.8%
CT	CWB	148.38	100.16	48.22	36.68	0.76	9.4%

Figure 3.10: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Lacombe Area

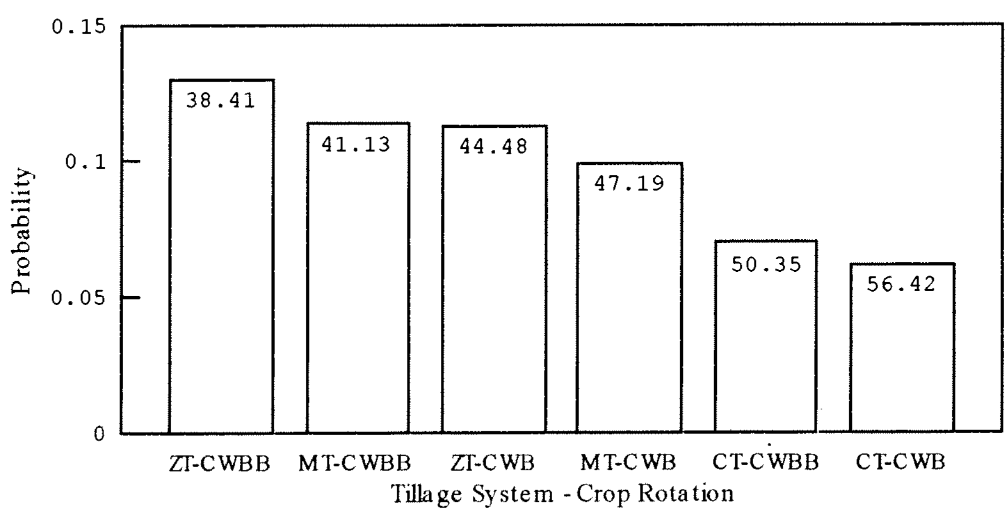


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.11: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Lacombe Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWBB	142.15	103.74	38.41	34.07	0.89	13.0%
MT	CWBB	142.15	101.02	41.13	34.07	0.83	11.4%
ZT	CWB	148.38	103.90	44.48	36.68	0.82	11.3%
MT	CWB	148.38	101.19	47.19	36.68	0.78	9.9%
CT	CWBB	142.15	91.80	50.35	34.07	0.68	7.0%
CT	CWB	148.38	91.96	56.42	36.68	0.65	6.2%

Figure 3.11: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Lacombe Area

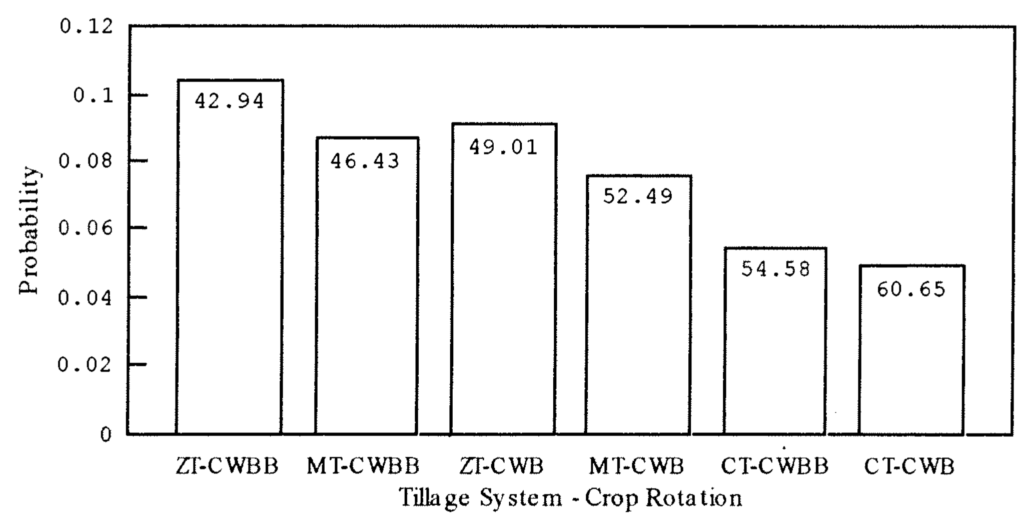


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.12: Probability of Negative Net Revenues for the 1600 Cultivated Acre Farm in the Lacombe Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWBB	142.15	99.21	42.94	34.07	0.79	10.4%
MT	CWBB	142.15	95.72	46.43	34.07	0.73	8.7%
ZT	CWB	148.38	99.37	49.01	36.68	0.75	9.1%
MT	CWB	148.38	95.89	52.49	36.68	0.70	7.6%
CT	CWBB	142.15	87.57	54.58	34.07	0.62	5.4%
CT	CWB	148.38	87.73	60.65	36.68	0.60	4.9%

Figure 3.12: Probability of Negative Net Revenues for the 1600 Cultivated Acre Farm in the Lacombe Area

