MULTI-FACTOR PRODUCTIVITY GROWTH

IN SASKATCHEWAN CROPS

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By

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ABSTRACT

This study provides *ex ante* estimates of multi factor productivity (MFP) growth in the Saskatchewan agricultural sector on a crop by crop basis, using a time series of partial budgets from representative crop planning Guide. The study considers six major crops in Saskatchewan: spring wheat, durum wheat, feed barley, feed peas, large green lentils and canola.MFP growth is compared across crops, soil zones and cropping systems. Over the 1993-2013 period all six crops MFP grew at rates of over 2.56% per year. Feed peas and canola showed the fastest growth rates of 4.68% and 4.01%, respectively. The MFP growth ofcrops seeded on summer-fallow was slower than crops seeded into stubble using conventional tillage and zero tillage. The best soil zone for durum wheat and lentils, in term of productivity growth, was the Brown Soil zone; while for peas and canola, it is the Dark Brown Soil zone. Spring wheat and barley grown in different soil zones had very similar productivity gains.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Multi-factor Productivity (MFP) is the measured ratio of an output index to an input index of a production process.[1] MFP growth captures the change in outputs unexplained by the growth in observable inputs applied, such as technical change, scale effects, and climate change. As an important source of economic growth, productivity growth is frequently measured and reported.

MFP growth is a measurement that provides insights into an economic entity's sustainability and development over time. In the agricultural industry, productivity growth is generally adopted as a key indicator of agricultural competitiveness. Total factor productivity growth for crops and livestock sectors in Canada was estimated between less than 1.0% and 1.4% per annum during the period between 1961 and 2005 (Veeman and Gray, 2010). Stewart (2006) disaggregates overall agricultural productivity performance into the level of crops and livestock sectors, by assessing Prairie agriculture during the 1940-2004 period. His study estimated that overall productivity growth in Prairie agriculture averaged 1.56% annually over the entire period, contributing to over two-thirds of the output growth. For the Saskatchewan crop sector, he found that productivity grew at 1.76% per year between 1940 and 2004, and slower growth between 1990 and 2004 - 0.39% per year (Stewart. 2006). A recent study (Awada and Gray, 2014) indicates that the annual productivity growth rate in the Saskatchewan crop sector was 1.7% in 1991-2000 period and a much higher growth rate of 5.4% during the 2001-2010 period.

Due to the economic significance of agricultural productivity, it is meaningful compare productivity performance across sectors and jurisdictions. For example,

[1] Multi-factor productivity is also known as total factor productivity. In this study, the term of multi-factor productivity is preferred because all factors of production (e.g. rainfall) cannot be practically included in the production function.

Veeman*et al.* (1998) reported productivity growth in Alberta agriculture lagged behind average values of Prairie agriculture, especially in the livestock sector. Stewart's (2006) study compares each Prairie province's productivity performance in both aggregate level (i.e., overall Prairie agriculture) and disaggregated level (i.e., crops and livestock), offering a more detailed view to examine the productivity in Prairie agriculture.

In a review of the literature I was unable to find any published studies that estimate productivity growth of specific crops. A plausible reason for this apparent void is that input data at the disaggregated level of a crop are generally unavailable. For example, while fertilizer expenditure may be available at a farm level or at an aggregate level for a region, the fertilizer use for individual crops is not. This issue is even more difficult in the case of machinery use that needs to be allocated to specific crops. This thesis overcomes these data limitations by using a time series of partial budgets, which by deliberate design allocate costs to specific crop production activities. The availability of a time series of partial budgets used in this study not only enables the estimation of productivity growth for a specific crop, but also for specific crops in various soil zones and with various farming practices. This specific data source allows a disaggregation of productivity improvement, absent in other studies.

1.2 Background

In this section, changes in two major aspects in the Saskatchewan crop sector are discussed. Section 1.2.1 provides background of production, yields, acres, and farm size in the Saskatchewan crop sector over the 1993-2013 period. Section 1.2.2 demonstrates how cropping systems (including summer-fallow, conventional tillage, minimum tillage and zero tillage) have changed over past decades. Changes in acres of various cropping systems are then presented.

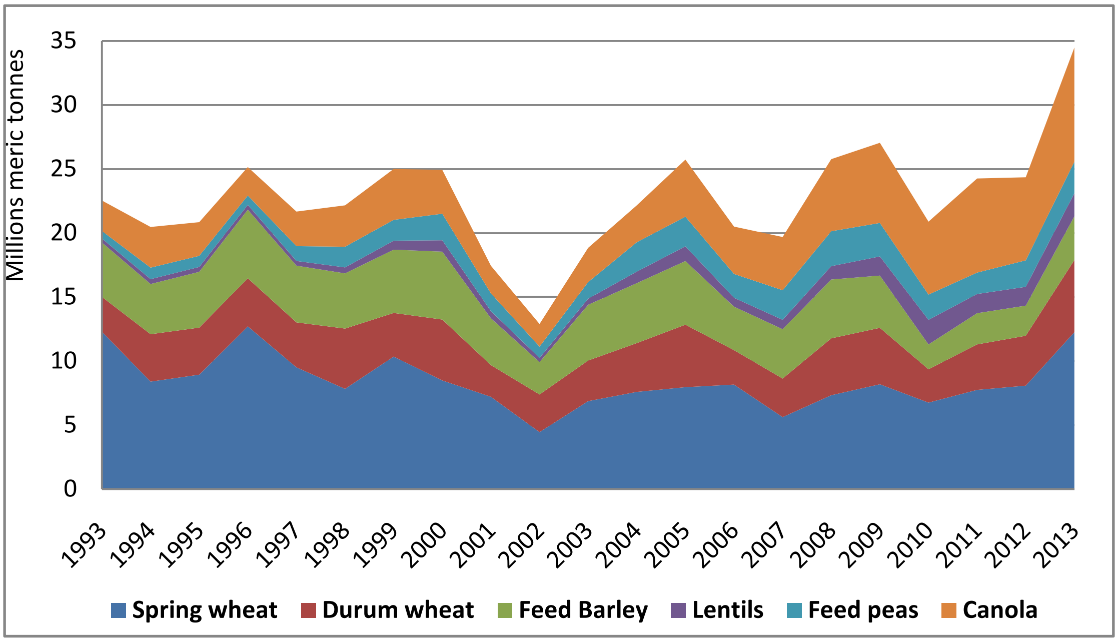
1.2.1 Changes in Crop Production

In Saskatchewan, the number of farms reporting land in crops decreased from 58,650 in 1991 to 34,185 in 2011, while crop acres per farm increased by nearly 88%

(Statistics Canada, 2014). In this sub-section, changes in production, yields and acres of the Saskatchewan major crops are discussed.

Figure 1.1demonstrates the production of six principal field crops in Saskatchewan between 1993 and 2013. The total production has increased over 53% in 20 years, from 22.5 to 34.5 million metric tonnes. Production share of cereal crops (e.g., spring wheat, barley) has shown a decline trend, while production shares of canola and pulse crops (e.g., lentils, peas) have increased significantly. Barley and durum wheat production basically remained stable over time.

