University of Alberta

Risk and Return Comparisons of Crop Rotations and Tillage Systems for Selected Areas in Alberta

by

Charles Clement Orlick ©

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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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Chapter 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 (1992) 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.

Chapter 2: Theoretical Considerations

The study being undertaken here is a simulation of a farmer producing grain crops, and maximizing his well being. The production of these crops requires that farmer's "combine and coordinat[e] materials and forces (inputs, factors, resources, or productive services) in the creation of some good... (output or product)." (Beattie and Taylor, 1985, pg 3) This chapter will describe some of the theoretical considerations underlying this simulation. The chapter is divided into three parts: the production function, the net revenue function, and production in the presence of risk or uncertainty.

2.1 The Production Function

Beattie and Taylor (1985, pg 3) define a production function as follows:

> "A production function is a quantitative or mathematical description of the various technical production possibilities faced by a firm. The production function gives the maximum output(s) in physical terms for each level of inputs in physical terms."

The mathematical representations for production can range in complexity from very simple, to very complex and abstract systems of equations. A simple representation may be written implicitly as follows:

$$F(y_1, y_2, \ldots, y_m; x_1, x_2, \ldots x_n) = 0$$

Where:

> y represents the quantities of outputs, of which there are m, that can be produced from a given set of inputs,
>
> x represents the quantities of inputs, of which there are n, required to produce the outputs.

Some inputs to production may be fixed and do not change (or cannot be changed) with the level of output. These are referred to as fixed factors of production, or fixed inputs. Examples of fixed factors of production are the quantity of land suitable for production of grain crops, and the quantity of labour a farmer can provide himself. By changing the level of use for some inputs, the level of output may change. These inputs are referred to as variable inputs. Examples of variable inputs to production are the quantity of fertilizer applied, and the quantity of herbicide that is applied to control weeds. The production function for a particular output can be written explicitly as follows:

$$\hat{y}_i = f(x_1, x_2, \ldots x_k | x_{k+1} \ldots x_n)$$

Where,

$\hat{y}_i$, represents the estimated quantity of the i^{th} output or product.
$x_1,\ldots,x_k$, represent the variable inputs.
$x_{k+1},\ldots,x_n$, represent the fixed inputs.

The previous description implies that the farmer has complete control and knowledge of the interaction among the inputs. However, a farmer seldom has complete control or knowledge about these interactions. The production function can be more meaningfully described as being the interaction of controllable and uncontrollable (or incompletely controllable) factors or inputs. The inputs (both fixed and variable) that can be controlled are considered the decision variables, and the uncontrollable inputs are considered stochastic or random variables. An example of a stochastic variable in agricultural production would be the weather (i.e. the amount of growing season precipitation, or the date of the first killing frost, etc.). The production function can now be represented as follows:

$$y = f(x_1 \ldots x_k | x_{k+1} \ldots x_n ; \theta_1, \theta_2, \ldots \theta_q)$$

Where:

$x_1, \ldots, x_k$ and $x_1, \ldots, x_n$, are as previously described,

$\theta_1, \ldots, \theta_q$, represent the stochastic elements of production.

2.2 The Net Revenue Function

A farmer's objectives are not usually just the amount of output produced, but more commonly the amount of profit or net revenue that is achieved. For the purposes of this study profit and net revenue will be used interchangeably. The objective, therefore becomes, to maximize the amount of net revenue. In accounting terms, profit is described as revenues from the exchange or sale of the products produced, minus costs of production. But there is also a technical relationship between the amount of output obtained and the amount of inputs used. Therefore profit is a more complex relationship than the accounting identity describes. The profit relationship for an output, per unit of production (for example one acre of crop), can be represented as follows:

$$\hat{\pi}_i = \hat{p}_i \hat{y}_i - \sum_{j=1}^{k} r_j x_j - \sum_{j=k+1}^{n} r_j x$$

$$\text{Subject to: } \hat{y}_i = f(x_1, \ldots x_k ; x_{k+1}, \ldots, x_n ; \theta_1, \ldots, \theta_q)$$

Where:

$\hat{\pi}_i$ represents the expected net revenue for the i^{th} output or product,
$\hat{p}_i$ represents the predicted price received for the i^{th} output or product,
$\hat{y}_i$ represents an estimated quantity of the i^{th} output or product,
r_j represents the price paid for the j^{th} input used,
$x_1, \ldots, x_k$ and $x_{k+1}, \ldots, x_n$ represent the quantities of inputs used,
$\theta_1, \ldots, \theta_q$ represents the stochastic elements of production for the i^{th} crop or product.

The decision rule for maximizing the net revenue from the j^{th} input used in production of the i^{th} product requires that the marginal physical product equal the ratio of input price to the price expected to be received for the i^{th} product. The marginal physical product is the amount of additional output that can be produced from using one additional unit of the j^{th} input. This rule can be expressed as follows:

$$\frac{\partial \hat{y}_i}{\partial x_j} = \frac{r_j}{\hat{p}_i}$$

Furthermore a farmer may use multiple inputs in the production of a single output. The rule for optimizing the combination of inputs used in production is that the marginal rate of substitution between the inputs will equal the ratio of the prices of those inputs, or:

$$-\frac{\partial x_j}{\partial x_k} = \frac{r_k}{r_j}$$

The marginal rate of substitution is the rate of change in use of say the j^{th} input when (and if) the k^{th} input is substituted into production. An often used example of this is the trade-off between land and labour in production.

A farmer may produce multiple products. To optimize the combination of crops produced, given the expected price for each of the crops, the marginal rate of transformation of products equal the ratio of those products' prices, or:

$$-\frac{\partial \hat{y}_i}{\partial \hat{y}_g} = \frac{\hat{p}_g}{\hat{p}_i}$$

For example wheat might be substituted for canola, or wheat on fallow might be substituted for wheat on stubble.

The expected net revenue function for the whole farm, is the sum of the per unit net revenues multiplied by the number of units in each of the m activities, or:

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

where:

$\hat{\pi}$, represents the expected net revenue for the whole farm,

$\hat{\pi}_i$, represents the expected net revenue derived from the i^{th} output,
a_i, represents the proportion of land taken up by the i^{th} crop (assuming here that the unit of production is one acre of land,
Subject to: $\sum_{i=1}^{m} a_i = 1$

2.3 Production Under Uncertainty

If a farmer is acting as an economically rational agent, then he will be maximizing his objective function, which in this case is expected net revenue. When uncertainty is included in the discussion, then the issues of risk and farmer behaviour in the presence of risk must also be included.

John Antle, in his landmark presentation to the American Agricultural Economics Association, suggests that the definition of risk is not important. He states "...risk or uncertainty are equivalent and mean very simply that some variables in the objective function are random variables." (Antle, 1983, pg 1099) He further defends this contention as follows: "The optimal solutions of parametric maximization models are defined in terms of the parameters of the probability distributions and the utility function. This is true regardless of what characteristics of the probability distribution, ... are defined as measuring risk." (Antle, 1983, pg 1100) This study will also consider risk and uncertainty as being equivalent.

The origins of this probabilistic approach to economic analysis date back to Bernoulli and his suggestion that people do not maximize utility in the presence of risk (i.e.. max U(x)). Rather they maximize their expectations of utility (i.e.. max E[U(x)]), where x represents a quantity of economic activity. Von Neuman and Morgenstern are credited with developing a set of axioms that allow researchers to formalize expected utility theory. (Buschena and Zilberman, 1994, pg 428-429) These axioms can be summarized as follows:

1. Ordering: it is possible to order any two preferences.

2. Transitivity: if A is preferred to B, and B is preferred to C, then A is preferred to C.

3. Continuity (also sometimes referred to as Certainty Equivalent): Assume that A is preferred to B, and B is preferred to C. The axiom asserts that there exists some probability P, $0<P<1$, such that the choice-maker is indifferent between outcome B with certainty and a lottery ticket (P, A, C).

4. Independence: If A is preferred to B, and C is another choice, the preference ordering between A and B will not be affected by C.
(Henderson and Quandt, 1980, pg 53)

If the above axioms hold, then a utility function will exist with the following properties:

1. If A is preferred to B, then U(A) > U(B).

2. The utility of a risky choice or action (an outcome unknown when the choice is made) is its expected utility.

$$E[U(x)] = \Sigma \rho_j U(x_j)$$

Where:

ρ_j = probability that $x = x_j$

3. U(x) will have an arbitrary scale (i.e. U(x) will be uniquely ordinal).

The shape of the decision maker's utility function characterizes his or her attitude with respect to risk. These attitudes are divided into three broad categories:

1. Risk Averse- where the decision maker prefers the expected outcome of the risky choice to the risky choice itself,

$$U(E[x]) > E[U(x)]$$

These functions are consistent with concave utility functions.

2. Risk Neutral- where the decision maker is indifferent between the expected outcome of the risky choice or the risky choice itself,

$$U(E[x]) = E[U(x)]$$

These functions are consistent with linear utility functions.

3. Risk Preferring- where the decision maker will prefer the risky choice to the expected outcome of the risky choice,

$$E[U(x)] > U(E[x])$$

These functions are consistent with a convex utility function.

Utility functions themselves are difficult to estimate and measure, and as a consequence the measurement of risk may also be difficult to estimate given the conditions described above. Instead of directly estimating utility functions and risk, Markowitz is cited (Brealey et al, 1992, pg 171) as developing an analytical technique which facilitates the ranking of pairs of risky choices. This ranking of risky choices is known as Mean-Variance (E-V) criterion. The assumptions needed are:

1.) U(x) is of a quadratic form.

and/ or

2.) x is distributed normally. (Barry, ed., 1984, pg 39).

Young describes expected utility maximization using a Taylor series expansion and that provides some further explanation for the use of the previous criteria. The result is a description of the expected utility function in terms of a mean (μ_x) and variance (σ_x^2) of the expected value (x). (Barry, ed., 1984, pg 34) From Young's explanation a simpler function can be written as follows:

$$E(U(x)) = f(\mu_x, \sigma_x^2)$$

This description assumes that *U(x)* is a quadratic function and/or x is distributed normally around its mean, μ_x . It must also be accepted that the variance of x, σ_x^2 , or the standard deviation of x, σ_x , is a satisfactory measure of risk.

The mean-variance (E-V) frontier, derived from this analysis, indicates the risk efficient set. This risk efficient set is where: for every level of x, the variance is as small as possible. The variance (or standard deviation) becomes an "unambiguous, single dimensional index of risk." (Barry ed., 1984, pg 39-40)

As an example of an E-V problem let $\bar{x}_A$ and $\bar{x}_B$ be two expected outcomes, and σ_A^2 and σ_B^2 be the variance associated with the expected outcomes. If:

$$\bar{x}_A \geq \bar{x}_B ,$$

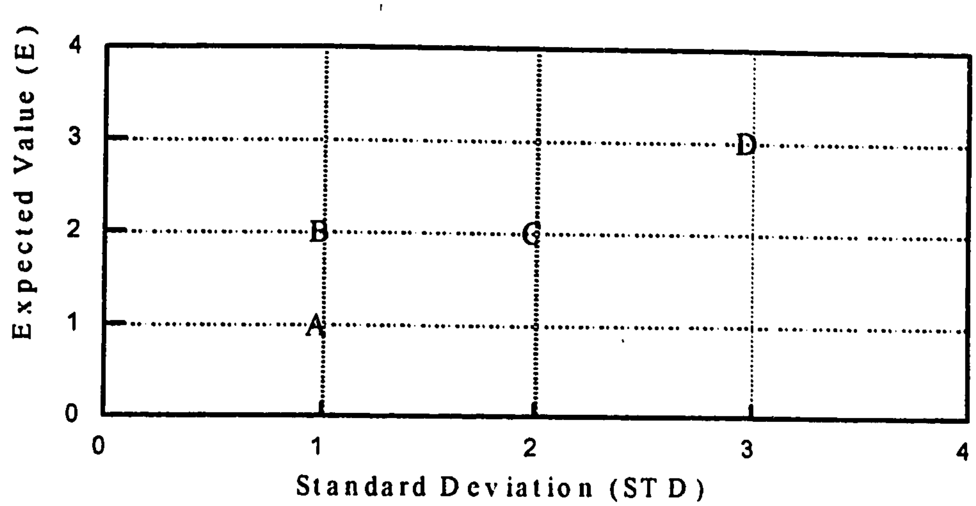
and

$$\sigma_A^2 \leq \sigma_B^2 ,$$

and at least one of these inequalities is strict,

then no risk averse person will prefer or choose B to A. (Buschena and Zilberman, 1994) Figure 2-1 illustrates an expansion of this argument to four choices, A, B, C, D. Choices A and B have the same variance, but choice B has a greater expected value. Therefore choice B is preferred to choice A. Choices B and C have the same expected value, but choice C has a larger variance. Therefore choice B is preferred over choice C. It is not possible to choose between B and D without more information about the decision maker's utility function. This illustration uses standard deviation as a proxy term for variance, and Young states that this is acceptable. Young further suggests that in some situations standard deviation may be a more descriptive statistic because it is in the same units as the expected value.

Figure 2.1: An E-V Illustration



E-V analysis is a method of comparing the expected outcomes of different activities, or combinations of activities, relative to the variability of the expected outcomes. E-V analysis is not a tool to make decisions about what a decision maker should do, but rather a tool to evaluate the outcomes a decision maker would face if a particular action were taken. Additionally, E-V analysis does not allow for making statements about a decision maker's utility function; E-V analysis assumes a utility function exists and that it conforms to the requirements previously defined.

In terms of the revenue function, described as the focus of this study, the objective function can be simplified to:

$$\max g(E[\pi], \sigma_\pi).$$

Where $g(\bullet)$ represents the decision makers utility of net revenue function.

Young cites several studies which use various methods of estimating the components of $g(\bullet)$. The differences between methodologies employed follow from the researcher's hypotheses about how risk is being imposed upon the decision maker (i.e. is risk entering the production function through the supply of inputs, price of inputs, quantity of outputs, or the price of the outputs). (Buschena and Zilberman, 1994, and Barry ed., 1984, pg 40) Young (1979) and Buschena and Zilberman (1994) provide reviews of the different methods used and results obtained from agricultural risk measurement studies. These studies generally conclude that farmers are risk averse.

For the purposes of this study the decision maker's utility function will not be estimated. The function $g(\bullet)$ will be considered the utility function, and to facilitate the ranking of alternatives in terms of their relative riskiness, the measure of expected net revenue, standard deviation of net revenue, will be employed. Young indicates that this method of estimating the parameters is appropriate when objective information is being used to arrive at a positive estimate. (Barry ed., 1984, pg 40)

To facilitate the ranking of alternatives Barry, Hopkin and Baker (1988) suggest using the coefficient of variation. The coefficient of variation (CV) is defined as:

$$CV = \frac{\sigma_{\hat{\pi}}}{\hat{\pi}}$$

where:

$\sigma_{\hat{\pi}}$ represents the standard deviation of the expected net revenue $\hat{\pi}$

The coefficient of variation measures the relative dispersion of net revenues around the expected value. A lower coefficient of variation would indicate that the variance of net revenues, relative to its expected value, is smaller than another alternative with a larger coefficient of variation. (Barry, Hopkin and Baker, 1988, pg 250) This measure only serves to provide a method of ranking alternatives, and does not require the estimation of, or comment on, a farmers risk preferences.

The CV allows for the relative ranking of the alternatives being examined but says little about the profitability of the alternative. Recall the definition of a Z-score as being:

$$z = \frac{C^0 - \mu}{\sigma}$$

Where:

C^0 represents the critical value being evaluated,
μ represents the mean or in this case expected value,
σ represents the standard deviation of the expected value.

The Z-score relates any normal distribution to the tabulated value of the standard normal distribution having a mean of 0 (zero) and a variance of 1 (unity). Therefore to calculate the probability of a value being less than the critical value, a Z-score is the only calculation needed. The probability can be obtained from a standard normal table or calculated from a polynomial approximation.