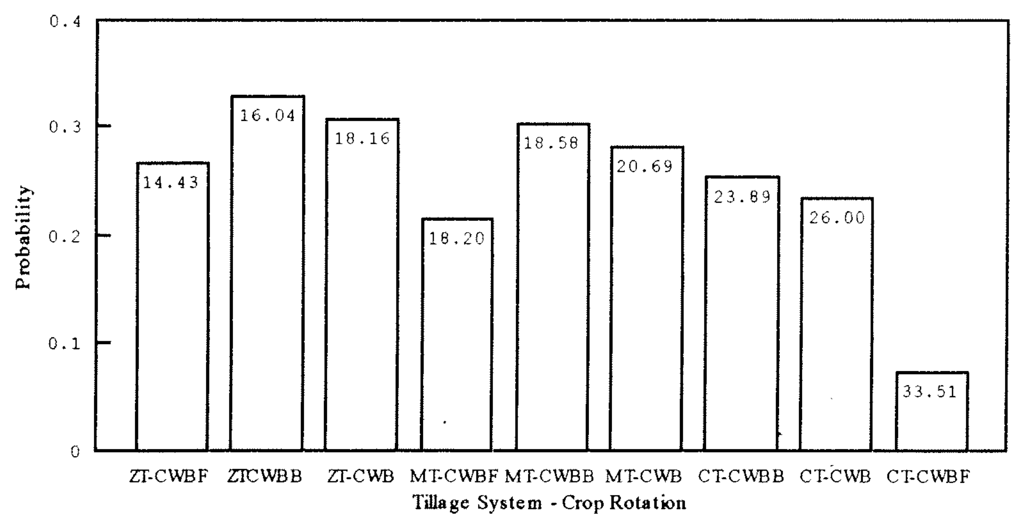


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.13: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Wainwright Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWBF	99.99	85.56	14.43	23.05	1.60	26.5%
ZT	CWBB	112.89	96.85	16.04	36.17	2.25	32.8%
ZT	CWB	116.33	98.17	18.16	35.95	1.98	30.6%
MT	CWBF	99.99	81.79	18.20	23.05	1.27	21.5%
MT	CWBB	112.89	94.31	18.58	36.17	1.95	30.4%
MT	CWB	116.33	95.64	20.69	35.95	1.74	28.2%
CT	CWBB	112.89	89.00	23.89	36.17	1.51	25.4%
CT	CWB	116.33	90.33	26.00	35.95	1.38	23.5%
CT	CWBF	99.99	66.48	33.51	23.05	0.69	7.3%

Figure 3.13: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Wainwright Area

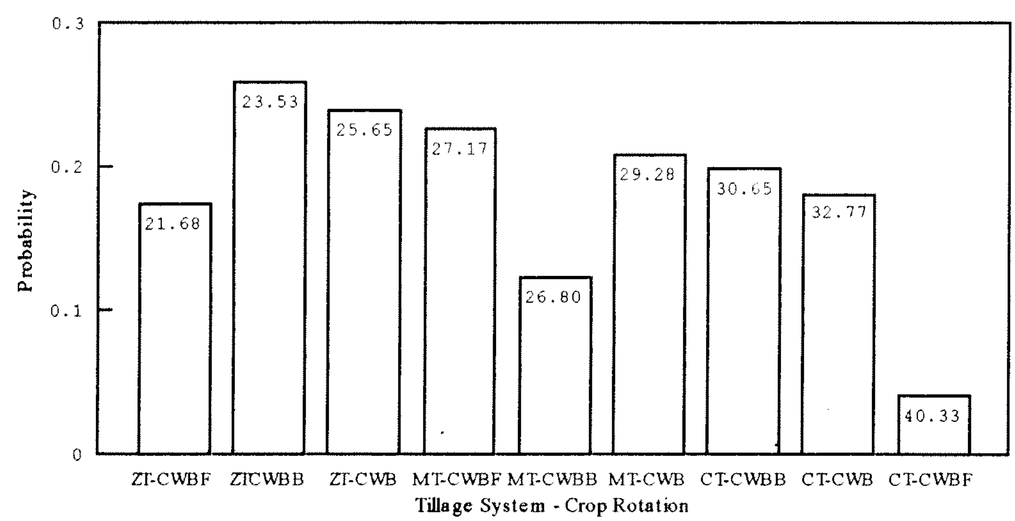


Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.14: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Wainwright Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWBF	99.99	78.31	21.68	23.05	1.06	17.4%
ZT	CWBB	112.89	89.36	23.53	36.17	1.54	25.8%
ZT	CWB	116.33	90.68	25.65	35.95	1.40	23.8%
MT	CWBB	112.89	85.72	27.17	36.17	1.33	22.6%
MT	CWBF	99.99	73.19	26.80	23.05	0.86	12.3%
MT	CWB	116.33	87.05	29.28	35.95	1.23	20.8%
CT	CWBB	112.89	82.24	30.65	36.17	1.18	19.8%
CT	CWB	116.33	83.56	32.77	35.95	1.10	18.1%
CT	CWBF	99.99	59.66	40.33	23.05	0.57	4.0%

Figure 3.14: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Wainwright Area

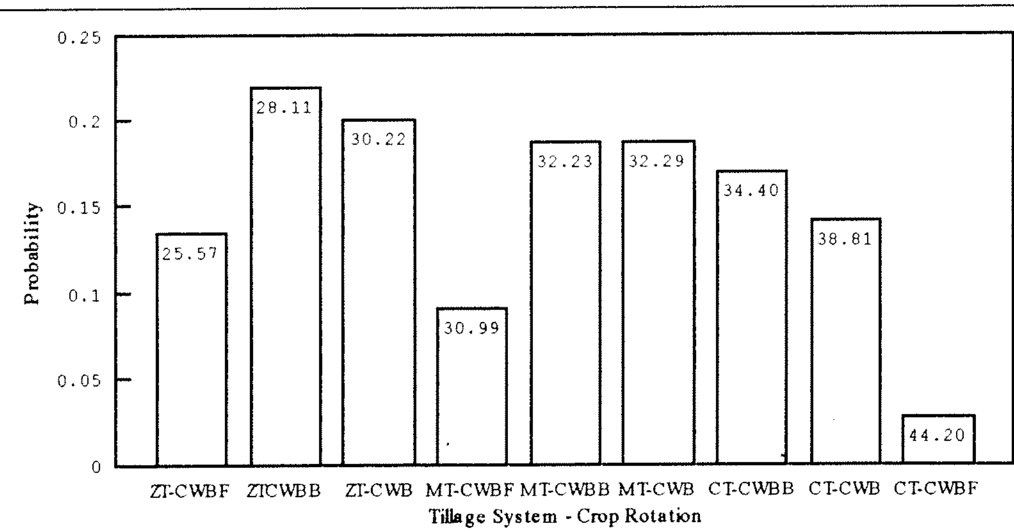


Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 3.15: Probability of Negative Net Revenues for the 1600 Cultivated Acre Farm in the Wainwright Area

Tillage System	Crop Rotation	Gross Revenue	Total Costs	Net Revenue	RMSE	Coefficient of Variation	P(NR<0) (as a %)
ZT	CWBF	99.99	74.42	25.57	23.05	0.90	13.4%
ZT	CWBB	112.89	84.78	28.11	36.17	1.29	21.9%
ZT	CWB	116.33	86.11	30.22	35.95	1.19	20.0%
MT	CWBF	99.99	69.00	30.99	23.05	0.74	8.9%
CT	CWBB	112.89	80.66	32.23	36.17	1.12	18.7%
MT	CWBB	112.89	80.60	32.29	36.17	1.12	18.6%
MT	CWB	116.33	81.93	34.40	35.95	1.05	17.0%
CT	CWB	116.33	77.52	38.81	35.95	0.93	14.0%
CT	CWBF	99.99	55.79	44.20	23.05	0.52	2.7%

Figure 3.15: Probability of Negative Net Revenues for the 1600 Cultivated Acre Farm in the Wainwright Area



Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

Section 4: Conclusions and Recommendations

This section is divided into five sections. The first three will describe conclusions that can be drawn from changing the variables for this study. The fourth section addresses the results in general terms, and the final section provides recommendations for future research that arise from this study.