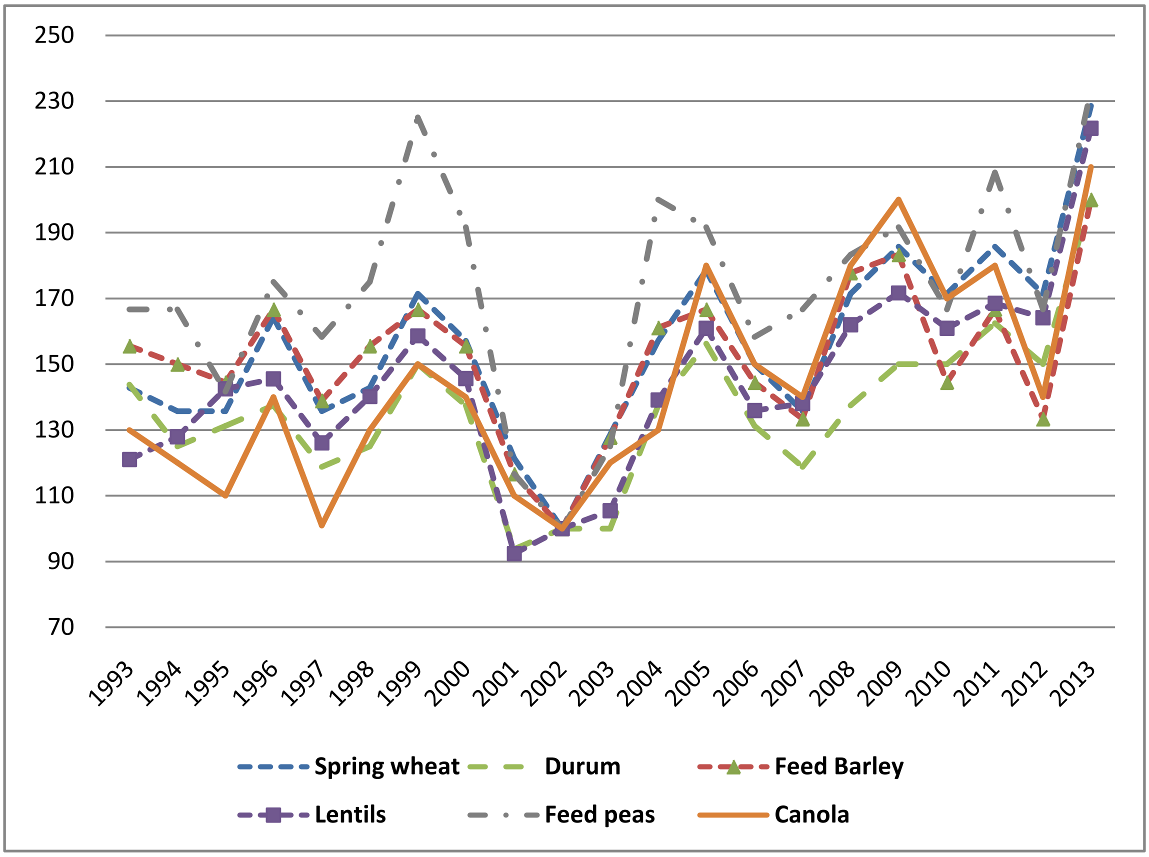
Figure 1.1 Production of Six Major Crops in Saskatchewan, 1993-2013



Source: Statistics Canada, CANSIM database, Table 001-0010 - Estimated areas, production, production and average farm price of principal field crops, in metric units, annual.

As shown in Figure 1.2 the per hectare yields of the six crops increased by approximately 47% between 1993 and 2013. During the 2001-2002 period the yields of all crops declined due to drought. After the drought the yields steadily rose until 2006 and then fluctuated around an increasing trend until 2013. The fastest yield increase is found in lentils, which increased significantly by 83.3% over the period. Both canola and spring wheat yields have grown by about 60%. Durum wheat and feed peas both grew about 40%. Barley yields showed the slowest growth over the period, increasing by 29%. Dramatic changes in yield performance of crops like canola and pulse crops have significantly affected cropping diversity, rotation and cultivated acres of crops.

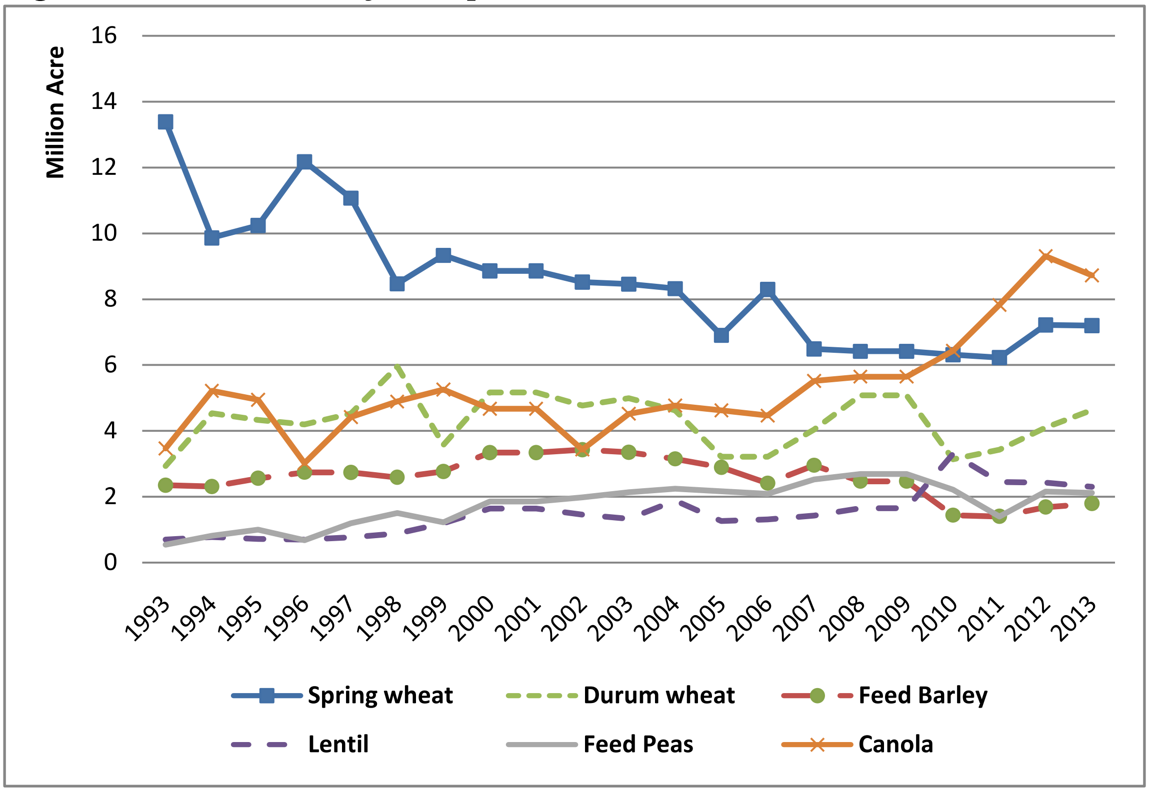
Figure1.2 Yield Index of Six Major Crops in Saskatchewan, 1993-2013 (2002=100)



Source: Statistics Canada. Table 001-0010 - Estimated areas, yield, production and average farm price of principal field crops, in metric units, annual

Acres of crop land in Saskatchewan have shifted from cereal crops toward canola and pulse crops between 1993 and 2013. In 1993, spring wheat was the dominant crop grown in the province, with 13.4 million acres, but decreased by 46% to 7.2 million acres in 2013. Feed barley acres also dropped, decreasing by 23.7% in 20 years. In 2010, canola overcame spring wheat to become the dominant crop in term of cultivated acres. Canola acres increased by 152%, from 3.5 million acres in 1993 to 8.7 million acres in 2013. Pulse crops, lentils and feed peas, have shown the largest increase in acres over the two decades, increasing by 228.7% and 289.1%, respectively. Durum wheat acres have remained relatively stable over time, fluctuating around 4.3 million acres.