If a critical value of zero is chosen then the Z-score is calculated as follows:

$$Z = -\frac{\mu}{\sigma} \quad = \quad -\frac{1}{CV}$$

To facilitate obtaining the probabilities directly form the Z-scores the following polynomial approximation can be used:

$$p(x) = 1 - \tfrac{1}{2}[1 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4]^{-4} + \varepsilon(x)$$

Where:

p(x) is the probability that x will be less than some critical value
$|\varepsilon(x)| < 2.5 \times 10^{-4}$
$c_1 = 0.196854$
$c_2 = 0.1151194$
$c_3 = 0.000344$
$c_4 = 0.019527$

(Source: Abramowitz, et al, 1964, pg 932)

From this calculation the probability of an expected net revenue being less than zero determined. The smaller the coefficient of variation the smaller is the probability of incurring a loss (i.e. a negative net revenue). Stated another way, the smaller the coefficient of variation the greater the probability of a profit (i.e. a positive net revenue).

Chapter 3: Methodology

This chapter will describe the economic and agronomic models used, and the individual study areas. Chapter 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 chapter 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 last section will detail the individual areas being studied and the various tillage and crop rotations being simulated.

3.1 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 Chapter 2 to describe the net revenue function.

3.1.1 Individual Crop Economic Model

The general economic model for individual crops was described in Chapter 2. The following sections describe the data sources required to determine prices, yields and costs.

3.1.1.1 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

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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.

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.

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.

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[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.

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:

---

[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.)

$\hat{e}_{i,t}$ 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.

As set out in the objectives, the variation or error between the predicted price and the actual price forms the basis of examining risk. It is important to test the error terms to determine if they are, on average, uniform throughout the sample, and to ensure that they are stochastic or random. Therefore the hypothesis to be tested for each crop's weighted price is as follows:

$$H_O: \sigma_1^2 = \sigma_2^2 = \ldots = \sigma_t^2 = \sigma^2$$

H_A: The above is not true.

Where:

$$\sigma^2 = \sum_{t=1}^{T} \left(\hat{e}_t\right)^2$$

Kmenta (1986, pg 293) suggests that the Goldfeld-Quandt test (GQ) is appropriate for testing the above hypothesis. This test is formulated on the basis that if the errors occur under conditions of homoscedasticity (i.e. H_0 is true) then the errors in one part of the sample will on average be the same as the errors in another part of the sample, and any fluctuations will be due to sampling fluctuations. The test itself is the ratio of the variance from one part of the sample to the variance in the other part of the sample. Kementa further explains that because the sample variance has a chi-squared distribution divided by their degrees of freedom, their ratio will have an F distribution. The GQ test statistic is constructed as follows:

$$s_1^2 = \frac{\sum (\dot{e}_t)^2}{n_1 - 2}, \ (t = 1, 2, \ldots, t)$$

$$s_2^2 = \frac{\sum (\dot{e}_t)^2}{n_2 - 2}, \ (n_2 = n_1 + p + 1, n_1 + p + 2, \ldots, n_1 + p + n_2)$$

$$\frac{s_2^2}{s_1^2} \sim F_{n_2 - 2, n_1 - 2}$$

Where:

n_1 is the number of observations in the first part,
n_2 is the number of observations in the second part,
p is the number of observations excluded from the s^2 calculation to provide some separation between the variances.

For these samples one observation has been left out of the calculation of the s_i^2. Kmenta suggests the separation of the two sample variances will reduce the probability of Type I error (i.e. accepting H_0 falsely). (Kmenta, 1986, pg 293)

After testing the weighted real price series for each crop, in each area, H_0 is not rejected and the variances are considered to be homoscedastistic (i.e. on average the variances are the constant over time). These test results are listed in Table 3-1.

Table 3.1: Goldfeldt-Quandt Test Results for Homoscedastisity in Weighted Real Crop Prices

Area	Crop		
	Wheat	Barley	Canola
Medicine Hat	0.703	0.543	N/A
Lethbridge	0.818	0.582	0.519
Trochu	1.078	0.880	0.519
Lacombe	0.593	0.586	0.519
Wainwright	0.642	0.550	0.519

Note: the critical F-statistic for $\alpha = 0.05$ is 4,28 with 6 and 6 degrees of freedom.

These results indicate that there is no detectable pattern in the error terms, therefore the errors can be considered random or stochastic.

3.1.1.2 Estimated Crop Yields

This section will further describe the variable $\hat{y}_i$ that was previously defined as, the estimated yield of the i^{th} crop. 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.

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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.

A mean crop yield is being used here so that the stochastic nature of the factors that affect plant growth (e.g. annual precipitation, frost free period, degree days, etc.) are reflected in both the mean and the variance of the area data. The stochastic nature of the yields is confirmed by testing for the presence of trends over time by regressing the yield of a particular crop against time. The test for a significant trend over time is performed by calculating a T-statistic for the slope coefficient. At significance level of 0.05, no trends were discovered with respect to the passage of time (i.e. the slope of regression line is not significantly different from 0).

The variance of the estimated crop yields were calculated as follows:

$$\sigma^2_{y_i} = \sum_{t=1}^{T} (y_{i,t} - \bar{y}_i)^2$$

Where:

$\sigma^2_{y_i}$ represents the variance of yield for the i^{th} crop,
$y_{i,t}$ represents the yield of the i^{th} crop in period t,
$\bar{y}_i$ represents the mean yield of this crop during this period.

3.1.1.3 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:

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

For the calculation of the variance of gross revenues it is important to test for stochastic independence. Steele and Torrie (1960) describe a test for this based upon the coefficient of correlation (ρ) between the random variables, using the null hypothesis :

$$H_o : \rho = 0.$$

The test is defined as follows:

$$t_{n-2} = \frac{\hat{\rho}_{p_i,y_i}}{\sqrt{\frac{(1-\hat{\rho}^2_{p_i,y_i})}{(n-2)}}}$$

Where:

$\hat{\rho}_{p_i,y_i}$ represents the correlation between real crop price for the i^{th} crop and the yield of the i^{th} crop. This is further defined as

$\rho_{p_i,y_i} = \frac{COV(p_i,y_i)}{\hat{\sigma}_{p_i}\hat{\sigma}_{y_i}}$ and

$$COV(p_i,y_i) = \frac{\sum_{t=1}^{T}(p_t-\bar{p})(y_t-\bar{y})}{n-1}.$$

The test statistic is compared to a students t -statistic with $n-2$ degrees of freedom. (Steele and Torrie, 1960, pg 190) The real price and the yield data for each area were tested using this procedure and it was found that the correlation coefficients were not significantly different from zero at an $\alpha=0.05$ or $\alpha=0.10$ level. Therefore the null hypothesis ($H_O : \rho = 0$) was not rejected. This indicates that the factors driving price changes are not statistically related to changes in yields at this level of disaggregation (i.e.. at the regional level)

3.1.1.4 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.

3.1.1.4.1 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.

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

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[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)

[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.

derived from the manufacturer's recommendation that this herbicide be applied at a rate of 1.0 *l* / ac.

3.1.1.5 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 chapter.

3.1.1.5.1 Machinery Capital Costs

The model calculates selected equipment sizes, and a power source (i.e. tractor) sized to match the selected equipment, based on minimizing the annual capital costs (i.e. the opportunity cost of the capital committed to owning a particular equipment complement), using time available to complete field operations and a real risk adjusted discount rate as the constraints. The minimization problem is solved by summing the average annual ownership cost and the average annual equipment repair cost functions. By solving this minimization problem the optimum ownership period is also established for each piece of equipment within the complement. The problem is summarized as follows:

$$\Sigma AC_{n^*} = \min_{n=1}^{N} [AK_n + AO_n]$$

Where:

AC_{n^*} = minimum annual cost of capital and operation in a cycle requiring replacement at the end of n^* years.

AK_n = annual annuity equivalent of the annual cost of capital invested in a particular machine,

AO_n = annual annuity equivalent of the annual cost of repairs for a particular machine.

A study by Rutledge and Russell (1971) was used as an initial reference for the number of hours that are probably available to perform field operations. It became apparent that the sizes of tillage equipment and air seeding equipment was not consistent with that available in Alberta. (Alberta Agriculture, 1985 and 1995).

Several sensitivity analysis were conducted using different combinations of probable hours available for tillage operations. It was discovered that, for example, minimum tillage, using a canola/wheat/fallow crop rotation in the Trochu area, when the hours available are reduced to 70 from 272, the tillage equipment sizes rise to resemble those available from the manufacturers. This could then be used as an estimate of the value farmers place on their time during the critical seeding window, and by extension the capital-timeliness trade-off the farmers are willing to make to ensure that critical operations are completed within an acceptable time frame.

These trade-offs were tested for each soil zone in this study and the results were similar. The machinery sizing model has therefore been adjusted to take into account these implicit costs on each of the farms. Table 3.2 lists the hours used for critical operations used in this study.

Table 3.2 Hours Available for Critical (Seeding) Operations

Tillage System	Cropping System			
	Continuous	1/4 Fallow	1/3 Fallow	1/2 Fallow
Conventional Till	272	272	272	175
Minimum Till	150	115	115	115
Zero Till	90	70	70	70

Because real expected cash flows are were being used throughout the analysis we must use a real (vs. nominal) risk adjusted discount rate.

The definition of the real discount rate being used here is that given by Brealy et al (1992):

$$r = \left(\frac{1+r_n}{1+\tau}\right) - 1$$

Where:

r is the real discount rate,
r_n is the nominal 3-month T-Bill rate as reported by Statistics Canada (considered to be risk free),
τ annual inflation rate as defined by Statistics Canada.

The discount rate required is adjusted for risk as follows:

$$r_r = r + \delta$$

Where:

r_r represents the risk adjusted real discount rate,

δ represents a risk premium.

The risk premium is difficult to establish. Oberg reports in his research about farm machinery depreciation, that the apparent risk premium attributable to the ownership of farm machinery is "not much over half that found on a diversified portfolio of TSE common shares." (Oberg, 1991, pg 69)

Brealy et al report research that has demonstrated the average risk premium associated with a diversified portfolio of TSE 300 Composite Index stocks to be 7.4%. (Brealy et al, 1992, pg 142-143) For the purposes of this study a risk premium of 4.3% will be added to the real T-Bill rate of 3.7%, resulting in a risk adjusted real discount rate of 8.0%.

3.1.1.5.3 Machinery Annual Repair Costs

Woloshyn's model also used the equipment complement whose size was calculated, together with the fixed size equipment, and calculated the estimated repair costs based upon methodology developed by the American researchers. Woloshyn pointed out that while the data they based their repair cost models on were derived from studies conducted in the corn belt of the United States, there had been little similar work performed in Canada previously.

3.1.1.5.4 Annual Fuel Costs

The fuel costs are derived within the Woloshyn model, by using the ASAE formulas for fuel consumption. These formulas use such factors as draft, field efficiency, engine horsepower, and hours of operation. Draft is dependant on the type of soil the implement is being drawn through, differences will be observed based upon the soil type being farmed.

The diesel fuel price was obtained from Alberta Agriculture's Statistics Branch and is the average price paid in Alberta during June 1994. (Alberta Agriculture, 1994a)

3.1.2 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:

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

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.

3.1.3 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 in Chapter 2 was used to calculate and interpret the probability of an expected net revenue being less than zero.

3.2 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.

3.2.1 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,

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,

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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.

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.

3.2.2 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.

3.2.2.1 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.

3.2.2.2 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.

3.2.2.3 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.

3.3 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..

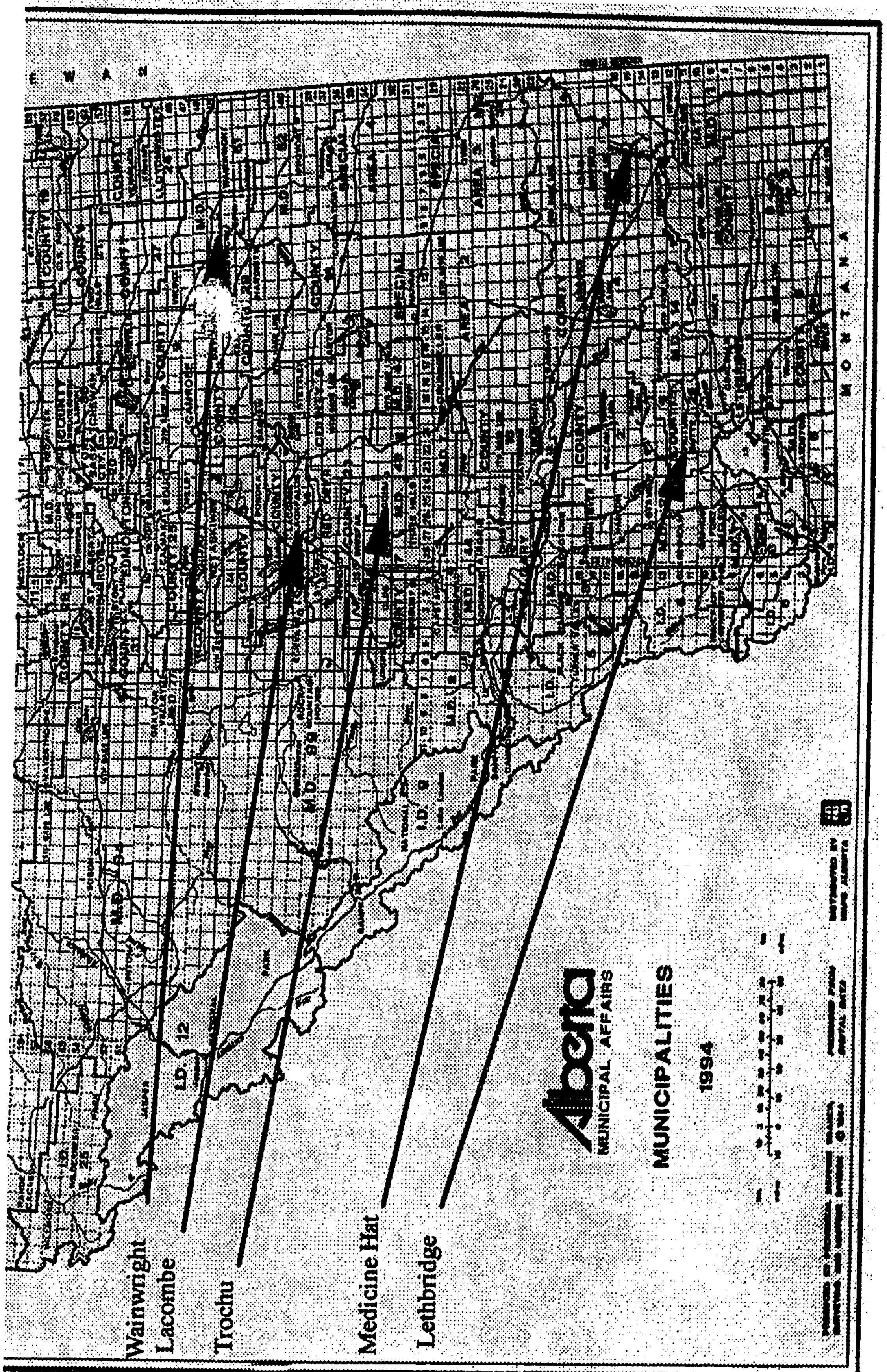
3.3.1 Medicine Hat Area

This study area is comprises 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)

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.

Figure 3-1: Study Areas



3.3.1.1 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).

3.3.1.2 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 chapter, 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 chapter, provides the details of the equipment use and scheduling for the fallow crop rotation systems.

3.3.2 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)

3.3.2.1 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).

3.3.2.2 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 chapter, 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 chapter, provides the details of the equipment used and scheduling for the fallow crop rotation systems.

3.3.3 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 5^0 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.

3.3.3.1 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)

3.3.3.2 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 chapter, 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 chapter, provides the details of the equipment used and scheduling for the fallow crop rotation systems.

3.3.4 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.

3.3.4.1 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)

3.3.4.2 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 chapter, provides the details of the equipment usage and scheduling for the continuous crop rotation system.

3.3.5 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.

3.3.5.1 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)

3.3.5.2 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 chapter, 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 chapter, provides the details of the equipment usage and scheduling for the fallow crop rotation systems.

3.4 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 3.3 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 3.4 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 3.5 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 3.6 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 3.7 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.