4.1 Crop Input Costs

The types of crop inputs were held constant across all the areas studied, but amounts of the individual crop inputs varied from area to area. This results from differing agronomic requirements of each area studied, and reflect the climatic condition and soil type differences.

An important component of minimum and zero tillage systems is the replacement of mechanical tillage with herbicides. This was found to increase the crop input costs. The chemical tillage replacement used in this study was glyphosate, and at advertised rates of application and price, crop input costs increased from $2.58/acre to $14.93 /acre when used.

4.2 Machinery Costs

The machinery costs also differed among areas. The differences are a result of the types of equipment used, the soil's effect on horsepower requirements, and the tillage system used. Generally the conventional tillage system had the lowest costs when fallow was included in the crop rotation. The minimum tillage systems had the highest machinery costs, reflecting the higher capital costs associated with a mixture of the types of equipment in the complement.

The minimum tillage systems, under a fallow crop rotation, were from 17% to 31% more expensive than the conventional tillage system. The same crop rotations using a zero tillage system had machinery costs that were from 4% to 27% greater than the conventional tillage system. In a continuous cropping rotation, minimum tillage systems were from 4% to 27%, and zero tillage systems were 2.5% to 16% more expensive than conventional tillage systems.

All the tillage systems demonstrated machinery cost reductions, on a per acre basis, as the number of cultivated acres was increased from 960 to 1600 cultivated acres. These cost reductions were from 20% to 22% in all the areas.

4.3 Revenue Predictions and Variance

Yield information was combined with price information to generate revenue predictions. The prices used in this study were weighted for historical grade and adjusted to reflect 1994 freight costs. A one year lagged prediction model was used to forecast prices (i.e. last years price was used to predict this years price). It was found that the adjusted weighted prices also varied with the area under consideration. This is a result of area differences in the grades of grain that are produced, and freight costs. A mean yield based on 18 years of crop information was used to form yield expectations. Since both price and yield expectations varied among areas, therefore the gross revenue expectations and variances differed among areas.

4.4 Risk Comparisons

In view of the localization of results this section will report the risk efficient options by the area studied.

4.4.1 Medicine Hat Area

In the Medicine Hat area the most efficient combination of tillage system and crop rotation, from a risk perspective, is conventional tillage using a wheat/fallow crop rotation grown on 1600 cultivated acres. This combination has a smaller probability of generating a negative net revenue than the same combinations of tillage and crop rotation grown on 1280 and 960 cultivated acres. From these results it can also be concluded that size economies play a role in the risk efficiency of tillage and crop rotation combinations.

4.4.2 Lethbridge Area

In the Lethbridge area the most efficient combination of tillage system and crop rotation, from a risk perspective, is conventional tillage using a wheat/wheat/barley/ fallow crop rotation on 1600 cultivated acres. The wheat/fallow crop rotation, while generating a smaller expected net revenue, ranked very close to the wheat/wheat/barley fallow crop rotation when the probability of generating a negative net revenue is considered.

4.4.3 Trochu Area

In the Trochu area the most efficient combination of tillage system and crop rotation, from a risk perspective, is conventional tillage using a canola/wheat/fallow rotation grown on 1600 cultivated acres. These results are consistent with those from the Lethbridge area where adding fallow to a crop rotation reduces the expected net revenue but also reduces the probability of generating a negative expected net revenue.

4.4.4 Lacombe Area

In the Lacombe area the most efficient combination of tillage system and crop rotation, from a risk perspective, is conventional tillage using a canola/wheat/barley/barley crop rotation grown on 1600 cultivated acres. This combination is also more efficient than the same combination of tillage and crop rotation grown on 1280 cultivated acres and 960 cultivated acres.

4.4.5 Wainwright Area

In the Wainwright area the most efficient combination of tillage system and crop rotation, from a risk perspective, is conventional tillage using a canola/wheat/barley/fallow rotation grown on 1600 cultivated acres. These results are consistent with the other areas where fallow was included as part of the crop rotation.

4.5 General Results

In areas where moisture is a limiting factor of production, fallow is a risk minimizing technique. This corresponds to moving from areas of light coloured soil where moisture is the most limiting, to areas of darker coloured soils where moisture is less limiting to crop production; or from the southeast portion of the province in a northwestern direction.

It was also found that the costs associated with the minimum and zero tillage systems were consistently higher than those for conventional tillage systems. These results also indicate that size economies within the tillage system machinery costs play a role in the risk efficiency crop production, that is machinery costs per acre decline as the number of cultivated acres increase.

The results of this study provide additional insights to why farmers appear to be reluctant to adopt the conservation tillage technologies described here as minimum and zero tillage. Farmers appear to be aware of how the cost structures are effected by changes to production methods and that, although fallow reduces their expected net revenues, it also reduces their risk.

4.6 Recommendation's For Further Research

This study assumed that there were no per acre yield differences across tillage systems. Furthermore the yield data provided no indication of the land use history. Further research should be directed towards addressing these issues by incorporating yield response research into the framework of this study.

The four soil zones tested in this study represented most of the cropped land in Alberta. An extension of this study may be to examine the risk effects of tillage system and crop rotation in the Grey Wooded soil zone. This soil is typical of the areas north of those studied here.

This study assumed that a farmer's expectations were fixed and do not change over time. A study incorporating flex-cropping decision rules and/or the purchase of crop insurance into the frame work of this study may provide additional insights into farmer's behaviour when facing uncertainty. Young (1979) and Antle (1983) provide some ideas for incorporating dynamics into research about farmer's behaviour when faced with uncertainty or risk.

Bibliography

Abramowitz, Milton and Irene A. Stegun (Editors). (1964). Handbook of Mathematical Functions with Formulas, Graphs and Mathematical Tables. The National Bureau of Standards. Applied Mathematical Seris 55. United States Department of Commerce.