Figure 1.3 Acres of Six Major Crops in Saskatchewan, 1993-2013



Source: Author's calculation based on Statistics Canada data and Nagy's Prairie Crop Energy Model (PCEM) (2001).

1.2.2 Changes in Cropping Systems

Tillage practices have changed substantially showing a trend to a lesser disturbance of the soil. Adoption of reduced-tillage systems have taken place in Canada over time, with the highest adoption rates being found in Saskatchewan (Statistics Canada, 2014). During the 1960s summer-fallow was a dominant practice in Saskatchewan, with around 17 million acres of fallow land representing about 45% of total cultivated area. In 2013this percentage dropped down to under 7% (2.7 million acres), with more farmers adopting zero tillage practice (Saskatchewan Agriculture, 2014). In the census year 2011, there were 16,032 famers in Saskatchewan who applied zero tillage seeding. They constituted 55.8% of total numbers of farms reporting, and the percentage was 30% in 2001and 13.5% in 1991. As shown in Table 1.1, the acres under zero tillage increased from 3.3 million in 1991to 23 million in 2011, accounting for 63.3% of total land in crops (Statistics Canada, 2014).[2]

Table 1-1 Zero Tillage Adoption in Saskatchewan, 1991 – 2011

	Total land in crops		Zero tillage seeding		Summer-fallow land		% of Acres	
	Number of farms	Acres	Number of farms	Acres	Number of farms	Acres	Zero tillage	Summer -fallow
1991	58650	33257706	7659	3342896	45577	14116713	10.05%	42.45%
1996	54226	35579845	10690	7250545	37597	10950353	20.38%	30.78%
2001	48055	37994752	13248	13491077	28114	7738453	35.51%	20.37%
2006	41056	36967225	15448	19839959	18779	6001296	53.67%	16.23%
2011	34185	36395993	16032	23034858	10378	3571933	63.29%	9.81%

Source: Statistics Canada. Table 004-0002 and Table 004-0010.

Before zero tillage was developed and adopted, summer-fallow was a domain cropping practice. With the practice of summer-fallow farmers tend to leave land fallow for 18 months after harvesting a crop, with the purpose to provide adequate moisture and nitrogen for growing crops in the following season. Weeds are controlled by tillage or herbicides in the summer-fallowed land.[3] A major problem caused by intensive tillage of this practice was the degradation of soil quality due to soil erosion and soil organic matter depletion. By the 1990s, reduced-tillage systems were well developed to address this problem. Reduced-tillage, consisting of minimum tillage and zero tillage,[4] tends to leave more of the crop residue in the soil and to use more chemicals to control weeds with less or no disturbance to the soil. Minimum tillage practice applies just one pass of tillage to control weeds in spring, and zero tillage practice allows the soil not to be disturbed by tillage. Within conventional tillage system, it requires at least two passes of tillage, in both fall and spring, while

[2] Much of zero-tillage areas are concentrated on the Dark Brown and Black Soil zones. And an increasing amount of acres are found in the Brown Soil zone due to changes in cropping system and climatic conditions.
[3] Summer-fallow includes both tillage-fallow and chem-fallow. In Saskatchewan, the percentage of chem-fallow consisted of summer-fallow lands has increased largely, from 23.6% in the census year 1991 to 62.5% in the census year 2011.
[4] Reduced-tillage is also referred to as “conservation tillage”.

even with this, farmers have increasingly substituted herbicide applications for some tillage operations over time.

Table 1-2 The Difference in Crop Production Systems by Field Operations and Machinery Passes

Season	Field Operation	Requirements			Machinery Passes		
		CT	MT	ZT	CT	MT	ZT
Fall	Harvest	Yes	Yes	Yes	1	1	1
	Tillage to control weed	Yes	No	No	2	0	0
	Spray for winter annual weed	No	Yes	Yes	0	1	1
Spring	Tillage to control weed	Yes	Yes	No	2	1	0
	Pre-seed burn-off	No	Yes	Yes	0	1	1
	Seeding & banding fertilizer	Yes	Yes	Yes	1	1	1
	Post-emergent herbicide	Yes	Yes	Yes	1	1	1
Summer	Crop monitoring	Yes	Yes	Yes	1	1	1

Source: Adapted from University of Saskatchewan. Guide to Farm Practice in Saskatchewan, 1983 (SASCC, 1983)

Under the reduced-tillage seeding systems, crop production requires less labour and machinery inputs but more herbicides and fertilizers. Without land being left fallow, crop rotation becomes more intensive and diverse. Reduced-tillage practices have also brought significant benefits to the environment, including carbon sequestration, increase of soil organic matter storage, and reduction of agricultural greenhouse gases emissions. The effect of environmental improvement on agricultural productivity performances not reflected in productivity measurement, indicating that the recent productivity growth rates are understated (Veeman and Gray, 2010).

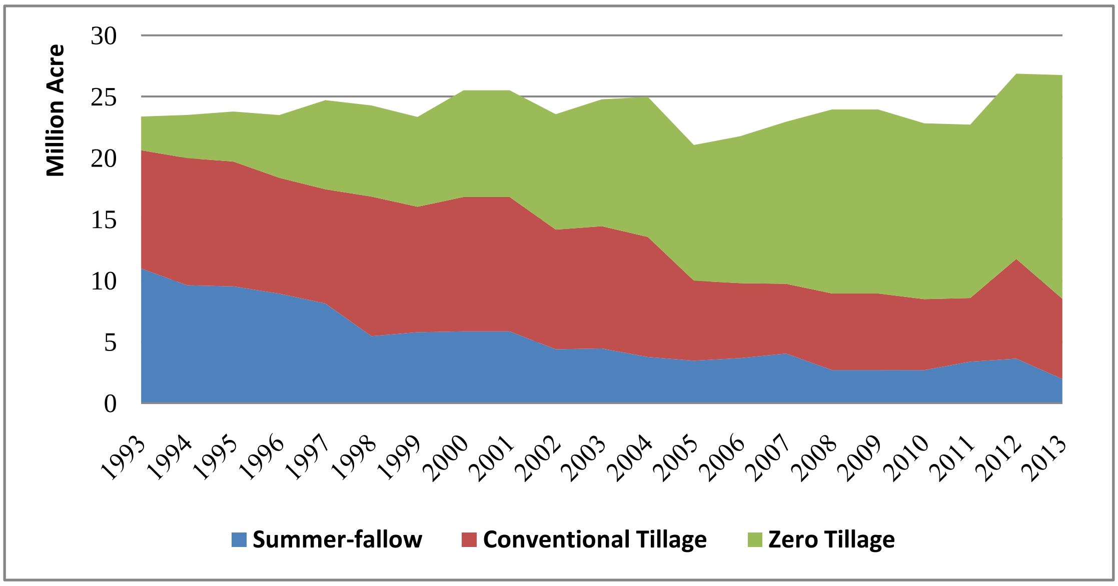
Considering these changes occurred over recent decades, productivity measurement can be used as an indicator to evaluate development in the Saskatchewan crop sector. As mentioned in the previous section, literature of individual crops' productivity performance is absent. Statistics Canada does not provide input and output data at levels of individual crops and cropping systems. In order to fill the void this study applies provincial partial budgets, as a means to measure individual crop productivity growth rates, comparing various crops across different soil zones and different cropping practices in Saskatchewan.