Chapter 4: Results

This chapter 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.

4.1 Crop Input Costs

The previous chapter 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.

4.1.1 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 for minimum tillage, and $26.40 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 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 A4a to A4c and A5a to A5c 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 A6a to A6c and

A7a to A7c in Appendix A for detailed breakdowns of the crop input costs for the continuous cropping rotations.

4.1.2 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 for minimum tillage, and $26.40 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 B4a to B4c and B5a to B5c 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 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 B6a to B6c and B7a to B7c in Appendix B for detailed breakdowns of the crop input costs.

4.1.3 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 tables C6a to C6c 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 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 C4a to C4c and C5a to C5 in Appendix C for detailed breakdowns of the crop input costs.

4.1.4 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 chapter.

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.

4.1.5 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. Tables E6a to E6c 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 E4a to E4c and E5a to E5c in Appendix E for detailed breakdowns of the crop input costs.

4.2 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) details the changes in total machinery costs from increasing the farm size.

4.3 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.

4.3.1 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. Table A3 in Appendix A illustrates the relative magnitude of the RMSE for the crop rotations tested in this area.

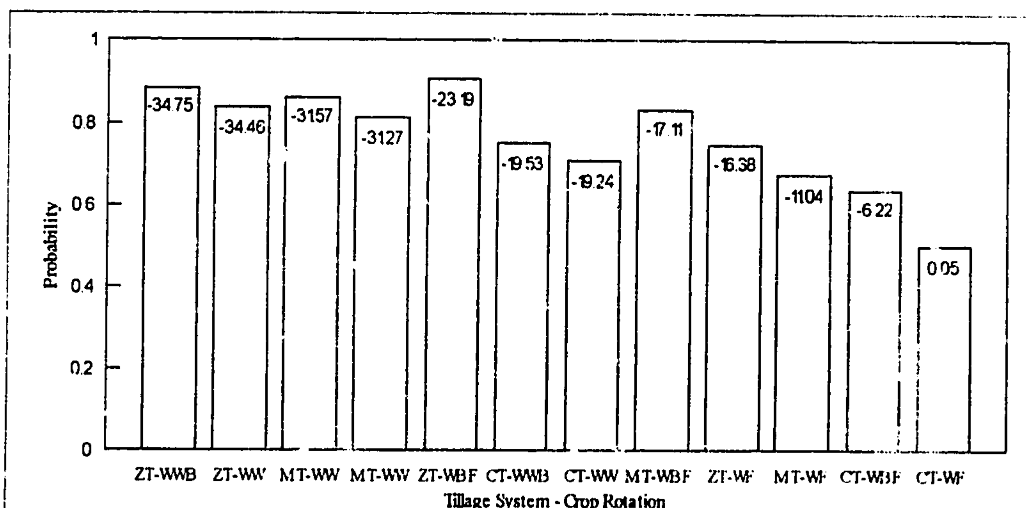
Thirty six combinations of crop rotation, tillage system and farm size were analyzed in this area. Of the 36, five resulted in positive net revenues. These five were for conventional tillage and either a proportion of 1/2 or 1/3 fallow in the rotations. Farms of the 960 acre size having the conventionally 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 4.1 to 4.3 and Figures 4.1 to 4.3, show the expected net revenues and probability of negative expected net revenue results for this area.

Table 4.1: 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.[illegible]	-11.04	24.50	-2.22	67.4%
CT	WBF	48.36	54.[illegible]	-6.22	17.65	-2.84	63.8%
CT	WF	48.04	47.[illegible]	0.05	24.50	490.00	49.9%

Figure 4.1: Probability of Negative Net Revenue for the 960 Cultivated Acre Farm in the Medicine Hat Area

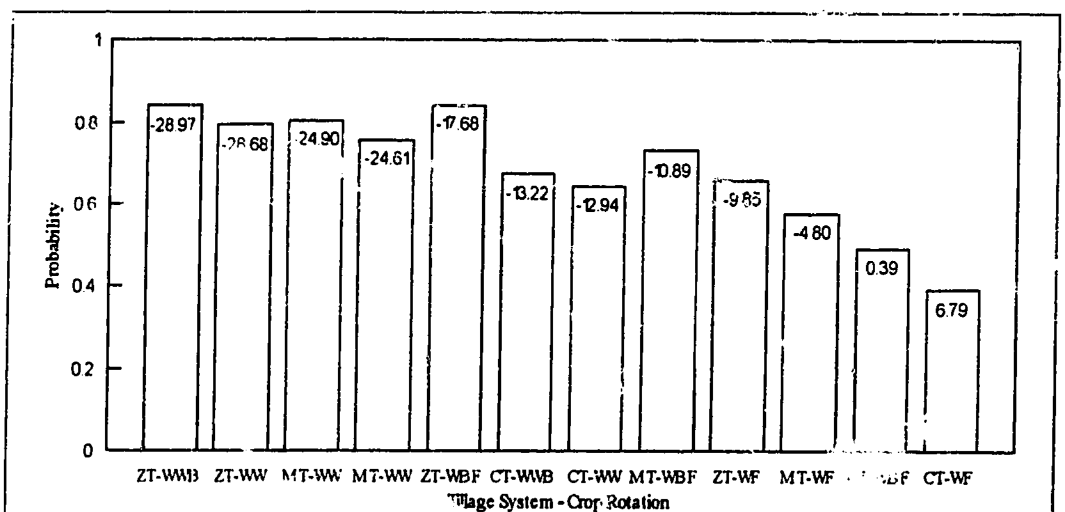


Note: the number at the top of each bar is the expected net revenue ($/cult ac)

Table 4.2: 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	79.86	-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 4.2: Probability of Negative Net Revenue for the 1280 Cultivated Acre Farm in the Medicine Hat Area

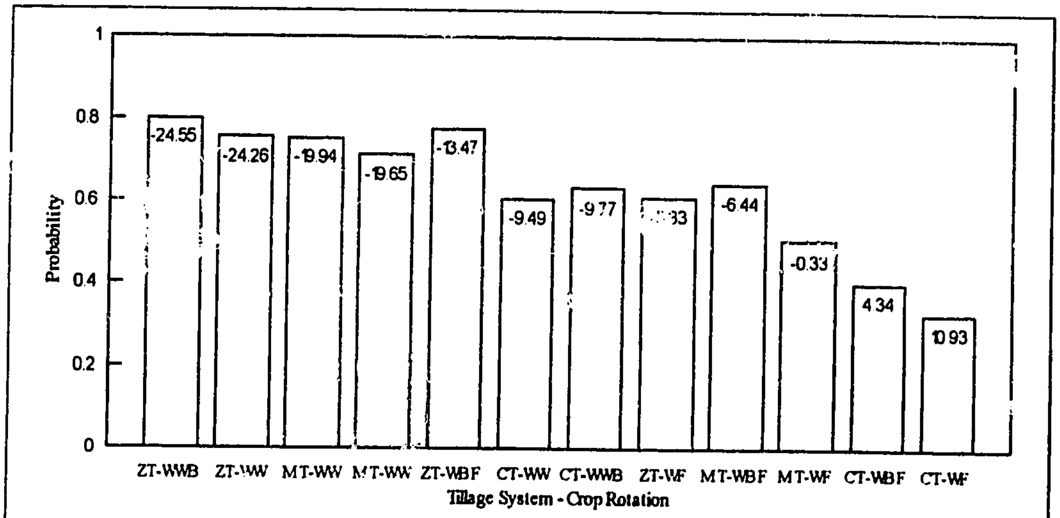


Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.3: 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	51.0%
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 4.3: 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.)

4.3.2 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). Table B3 in Appendix B shows 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 4.4 to 4.6 and figures 4.4 to 4.6, provide a listing and illustrations of the net revenue and probability of negative net revenue results for this area.

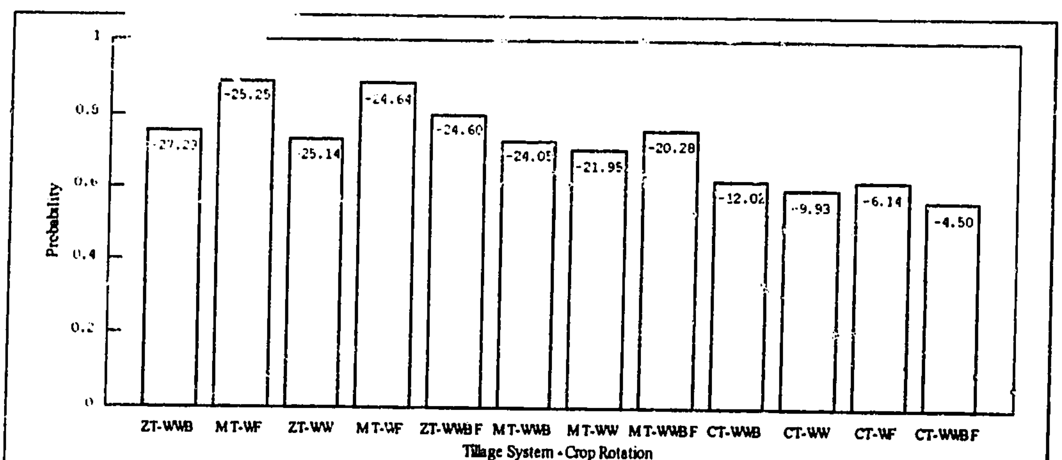
4.3.3 Trochu Area

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.

Table 4.4: 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 4.4: Probability of Negative Net Revenue for the 960 Acre Farm in the Lethbridge Area

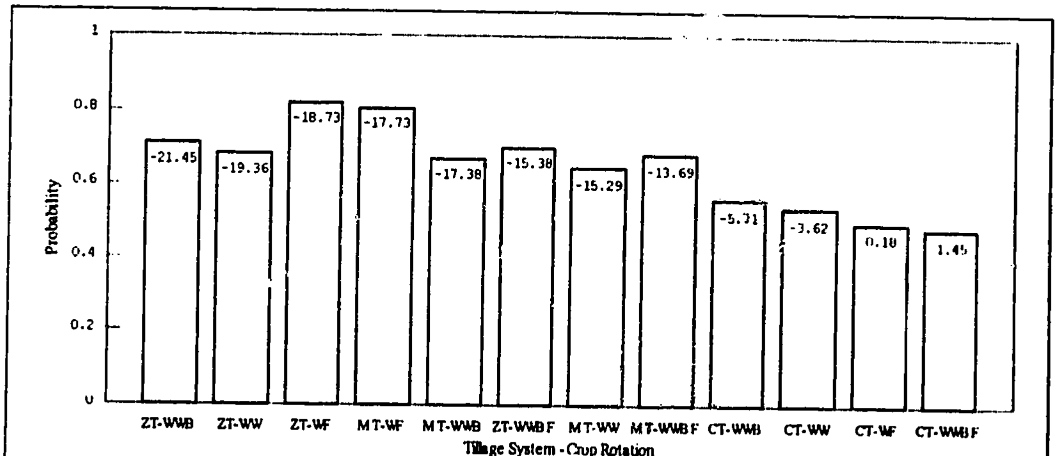


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.5: 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	[illegible].4%
MT	WWBF	52.29	65.98	-13.69	29.30	-2.14	63.0%
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 4.5: Probability of Negative Net Revenue for the 1280 Acre Farm in the Lethbridge Area

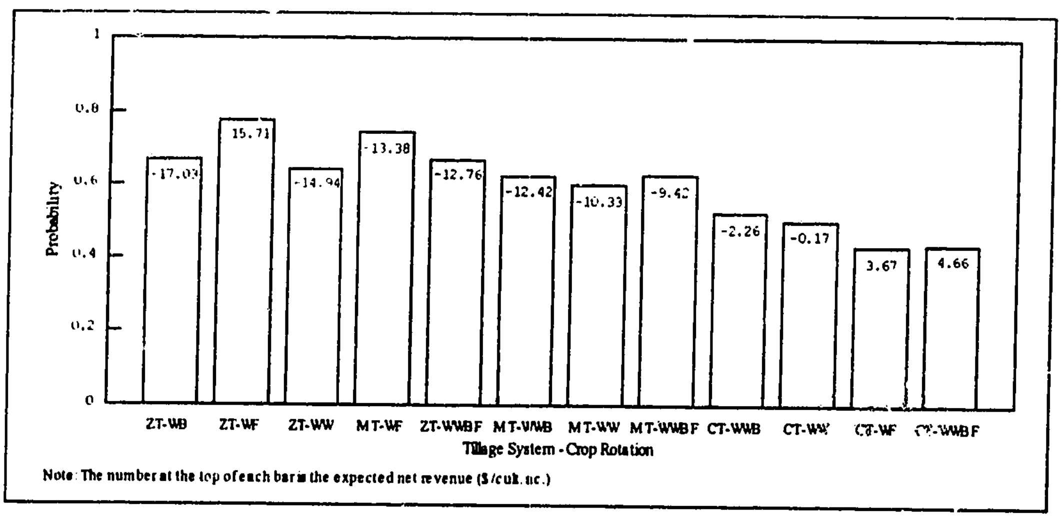


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.6: 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 4.6: Probability of Negative Net Revenue for the 1600 Acre Farm in the Lethbridge Area



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).

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). Table C3 in Appendix C illustrates 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 4.7 to 4.9 and Figures 4.7 to 4.9, display the net revenues and probabilities of generating a negative net revenue in this area.

4.3.4 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. Table D3 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 4.10 to 4.12 and Figures 4.10 to 4.12 detail the expected net revenues and probabilities of generating a negative expected net revenue.

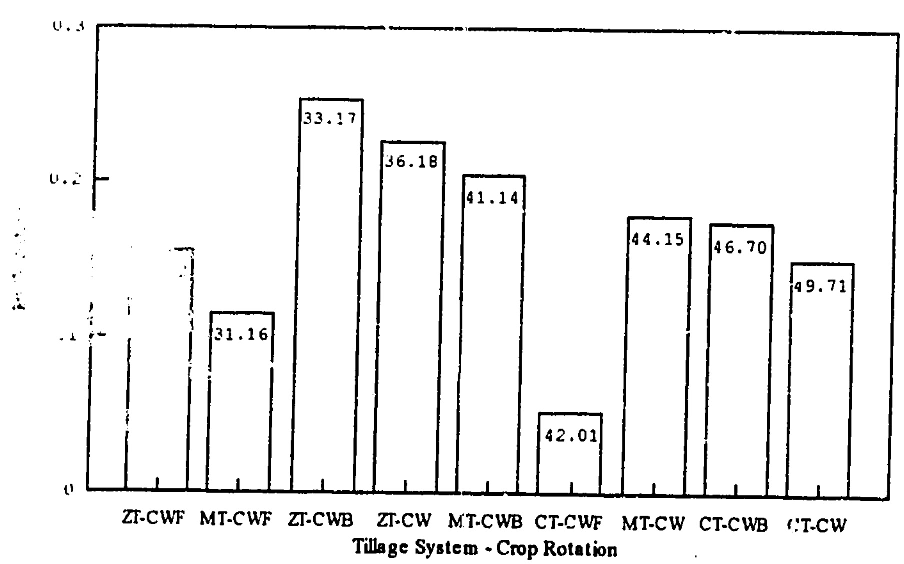
4.3.5 Wainwright Area

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 4.7: 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 4.7: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Trochu Area