Alberta Agriculture (1994a). Agricultural Prices and Indexes. Edmonton: Alberta Agriculture, Market Analysis and Statistics Branch.

Alberta Agriculture (1994b). Agriculture Fact Sheet 1993 (AGDEX 853). Edmonton: Alberta Agriculture, Market Analysis and Statistics Branch.

Alberta Agriculture (1985). Farm Machinery Costs (AGDEX 825-12). Edmonton: Alberta Agriculture, Production and Resource Economics Branch.

Alberta Agriculture (1995). Farm Machinery Costs (AGDEX 825-12, Draft Copy). Edmonton: Alberta Agriculture, Production and Resource Economics Branch.

Alberta Agriculture. Various Years. Statutory Grain Freight Rates From Alberta to Vancouver, Prince Rupert and Thunder Bay (AGDEX 843-4). Edmonton.

Alberta Energy and Natural Resources (1983). Soil Capability for Agriculture: A Summary and Application of Canada Land Inventory Data in Alberta. Edmonton: Alberta Energy and Natural Resources, Resource Planning Branch

Antle, J. M. (1983). Incorporating Risk in Production Analysis. American Journal of Agricultural Economics, 65, 1099- 1106.

Bauer, L., & McEvoy, M. J. (1990). An Economic Evaluation of Tillage Systems on Dark Brown Soils in Alberta (Farming for the Future Report No. 84-0360 and 87-0093, Project Report No. 90-05). Edmonton: University of Alberta, Department of Rural Economy.

Bauer, L., Novak, F., Armstrong, G., & Staples, B. (1992). An Economic Analysis of Alternative Cropping Decisions Under Uncertainty (Project Report 92- 07, Farming for the Future Project 55-57238). Edmonton: University of Alberta, Department of Rural Economy.

Beattie, B. R., & Taylor, C. R. (1985). The Economics of Production. Toronto: John Wiley & Sons, Inc.

Bohrnstedt, G. W., & Goldberger, A. S. (1969). On Exact Covariance of Products of Random Variables. American Statistical Association Journal, 64, pg 1439- 1442.

Brorsen, B. W., Chavas, J., & Grant, W. R. (1987). A Market Equilibrium Analysis of the Impact of Risk on The U.S. Rice Industry. American Journal of Agricultural Economics, 69, 733-739.

Boyda, A. C. (1988). Risk and Returns on Alberta Grain Farms. Edmonton: University of Alberta (MSc Thesis).

Brealy, R., Myers, S., Sick, G., & Giammarino, R. (1992). Principles of Corporate Finance (Second Canadian Edition). Toronto: McGraw-Hill Ryerson Limited.

Canadian Grains Council. Various Years. Canadian Grains Industry Statistical Handbook. Winnepeg.

Dzikowski, P., & Heywood, R. T. (1990). Agroclimatic Atlas of Alberta (AGDEX 071-1). Edmonton, Alta.: Alberta Agriculture.

Fox, G., & Dickson, E. J. (1988). What's Economic About the Economic Costs of Soil Erosion to Canadian Farmers? (Discussion Paper No. DP88/3). Guelph, On.: University of Guelph, Department of Agricultural Economics and Business.

Govindasamy, N. (1983). An Economic Analysis of Continuous Cropping in the Dark Brown Soil Zone of Alberta. Edmonton: University of Alberta, Department of Rural Economy (MSc Thesis).

Kiker, C., & Lynne, G. (1986). An Economic Model of Soil Conservation: Comment. American Journal of Agricultural Economics, 68, 739-742.

Lerohl, M. L., Anderson, M. S., & Robertson, J. A. (1990). Soil Erosion Implications of Selected Agricultural Programs (Project Report No. 90-09). Edmonton: University of Alberta, Department of Rural Economy.

Malhi, S. S., Mumey, G., O'Sullivan, P. A., & Harker, K. N. (1988). An Economic Comparison of Barley Production Under Zero and Conventional Tillage. Soil & Tillage Research, 11, 159- 166.

Marv Anderson & Associates Limited (1981). Factors Affecting Summerfallow Acreage In Alberta. Edmonton: Environment Council Of Alberta.

McConnell, K. E. (1983). An Economic Model of Soil Erosion. American Journal of Agricultural Economics, 65, 83- 89.

Orlick, Charles C. (1995). Risk and Return Comparisons of Crop Rotations and Tillage Systems for Selected Areas in Alberta. Edmonton: University of Alberta, Department of Rural Economy (MSc Thesis).

Pope, R. D., & Just, R. E. (1991). On Testing the Structure of Risk Preferences in Agricultural Supply Analysis. American Journal of Agricultural Economics, 73,

Seitz, W. D., & Swanson, E. R. (1980). Economics of Soil Conservation from the Farmers Perspective. American Journal of Agricultural Economics, 62, 1084- 1088.

Smith, E. G., Peters, T. L., Zentner, R. P., Larney, F. J., Lndwall, C. W., Moulin, A. P., & Bowren, K. E. (1994). Economics of Conservation Tillage Systems in Dry and Humid Regions of the Canadian Prairies (CAESA Project No. RES-004-93). : Canada-Alberta Environmentally Sustainable Agriculture Agreement.

Statistics Canada, (1994a). Agriculture Economic Statistics (Catalogue No. 21-603E). Ottawa, On.: Government of Canada.

Statistics Canada (1994b). Consumer Prices and Price Indexes (Catalogue 62-010 Quarterly). Ottawa, On.: Government of Canada.

Statistics Canada, (1992a). Agricultural Profile of Alberta, Part 1 and Part 2 (Catalogue No. 95-382 and 95-383). Ottawa, On.: Government of Canada.

Statistics Canada, (1992b). Trends and Highlights of Canadian Agriculture and its People (Catalogue 96-303E. Ottawa, On.: Government of Canada.

Statistics Canada (1991). Farm Input Price Index (Catalogue 62-004 Quarterly). Ottawa: Government of Canada.

Stonehouse, D. P. (1991). The Economics of Tillage for Large-scale Mechanized Farms. Soil & Tillage Research, 20, 333- 351.

Toogood, J. A. (1989). The Story of Soil and Water Conservation in Alberta (AGDEX 570-2). Edmonton: Alberta Agriculture and Canada-Alberta Soil Conservation Initiative.