The partial budgets employed in the study are from the Crop Planning Guide, which have been published annually from the Saskatchewan Ministry of Agriculture since 1991. The documents are designed to assist farmers in making cropping decisions by providing estimates of cropping costs. Crop Planning Guide contains three types of budgets: 1) crops seeded on summer-fallow land (using tillage fallow and chemical fallow); 2) crops seeded on stubble using conventional tillage; and 3) crops seeded on stubble using zero tillage. There are six crops included in each budget: spring wheat, durum wheat, feed barley, lentils, feed peas and canola. More data information is discussed in Chapter 3.

Figure 1.4 shows changes in acres under summer-fallow, conventional tillage and zero tillage in all six crop sectors between 1993 and 2013.[5] Acres under zero tillage have increased significantly by over five times, from 2.8 to 18.2 million acres in 20 years. Meanwhile, fallow acres have declined continuously over time, by about 82%, having less than 2 million acres in 2013. Acres under conventional tillage remained around 10 million acres between 1993 and 2004, and then dropped to around 6.3 million acres during the 2005 - 2013 period. Among three categories of cropping systems, the share of zero tillage acres has increased largely from 11.8% to 68.2% over the 20 years. The shares of summer-fallow acres and conventional tillage acres have dropped to 7.34% and 24.4% in 2013, respectively, both from over 40% in 1993.

[5] This type of data are absent in public database and publications. Nagy's PCEM (2001) is applied to estimate the data.

Figure 1.4 Acres of Cropping Systems in Saskatchewan Six Crop Sectors, 1993-2013



Source: Author's calculation based on Statistics Canada data and Nagy's PCEM (2001).

1.3 Objectives

The study aims to provide insights into how individual crops, soil zones, and cropping systems have performed in MFP growth. As a result, the overall objective is achieved by three sub-objectives:

1. To estimate MFP growth of a specific crop with a specific farming practices in a specific soil zones.
2. To aggregate results of specific crop species and compare at the following two levels:
   1) Compare crops; for example, feed peas vs. canola
   2) Compare both soil zones and cropping systems of the same crop; for example canola in the Brown Soil zone vs. canola in the Dark Brown Soil zone
3. To compare MFP growth of two major crops in Saskatchewan, spring wheat and canola, in terms of soil zones and technologies.

1.4 Outline

The study contents are displayed through the following six chapters:

Chapter 1: Introduction. The background of productivity performance in the Canadian and Saskatchewan crop sectors and existing related studies are delineated in this first chapter. It highlights the absence of studies on agricultural productivity on the level of individual crops in order to indicate the contribution of this study. The objectives of this project are then outlined.

Chapter 2: Productivity Measurement Methodology. In this chapter, a discussion of various optional methodologies of productivity measurement is undertaken. An appropriate methodology is determined to be applied in measuring multi-factor productivity growth.

Chapter 3: Input and Output Data. The detailed description of input and output data collected in this study is explained in Chapter 3. It includes the sources of data, data processing, methodology of input and output categorization, and historical situations of outputs and inputs of Saskatchewan crops.

Chapter 4: Empirical Results of Productivity Performance: Crop Species. The primary MFP measurements of all crop sub-groups are presented in Chapter 4. Aggregate results of productivity growth in each crop sector are also provided. Finally, detailed results of productivity estimations are presented and discussed, and comparisons in the situation of productivity growth of each crop are made.

Chapter 5: Case study: Spring Wheat vs. Canola. The comparison between spring wheat and canola turns out to be the most interesting case. This chapter exhibits the comparison across productivity gains of two crops in different soil zones and with different cropping systems. Discussions about how productivity gains of the two crops vary in soil environments and with cropping systemsare also demonstrated in the chapter.

Chapter 6: Conclusions and Policy Implications. Numerous critical conclusions of the overall study are presented in this chapter. Based on the findings in this project, implications for agricultural policy are suggested in order to achieve a greater productivity performance in the Saskatchewan crop sector. Additionally, some advice and questions that arose during the research process are pointed out in the interest of further studies. Moreover, with the understanding of the spring wheat versus canola case, potential topics of further study are suggested, such as different aggregation options and adoption of more inputs.

CHAPTER 2: PRODUCTIVITY MEASUREMENT METHODOLOGY

2.1 Introduction

Measuring productivity growth in agriculture is an imperative but challenging task because results can vary depending on different methodologies utilized. Numerous studies have been done by applying different methodologies and various levels of data (national, regional or provincial), and have generated remarkable results for different research questions. This study will estimate multi-factor productivity (MFP) using the Törnqvist-Theil indexing procedure, using the *ex ante* partial budgets provincial government crop planning guides, in order to analyze productivity performances among different crop species in Saskatchewan.

Chapter 2 discusses the primary existing methodologies of productivity measurements, and explains why the method of MFP with the Törnqvist-Theil index numbers is chosen as the appropriate measurement. Moreover, it demonstrates how the indexing procedure is applied in the study.

2.2 Literature of Productivity Measurements

Methodologies of measuring MFP estimations are various and have their own different merits and drawbacks depending on different conceptions and assumptions made. The principal methodologies include three categories: index numbers procedure, econometric model and a combination of index numbers approach and econometric techniques. A brief discussion of each approach is required as means of describing the rational for choice of methodology made for this study.

First, the index numbers approach has a significant advantage in that it is not limited by the number of outputs and inputs, and also degrees of freedom issues. The number and size of input and output data in productivity studies can be massive, but some other methodologies are constrained by data size. The index numbers approach has few conceptual defects and requires a number of strong assumptions. For example, outliers in the data, heterogeneity and measurement error issues could not be interpreted clearly by using index number measurements. The simple index numbers procedure is unable to provide measures of technical change, scale effects or technical inefficiency (Capalbo, 1988). Nevertheless, indexing approaches have been constantly applied and developed over the last few decades, generating more flexible functional forms and relaxing some assumptions required.

The econometric procedure can measure the shift in the production and cost function, and estimate effects of technology changes on production (Antle and Capalbo, 1988). Compared to the index numbers approach, it appears more flexible due to fewer strong assumptions, and heterogeneity and measurement errors can be accommodated in the framework. However, when applying the econometric approach input-output separability must be assumed, which means that outputs are required to be aggregated into a single index (Capalbo, 1988). In agricultural economics, this assumption is worth careful consideration, because the numbers of inputs are generally shared in multiple outputs in agricultural production.

A procedure of combining the index numbers approach with econometric techniques can bring the merits of both approaches and overcome some deficiencies mentioned above. However, the procedure requires more computational complexity and imposition of additional distributional assumptions. Estimation errors issues may be addressed when using a relatively small dataset (Darkuet al., 2012).

The index number approach is adopted in this study. Given the large number of agricultural inputs and the need for “separability” assumption, the econometric approach and the combined approaches are both ruled out. Because the index number approach is chosen this leaves the important question of which index number approach can minimize its conceptual deficiencies.

Among various index approaches, there are generally two types, fixed-weight approach (Laspeyres and Paasche indexes) and flexible-weight approach (Divisia index and Törnqvist-Theil index). Both types are discussed in the following sections.

2.3 Fixed-Weight Approach: Laspeyres and Paasche Indexes

Aggregation of input and output data can be processed by employing indexing procedures. Choosing an appropriate indexing procedure is critical to measure productivity gains. The Laspeyres and Paasche indexes are basic and the most conventional procedures, discussed in order to provide an assessment of two indexing numbers.