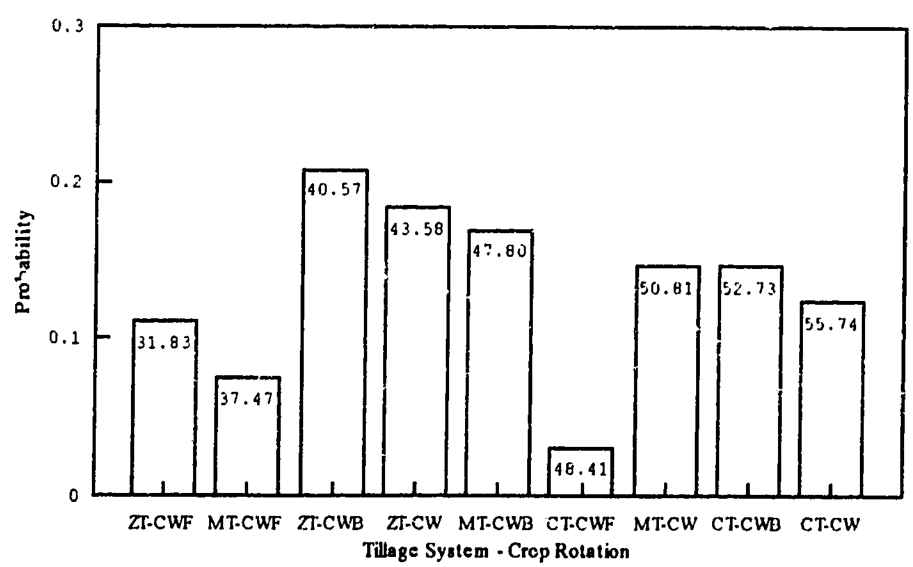


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.8: 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 4.8: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Trochu Area

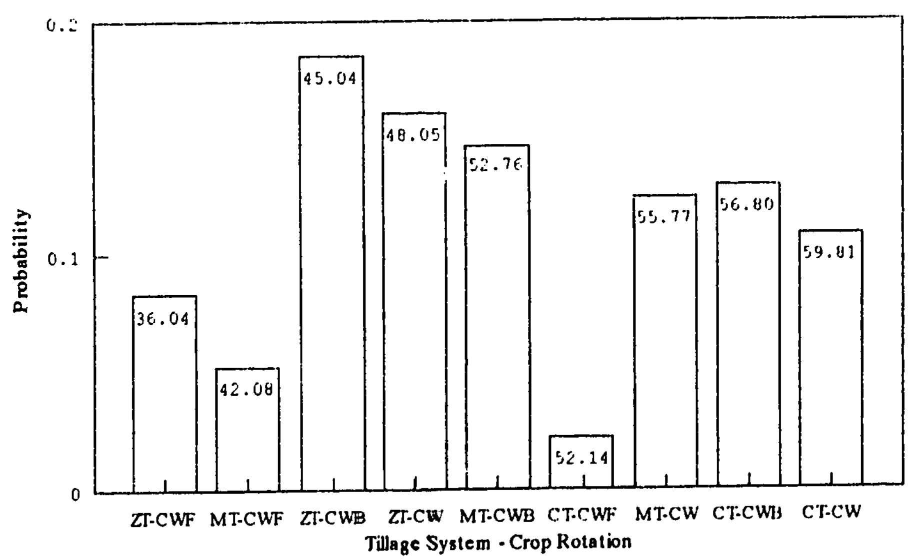


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.9: 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 4.9: 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).

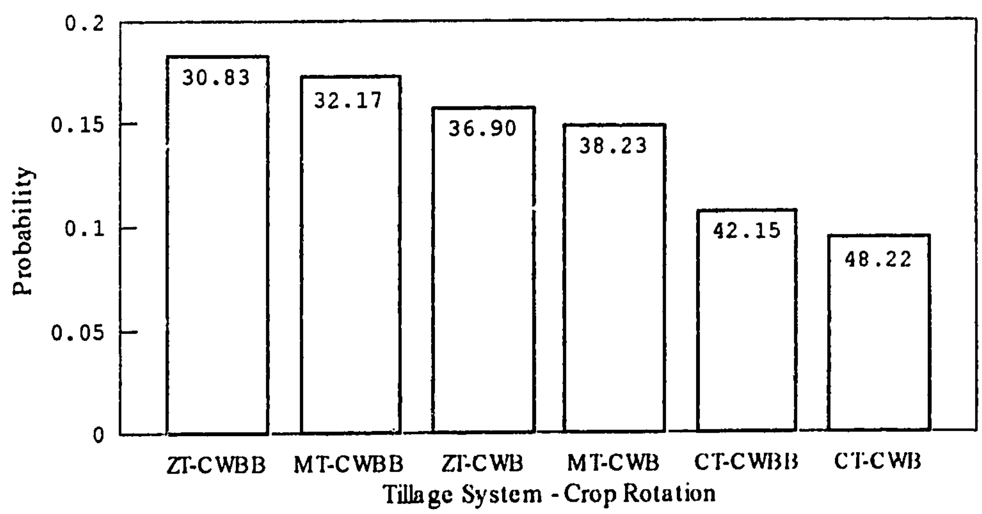
The CWBF rotation had the lowest RMSE of predicted gross revenue and the continuous CWBB rotation had the highest RMSE of predicted gross revenue. The relative ranking of the RMSE (lowest to highest) is as follows: CWBF ($23.05), CWB ($35.95), and CWBB ($36.17). Once again it appears that adding one 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.. Table E3 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,

Table 4.10: 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 4.10: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Lacombe Area

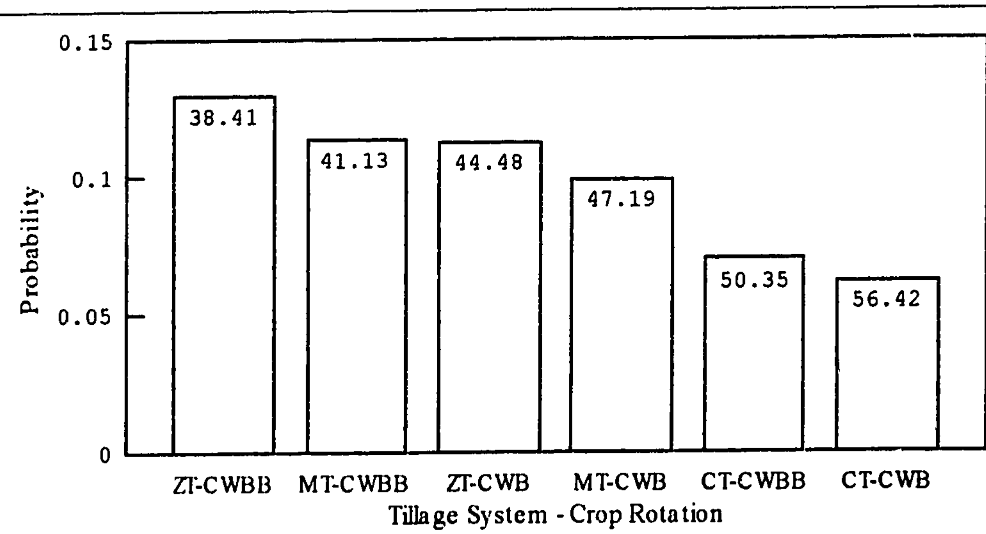


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.11: 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 4.11: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Lacombe Area

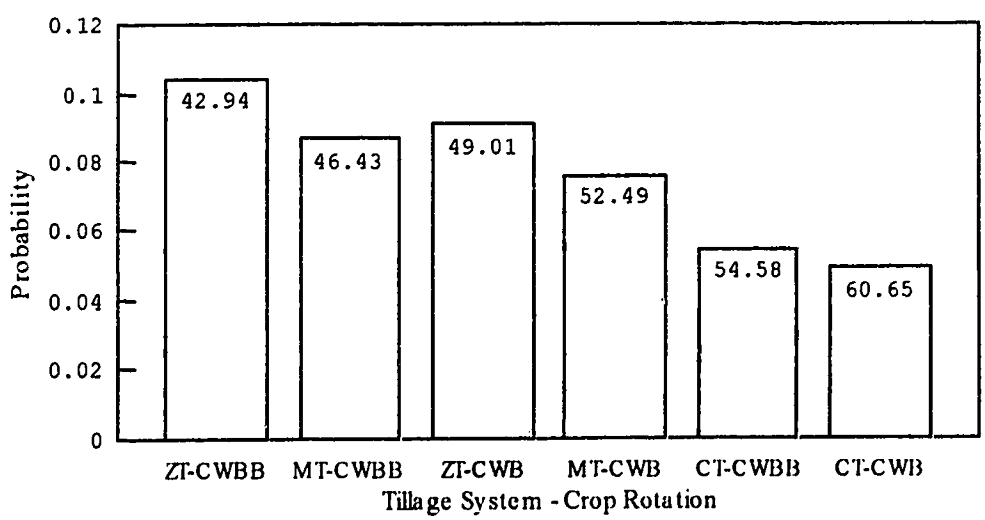


Note: The number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.12: 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 4.12: 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.)

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 4.13 to 4.15 and Figures 4.13 to 4.15 detail the expected net revenues and probabilities of generating a negative expected net revenue.

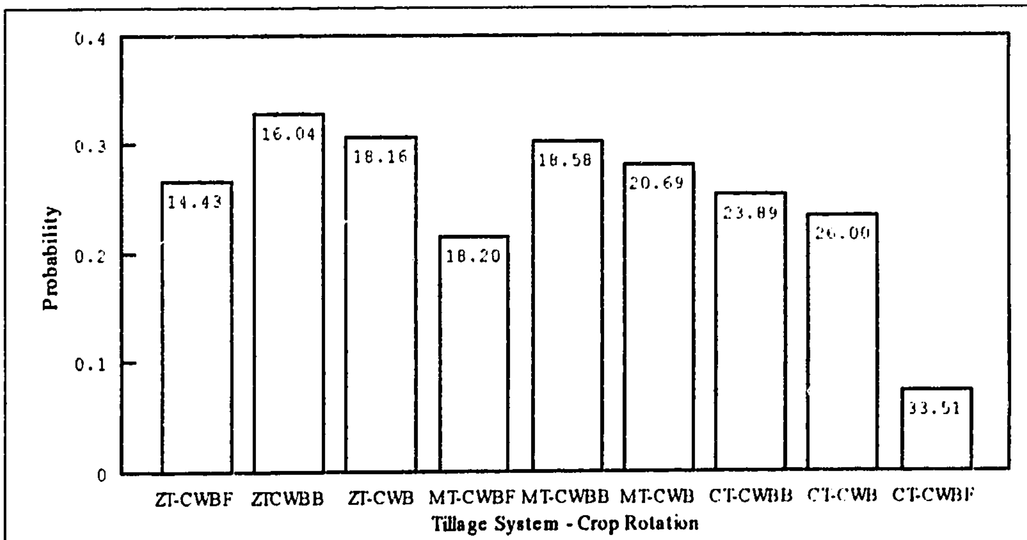
4.4 Generalizations From All Results

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 4.13: 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 4.13: Probability of Negative Net Revenues for the 960 Cultivated Acre Farm in the Wainwright Area

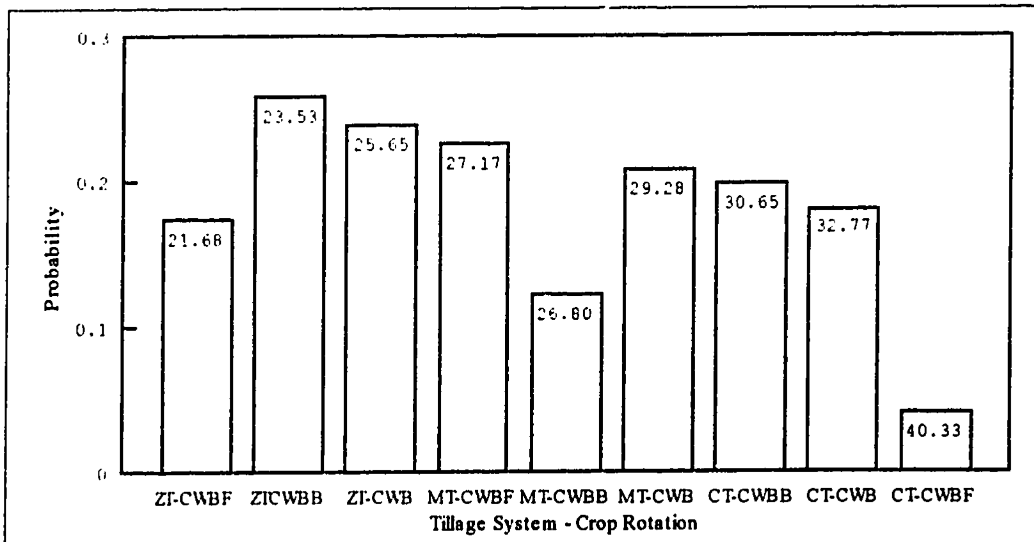


Note: the number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.14: 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 4.14: Probability of Negative Net Revenues for the 1280 Cultivated Acre Farm in the Wainwright Area

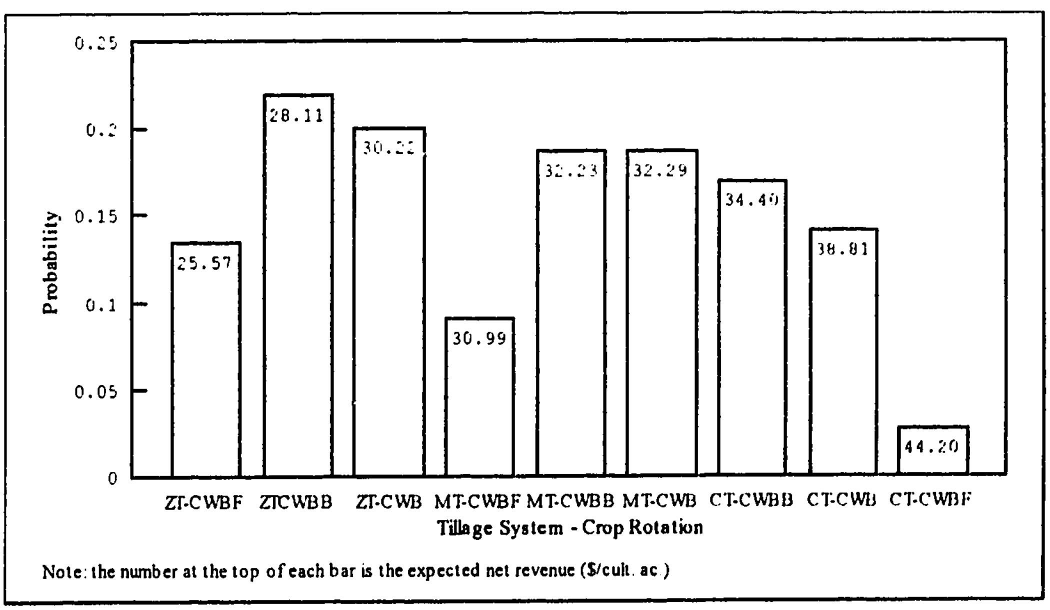


Note. the number at the top of each bar is the expected net revenue ($/cult. ac.)

Table 4.15: 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 4.15: Probability of Negative Net Revenues for the 1600 Cultivated Acre Farm in the Wainwright Area



Chapter 5: Conclusions and Recommendations

This chapter 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.

5.1 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.

5.2 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.

5.3 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.

5.4 Risk Comparisons

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

5.4.1 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.

5.4.2 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.

5.4.3 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.

5.4.4 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.

5.4.5 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.

5.5 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.

5.6 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.

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Appendices

Appendix A: Results for Medicine Hat

Table A1: Crop Yields for the Medicine Hat Area (bu./ac.)

Year	Fallow Wheat	Stubble Wheat	Fallow Barley	Stubble Barley
76	28.30	11.77	40.39	19.35
77	12.19	8.08	15.56	12.29
78	24.18	17.37	37.90	22.54
79	25.54	13.52	34.88	23.43
80	26.69	10.94	39.91	14.89
81	30.85	17.17	44.53	30.15
82	32.41	24.22	54.13	29.83
83	31.44	21.18	50.77	31.73
84	15.16	5.91	18.43	11.63
85	11.25	7.23	14.71	5.66
86	28.71	17.26	38.97	23.03
87	22.79	17.05	33.54	25.45
88	10.48	5.00	13.09	3.58
89	11.41	8.49	13.69	4.16
90	13.14	6.94	17.27	6.72
91	39.58	27.83	49.98	45.39
92	33.83	12.29	47.41	28.81
93	35.53	28.76	22.64	22.64
Mean	24.08	14.50	32.94	20.37
Standard Deviation	9.51	7.38	13.71	10.77

Table A2: Weighted Crop Prices for the Medicine Hat Area ($'s/bu.)