Van Kooten, G. C. (1990). Soil Conservation and Sustainable Agriculture on the Canadian Great Plains: An Alternative View (FMSA Discussion Paper No. 1). Vancouver, B.C.: University of British Columbia, Department of Agricultural Economics.

Woloshyn, P. A. (1990). Fixed Cost Compensation in Farmland Expropriation. Edmonton: University of Alberta, Department of Rural Economy (MSc Thesis).

Young, D. L. (1979). Risk Preferences of Agricultural Producers: Their Use in Extension and Research. American Journal of Agricultural Economics, 61, 1063- 1070.

Zentner, R. P., Bowren, K. E., Stephenson, J. E., Campbell, C. A., Moulin, A., & Townley-Smith, L. (1990). Effects of Rotation and Fertillization on Economics of Crop Production in the Black Soil Zone of North-Central Saskatchewan. Canadian Journal of Plant Science, 70, 837- 851.

Zentner, R. P., Selles, F., Campbell, C. A., Hanford, K., & McConkey, B. G. (1992). Economics of Fertillizer- N Management for Zero-Tillage Continuous Spring Wheat in the Brown Soil Zone. Canadian Journal of Soil Science, 72, 981- 995.

Zentner, R. P., Sonntag, B. H., & Lee, G. E. (1978). Simulation Model For Dryland Crop Production in the Canadian Prairies. Agricultural Systems, 3, 241- 251.

Zentner, R. P., Spratt, E. D., Reisdorf, H., & Campbell, C. A. (1987). Effect of Crop Rotation and N and P Fertilizer on Yields of Spring Wheat Grown on a Black Chernozemic Clay. Canadian Journal of Plant Science, 67, 965- 982.

Appendix A: Medicine Hat Area

Table A1: Expected Gross Revenue, Costs and Net Revenue for the Medicine Hat Area (Wheat on Fallow Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		48.04	48.04	48.04	48.04	48.04	48.04	48.04	48.04	48.04
Crop Input Costs										
Seed		3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38
Fertilizer	N	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.97
	Phosphate	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Herbicide	Selective	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
	Glyphosate				4.98	4.98	4.98	14.93	14.93	14.93
Total Crop Input Costs		11.48	11.48	11.48	16.45	16.45	16.45	26.40	26.40	26.40
Machinery Costs										
Capital		32.71	25.84	21.51	39.40	32.56	28.05	35.45	28.87	25.81
Repairs		2.20	2.34	2.53	1.78	2.11	2.14	1.50	1.55	1.58
Fuel		1.60	1.60	1.60	1.45	1.73	1.73	1.07	1.07	1.07
Total Machinery Costs		36.52	29.78	25.63	42.63	36.39	31.92	38.02	31.49	28.47
Total Costs		47.99	41.25	37.11	59.08	52.84	48.37	64.42	57.89	54.87
Projected Net Revenue		0.05	6.79	10.93	-11.04	-4.80	-0.33	-16.38	-9.85	-6.83
RMSE		24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50
P(E[NR]<0)		49.9%	39.1%	32.7%	67.4%	57.8%	50.5%	74.8%	65.6%	61.0%

Table A2: Expected Gross Revenue, Costs and Net Revenue for the Medicine Hat Area (Wheat, Barley, Fallow Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		48.36	48.36	48.36	48.36	48.36	48.36	48.36	48.36	48.36
Crop Input Costs										
Seed		4.35	4.35	4.35	4.35	4.35	4.35	4.35	4.35	4.35
Fertilizer	N	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93
	Phosphate	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09
Herbicide	Selective	3.85	3.85	3.85	3.85	3.85	3.85	3.85	3.85	3.85
	Glyphosate				3.32	3.32	3.32	13.27	13.27	13.27
Total Crop Input Costs		16.22	16.22	16.22	19.54	19.54	19.54	29.49	29.49	29.49
Machinery Costs										
Capital		33.02	26.35	22.12	42.00	35.72	31.05	38.65	33.05	28.60
Repairs		3.38	3.44	3.72	2.24	2.31	2.52	2.02	2.11	2.35
Fuel		1.96	1.96	1.96	1.68	1.68	1.68	1.39	1.39	1.39
Total Machinery Costs		38.36	31.75	27.80	45.93	39.71	35.26	42.06	36.55	32.34
Total Costs		54.58	47.97	44.02	65.47	59.25	54.80	71.55	66.04	61.83
Projected Net Revenue		-6.22	0.39	4.34	-17.11	-10.89	-6.44	-23.19	-17.68	-13.47
RMSE		17.65	17.65	17.65	17.65	17.65	17.65	17.65	17.65	17.65
P(E[NR]<0)		63.8%	49.1%	40.3%	83.4%	73.2%	64.3%	90.5%	84.2%	77.7%

Table A3: Expected Gross Revenue, Costs and Net Revenue for the Medicine Hat Area (Continuous Wheat Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		57.85	57.85	57.85	57.85	57.85	57.85	57.85	57.85	57.85
Crop Input Costs										
Seed		6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06	10.06	10.06	10.06	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		33.71	33.71	33.71	33.71	33.71	33.71	43.66	43.66	43.66
Machinery Costs										
Capital		35.61	28.69	24.94	47.39	40.57	35.13	42.93	36.93	31.97
Repairs		5.04	5.65	5.95	4.82	4.98	5.46	3.69	3.91	4.45
Fuel		2.74	2.74	2.74	3.20	3.20	3.20	2.03	2.03	2.03
Total Machinery Costs		43.38	37.08	33.63	55.41	48.75	43.79	48.65	42.87	38.45
Total Costs		77.09	70.79	67.34	89.12	82.46	77.50	92.31	86.53	82.11
Projected Net Revenue		-19.24	-12.94	-9.49	-31.27	-24.61	-19.65	-34.46	-28.68	-24.26
RMSE		35.32	35.32	35.32	35.32	35.32	35.32	35.32	35.32	35.32
P(E[NR]<0)		70.7%	64.3%	60.6%	81.2%	75.7%	71.1%	83.5%	79.1%	75.4%