Simplicity is an advantage of the Laspeyres index. Many national statistical institutions apply it to measure general productivity gains, such as GDP growth rates. The Laspeyres input quantity index can be written as:

$$\frac{X_t}{X_{t-1}} = \frac{\sum_{i=1}^{n} p_{i,t-1} x_{i,t}}{\sum_{i=1}^{n} p_{i,t-1} x_{i,t-1}} \qquad (2.1)$$

where X_t is aggregate input in period t; X_{t-1} aggregate input is in period t-1, which is the base period; p and x represent input price and quantity, respectively. The Laspeyres index calculates changes in quantity by holding base period prices fixed.

The feature as well as the shortcoming of the Laspeyres index is using fixed prices in the base period to measure quantity changes for continuous periods. Calculation of input expense in each period is related to price in the previous period rather than the concurrent period. Thus, a bias of measurement occurs due to the overlooking of the price effect on quantity in the same period. For example, in an agricultural productivity study, a drought in year *t* can affect yields and prices in that period or further. The productivity results are sensitive to the choice of a base period. In this case, it would be biased in choosing year *t* as the base period.

Another criticism is that the Laspeyres index implies perfect substitution between all inputs, because the index is an underlying linear production function (Christensen, 1975). However, inputs in most production processes are not perfect substitutes, especially in agricultural production.

The Paasche index resembles the Laspeyres one, except it applies the end periods for weighting. The input index can be written as:

$$\frac{X_t}{X_{t-1}} = \frac{\sum_{i=1}^{n} p_{i,t} x_{i,t}}{\sum_{i=1}^{n} p_{i,t} x_{i,t-1}} \qquad (2.2)$$

The Paasche index implies that inputs are perfect complements (Antle and Capalbo, 1988). This inflexible assumption means the Paasche index cannot be satisfactory to deal with reality.

In conclusion, both the Laspeyres and Paasche indexes share a problem of their choice of weighting period. Employing either base period or end period to weight in aggregation can generate a bias in results. As an example, the measurement of quantity changes can be underestimated during the period of increasing prices, by using the Laspeyres index. In the same circumstance, the measurement can be overestimated by using the Paasche index.

2.4 Flexible-Weight Approach: Divisia Index and Törnqvist-Theil Index

Divisia (1926) introduced a flexible-weight index approach to measure continuous price and quantity indexes over time. Divisia index is a continuous time weighted sum of the growth rates of variables. The expressions of Divisia index are as followings:

$$Q_t = \sum_{j=1}^{m} \dot{p}_{j,t} \widehat{q_{j,t}} = \left(\frac{p_{j,t} q_{j,t}}{R}\right)\left(\frac{\partial q_{j,t}/\partial t}{q_{j,t}}\right) \qquad (2.3)$$

$$X_t = \sum_{i=1}^{n} \dot{w}_{i,t} \widehat{x_{i,t}} = \left(\frac{w_{i,t} x_{i,t}}{C}\right)\left(\frac{\partial x_{j,t}/\partial t}{x_{j,t}}\right) \qquad (2.4)$$

where p and w are prices of output and input; q and x are quantities of output and input; R is total revenue and C is total cost. $\dot{p}_j$ is the revenue share of output j while $\dot{w}_j$ is the cost share of input i; $\hat{q}$ and $\hat{x}$ represent growth rates of output and input, respectively, in period t.

Shares of revenue and cost provide weighted proportions of various components. They are flexible over time which allows for both the base period and comparison period to be taken into account, solving problems of the fixed-weight approach stated above. Implementation of the Divisia index requires a discrete approximation. As a second-order approximation of the Divisia index, the Törnqvist-Theil index is commonly used by many countries and institutions to measure official price and productivity statistics.

The Törnqvist-Theil index is a weighted price index across discrete time periods applying weighted averages of growth rates in prices based on weighted shares of quantity over the two periods (Tornqvist, 1936). Being one of the *superlative* indexes is a reason why the Törnqvist index is frequently adopted.

As defined by Diewert (1987), if the index formula is *exact* for a homogeneous aggregator functional form, it is a *superlative* index. The Törnqvist-Theil index turns out to be exact for the linear homogeneous translog production function. The flexible functional form releases the limitations of perfect substitutions or complements between factors of production, permitting flexibility in inputs' elasticity of substitution. Therefore, more practically, different effects of factors on productivity, such as technology changes, returns to scale, etc., can be examined in an empirical framework with applying the Törnqvist-Theil index.

2.5 MFP Measurement Using the Törnqvist-Theil Indexing Procedure

Kendrick (1961) and Denison (1962) developed a growth accounting method by regarding MFP as a residual measure. The method is capable of estimating the contributions of input growth, scale impact, efficiency and technological change to output growth. Compared to partial factor productivity measurement, MFP is more conceptually advanced by adopting overall factor inputs. MFP measurement can provide more insights to policy making, by examining determinants of productivity growth, effects of research and development investments on productivity, degree of efficiency, etc. In this study, the Törnqvist-Theil index is applied to estimate MFP growth rates.

The study measures MFP growth rates with the Törnqvist-Theil indexing procedure, by calculating growth changes of outputs (Q^T) and inputs (X^T). The formulas are as follows:

$$MFP^T = Q^T - X^T$$

$$Q^T = \sum_{j=1}^{m}\left(\frac{r_{j,t}+r_{j,t-1}}{2}\right)(lnq_{j,t} - lnq_{j,t-1})$$

$$X^T = \sum_{i=1}^{n}\left(\frac{s_{i,t}+s_{i,t-1}}{2}\right)(lnx_{i,t} - lnx_{i,t-1}) \qquad (2.5)$$

where *r* is the revenue share of output j, and *q* is the quantity of output j*;* *s* is the cost share of input i, and *x* is the quantity of input i.

For the Törnqvist-Theil index, its properties of the translog functional form as well as the arithmetic average of shares across two periods have proven it superior to the Laspeyres and Paasche indexes. As a conclusion, to study agricultural productivity with a large number of factor inputs and outputs, choosing the Törnqvist-Theil index turns out to be the most appropriate practice to measure MFP growth rates.

CHAPTER 3: INPUT AND OUTPUT DATA

3.1 Introduction

The measurement of productivity gains in this study requires both price and quantity data on inputs and outputs of crop production in Saskatchewan. With the study objective of estimating productivity growth for individual crops, partial crop budgets and price index data that have detailed information at the disaggregated level are needed.

3.2 Data Sources

The dataset of this study is comprised of three parts: Crop Planning Guide, acre measurement and farm input price index. Not all data can be collected directly from public databases and publications, so data processing is required. Additional conversion, imputation, weighting, and extrapolation of data are also explained in the following sub-sections.

3.2.1 Crop Planning Guide

The primary source of data is the Crop Planning Guide (CPG), providing information of input expenses, output prices, and yields of crop production to this study from 1993 to 2013. CPG is a partial crops budget provided annually by the Saskatchewan Ministry of Agriculture (Saskatchewan Agriculture, 2013). This guide provides estimates of both yields and costs of production for various crops on both summer-fallow and stubble in the three main soil zones (Brown, Dark Brown and Black) of Saskatchewan.