	Wheat				Barley			
Year	Nominal	Real Actual	Real Predicted	Error	Nominal	Real Actual	Real Predicted	Error
76	2.90	8.65			1.98	6.05		
77	2.88	8.02	8.65	-0.63	1.84	5.30	6.05	-0.75
78	3.85	9.66	8.02	1.64	2.08	5.44	5.30	0.14
79	5.02	11.35	9.66	1.68	2.40	5.68	5.44	0.23
80	5.65	11.56	11.35	0.21	3.38	7.09	5.68	1.41
81	5.11	9.37	11.56	-2.19	2.96	5.62	7.09	-1.47
82	4.78	7.96	9.37	-1.41	2.37	4.17	5.62	-1.45
83	4.81	7.58	7.96	-0.38	2.84	4.63	4.17	0.46
84	4.72	7.13	7.58	-0.45	2.27	3.63	4.63	-1.00
85	3.82	5.69	7.13	-1.44	2.11	3.33	3.63	-0.30
86	3.00	4.41	5.69	-1.29	1.97	3.01	3.33	-0.32
87	3.03	4.28	4.41	-0.13	1.77	2.65	3.01	-0.36
88	4.88	6.40	4.28	2.13	3.16	4.27	2.65	1.62
89	3.92	5.07	6.40	-1.33	2.68	3.58	4.27	-0.70
90	3.08	4.00	5.07	-1.07	1.83	2.55	3.58	-1.02
91	3.04	3.75	4.00	-0.25	1.96	2.56	2.55	0.01
92	3.23	3.91	3.75	0.16	1.99	2.57	2.56	0.01
93	3.33	3.99	3.91	0.08	1.81	2.41	2.57	-0.16
Mean	3.95	6.82			2.30	4.14		
Standard Deviation	0.93	2.60			0.50	1.44		
Predicted Price			3.99				2.41	
RMSE			1.20				0.86	

Table A3: Crop Programs, Expected Yields and Expected Gross Revenue for the Medicine Hat Area

Description	Crop Programs WF	WBF	WW	WWB
Proportion Fallow	50.00%	33.33%		
Proportion Wheat on Fallow	50.00%	33.33%		
Proportion Wheat on Stubble			100.00%	66.67%
Proportion Barley on Fallow				
Proportion Barley on Stubble		33.33%		33.33%
Yield Wheat on Fallow	24.08	24.08	24.08	24.08
Yield Wheat on Stubble	14.50	14.50	14.50	14.50
Yield Barley on Fallow	32.94	32.94	32.94	32.94
Yield Barley on Stubble	20.37	20.37	20.37	20.37
Weighted Wheat Yield	12.04	8.03	14.50	9.67
Weighted Barley Yield		6.79		6.79
Predicted Wheat Price	3.99	3.99	3.99	3.99
Predicted Barley Price	2.41	2.41	2.41	2.41
Predicted Gross Revenue	48.04	48.36	57.85	54.90
RMSE	24.50	17.65	35.32	29.11

Table A4a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Medicine Hat Area (Wheat on Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		48.04	48.04	48.04
Crop Input Costs				
Seed		3.38	3.38	3.38
Fertilizer	N	2.97	2.97	2.97
	Phosphate	1.99	1.99	1.99
Herbicide	Selective	3.15	3.15	3.15
	Glyphosate			
Total Crop Input Costs		11.48	11.48	11.48
Machinery Costs				
Capital		32.71	25.84	21.51
Repairs		2.20	2.34	2.53
Fuel		1.60	1.60	1.60
Total Machinery Costs		36.52	29.78	25.63
Total Costs		47.99	41.25	37.11
Projected Net Revenue		0.05	6.79	10.93
RMSE		24.50	24.50	24.50

Table A4b:Gross Revenue, Costs, and Net Revenue for the 1280 Acre Farm in the Medicine Hat Area (Wheat on Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		48.04	48.04	48.04
Crop Input Costs				
Seed		3.38	3.38	3.38
Fertilizer	N	2.97	2.97	2.97
	Phosphate	1.99	1.99	1.99
Herbicide	Selective	3.15	3.15	3.15
	Glyphosate	4.98	4.98	4.98
Total Crop Input Costs		16.45	16.45	16.45
Machinery Costs				
Capital		39.40	32.56	28.05
Repairs		1.78	2.11	2.14
Fuel		1.45	1.73	1.73
Total Machinery Costs		42.63	36.39	31.92
Total Costs		59.08	52.84	48.37
Projected Net Revenue		-11.04	-4.80	-0.33
RMSE		24.50	24.50	24.50

Table A4c: Gross Revenue, Costs, and Net Revenue for the 1600 Acre Farm in the Medicine Hat Area (Wheat on Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		48.04	48.04	48.04
Crop Input Costs				
Seed		3.38	3.38	3.38
Fertilizer	N	2.97	2.97	2.97
	Phosphate	1.99	1.99	1.99
Herbicide	Selective	3.15	3.15	3.15
	Glyphosate	14.93	14.93	14.93
Total Crop Input Costs		26.40	26.40	26.40
Machinery Costs				
Capital		35.45	28.87	25.81
Repairs		1.50	1.55	1.58
Fuel		1.07	1.07	1.07
Total Machinery Costs		38.02	31.49	28.47
Total Costs		64.42	57.89	54.87
Projected Net Revenue		-16.38	-9.85	-6.83
RMSE		24.50	24.50	24.50

Table A4d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Medicine Hat Area (Wheat on Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-18.45%	-22.68%
Minimum Tillage	0.00%	-10.56%	-18.12%
Zero Tillage	0.00%	-10.13%	-14.83%

Table A4e: Total Cost Changes From Conventional Tillage in the Medicine Hat Area (Wheat on Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	23.10%	28.09%	30.36%
Zero Tillage	34.23%	40.33%	47.86%

Table A5a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Medicine Hat Area (Wheat, Barley, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		48.36	48.36	48.36
Crop Input Costs				
Seed		4.35	4.35	4.35
Fertilizer	N	4.93	4.93	4.93
	Phosphate	3.09	3.09	3.09
Herbicide	Selective	3.85	3.85	3.85
	Glyphosate			
Total Crop Input Costs		16.22	16.22	16.22
Machinery Costs				
Capital		33.02	26.35	22.12
Repairs		3.38	3.44	3.72
Fuel		1.96	1.96	1.96
Total Machinery Costs		38.36	31.75	27.80
Total Costs		54.58	47.97	44.02
Projected Net Revenue		-6.22	0.39	4.34
RMSE		17.65	17.65	17.65

Table A5b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Medicine Hat Area (Wheat, Barley, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		48.36	48.36	48.36
Crop Input Costs				
Seed		4.35	4.35	4.35
Fertilizer	N	4.93	4.93	4.93
	Phosphate	3.09	3.09	3.09
Herbicide	Selective	3.85	3.85	3.85
	Glyphosate	3.32	3.32	3.32
Total Crop Input Costs		19.54	19.54	19.54
Machinery Costs				
Capital		42.00	35.72	31.05
Repairs		2.24	2.31	2.52
Fuel		1.68	1.68	1.68
Total Machinery Costs		45.93	39.71	35.26
Total Costs		65.47	59.25	54.80
Projected Net Revenue		-17.11	-10.89	-6.44
RMSE		17.65	17.65	17.65

Table A5c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Medicine Hat Area (Wheat, Barley, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		48.36	48.36	48.36
Crop Input Costs				
Seed		4.35	4.35	4.35
Fertilizer	N	4.93	4.93	4.93
	Phosphate	3.09	3.09	3.09
Herbicide	Selective	3.85	3.85	3.85
	Glyphosate	13.27	13.27	13.27
Total Crop Input Costs		29.49	29.49	29.49
Machinery Costs				
Capital		38.65	33.05	28.60
Repairs		2.02	2.11	2.35
Fuel		1.39	1.39	1.39
Total Machinery Costs		42.06	36.55	32.34
Total Costs		71.55	66.04	61.83
Projected Net Revenue		-23.19	-17.68	-13.47
RMSE		17.65	17.65	17.65

Table A5d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Medicine Hat Area (Wheat, Barley, Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-17.23%	-27.54%
Minimum Tillage	0.00%	-13.54%	-23.23%
Zero Tillage	0.00%	-13.10%	-23.11%

Table A5e: Total Cost Changes from Conventional Tillage in the Medicine Hat Area (Wheat, Barley, Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	19.95%	23.51%	24.49%
Zero Tillage	31.09%	37.66%	40.46%

Table A6a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Medicine Hat Area (Continuous Wheat Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		57.85	57.85	57.85
Crop Input Costs				
Seed		6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30
	Glyphosate			
Total Crop Input Costs		33.71	33.71	33.71
Machinery Costs				
Capital		35.61	28.69	24.94
Repairs		5.04	5.65	5.95
Fuel		2.74	2.74	2.74
Total Machinery Costs		43.38	37.08	33.63
Total Costs		77.09	70.79	67.34
Projected Net Revenue		-19.24	-12.94	-9.49
RMSE		35.32	35.32	35.32

Table A6b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Medicine Hat Area (Continuous Wheat Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		57.85	57.85	57.85
Crop Input Costs				
Seed		6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30
	Glyphosate			
Total Crop Input Costs		33.71	33.71	33.71
Machinery Costs				
Capital		47.39	40.57	35.13
Repairs		4.82	4.98	5.46
Fuel		3.20	3.20	3.20
Total Machinery Costs		55.41	48.75	43.79
Total Costs		89.12	82.46	77.50
Projected Net Revenue		-31.27	-24.61	-19.65
RMSE		35.32	35.32	35.32

Table A6c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Medicine Hat Area (Continuous Wheat Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		57.85	57.85	57.85
Crop Input Costs				
Seed		6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		43.66	43.66	43.66
Machinery Costs				
Capital		42.93	36.93	31.97
Repairs		3.69	3.91	4.45
Fuel		2.03	2.03	2.03
Total Machinery Costs		48.65	42.87	38.45
Total Costs		92.31	86.53	82.11
Projected Net Revenue		-34.46	-28.68	-24.26
RMSE		35.32	35.32	35.32

Table A6d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Medicine Hat Area (Continuous Wheat Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-14.53%	-22.49%
Minimum Tillage	0.00%	-12.02%	-20.97%
Zero Tillage	0.00%	-11.88%	-20.97%

Table A6e: Total Cost Changes from Conventional Tillage in the Medicine Hat Area (Continuous Wheat Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	15.60%	16.48%	15.09%
Zero Tillage	19.74%	22.23%	21.94%

Table A7a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Medicine Hat Area (Continuous Wheat, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		54.90	54.90	54.90
Crop Input Costs				
Seed		6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95
	Glyphosate			
Total Crop Input Costs		31.05	31.05	31.05
Machinery Costs				
Capital		35.61	28.69	24.94
Repairs		5.04	5.65	5.95
Fuel		2.74	2.74	2.74
Total Machinery Costs		43.38	37.08	33.63
Total Costs		74.43	68.12	64.67
Projected Net Revenue		-19.53	-13.22	-9.77
RMSE		29.11	29.11	29.11

Table A7b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Medicine Hat Area (Continuous Wheat, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		54.90	54.90	54.90
Crop Input Costs				
Seed		6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95
	Glyphosate			
Total Crop Input Costs		31.05	31.05	31.05
Machinery Costs				
Capital		47.39	40.57	35.13
Repairs		4.82	4.98	5.46
Fuel		3.20	3.20	3.20
Total Machinery Costs		55.42	48.75	43.79
Total Costs		86.47	79.80	74.84
Projected Net Revenue		-31.57	-24.90	-19.94
RMSE		29.11	29.11	29.11

Table A7c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Medicine Hat Area (Continuous Wheat, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		54.90	54.90	54.90
Crop Input Costs				
Seed		6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		41.00	41.00	41.00
Machinery Costs				
Capital		42.93	36.93	31.97
Repairs		3.69	3.91	4.45
Fuel		2.03	2.03	2.03
Total Machinery Costs		48.65	42.87	38.45
Total Costs		89.65	83.87	79.45
Projected Net Revenue		-34.75	-28.97	-24.55
RMSE		29.11	29.11	29.11

Table A7d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Medicine Hat Area (Continuous Wheat, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-14.54%	-22.49%
Minimum Tillage	0.00%	-12.04%	-20.98%
Zero Tillage	0.00%	-11.88%	-20.97%

Table A7e: Total Cost Changes from Conventional Tillage in the Medicine Hat Area (Continuous Wheat, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	16.17%	17.13%	15.72%
Zero Tillage	16.28%	24.55%	17.99%

Appendix B: Results for Lethbridge

Table B1: Crop Yields for the Lethbridge Area (bu./ac.)

Year	Fallow Wheat	Stubble Wheat	Fallow Barley	Stubble Barley
76	29.45	16.35	42.94	26.65
77	22.90	18.95	41.35	33.04
78	33.41	31.63	45.81	46.46
79	22.63	17.37	30.76	27.45
80	32.42	27.46	60.76	46.62
81	38.33	35.42	66.72	57.62
82	28.11	18.61	48.23	32.41
83	26.92	17.11	47.88	32.34
84	13.99	4.07	21.11	7.20
85	13.36	7.81	16.94	7.70
86	24.88	21.87	37.20	31.14
87	32.56	27.73	59.60	47.42
88	14.22	5.25	27.21	8.78
89	24.25	18.10	38.20	23.79
90	23.10	21.16	40.99	32.20
91	34.39	26.40	57.74	38.34
92	25.42	13.82	46.23	23.03
93	34.31	28.91	57.35	51.16
Mean	26.37	19.89	43.72	31.85
Standard Deviation	7.37	8.77	13.84	14.69

Table B2: Weighted Crop Prices for the Lethbridge Area ($'s/bu.)

	Wheat				Barley			
Year	Nominal	Real Actual	Real Predicted	Error	Nominal	Real Actual	Real Predicted	Error
76	2.88	7.89			2.13	5.85		
77	2.77	7.05	7.89	-0.85	1.84	4.68	5.85	-1.17
78	3.33	7.78	7.05	0.73	2.10	4.89	4.68	0.21
79	4.75	10.16	7.78	2.38	2.55	5.45	4.89	0.55
80	5.26	10.20	10.16	0.05	3.45	6.69	5.45	1.25
81	4.96	8.57	10.20	-1.64	3.00	5.18	6.69	-1.51
82	4.41	6.86	8.57	-1.71	2.54	3.95	5.18	-1.23
83	4.82	7.10	6.86	0.24	2.85	4.20	3.95	0.25
84	4.64	6.54	7.10	-0.56	2.77	3.90	4.20	-0.29
85	3.95	5.36	6.54	-1.18	2.51	3.41	3.90	-0.50
86	2.74	3.57	5.36	-1.79	1.79	2.33	3.41	-1.07
87	3.07	3.83	3.57	0.26	1.65	2.06	2.33	-0.27
88	4.84	5.80	3.83	1.97	2.85	3.42	2.06	1.36
89	3.83	4.37	5.80	-1.43	2.49	2.84	3.42	-0.58
90	3.05	3.32	4.37	-1.05	1.82	1.98	2.84	-0.86
91	3.04	3.14	3.32	-0.18	1.98	2.05	1.98	0.06
92	2.99	3.04	3.14	-0.10	1.87	1.90	2.05	-0.14
93	3.38	3.38	3.04	0.33	1.66	1.66	1.90	-0.24
Mean	3.82	6.00			2.33	3.69		
Standard Deviation	0.89	2.38			0.53	1.54		
Predicted Price			3.38				1.66	
RMSE			1.21				0.83	

Table B3: Crop Programs, Expected Yields and Expected Gross Revenue for the Lethbridge Area

	Crop Programs			
Description	WF	WWBF	WW	WWB
Proportion Fallow	50.00%	25.00%		
Proportion Wheat on Fallow	50.00%	25.00%		
Proportion Wheat on Stubble		25.00%	100.00%	66.67%
Proportion Barley on Fallow				
Proportion Barley on Stubble		25.00%		33.33%
Yield Wheat on Fallow	26.37	26.37	26.37	26.37
Yield Wheat on Stubble	19.89	19.89	19.89	19.89
Yield Barley on Fallow	43.72	43.72	43.72	43.72
Yield Barley on Stubble	31.85	31.85	31.85	31.85
Weighted Wheat Yield	13.18	11.56	19.89	13.26
Weighted Barley Yield		7.96		10.62
Predicted Wheat Price	3.38	3.38	3.38	3.38
Predicted Barley Price	1.66	1.66	1.66	1.66
Predicted Gross Revenue	44.52	52.29	67.17	62.42
RMSE	20.66	29.30	41.33	39.84