Table A4: Expected Gross Revenue, Costs and Net Revenue for the Medicine Hat Area (Wheat, Wheat, Barley Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		54.90	54.90	54.90	54.90	54.90	54.90	54.90	54.90	54.90
Crop Input Costs										
Seed		6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		31.05	31.05	31.05	31.05	31.05	31.05	41.00	41.00	41.00
Machinery Costs										
Capital		35.61	28.69	24.94	47.39	40.57	35.13	42.93	36.93	31.97
Repairs		5.04	5.65	5.95	4.82	4.98	5.46	3.69	3.91	4.45
Fuel		2.74	2.74	2.74	3.20	3.20	3.20	2.03	2.03	2.03
Total Machinery Costs		43.38	37.08	33.63	55.42	48.75	43.79	48.65	42.87	38.45
Total Costs		74.43	68.12	64.67	86.47	79.80	74.84	89.65	83.87	79.45
Projected Net Revenue		-19.53	-13.22	-9.77	-31.57	-24.90	-19.94	-34.75	-28.97	-24.55
RMSE		29.11	29.11	29.11	29.11	29.11	29.11	29.11	29.11	29.11
P(E[NR]<0)		74.9%	67.5%	63.2%	86.1%	80.4%	75.3%	88.4%	84.0%	80.0%

Appendix B: Lethbridge Area

Table B1: Expected Gross Revenue, Costs and Net Revenue for the Lethbridge Area (Wheat on Fallow Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		44.52	44.52	44.52	44.52	44.52	44.52	44.52	44.52	44.52
Crop Input Costs										
Seed		3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38
Fertilizer	N	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03	5.03
	Phosphate	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30
Herbicide	Selective	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15	3.15
	Glyphosate				9.95	9.95	9.95	14.93	14.93	14.93
Total Crop Input Costs		16.86	16.86	16.86	26.81	26.81	26.81	31.78	31.78	31.78
Machinery Costs										
Capital		31.10	24.60	21.00	39.17	32.23	27.85	35.41	28.84	25.79
Repairs		1.45	1.63	1.74	1.76	1.79	1.83	1.50	1.55	1.58
Fuel		1.25	1.25	1.25	1.42	1.42	1.42	1.08	1.08	1.08
Total Machinery Costs		33.80	27.48	23.99	42.35	35.44	31.09	37.99	31.47	28.45
Total Costs		50.66	44.34	40.85	69.16	62.25	57.90	69.77	63.25	60.23
Projected Net Revenue		-6.14	0.18	3.67	-24.64	-17.73	-13.38	-25.25	-18.73	-15.71
RMSE		20.66	20.66	20.66	20.66	20.66	20.66	20.66	20.66	20.66
P(E[NR]<0)		61.7%	49.7%	43.0%	88.3%	80.4%	74.1%	88.9%	81.7%	77.6%

Table B2: Expected Gross Revenue, Costs and Net Revenue for the Lethbridge Area (Wheat, Wheat, Barley, Fallow Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		52.29	52.29	52.29	52.29	52.29	52.29	52.29	52.29	52.29
Crop Input Costs										
Seed		4.95	4.95	4.95	4.95	4.95	4.95	4.95	4.95	4.95
Fertilizer	N	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98
	Phosphate	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Herbicide	Selective	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46	4.46
	Glyphosate				2.49	2.49	2.49	12.44	12.44	12.44
Total Crop Input Costs		20.36	20.36	20.36	22.84	22.84	22.84	32.79	32.79	32.79
Machinery Costs										
Capital		32.15	25.85	22.46	45.20	38.38	34.00	40.31	30.46	27.79
Repairs		2.60	2.94	3.13	2.53	2.76	2.87	2.23	2.86	2.92
Fuel		1.69	1.69	1.69	2.00	2.00	2.00	1.56	1.56	1.56
Total Machinery Costs		36.44	30.48	27.28	49.73	43.14	38.87	44.09	34.87	32.26
Total Costs		56.79	50.84	47.63	72.57	65.98	61.71	76.89	67.67	65.05
Projected Net Revenue		-4.50	1.45	4.66	-20.28	-13.69	-9.42	-24.60	-15.38	-12.76
RMSE		29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
P(E[NR]<0)		56.1%	48.0%	43.7%	75.6%	68.0%	62.6%	79.9%	70.0%	66.9%

Table B3: **Expected Gross Revenue, Costs and Net Revenue for the Lethbridge Area (Continuous Wheat Crop Rotation)**

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		67.17	67.17	67.17	67.17	67.17	67.17	67.17	67.17	67.17
Crop Input Costs										
Seed		6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06	10.06	10.06	10.06	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.30
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		33.71	33.71	33.71	33.71	33.71	33.71	43.66	43.66	43.66
Machinery Costs										
Capital		35.61	28.69	24.94	47.39	40.57	35.13	42.93	36.93	31.97
Repairs		5.04	5.65	5.95	4.82	4.98	5.46	3.69	3.91	4.45
Fuel		2.74	2.74	2.74	3.20	3.20	3.20	2.03	2.03	2.03
Total Machinery Costs		43.39	37.08	33.63	55.41	48.75	43.79	48.65	42.87	38.45
Total Costs		77.10	70.79	67.34	89.12	82.46	77.50	92.31	86.53	82.11
Projected Net Revenue		-9.93	-3.62	-0.17	-21.95	-15.29	-10.33	-25.14	-19.36	-14.94
RMSE		41.33	41.33	41.33	41.33	41.33	41.33	41.33	41.33	41.33
P(E[NR]<0)		59.5%	53.5%	50.2%	70.3%	64.4%	59.9%	72.9%	68.1%	64.1%

Table B4: Expected Gross Revenue, Costs and Net Revenue for the Lethbridge Area (Wheat, Wheat, Barley, Fallow Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Projected Gross Revenue		62.42	62.42	62.42	62.42	62.42	62.42	62.42	62.42	62.42
Crop Input Costs										
Seed		6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		31.04	31.04	31.04	31.04	31.04	31.04	40.99	40.99	40.99
Machinery Costs										
Capital		35.61	28.69	24.94	47.39	40.57	35.13	42.93	36.93	31.97
Repairs		5.04	5.65	5.95	4.82	4.98	5.46	3.69	3.91	4.45
Fuel		2.74	2.74	2.74	3.20	3.20	3.20	2.03	2.03	2.03
Total Machinery Costs		43.39	37.08	33.63	55.42	48.75	43.79	48.65	42.87	38.45
Total Costs		74.43	68.12	64.67	86.46	79.79	74.83	89.64	83.86	79.44
Projected Net Revenue		-12.01	-5.70	-2.25	-24.04	-17.37	-12.41	-27.22	-21.44	-17.02
RMSE		39.84	39.84	39.84	39.84	39.84	39.84	39.84	39.84	39.84
P(E[NR]<0)		61.8%	55.7%	52.2%	72.7%	66.9%	62.2%	75.3%	70.5%	66.6%