It is notable to point out that the budgeting figures of CPG are *ex ante* yields and production costs, which are forecast for the coming crop year based on historical statistics and numerous general assumptions (see Appendix B). This implies that CPG estimates are not always consistent with statistics of respective years or each farm's observed yields and production costs. Compared with *ex post* data, the most significant difference is that *ex ante* data exclude weather impact on output and input uses. Consequently, relatively smooth changes in output and productivity growth over years are expected.

CPG presents information related to different major crops in Saskatchewan on both summer-fallow and stubble in various soil zones. The study considers six individual crops: *spring wheat, durum wheat, feed barley, feed peas, large green lentils and canola*. Each crop sector is classified into at most nine sub-groups: each crop-category contains three groups of soil zones (i.e., Brown, Dark Brown and Black) and each group of soil zone contains three sub-groups of technologies (i.e., summer-fallow, conventional tillage and zero tillage).[6] There are 45 sub-groups generated in the study.[7] Each sub-group is independent to estimate productivity growth rates. Also, all sub-groups are considered as the foundational basis for aggregations of levels of soil zones, technologies and crop species.

CPG measurements of yields, prices and costs of production are provided with the unit of *per acre*. Consequently, data of total acres of each crop, and crop acre in each soil zone and also with each technology, are required in order to calculate aggregated measurements of production and costs. For example, given data of both acres and yield per acre of summer-fallow spring wheat in each of the three soil zones, total output of summer-fallow spring wheat at levels of both soil zone and province can be estimated with multiplication and summation. The same procedure can be applied to estimate outputs and inputs of other specific crops at the soil zone, technology and provincial level.

The period in the study is between 1993 and 2013. CPG dated from 1987, but documents of the first five years have different formats and incomplete information compared to the subsequent years' documents. Thus, data during the 1987-1992

[6] In CPG documents, conventional tillage is described as "conventional seeded stubble" and zero tillage is described as "direct seeded stubble".

[7] Estimates for few crops in certain soil zones and during few years are not provided in the Crop Planning Guide. The absent sub-groups include peas in the Brown Soil zone, canola the intheBrown Soil zone, and durum wheat in the Black Soil zone, which are 9 sub-groups in total.

period are not applied in this study. It is worthy to note that not all sub-groups share the same time series. One exception is the period of data for feed peas - from 1993 to 2012, because that in 2013 CPG started to provide estimates for edible peas instead of feed peas. Also, CPG terminates estimates for stubble seeded crops using conventional tillage after 2009. Other ones are found in groups of fallow seeded large green lentils and feed peas in 2012 and 2013.

With additional data processing, there are three major adjustments of CPG data being made in order to improve the dataset of this study:

1) As shown in CPG, it separately provides expenses of the “summer-fallow” category (e.g., herbicides, machinery, utilities) and expenses of the “fallow seeded crops” category, so an aggregation of the two categories is required in order to calculate total expenses of summer-fallow crop production. Given that the “summer-fallow” category consists of “tillage fallow” and “chem fallow”, the first step is to calculate a weighted summation of total summer-fallow expenses, based on the percentage of each fallow acre. In order to estimate percentage shares of tillage fallow and chem fallow in total summer-fallowed land, the data are derived from the Census of Agriculture between 1991 and 2011, and geometric means of every two census years are calculated for intercensal years (Statistics Canada, 2012). For 2012 and 2013 year, values are measured with the help of the forecast function in Microsoft Excel. The second step is to add total summer-fallow expenses to expenses of fallow seeded crops, resulting in total expenses of summer-fallow crops. Thus, total expenses of summer-fallow crops in each year during the 1993-2013 period are measured by the above two steps.

2) The expenses category of “custom work and hired labour” in CPG is divided into two individual categories (i.e., “custom work” and “hired labour”) with weighted averages. The averages are weighted based on their expense ratios, for which the data are collected from CANSIM database of Statistics Canada.

3) In CPG, the “labour and management” category provides *ex ante* expenses of operators’ labour and management. The data have been terminated since 2000 and it is

suggested farmers are to determine their own costs.[8] In this study, post-2000 measurements are calculated according to the formula used in CPG, which is labour and management cost per acre is equal to living costs divided by cultivated acres. The related data are collected from Statistics Canada. Consumer Price Indexes of all items in Saskatchewan are applied to measure living costs. Measurements of cultivated acres in 2001, 2006 and 2011 are derived from the Census of Agriculture. In terms of values of other years, both the geometric means method and the forecast function in Excel are applied to estimate.

3.2.2 Acres Measurement

Measurements of crop acres of each sub-group are the second component of the dataset. The data are estimated with the help of the Prairie Crop Energy Model (PCEM), based on *ex post* data derived from Statistics Canada. PCEM is developed to measure the regional impacts of different farming practices on non-renewable energy use in Prairie agriculture, among various crops and crop districts (Nagy, 2001). In this study, the model is applied to estimate acres of different crops with summer-fallow, conventional tillage and zero tillage in each crop district in Saskatchewan during the 1993-2013 period. The detailed measurements are presented in Appendix A.[9]

3.2.3 Farm Input Price Index

Lastly, data of farm input price index are necessarily required to estimate productivity growth. The data are mostly collected from Statistics Canada (i.e., CANSIM database and the Census of Agriculture), and the Saskatchewan Ministry of Agriculture. CPG documents also provide partial price information, such as commercial seed, fuel and fertilizer prices. Awada and Gray's (2014) dataset is an additional source for some data which are unavailable in public databases and publications.

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[8] The CPG explains that the value "varies greatly and depends on both the farm manager's needs as well as the ability of the farm to generate income".

[9] The model assumes that summer-fallow acres of feed barley, lentils and peas are zero due to their acres are not considerable.

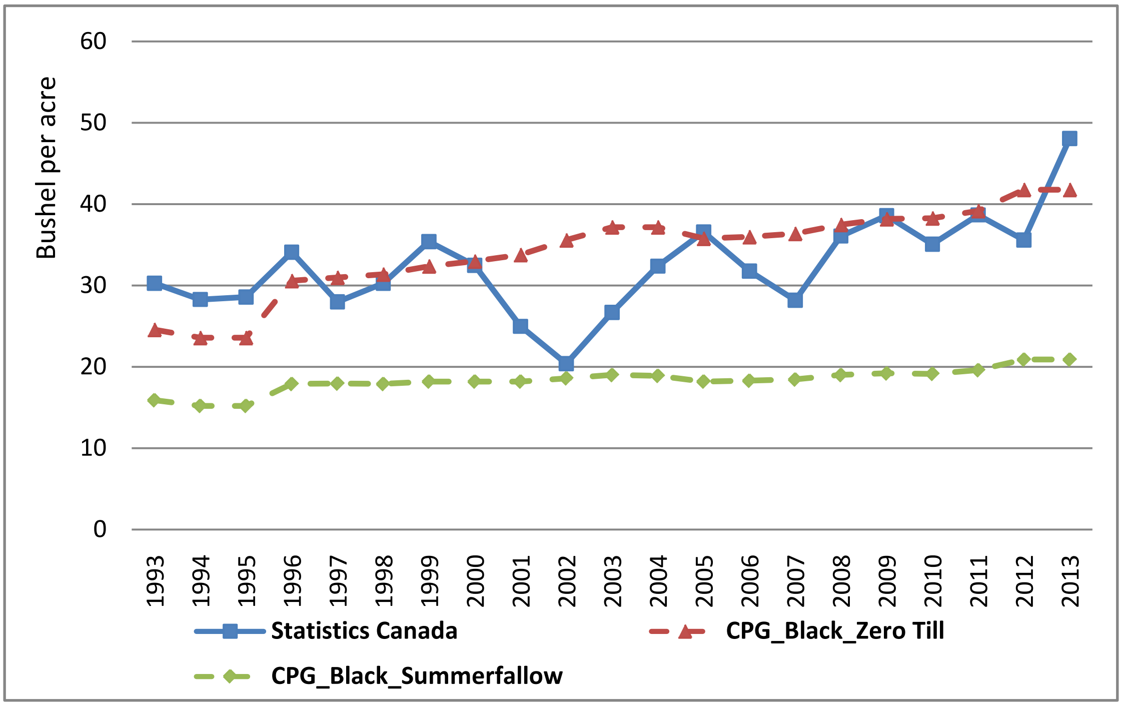
The data during the study period of 1993-2013 consists of three CANSIM tables: Table 328-0001: 1986-1999; Table 328-0014: 1998-2007; and Table 328-0015: 2002-2013. However, these tables have some inconsistencies in terms of formats and contents. For example, Table 328-0014 presents input data at geographic levels of only Canada, Eastern Canada and Western Canada, rather than looking at individual provinces (other two tables provide data of individual provinces). It implies that Saskatchewan data of the partial time series are unavailable in Statistics Canada. In this case, Western Canada data are adopted as a substitute. Another inconsistency is that contents of a few inputs are terminated during some periods. The inputs include pesticides, land, building depreciation, machinery depreciation, machinery repair, and custom work. Awada and Gray's (2014) dataset provides price indexes of those inputs.