Table B4a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Lethbridge Area (Wheat on Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		52.29	52.29	52.29
Crop Input Costs				
Seed		4.95	4.95	4.95
Fertilizer	N	5.98	5.98	5.98
	Phosphate	4.97	4.97	4.97
Herbicide	Selective	4.46	4.46	4.46
	Glyphosate			
Total Crop Input Costs		20.36	20.36	20.36
Machinery Costs				
Capital		32.15	25.85	22.46
Repairs		2.60	2.94	3.13
Fuel		1.69	1.69	1.69
Total Machinery Costs		36.44	30.48	27.28
Total Costs		56.79	50.84	47.63
Projected Net Revenue		-4.50	1.45	4.66
RMSE		29.30	29.30	29.30

Table B4b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Medicine Hat Area (Wheat on Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		52.29	52.29	52.29
Crop Input Costs				
Seed		4.95	4.95	4.95
Fertilizer	N	5.98	5.98	5.98
	Phosphate	4.97	4.97	4.97
Herbicide	Selective	4.46	4.46	4.46
	Glyphosate	2.49	2.49	2.49
Total Crop Input Costs		22.84	22.84	22.84
Machinery Costs				
Capital		45.20	38.38	34.00
Repairs		2.53	2.76	2.87
Fuel		2.00	2.00	2.00
Total Machinery Costs		49.73	43.14	38.87
Total Costs		72.57	65.98	61.71
Projected Net Revenue		-20.28	-13.69	-9.42
RMSE		29.30	29.30	29.30

Table B4c: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Medicine Hat Area (Wheat on Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		44.52	44.52	44.52
Crop Input Costs				
Seed		3.38	3.38	3.38
Fertilizer	N	5.03	5.03	5.03
	Phosphate	5.30	5.30	5.30
Herbicide	Selective	3.15	3.15	3.15
	Glyphosate	14.93	14.93	14.93
Total Crop Input Costs		31.78	31.78	31.78
Machinery Costs				
Capital		35.41	28.84	25.79
Repairs		1.50	1.55	1.58
Fuel		1.08	1.08	1.08
Total Machinery Costs		37.99	31.47	28.45
Total Costs		69.77	63.25	60.23
Projected Net Revenue		-25.25	-18.73	-15.71
RMSE		20.66	20.66	20.66

Table B4d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Lethbridge (Wheat on Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-18.70%	-29.02%
Minimum Tillage	0.00%	-16.31%	-26.59%
Zero Tillage	0.00%	-17.16%	-25.10%

Table B4e: Total Cost Changes From Conventional Tillage in the Lethbridge Area (Wheat on Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	25.29%	28.96%	29.58%
Zero Tillage	12.38%	14.50%	18.59%

Table B5a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Lethbridge Area (Wheat, Wheat, Barley,Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		52.29	52.29	52.29
Crop Input Costs				
Seed		4.95	4.95	4.95
Fertilizer	N	5.98	5.98	5.98
	Phosphate	4.97	4.97	4.97
Herbicide	Selective	4.46	4.46	4.46
	Glyphosate			
Total Crop Input Costs		20.36	20.36	20.36
Machinery Costs				
Capital		32.15	25.85	22.46
Repairs		2.60	2.94	3.13
Fuel		1.69	1.69	1.69
Total Machinery Costs		36.44	30.48	27.28
Total Costs		56.79	50.84	47.63
Projected Net Revenue		-4.50	1.45	4.66
RMSE		29.30	29.30	29.30

Table B5b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Lethbridge Area (Wheat, Wheat, Barley,Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		52.29	52.29	52.29
Crop Input Costs				
Seed		4.95	4.95	4.95
Fertilizer	N	5.98	5.98	5.98
	Phosphate	4.97	4.97	4.97
Herbicide	Selective	4.46	4.46	4.46
	Glyphosate	2.49	2.49	2.49
Total Crop Input Costs		22.84	22.84	22.84
Machinery Costs				
Capital		45.20	38.38	34.00
Repairs		2.53	2.76	2.87
Fuel		2.00	2.00	2.00
Total Machinery Costs		49.73	43.14	38.87
Total Costs		72.57	65.98	61.71
Projected Net Revenue		-20.28	-13.69	-9.42
RMSE		29.30	29.30	29.30

Table B5c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Lethbridge Area (Wheat, Wheat, Barley, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		52.29	52.29	52.29
Crop Input Costs				
Seed		4.95	4.95	4.95
Fertilizer	N	5.98	5.98	5.98
	Phosphate	4.97	4.97	4.97
Herbicide	Selective	4.46	4.46	4.46
	Glyphosate	12.44	12.44	12.44
Total Crop Input Costs		32.79	32.79	32.79
Machinery Costs				
Capital		40.31	30.46	27.79
Repairs		2.23	2.86	2.92
Fuel		1.56	1.56	1.56
Total Machinery Costs		44.09	34.87	32.26
Total Costs		76.89	67.67	65.05
Projected Net Revenue		-24.60	-15.38	-12.76
RMSE		29.30	29.30	29.30

Table B5d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Lethbridge Area (Wheat, Wheat, Barley, Fallcw Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-16.35%	-25.14%
Minimum Tillage	0.00%	-13.25%	-21.84%
Zero Tillage	0.00%	-20.91%	-26.84%

Table B5e: Total Cost Changes from Conventional Tillage in the Lethbridge Area (Wheat, Wheat, Barley, Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	36.48%	41.53%	42.49%
Zero Tillage	21.01%	14.41%	18.26%

Table B6a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Lethbridge Area (Continuous Wheat Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		67.17	67.17	67.17
Crop Input Costs				
Seed		6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30
	Glyphosate			
Total Crop Input Costs		33.71	33.71	33.71
Machinery Costs				
Capital		35.61	28.69	24.94
Repairs		5.04	5.65	5.95
Fuel		2.74	2.74	2.74
Total Machinery Costs		43.39	37.08	33.63
Total Costs		77.10	70.79	67.34
Projected Net Revenue		-9.93	-3.62	-0.17
RMSE		41.33	41.33	41.33

Table B6b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Lethbridge Area (Continuous Wheat Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		67.17	67.17	67.17
Crop Input Costs				
Seed		6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30
	Glyphosate			
Total Crop Input Costs		33.71	33.71	33.71
Machinery Costs				
Capital		47.39	40.57	35.13
Repairs		4.82	4.98	5.46
Fuel		3.20	3.20	3.20
Total Machinery Costs		55.41	48.75	43.79
Total Costs		89.12	82.46	77.50
Projected Net Revenue		-21.95	-15.29	-10.33
RMSE		41.33	41.33	41.33

Table B6c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Lethbridge Area (Continuous Wheat Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		67.17	67.17	67.17
Crop Input Costs				
Seed		6.75	6.75	6.75
Fertilizer	N	10.06	10.06	10.06
	Phosphate	10.60	10.60	10.60
Herbicide	Selective	6.30	6.30	6.30
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		43.66	43.66	43.66
Machinery Costs				
Capital		42.93	36.93	31.97
Repairs		3.69	3.91	4.45
Fuel		2.03	2.03	2.03
Total Machinery Costs		48.65	42.87	38.45
Total Costs		92.31	86.53	82.11
Projected Net Revenue		-25.14	-19.36	-14.94
RMSE		41.33	41.33	41.33

Table B6d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Lethbridge Area (Continuous Wheat Crop Rotation)

Tillage System	Cultivated Acres 960	1280	1600
Conventional Tillage	0.00%	-14.54%	-22.50%
Minimum Tillage	0.00%	-12.02%	-20.97%
Zero Tillage	0.00%	-11.88%	-20.97%

Table B6e: Total Cost Changes from Conventional Tillage in the Lethbridge Area (Continuous Wheat Crop Rotation)

Tillage System	Cultivated Acres 960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	27.70%	31.47%	30.23%
Zero Tillage	12.12%	15.61%	14.35%

Table B7a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Lethbridge Area (Continuous Wheat, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		62.42	62.42	62.42
Crop Input Costs				
Seed		6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95
	Glyphosate			
Total Crop Input Costs		31.04	31.04	31.04
Machinery Costs				
Capital		35.61	28.69	24.94
Repairs		5.04	5.65	5.95
Fuel		2.74	2.74	2.74
Total Machinery Costs		43.39	37.08	33.63
Total Costs		74.43	68.12	64.67
Projected Net Revenue		-12.01	-5.70	-2.25
RMSE		39.84	39.84	39.84

Table B7b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Lethbridge Area (Continuous Wheat, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		62.42	62.42	62.42
Crop Input Costs				
Seed		6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95
	Glyphosate			
Total Crop Input Costs		31.04	31.04	31.04
Machinery Costs				
Capital		47.39	40.57	35.13
Repairs		4.82	4.98	5.46
Fuel		3.20	3.20	3.20
Total Machinery Costs		55.42	48.75	43.79
Total Costs		86.46	79.79	74.83
Projected Net Revenue		-24.04	-17.37	-12.41
RMSE		39.84	39.84	39.84

Table B7c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Lethbridge Area (Continuous Wheat, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Projected Gross Revenue		62.42	62.42	62.42
Crop Input Costs				
Seed		6.60	6.60	6.60
Fertilizer	N	9.66	9.66	9.66
	Phosphate	8.83	8.83	8.83
Herbicide	Selective	5.95	5.95	5.95
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		40.99	40.99	40.99
Machinery Costs				
Capital		42.93	36.93	31.97
Repairs		3.69	3.91	4.45
Fuel		2.03	2.03	2.03
Total Machinery Costs		48.65	42.87	38.45
Total Costs		89.64	83.86	79.44
Projected Net Revenue		-27.22	-21.44	-17.02
RMSE		39.84	39.84	39.84

Table B7d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Lethbridge Area (Continuous Wheat ,Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-14.54%	-22.50%
Minimum Tillage	0.00%	-12.04%	-20.99%
Zero Tillage	0.00%	-11.88%	-20.97%

Table B7e: Total Cost Changes from Conventional Tillage in the Lethbridge Area (Continuous Wheat, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	27.74%	31.48%	30.23%
Zero Tillage	12.13%	15.62%	14.35%

Appendix C: Results for Trochu

Table C1: Crop Yields for the Trochu Area (bu./ac.)

Year	Fallow Wheat	Stubble Wheat	Fallow Barley	Stubble Barley	Fallow Canola	Stubble Canola
76	41.24	27.26	57.23	42.31	27.13	18.33
77	35.04	21.50	57.62	39.41	28.33	19.77
78	37.30	29.26	59.35	45.34	25.03	19.72
79	34.77	27.97	57.74	45.66	23.64	19.57
80	36.62	33.94	55.25	52.81	25.80	21.40
81	43.13	38.22	67.73	62.01	34.14	28.30
82	45.58	39.17	71.32	61.14	30.96	24.94
83	43.50	34.96	66.18	56.85	28.49	22.71
84	34.90	16.57	49.18	22.60	20.42	9.16
85	27.37	13.65	42.97	14.13	13.47	6.21
86	49.85	48.44	76.45	75.02	32.34	27.07
87	42.77	37.08	75.97	64.42	34.65	25.71
88	41.56	30.25	70.82	55.29	29.17	21.74
89	42.47	31.69	63.69	46.17	22.92	17.17
90	45.91	44.04	69.59	64.60	25.28	24.50
91	42.60	37.25	62.63	54.82	27.45	22.31
92	36.26	34.17	59.33	56.45	22.40	20.31
93	37.61	35.22	64.23	58.97	28.66	23.17
Mean	39.92	32.26	62.63	51.00	26.68	20.67
Standard Deviation	5.34	8.81	8.83	14.93	5.13	5.61

Table C2: Weighted Crop Prices for the Trochu Area ($'s/bu.)

Year	Wheat Nominal	Wheat Real Actual	Wheat Real Predicted	Wheat Error	Barley Nominal	Barley Real Actual	Barley Real Predicted	Barley Error	Canola Nominal	Canola Real Actual	Canola Real Predicted	Canola Error
76	3.11	8.54			2.87	6.56			5.15	14.14		
77	3.01	7.66	8.54	-0.88	2.75	5.29	6.56	-1.28	6.31	16.03	14.14	1.89
78	3.86	9.00	7.66	1.35	3.59	5.65	5.29	0.36	6.33	14.77	16.03	-1.26
79	5.22	11.15	9.00	2.15	4.94	6.24	5.65	0.59	6.56	14.02	14.77	-0.75
80	5.54	10.74	11.15	-0.41	5.24	6.82	6.24	0.58	6.19	12.02	14.02	-2.00
81	5.37	9.27	10.74	-1.48	5.06	5.61	6.82	-1.21	6.24	10.77	12.02	-1.25
82	4.97	7.73	9.27	-1.53	4.65	4.19	5.61	-1.43	6.31	9.82	10.77	-0.94
83	5.19	7.65	7.73	-0.09	4.87	4.59	4.19	0.40	8.60	12.66	9.82	2.83
84	4.98	7.03	7.65	-0.62	4.65	4.32	4.59	-0.27	7.98	11.26	12.66	-1.39
85	4.02	5.46	7.03	-1.57	3.66	3.88	4.32	-0.44	6.06	8.22	11.26	-3.04
86	2.69	3.50	5.46	-1.96	2.32	2.54	3.88	-1.34	4.54	5.91	8.22	-2.31
87	3.41	4.26	3.50	0.75	3.03	2.54	2.54	-0.00	5.83	7.28	5.91	1.36
88	5.03	6.04	4.26	1.78	4.59	4.11	2.54	1.57	6.78	8.14	7.28	0.86
89	4.47	5.11	6.04	-0.92	3.98	3.49	4.11	-0.62	6.06	6.92	8.14	-1.22
90	3.61	3.93	5.11	-1.18	3.04	2.62	3.49	-0.87	5.85	6.38	6.92	-0.54
91	3.62	3.74	3.93	-0.19	3.05	2.62	2.62	-0.00	5.40	5.58	6.38	-0.81
92	2.37	2.41	3.74	-1.33	1.77	2.40	2.62	-0.21	6.26	6.37	5.58	0.79
93	3.68	3.68	2.41	1.27	3.05	2.35	2.40	-0.05	7.10	7.09	6.37	0.72
Mean	4.12	6.00			3.73	6.00			6.31	6.00		
Standard Deviation	1.00	2.38			1.05	2.38			0.93	2.38		
Predicted Price			3.68				2.35				7.09	
RMSE			1.28				0.83				1.59	

Table C3: Crop Programs, Expected Yields and Expected Gross Revenue for the Trochu Area

Description	CWB	Crop Programs CW	CWF
Proportion Fallow			33.33%
Proportion Wheat on Fallow			
Proportion Wheat on Stubble	33.33%	50.00%	33.33%
Proportion Barley on Fallow			
Proportion Barley on Stubble	33.33%		
Proportion Canola on Fallow			33.33%
Proportion Canola on Stubble	33.33%	50.00%	
Yield Wheat on Fallow	39.92	39.92	39.92
Yield Wheat on Stubble	32.26	32.26	32.26
Yield Barley on Fallow	62.63	62.63	62.63
Yield Barley on Stubble	51.00	51.00	51.00
Yield Conola on Fallow	26.68	26.68	26.68
Yield Canola on Stubble	20.67	20.67	20.67
Weighted Wheat Yield	10.75	16.13	10.75
Weighted Barley Yield	17.00		
Weighted Canola Yield	6.89	10.34	8.89
Predicted Wheat Price	3.68	3.68	3.68
Predicted Barley Price	2.35	2.35	2.35
Predicted Canola Price	7.09	7.09	7.09
Predicted Gross Revenue	128.39	132.69	102.68
RMSE	50.05	48.28	25.99