Appendix C: Trochu Area

Table C1: Expected Gross Revenue, Costs and Net Revenue for the Trochu Area (Canola, Wheat, Barley Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		128.39	128.39	128.39	128.39	128.39	128.39	128.39	128.39	128.39
Crop Input Costs										
Seed		5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92
Fertilizer	N	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83	10.83
	Phosphate	6.18	6.18	6.18	6.18	6.18	6.18	6.18	6.18	6.18
Herbicide	Selective	8.92	8.92	8.92	8.92	8.92	8.92	8.92	8.92	8.92
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		31.84	31.84	31.84	31.84	31.84	31.84	41.79	41.79	41.79
Machinery Costs										
Capital		41.19	34.81	30.17	47.39	40.57	35.13	47.43	39.81	34.80
Repairs		5.22	5.57	6.14	4.82	4.98	5.46	3.69	3.92	4.46
Fuel		3.44	3.44	3.44	3.20	3.20	3.20	2.30	2.30	2.30
Total Machinery Costs		49.85	43.82	39.75	55.41	48.75	43.79	53.43	46.03	41.56
Total Costs		81.69	75.66	71.59	87.25	80.59	75.63	95.22	87.82	83.35
Expected Net Revenue		46.70	52.73	56.80	41.14	47.80	52.76	33.17	40.57	45.04
RMSE		50.05	50.05	50.05	50.05	50.05	50.05	50.05	50.05	50.05
P(E[NR]<0)		17.6%	14.6%	12.8%	20.6%	17.0%	14.6%	25.4%	20.9%	18.4%

Table C2: Expected Gross Revenue, Costs and Net Revenue for the Trochu Area (Canola, Wheat, Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		132.69	132.69	132.69	132.69	132.69	132.69	132.69	132.69	132.69
Crop Input Costs										
Seed		6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38
Fertilizer	N	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82
	Phosphate	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96
Herbicide	Selective	9.98	9.98	9.98	9.98	9.98	9.98	9.98	9.98	9.98
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		33.13	33.13	33.13	33.13	33.13	33.13	43.08	43.08	43.08
Machinery Costs										
Capital		41.19	34.81	30.17	47.39	40.57	35.13	47.43	39.81	34.80
Repairs		5.22	5.57	6.14	4.82	4.98	5.46	3.69	3.92	4.46
Fuel		3.44	3.44	3.44	3.20	3.20	3.20	2.30	2.30	2.30
Total Machinery Costs		49.85	43.82	39.75	55.41	48.75	43.79	53.43	46.03	41.56
Total Costs		82.98	76.95	72.88	88.54	81.88	76.92	96.51	89.11	84.64
Expected Net Revenue		49.71	55.74	59.81	44.15	50.81	55.77	36.18	43.58	48.05
RMSE		48.28	48.28	48.28	48.28	48.28	48.28	48.28	48.28	48.28
P(E[NR]<0)		15.2%	12.4%	10.8%	18.0%	14.7%	12.4%	22.7%	18.4%	16.0%

Table C3: Expected Gross Revenue, Costs and Net Revenue for the Trochu Area (Canola, Wheat, Fallow Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		102.68	102.68	102.68	102.68	102.68	102.68	102.68	102.68	102.68
Crop Input Costs										
Seed		4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25	4.25
Fertilizer	N	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28
	Phosphate	4.86	4.86	4.86	4.86	4.86	4.86	4.86	4.86	4.86
Herbicide	Selective	6.65	6.65	6.65	6.65	6.65	6.65	6.65	6.65	6.65
	Glyphosate				3.32	3.32	3.32	13.27	13.27	13.27
Total Crop Input Costs		21.03	21.03	21.03	24.35	24.35	24.35	34.30	34.30	34.30
Machinery Costs										
Capital		35.06	28.48	24.45	43.05	36.68	31.85	38.65	33.05	28.60
Repairs		2.62	2.80	3.11	2.31	2.38	2.60	2.02	2.11	2.35
Fuel		1.95	1.95	1.95	1.81	1.81	1.81	1.39	1.39	1.39
Total Machinery Costs		39.63	33.23	29.51	47.17	40.86	36.25	42.06	36.55	32.34
Total Costs		60.67	54.27	50.54	71.52	65.21	60.60	76.36	70.85	66.64
Expected Net Revenue		42.01	48.41	52.14	31.16	37.47	42.08	26.32	31.83	36.04
RMSE		25.99	25.99	25.99	25.99	25.99	25.99	25.99	25.99	25.99
P(E[NR]<0)		5.3%	3.1%	2.2%	11.5%	7.5%	5.3%	15.6%	11.1%	8.3%

Appendix D: Lacombe Area

Table D1: Expected Gross Revenue, Costs and Net Revenue for the Lacombe Area (Canola, Wheat, Barley, Barley Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
Cultivated Acres		960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		142.15	142.15	142.15	142.15	142.15	142.15	142.15	142.15	142.15
Crop Input Costs										
Seed		6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50	6.50
Fertilizer	N	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40	12.40
	Phosphate	9.27	9.27	9.27	9.27	9.27	9.27	9.27	9.27	9.27
Herbicide	Selective	16.54	16.54	16.54	16.54	16.54	16.54	16.54	16.54	16.54
	Glysophate							9.95	9.95	9.95
Total Crop Input Costs		44.71	44.71	44.71	44.71	44.71	44.71	54.66	54.66	54.66
Machinery Costs										
Capital		43.46	34.74	30.17	55.76	46.61	40.83	50.38	42.57	37.50
Repairs		7.05	7.57	7.91	4.93	5.12	5.60	3.71	3.94	4.48
Fuel		4.78	4.78	4.78	4.58	4.58	4.58	2.57	2.57	2.57
Total Machinery Costs		55.29	47.09	42.86	65.27	56.31	51.02	56.66	49.08	44.55
Total Costs		100.00	91.80	87.57	109.98	101.02	95.72	111.32	103.74	99.21
Expected Net Revenue		42.15	50.35	54.58	32.17	41.13	46.43	30.83	38.41	42.94
RMSE		34.07	34.07	34.07	34.07	34.07	34.07	34.07	34.07	34.07
P(E[NR]<0)		10.8%	7.0%	5.4%	17.3%	11.4%	8.7%	18.3%	13.0%	10.4%