3.3 Crop Outputs

As explained above, data at disaggregated levels are unavailable in Statistics Canada or other public datasets until this issue is solved by the existence of the CPG documents. In this study, output data derived from CPG are *ex ante* yields per acre of various crops in different soil zones and with different cropping systems during the 1993 - 2013 period. This series of data is different from *ex post* data such as Statistics Canada data, showing a more stable trend over time. Figure 3.1 shows comparisons between them by presenting an example of spring wheat yield.

In the comparisons of yields per acre, there are three groups presented as an example: spring wheat (derived from Statistics Canada), summer-fallow spring wheat in the Black Soil zone (derived from CPG) and zero tillage spring wheat in the Black Soil zone (derived from CPG). As the figure shown, the *ex ante* data of CPG have more stable trends than the *ex post* data of Statistics Canada, exhibiting relatively smoother curves. The reason why the CPG data curves are smoother is mainly because CPG excludes the climate factor (e.g., rainfall) affecting agricultural production, projecting expenses and output of crop production of the following year without considering climate effects. For example, it is apparent to see that *ex post* yields dropped in 2002 due to drought, but not reflecting in *ex ante* data. Overall, the trends shown by the two data sources seem to be similar in a long-term perspective.

Figure 3.1 Statistics Canada VS. Crop Planning Guide: Spring Wheat Yield, 1993-2013



Source: Statistics Canada (2013b). Table 001-0017; and annual Crop Planning Guide (Saskatchewan Agriculture, 2013).

3.4 Crops Inputs

To accomplish significant MFP measurements, it is critical to properly apply production input prices and quantities. The factor inputs used to measure productivity in this study are derived from Crop Planning Guide documents. In order to organize numerous inputs, a relatively common classification method is applied in the study. The categories of inputs are classified into four categories: capital, land, labour and materials (Adamowicz, 1986 and Stewart, 2006). Table 3.1 displays the composition of inputs used in the study. In the next two sections, changes of inputs price index and quantity index over the study period are presented and discussed, based on the four input categories.

Table 3-1 Inputs Summary for Crops Activity

Capital / Land	Labour / Materials
Capital • Machinery and equipment investment • Machinery and equipment depreciation • Machinery and equipment repair **Land** • Land • Building investment • Building repair • Building depreciation • Property tax	**Labour** • Paid labour • Unpaid labour **Materials** • Seed • Fertilizer, including Nitrogen and Phosphorus • Chemical, chiefly Herbicides, • Machinery operating, including Fuel, Repair • Custom work • Utilities & Miscellaneous

3.5 Price index

The following four figures display how price indexes of each input have varied over time, classified by the four categories (i.e., capital, land, labour and material). The base year is 2002. During the period between 1993 and 2013, all input prices experience increase trends to varying degrees.

1) For the Capital category, the price indexes have climbed steadily over time. The price index of machinery and equipment has the largest rise by over 200%. Both depreciation and repair price indexes show an over 50% increase.

2) The price indexes of the Land category generally have nearly doubled during the 20 years. Building prices increased rapidly since 2001 and reached a peak in 2008. Both land and building depreciation price indexes have shown a dramatic rise to a record in 2012 but decreased in the subsequent year.

3) The Labour category contains unpaid labour (farmer labour) and paid labour (hired labour). The price index of unpaid labour has risen by 55% while paid labour has increased by nearly 250%. After 2001, the higher relative increase in rates of paid labour to unpaid labour caused a divergence between these two inputs which had kept the similar increasing pace before 2003. This divergence has been driven by the oil boom that has driven up the cost of skilled labour.

4) Many ups and downs of price indexes are observed in the Material category, because material input prices are quite variable in the market. Especially after 2001, most input prices have shown fluctuating increases. For inputs of seed, nitrogen, phosphorus, fuel and custom work, the prices have more than doubled over the period. Specifically, custom work price began to climb since 2005 and then increased dramatically between 2010 and 2012. By contrast, herbicide and utility prices have relatively not changed much during the period.[10]

[10] Some farm input price indexes (e.g. seed of various crops, chemical, fertilizer, and fuel) are derived from the Crop Planning Guide, which are estimates projected for the following crop year. In Figure 3.5, the seed price index is presented by general seed prices which are derived from Statistics Canada.

Figure 3.2 Capital Category Price Indexes, 1993-2013 (2002 = 100)