Table C4a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Trochu Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		128.39	128.39	128.39
Crop Input Costs				
Seed		5.92	5.92	5.92
Fertilizer	N	10.83	10.83	10.83
	Phosphate	6.18	6.18	6.18
Herbicide	Selective	8.92	8.92	8.92
	Glyphosate			
Total Crop Input Costs		31.84	31.84	31.84
Machinery Costs				
Capital		41.19	34.81	30.17
Repairs		5.22	5.57	6.14
Fuel		3.44	3.44	3.44
Total Machinery Costs		49.85	43.82	39.75
Total Costs		81.69	75.66	71.59
Expected Net Revenue		46.70	52.73	56.80
RMSE		50.05	50.05	50.05

Table C4b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Trochu Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		128.39	128.39	128.39
Crop Input Costs				
Seed		5.92	5.92	5.92
Fertilizer	N	10.83	10.83	10.83
	Phosphate	6.18	6.18	6.18
Herbicide	Selective	8.92	8.92	8.92
	Glyphosate			
Total Crop Input Costs		31.84	31.84	31.84
Machinery Costs				
Capital		47.39	40.57	35.13
Repairs		4.82	4.98	5.46
Fuel		3.20	3.20	3.20
Total Machinery Costs		55.41	48.75	43.79
Total Costs		87.25	80.59	75.63
Expected Net Revenue		41.14	47.80	52.76
RMSE		50.05	50.05	50.05

Table C4c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Trochu Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		128.39	128.39	128.39
Crop Input Costs				
Seed		5.92	5.92	5.92
Fertilizer	N	10.83	10.83	10.83
	Phosphate	6.18	6.18	6.18
Herbicide	Selective	8.92	8.92	8.92
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		41.79	41.79	41.79
Machinery Costs				
Capital		47.43	39.81	34.80
Repairs		3.69	3.92	4.46
Fuel		2.30	2.30	2.30
Total Machinery Costs		53.43	46.03	41.56
Total Costs		95.22	87.82	83.35
Expected Net Revenue		33.17	40.57	45.04
RMSE		50.05	50.05	50.05

Table C4d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Trochu Area (Canola, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-12.10%	-20.26%
Minimum Tillage	0.00%	-12.02%	-20.97%
Zero Tillage	0.00%	-13.84%	-22.21%

Table C4e: Total Cost Changes From Conventional Tillage in the Trochu Area (Canola, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	6.81%	6.52%	5.64%
Zero Tillage	16.56%	16.07%	16.43%

Table C5a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Trochu Area (Canola, Wheat Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		132.69	132.69	132.69
Crop Input Costs				
Seed		6.38	6.38	6.38
Fertilizer	N	10.82	10.82	10.82
	Phosphate	5.96	5.96	5.96
Herbicide	Selective	9.98	9.98	9.98
	Glyphosate			
Total Crop Input Costs		33.13	33.13	33.13
Machinery Costs				
Capital		41.19	34.81	30.17
Repairs		5.22	5.57	6.14
Fuel		3.44	3.44	3.44
Total Machinery Costs		49.85	43.82	39.75
Total Costs		82.98	76.95	72.88
Expected Net Revenue		49.71	55.74	59.81
RMSE		48.28	48.28	48.28

Table C5b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Trochu Area (Canola, Wheat Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		132.69	132.69	132.69
Crop Input Costs				
Seed		6.38	6.38	6.38
Fertilizer	N	10.82	10.82	10.82
	Phosphate	5.96	5.96	5.96
Herbicide	Selective	9.98	9.98	9.98
	Glyphosate			
Total Crop Input Costs		33.13	33.13	33.13
Machinery Costs				
Capital		47.39	40.57	35.13
Repairs		4.82	4.98	5.46
Fuel		3.20	3.20	3.20
Total Machinery Costs		55.41	48.75	43.79
Total Costs		88.54	81.88	76.92
Expected Net Revenue		44.15	50.81	55.77
RMSE		48.28	48.28	48.28

Table C5c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Trochu Area (Canola, Wheat Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		132.69	132.69	132.69
Crop Input Costs				
Seed		6.38	6.38	6.38
Fertilizer	N	10.82	10.82	10.82
	Phosphate	5.96	5.96	5.96
Herbicide	Selective	9.98	9.98	9.98
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		43.08	43.08	43.08
Machinery Costs				
Capital		47.43	39.81	34.80
Repairs		3.69	3.92	4.46
Fuel		2.30	2.30	2.30
Total Machinery Costs		53.43	46.03	41.56
Total Costs		96.51	89.11	84.64
Expected Net Revenue		36.18	43.58	48.05
RMSE		48.28	48.28	48.28

Table C5d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Trochu Area (Canola, Wheat Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-12.09%	-20.26%
Minimum Tillage	0.00%	-12.02%	-20.97%
Zero Tillage	0.00%	-13.84%	-22.20%

Table C5e: Total Cost Changes From Conventional Tillage in the Trochu Area (Canola, Wheat Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	6.70%	6.41%	5.54%
Zero Tillage	16.30%	15.80%	16.14%

Table C6a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Trochu Area (Canola, Wheat, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		102.68	102.68	102.68
Crop Input Costs				
Seed		4.25	4.25	4.25
Fertilizer	N	5.28	5.28	5.28
	Phosphate	4.86	4.86	4.86
Herbicide	Selective	6.65	6.65	6.65
	Glyphosate			
Total Crop Input Costs		21.03	21.03	21.03
Machinery Costs				
Capital		35.06	28.48	24.45
Repairs		2.62	2.80	3.11
Fuel		1.95	1.95	1.95
Total Machinery Costs		39.63	33.23	29.51
Total Costs		60.67	54.27	50.54
Expected Net Revenue		42.01	48.41	52.14
RMSE		25.99	25.99	25.99

Table C6b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Trochu Area (Canola, Wheat, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		102.68	102.68	102.68
Crop Input Costs				
Seed		4.25	4.25	4.25
Fertilizer	N	5.28	5.28	5.28
	Phosphate	4.86	4.86	4.86
Herbicide	Selective	6.65	6.65	6.65
	Glyphosate	3.32	3.32	3.32
Total Crop Input Costs		24.35	24.35	24.35
Machinery Costs				
Capital		43.05	36.68	31.85
Repairs		2.31	2.38	2.60
Fuel		1.81	1.81	1.81
Total Machinery Costs		47.17	40.86	36.25
Total Costs		71.52	65.21	60.60
Expected Net Revenue		31.16	37.47	42.08
RMSE		25.99	25.99	25.99

Table C6c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Trochu Area (Canola, Wheat, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		102.68	102.68	102.68
Crop Input Costs				
Seed		4.25	4.25	4.25
Fertilizer	N	5.28	5.28	5.28
	Phosphate	4.86	4.86	4.86
Herbicide	Selective	6.65	6.65	6.65
	Glyphosate	13.27	13.27	13.27
Total Crop Input Costs		34.30	34.30	34.30
Machinery Costs				
Capital		38.65	33.05	28.60
Repairs		2.02	2.11	2.35
Fuel		1.39	1.39	1.39
Total Machinery Costs		42.06	36.55	32.34
Total Costs		76.36	70.85	66.64
Expected Net Revenue		26.32	31.83	36.04
RMSE		25.99	25.99	25.99

Table C6d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Trochu Area (Canola, Wheat, Fallow Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-16.15%	-25.55%
Minimum Tillage	0.00%	-13.38%	-23.14%
Zero Tillage	0.00%	-13.10%	-23.11%

Table C6e: Total Cost Changes From Conventional Tillage in the Trochu Area (Canola, Wheat, Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	17.89%	20.17%	19.91%
Zero Tillage	25.87%	30.56%	31.86%

Appendix D: Results for Lacombe

Table D1: Crop Yields for the Lacombe Area (bu./ac.)

Year	Fallow Wheat	Stubble Wheat	Fallow Barley	Stubble Barley	Fallow Canola	Stubble Canola
76	42.44	40.36	59.69	53.16	28.56	24.57
77	38.43	40.31	64.24	63.41	31.82	29.67
78	34.41	38.44	59.91	59.94	27.83	25.99
79	35.90	42.09	57.17	54.60	24.29	22.71
80	50.59	48.35	59.65	58.05	24.18	23.32
81	48.02	46.91	64.68	62.34	26.55	26.81
82	45.20	37.86	52.95	50.66	18.58	20.09
83	48.51	46.06	64.07	57.30	24.35	21.51
84	46.81	42.54	67.00	58.68	27.20	25.34
85	29.65	33.26	45.19	40.88	24.28	23.23
86	44.24	48.40	62.30	66.50	16.77	23.17
87	39.89	42.80	65.36	63.29	27.06	24.09
88	46.84	42.03	71.94	64.37	25.21	23.94
89	50.40	41.02	56.41	52.72	21.52	21.13
90	51.07	50.52	51.92	52.56	23.96	23.73
91	43.62	45.70	53.26	47.20	24.11	22.10
92	43.85	42.70	62.67	56.96	26.47	22.28
93	49.99	44.05	71.86	57.40	26.02	27.47
Mean	43.88	42.97	60.57	56.67	24.93	23.95
Standard Deviation	6.13	4.27	6.97	6.50	3.49	2.40

Table D2: Weighted Crop Prices for the Lacombe Area ($'s/bu.)

Year	Wheat Nominal	Wheat Real Actual	Wheat Real Predicted	Wheat Error	Barley Nominal	Barley Real Actual	Barley Real Predicted	Barley Error	Canola Nominal	Canola Real Actual	Canola Real Predicted	Canola Error
76	2.67	8.02			1.94	5.91			5.15	14.14		
77	2.37	6.70	8.02	-1.33	1.69	4.90	5.91	-1.01	6.31	16.03	14.14	1.89
78	2.96	7.56	6.70	0.86	1.77	4.70	4.90	-0.20	6.33	14.77	16.03	-1.26
79	4.54	10.31	7.56	2.75	2.29	5.42	4.70	0.72	6.56	14.02	14.77	-0.75
80	4.01	8.36	10.31	-1.95	2.91	6.15	5.42	0.73	6.19	12.02	14.02	-2.00
81	4.82	8.86	8.36	0.51	2.72	5.18	6.15	-0.98	6.24	10.77	12.02	-1.25
82	3.97	6.70	8.86	-2.16	2.11	3.75	5.18	-1.43	6.31	9.82	10.77	-0.94
83	4.26	6.77	6.70	0.07	2.76	4.51	3.75	0.76	8.60	12.66	9.82	2.83
84	4.13	6.29	6.77	-0.47	2.68	4.20	4.51	-0.30	7.98	11.26	12.66	-1.39
85	3.11	4.73	6.29	-1.57	2.02	3.19	4.20	-1.02	6.06	8.22	11.26	-3.04
86	1.77	2.79	4.73	-1.93	1.38	2.24	3.19	-0.95	4.54	5.91	8.22	-2.31
87	2.81	3.99	2.79	1.19	1.41	2.19	2.24	-0.05	5.83	7.28	5.91	1.36
88	3.96	5.28	3.99	1.29	2.50	3.47	2.19	1.28	6.78	8.14	7.28	0.86
89	3.64	4.74	5.28	-0.54	2.33	3.16	3.47	-0.30	6.06	6.92	8.14	-1.22
90	3.95	4.93	4.74	0.20	1.64	2.32	3.16	-0.84	5.85	6.38	6.92	-0.54
91	2.72	3.41	4.93	-1.53	1.87	2.45	2.32	0.12	5.40	5.58	6.38	-0.81
92	1.88	2.53	3.41	-0.88	1.69	2.24	2.45	-0.21	6.26	6.37	5.58	0.79
93	2.88	3.53	2.53	1.01	1.63	2.18	2.24	-0.06	7.10	7.09	6.37	0.72
Mean	4.12	6.00			3.73	6.00			6.31	6.00		
Standard Deviation	1.00	2.38			1.05	2.38			0.93	2.38		
Predicted Price			3.53				2.18				7.09	
RMSE			1.39				0.78				1.59	

Table D3: Crop Programs, Expected Yields and Expected Gross Revenue for the Lacombe Area

	Crop Programs	
Description	CWBB	CWB
Proportion Fallow		
Proportion Wheat on Fallow		
Proportion Wheat on Stubble	25.00%	33.33%
Proportion Barley on Fallow		
Proportion Barley on Stubble	50.00%	33.33%
Proportion Canola on Fallow		
Proportion Canola on Stubble	25.00%	33.33%
Yield Wheat on Fallow	43.88	43.88
Yield Wheat on Stubble	42.97	42.97
Yield Barley on Fallow	60.57	60.57
Yield Barley on Stubble	56.67	56.67
Yield Conola on Fallow	24.93	24.93
Yield Canola on Stubble	23.95	23.95
Weighted Wheat Yield	10.74	14.32
Weighted Barley Yield	28.33	18.89
Weighted Canola Yield	5.99	7.98
Predicted Wheat Price	3.53	3.53
Predicted Barley Price	2.18	2.18
Predicted Canola Price	7.09	7.09
Predicted Gross Revenue	142.15	148.38
RMSE	34.07	36.68

Table D4a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Lacombe Area (Canola, Wheat, Barley, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		142.15	142.15	142.15
Crop Input Costs				
Seed		6.50	6.50	6.50
Fertilizer	N	12.40	12.40	12.40
	Phosphate	9.27	9.27	9.27
Herbicide	Selective	16.54	16.54	16.54
	Glysophate			
Total Crop Input Costs		44.71	44.71	44.71
Machinery Costs				
Capital		43.46	34.74	30.17
Repairs		7.05	7.57	7.91
Fuel		4.78	4.78	4.78
Total Machinery Costs		55.29	47.09	42.86
Total Costs		100.00	91.80	87.57
Expected Net Revenue		42.15	50.35	54.58
RMSE		34.07	34.07	34.07

Table D4b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Lacombe Area (Canola, Wheat, Barley, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		142.15	142.15	142.15
Crop Input Costs				
Seed		6.50	6.50	6.50
Fertilizer	N	12.40	12.40	12.40
	Phosphate	9.27	9.27	9.27
Herbicide	Selective	16.54	16.54	16.54
	Glysophate			
Total Crop Input Costs		44.71	44.71	44.71
Machinery Costs				
Capital		55.76	46.61	40.83
Repairs		4.93	5.12	5.60
Fuel		4.58	4.58	4.58
Total Machinery Costs		65.27	56.31	51.02
Total Costs		109.98	101.02	95.72
Expected Net Revenue		32.17	41.13	46.43
RMSE		34.07	34.07	34.07

Table D4c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Lacombe Area (Canola, Wheat, Barley, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		142.15	142.15	142.15
Crop Input Costs				
Seed		6.50	6.50	6.50
Fertilizer	N	12.40	12.40	12.40
	Phosphate	9.27	9.27	9.27
Herbicide	Selective	16.54	16.54	16.54
	Glysophate	9.95	9.95	9.95
Total Crop Input Costs		54.66	54.66	54.66
Machinery Costs				
Capital		50.38	42.57	37.50
Repairs		3.71	3.94	4.48
Fuel		2.57	2.57	2.57
Total Machinery Costs		56.66	49.08	44.55
Total Costs		111.32	103.74	99.21
Expected Net Revenue		30.83	38.41	42.94
RMSE		34.07	34.07	34.07

Table D4d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Lacombe Area (Canola, Wheat, Barley, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-14.83%	-22.48%
Minimum Tillage	0.00%	-13.73%	-21.84%
Zero Tillage	0.00%	-13.38%	-21.37%

Table D4e: Total Cost Changes From Conventional Tillage in the Lacombe Area (Canola, Wheat, Barley, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	9.98%	10.05%	9.32%
Zero Tillage	11.32%	13.01%	13.29%

Table D5a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Lacombe Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		148.38	148.38	148.38
Crop Input Costs				
Seed		6.67	6.67	6.67
Fertilizer	N	12.58	12.58	12.58
	Phosphate	9.71	9.71	9.71
•Herbicide	Selective	15.92	15.92	15.92
	Glysophate			
Total Crop Input Costs		44.87	44.87	44.87
Machinery Costs				
Capital		43.46	34.74	30.17
Repairs		7.05	7.57	7.91
Fuel		4.78	4.78	4.78
Total Machinery Costs		55.29	47.09	42.86
Total Costs		100.16	91.96	87.73
Expected Net Revenue		48.22	56.42	60.65
RMSE		36.68	36.68	36.68

Table D5b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Lacombe Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		148.38	148.38	149.38
Crop Input Costs				
Seed		6.67	6.67	6.67
Fertilizer	N	12.58	12.58	12.58
	Phosphate	9.71	9.71	9.71
Herbicide	Selective	15.92	15.92	15.92
	Glysophate			
Total Crop Input Costs		44.87	44.87	44.87
Machinery Costs				
Capital		55.76	46.61	40.83
Repairs		4.93	5.12	5.60
Fuel		4.58	4.58	4.58
Total Machinery Costs		65.27	56.31	51.02
Total Costs		110.15	101.19	95.89
Expected Net Revenue		38.23	47.19	52.49
RMSE		36.68	36.68	36.68

Table D5c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Lacombe Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		148.38	148.38	148.38
Crop Input Costs				
Seed		6.67	6.67	6.67
Fertilizer	N	12.58	12.58	12.58
	Phosphate	9.71	9.71	9.71
Herbicide	Selective	15.92	15.92	15.92
	Glysophate	9.95	9.95	9.95
Total Crop Input Costs		54.82	54.82	54.82
Machinery Costs				
Capital		50.38	42.57	37.50
Repairs		3.71	3.94	4.48
Fuel		2.57	2.57	2.57
Total Machinery Costs		56.66	49.08	44.55
Total Costs		111.48	103.90	99.37
Expected Net Revenue		36.90	44.48	49.01
RMSE		36.68	36.68	36.68

Table D5d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Lacombe Area (Canola, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-14.83%	-22.48%
Minimum Tillage	0.00%	-13.73%	-21.84%
Zero Tillage	0.00%	-13.38%	-21.37%

Table D5e: Total Cost Changes From Conventional Tillage in the Lacombe Area (Canola, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	9.97%	10.03%	9.30%
Zero Tillage	11.30%	12.98%	13.27%

Appendix E: Results for Wainwright

Table E1: Crop Yields for the Wainwright Area (bu./ac.)