Table D2: Expected Gross Revenue, Costs and Net Revenue for the Lacombe Area (Canola, Wheat, Barley,Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
Cultivated Acres		960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		148.38	148.38	148.38	148.38	148.38	148.38	148.38	148.38	148.38
Crop Input Costs										
Seed		6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67	6.67
Fertilizer	N	12.58	12.58	12.58	12.58	12.58	12.58	12.58	12.58	12.58
	Phosphate	9.71	9.71	9.71	9.71	9.71	9.71	9.71	9.71	9.71
Herbicide	Selective	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92
	Glysophate							9.95	9.95	9.95
Total Crop Input Costs		44.87	44.87	44.87	44.87	44.87	44.87	54.82	54.82	54.82
Machinery Costs										
Capital		43.46	34.74	30.17	55.76	46.61	40.83	50.38	42.57	37.50
Repairs		7.05	7.57	7.91	4.93	5.12	5.60	3.71	3.94	4.48
Fuel		4.78	4.78	4.78	4.58	4.58	4.58	2.57	2.57	2.57
Total Machinery Costs		55.29	47.09	42.86	65.27	56.31	51.02	56.66	49.08	44.55
Total Costs		100.16	91.96	87.73	110.15	101.19	95.89	111.48	103.90	99.37
Expected Net Revenue		48.22	56.42	60.65	38.23	47.19	52.49	36.90	44.48	49.01
RMSE		36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68	36.68
P(E[NR]<0)		9.4%	6.2%	4.9%	14.9%	9.9%	7.6%	15.7%	11.3%	9.1%

Appendix E: Wainwright Area

Table E1: Expected Gross Revenue, Costs and Net Revenue for the Wainwright Area (Canola, Wheat, Barley, Barley Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		112.89	112.89	112.89	112.89	112.89	112.89	112.89	112.89	112.89
Crop Input Costs										
Seed		5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69
Fertilizer	N	10.41	10.41	10.41	10.41	10.41	10.41	10.41	10.41	10.41
	Phosphate	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
Herbicide	Selective	9.45	9.45	9.45	9.45	9.45	9.45	9.45	9.45	9.45
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		33.16	33.16	33.16	33.16	33.16	33.16	43.11	43.11	43.11
Machinery Costs										
Capital		46.05	38.87	33.33	52.39	43.62	38.01	47.69	39.94	34.83
Repairs		5.57	5.98	6.81	4.87	5.05	5.54	3.74	4.00	4.54
Fuel		4.22	4.22	4.22	3.89	3.89	3.89	2.30	2.30	2.30
Total Machinery Costs		55.84	49.08	44.36	61.15	52.56	47.44	53.74	46.25	41.67
Total Costs		89.00	82.24	77.52	94.31	85.72	80.60	96.85	89.36	84.78
Expected Net Revenue		23.89	30.65	35.37	18.58	27.17	32.29	16.04	23.53	28.11
RMSE		36.17	36.17	36.17	36.17	36.17	36.17	36.17	36.17	36.17
P(E[NR]<0)		25.4%	19.8%	16.4%	30.4%	22.6%	18.6%	32.8%	25.8%	21.9%

Table E2: Expected Gross Revenue, Costs and Net Revenue for the Wainwright Area (Canola, Wheat, Barley, Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		116.33	116.33	116.33	116.33	116.33	116.33	116.33	116.33	116.33
Crop Input Costs										
Seed		5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92
Fertilizer	N	10.56	10.56	10.56	10.56	10.56	10.56	10.56	10.56	10.56
	Phosphate	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51
Herbicide	Selective	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50
	Glyphosate							9.95	9.95	9.95
Total Crop Input Costs		34.49	34.49	34.49	34.49	34.49	34.49	44.44	44.44	44.44
Machinery Costs										
Capital		46.05	38.87	33.33	52.39	43.62	38.01	47.69	39.94	34.83
Repairs		5.57	5.98	6.81	4.87	5.05	5.54	3.74	4.00	4.54
Fuel		4.22	4.22	4.22	3.89	3.89	3.89	2.30	2.30	2.30
Total Machinery Costs		55.84	49.08	44.36	61.15	52.56	47.44	53.74	46.25	41.67
Total Costs		90.33	83.56	78.85	95.64	87.05	81.93	98.17	90.68	86.11
Expected Net Revenue		26.00	32.77	37.48	20.69	29.28	34.40	18.16	25.65	30.22
RMSE		35.95	35.95	35.95	35.95	35.95	35.95	35.95	35.95	35.95
P(E[NR]<0)		23.5%	18.1%	14.9%	28.2%	20.8%	16.9%	30.7%	23.8%	20.0%

Table E3: Expected Gross Revenue, Costs and Net Revenue for the Wainwright Area (Canola, Wheat, Barley, Fallow Crop Rotation)

		Conventional Tillage			Minimum Tillage			Zero Tillage		
	Cultivated Acres	960	1280	1600	960	1280	1600	960	1280	1600
Predicted Gross Revenue		99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Crop Input Costs										
Seed		4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44
Fertilizer	N	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44
	Phosphate	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63
Herbicide	Selective	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88
	Glyphosate				2.49	2.49	2.49	12.44	12.44	12.44
Total Crop Input Costs		24.39	24.39	24.39	26.87	26.87	26.87	36.82	36.82	36.82
Machinery Costs										
Capital		35.84	28.75	24.71	50.10	41.26	36.95	44.75	37.24	33.22
Repairs		3.74	4.00	4.17	2.45	2.69	2.80	2.23	2.49	2.62
Fuel		2.52	2.52	2.52	2.37	2.37	2.37	1.76	1.76	1.76
Total Machinery Costs		42.10	35.28	31.40	54.92	46.32	42.12	48.74	41.49	37.60
Total Costs		66.48	59.66	55.79	81.79	73.19	69.00	85.56	78.31	74.42
Expected Net Revenue		33.51	40.33	44.20	18.20	26.80	30.99	14.43	21.68	25.57
RMSE		23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05
P(E[NR]<0)		7.3%	4.0%	2.7%	21.5%	12.3%	8.9%	26.5%	17.4%	13.4%