Year	Fallow Wheat	Stubble Wheat	Fallow Barley	Stubble Barley	Fallow Canola	Stubble Canola
76	40.21	27.00	58.04	40.12	26.99	13.47
77	36.16	28.76	61.24	46.46	31.92	21.95
78	30.68	23.54	44.86	36.28	20.06	14.50
79	38.59	35.28	63.23	46.62	25.11	21.54
80	43.17	39.92	69.03	63.85	30.27	26.60
81	32.77	24.41	51.01	37.58	[illegible]	19.23
82	36.02	25.11	55.21	47.64	26.43	22.72
83	37.94	31.02	56.84	51.42	27.26	18.60
84	29.72	27.94	35.89	40.40	25.84	16.76
85	30.57	24.69	52.73	[illegible]	27.53	15.43
86	[illegible]	34.99	63.04	62.94	27.85	22.75
87	31.61	24.33	57.45	55.90	33.90	23.58
88	25.63	23.09	46.22	45.00	24.39	15.66
89	33.08	27.01	42.47	41.42	25.49	18.39
90	36.74	32.83	62.59	52.85	26.01	19.91
91	33.91	28.52	43.83	39.95	24.21	18.79
92	26.56	22.34	42.41	35.36	20.35	15.34
93	41.49	39.48	52.61	56.10	28.35	23.64
Mean	34.81	28.91	53.26	46.42	26.57	19.38
Standard Deviation	5.17	5.51	9.08	9.05	3.41	3.72

Table E2: Weighted Crop Prices for the Wainwright Area ($'s/bu.)

	Wheat				Barley				Canola			
Year	Nominal	Real Actual	Real Predicted	Error	Nominal	Real Actual	Real Predicted	Error	Nominal	Real Actual	Real Predicted	Error
76	2.71	8.11			1.62	5.61			5.15	14.14		
77	2.47	6.97	8.11	-1.14	1.69	4.91	5.61	-0.70	6.31	16.03	14.14	1.89
78	2.93	7.49	6.97	0.52	1.63	4.40	4.91	-0.51	6.33	14.77	16.03	-1.26
79	4.67	10.57	7.49	3.08	2.12	5.08	4.40	0.68	6.56	14.02	14.77	-0.75
80	4.57	9.45	10.57	-1.12	2.91	6.17	5.08	1.09	6.19	12.02	14.02	-2.00
81	4.89	8.99	9.45	-0.46	2.60	4.98	6.17	-1.19	6.24	10.77	12.02	-1.25
82	4.23	7.10	8.99	-1.88	[illegible]	3.69	4.98	-1.30	6.31	9.82	10.77	-0.94
83	4.19	6.65	7.10	-0.45	2.58	4.25	3.69	0.56	8.60	12.66	9.82	2.83
84	4.33	6.57	6.65	-0.08	2.57	4.05	4.25	-0.20	7.98	11.26	12.66	-1.39
85	3.41	5.14	6.57	-1.44	2.04	3.22	4.05	-0.82	6.06	8.22	11.26	-3.04
86	2.39	3.60	5.14	-1.54	1.66	2.60	3.22	-0.62	4.54	5.91	8.22	-2.31
87	2.84	4.02	3.60	0.42	1.30	2.05	2.60	-0.55	5.83	7.28	5.91	1.36
88	4.64	6.10	4.02	2.08	2.41	3.36	2.05	1.31	6.78	8.14	7.28	0.86
89	3.57	4.66	6.10	-1.44	2.17	2.99	3.36	-0.38	[illegible]	6.92	8.14	-1.22
90	2.87	3.75	4.66	-0.91	1.54	2.22	2.99	-0.77	[illegible]	6.38	6.92	-0.54
91	3.00	3.70	3.75	-0.05	1.86	2.44	2.22	0.22	[illegible]	5.58	6.38	-0.81
92	2.47	3.14	3.70	-0.56	1.75	2.31	2.44	-0.13	[illegible]	6.37	5.58	0.79
93	3.12	3.77	3.14	0.63	1.65	2.21	2.31	-0.10	7.10	7.09	6.37	0.72
Mean	3.52	6.10			2.02	3.70			6.31	9.85		
Standard Deviation	0.87	2.26			0.44	1.29			0.93	3.43		
Predicted Price			3.77				2.21				7.09	
RMSE			1.30				0.76				1.59	

Table E3: Crop Programs, Expected Yields and Expected Gross Revenue for the Wainwright Area

Description	Crop Programs CWBB	CWB	CWBF
Proportion Fallow			25.00%
Proportion Wheat on Fallow			
Proportion Wheat on Stubble	25.00%	33.33%	25.00%
Proportion Barley on Fallow			
Proportion Barley on Stubble	50.00%	33.33%	25.00%
Proportion Canola on Fallow			25.00%
Proportion Canola on Stubble	25.00%	33.33%	
Yield Wheat on Fallow	34.81	34.81	34.81
Yield Wheat on Stubble	28.91	28.91	28.91
Yield Barley on Fallow	53.26	53.26	53.26
Yield Barley on Stubble	46.42	46.42	46.42
Yield Conola on Fallow	26.57	26.57	26.57
Yield Canola on Stubble	19.38	19.38	19.38
Weighted Wheat Yield	7.23	9.64	7.23
Weighted Barley Yield	23.21	15.47	11.60
Weighted Canola Yield	4.85	6.46	6.64
Predicted Wheat Price	3.77	3.77	3.77
Predicted Barley Price	2.21	2.21	2.21
Predicted Canola Price	7.09	7.09	7.09
Predicted Gross Revenue	112.89	116.33	99.99
RMSE	36.17	35.95	23.05

Table E4a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Wainwright Area (Canola, Wheat, Barley, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		112.89	112.89	112.89
Crop Input Costs				
Seed		5.69	5.69	5.69
Fertilizer	N	10.41	10.41	10.41
	Phosphate	7.62	7.62	7.62
Herbicide	Selective	9.45	9.45	9.45
	Glyphosate			
Total Crop Input Costs		33.16	33.16	33.16
Machinery Costs				
Capital		46.05	38.87	33.33
Repairs		5.57	5.98	6.81
Fuel		4.22	4.22	4.22
Total Machinery Costs		[illegible]5.84	49.08	44.36
Total Costs		89.00	82.24	77.52
Expected Net Revenue		23.89	30.65	35.37
RMSE		36.17	36.17	36.17

Table E4b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Wainwright Area (Canola, Wheat, Barley, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		112.89	112.89	112.89
Crop Input Costs				
Seed		5.69	5.69	5.69
Fertilizer	N	10.41	10.41	10.41
	Phosphate	7.62	7.62	7.62
Herbicide	Selective	9.45	9.45	9.45
	Glyphosate			
Total Crop Input Costs		33.16	33.16	33.16
Machinery Costs				
Capital		52.39	43.62	38.01
Repairs		4.87	5.05	5.54
Fuel		3.89	3.89	3.89
Total Machinery Costs		61.15	52.56	47.44
Total Costs		94.31	85.72	80.60
Expected Net Revenue		18.58	27.17	32.29
RMSE		36.17	36.17	36.17

Table E4c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Wainwright Area (Canola, Wheat, Barley, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		112.89	112.89	112.89
Crop Input Costs				
Seed		5.69	5.69	5.69
Fertilizer	N	10.41	10.41	10.41
	Phosphate	7.62	7.62	7.62
Herbicide	Selective	9.45	9.45	9.45
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		43.11	43.11	43.11
Machinery Costs				
Capital		47.69	39.94	34.83
Repairs		3.74	4.00	4.54
Fuel		2.30	2.30	2.30
Total Machinery Costs		53.74	46.25	41.67
Total Costs		96.85	89.36	84.78
Expected Net Revenue		16.04	23.53	28.11
RMSE		36.17	36.17	36.17

Table E4d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Wainwright Area (Canola, Wheat, Barley, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-12.12%	-20.56%
Minimum Tillage	0.00%	-14.05%	-22.42%
Zero Tillage	0.00%	-13.94%	-22.46%

Table E4e: Total Cost Changes From Conventional Tillage in the Wainwright Area (Canola, Wheat, Barley, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	5.96%	4.24%	3.97%
Zero Tillage	8.82%	8.66%	9.36%

Table E5a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Wainwright Area (Canola, Wheat, Barley Crop Rotation)

Conventional Tillage				
	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		116.33	116.33	116.33
Crop Input Costs				
Seed		5.92	5.92	5.92
Fertilizer	N	10.56	10.56	10.56
	Phosphate	7.51	7.51	7.51
Herbicide	Selective	10.50	10.50	10.50
	Glyphosate			
Total Crop Input Costs		34.49	34.49	34.49
Machinery Costs				
Capital		46.05	38.87	33.33
Repairs		5.57	5.98	6.81
Fuel		4.22	4.22	4.22
Total Machinery Costs		55.84	49.08	44.36
Total Costs		90.33	83.56	78.85
Expected Net Revenue		26.00	32.77	37.48
RMSE		35.95	35.95	35.95

Table E5b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Wainwright Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		116.33	116.33	116.33
Crop Input Costs				
Seed		5.92	5.92	5.92
Fertilizer	N	10.56	10.56	10.56
	Phosphate	7.51	7.51	7.51
Herbicide	Selective	10.50	10.50	10.50
	Glyphosate			
Total Crop Input Costs		34.49	34.49	34.49
Machinery Costs				
Capital		52.39	43.62	38.01
Repairs		4.87	5.05	5.54
Fuel		3.89	3.89	3.89
Total Machinery Costs		61.15	52.56	47.44
Total Costs		95.64	87.05	81.93
Expected Net Revenue		20.69	29.28	34.40
RMSE		35.95	35.95	35.95

Table E5c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Wainwright Area (Canola, Wheat, Barley Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		116.33	116.33	116.33
Crop Input Costs				
Seed		5.92	5.92	5.92
Fertilizer	N	10.56	10.56	10.56
	Phosphate	7.51	7.51	7.51
Herbicide	Selective	10.50	10.50	10.50
	Glyphosate	9.95	9.95	9.95
Total Crop Input Costs		44.44	44.44	44.44
Machinery Costs				
Capital		47.69	39.94	34.83
Repairs		3.74	4.00	4.54
Fuel		2.30	2.30	2.30
Total Machinery Costs		53.74	46.25	41.67
Total Costs		98.17	90.68	86.11
Expected Net Revenue		18.16	25.65	30.22
RMSE		35.95	35.95	35.95

Table E5d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Wainwright Area (Canola, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-12.12%	-20.56%
Minimum Tillage	0.00%	-14.05%	-22.42%
Zero Tillage	0.00%	-13.94%	-22.46%

Table E5e: Total Cost Changes From Conventional Tillage in the Wainwright Area (Canola, Wheat, Barley Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	5.88%	4.17%	3.91%
Zero Tillage	8.69%	8.52%	9.21%

Table E6a: Gross Revenue, Costs, and Net Revenue for the Conventional Tillage System in the Wainwright Area (Canola, Wheat, Barley, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		99.99	99.99	99.99
Crop Input Costs				
Seed		4.44	4.44	4.44
Fertilizer	N	6.44	6.44	6.44
	Phosphate	5.63	5.63	5.63
Herbicide	Selective	7.88	7.88	7.88
	Glyphosate			
Total Crop Input Costs		24.39	24.39	24.39
Machinery Costs				
Capital		35.84	28.75	24.71
Repairs		3.74	4.00	4.17
Fuel		2.52	2.52	2.52
Total Machinery Costs		42.10	35.28	31.40
Total Costs		66.48	59.66	55.79
Expected Net Revenue		33.51	40.33	44.20
RMSE		23.05	23.05	23.05

Table E6b: Gross Revenue, Costs, and Net Revenue for the Minimum Tillage System in the Wainwright Area (Canola, Wheat, Barley, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		99.99	99.99	99.99
Crop Input Costs				
Seed		4.44	4.44	4.44
Fertilizer	N	6.44	6.44	6.44
	Phosphate	5.63	5.63	5.63
Herbicide	Selective	7.88	7.88	7.88
	Glyphosate	2.49	2.49	2.49
Total Crop Input Costs		26.87	26.87	26.87
Machinery Costs				
Capital		50.10	41.26	36.95
Repairs		2.45	2.69	2.80
Fuel		2.37	2.37	2.37
Total Machinery Costs		54.92	46.32	42.12
Total Costs		81.79	73.19	69.00
Expected Net Revenue		18.20	26.80	30.99
RMSE		23.05	23.05	23.05

Table E6c: Gross Revenue, Costs, and Net Revenue for the Zero Tillage System in the Wainwright Area (Canola, Wheat, Barley, Fallow Crop Rotation)

	Cultivated Acres	960	1280	1600
Predicted Gross Revenue		99.99	99.99	99.99
Crop Input Costs				
Seed		4.44	4.44	4.44
Fertilizer	N	6.44	6.44	6.44
	Phosphate	5.63	5.63	5.63
Herbicide	Selective	7.88	7.88	7.88
	Glyphosate	12.44	12.44	12.44
Total Crop Input Costs		36.82	36.82	36.82
Machinery Costs				
Capital		44.75	37.24	33.22
Repairs		2.23	2.49	2.62
Fuel		1.76	1.76	1.76
Total Machinery Costs		48.74	41.49	37.60
Total Costs		85.56	78.31	74.42
Expected Net Revenue		14.43	21.68	25.57
RMSE		23.05	23.05	23.05

Table E6d: Machinery Cost Changes from the 960 Cultivated Acre Size in the Wainwright Area (Canola, Wheat, Barley, Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	-16.21%	-25.41%
Minimum Tillage	0.00%	-15.66%	-23.30%
Zero Tillage	0.00%	-14.87%	-22.85%

Table E6e: Total Cost Changes From Conventional Tillage in the Wainwright Area (Canola, Wheat, Barley, Fallow Crop Rotation)

Tillage System	Cultivated Acres		
	960	1280	1600
Conventional Tillage	0.00%	0.00%	0.00%
Minimum Tillage	23.03%	22.68%	23.68%
Zero Tillage	28.69%	31.26%	33.40%