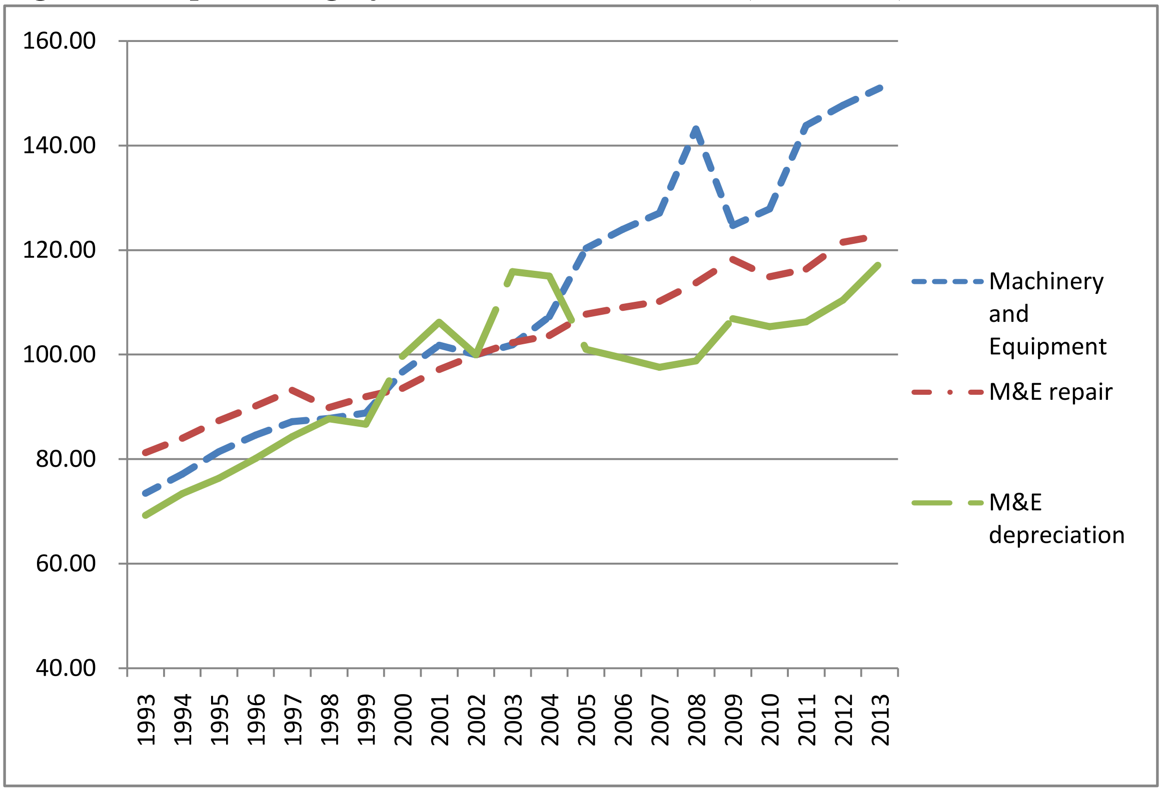


Figure 3.3 Land Category Price Indexes, 1993-2013 (2002 = 100)

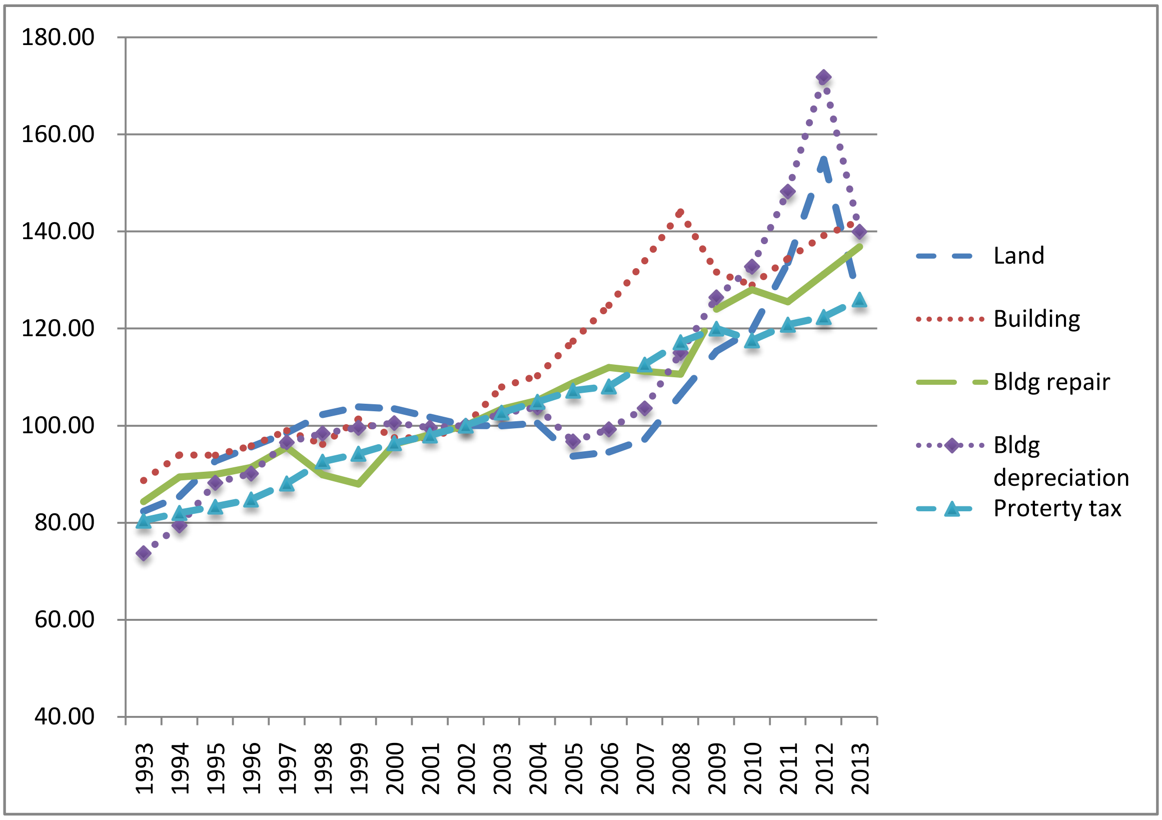


Figure 3.4 Labour Category Price Indexes, 1993-2013 (2002 = 100)

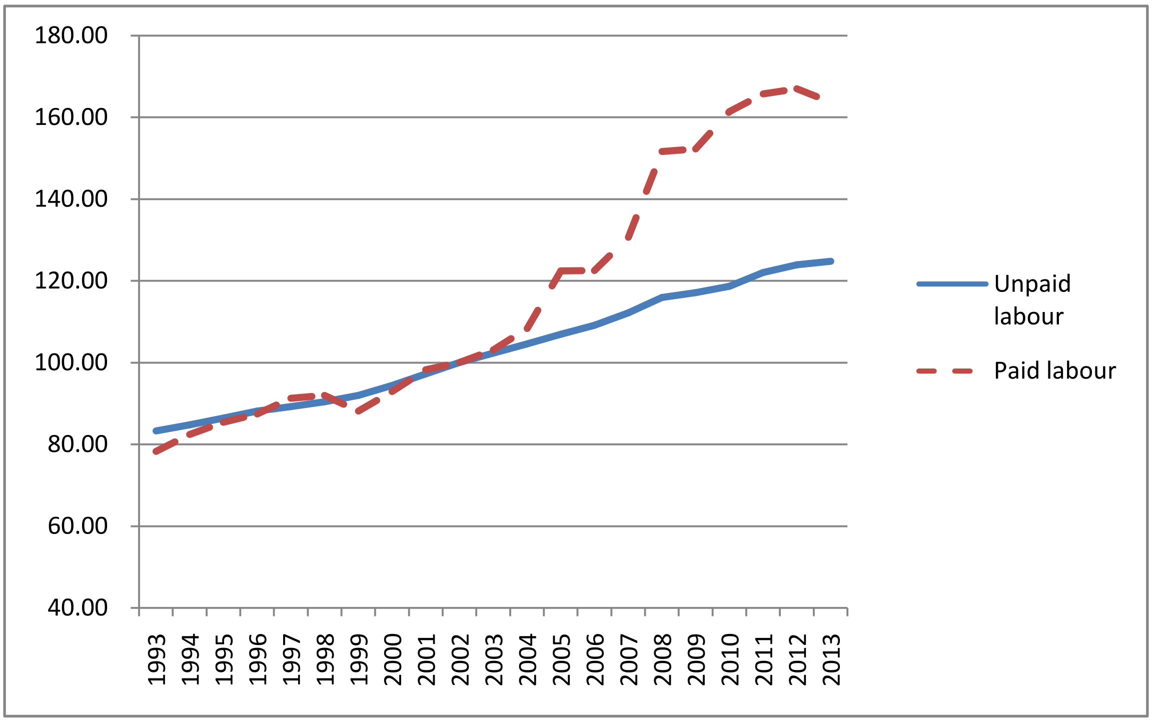
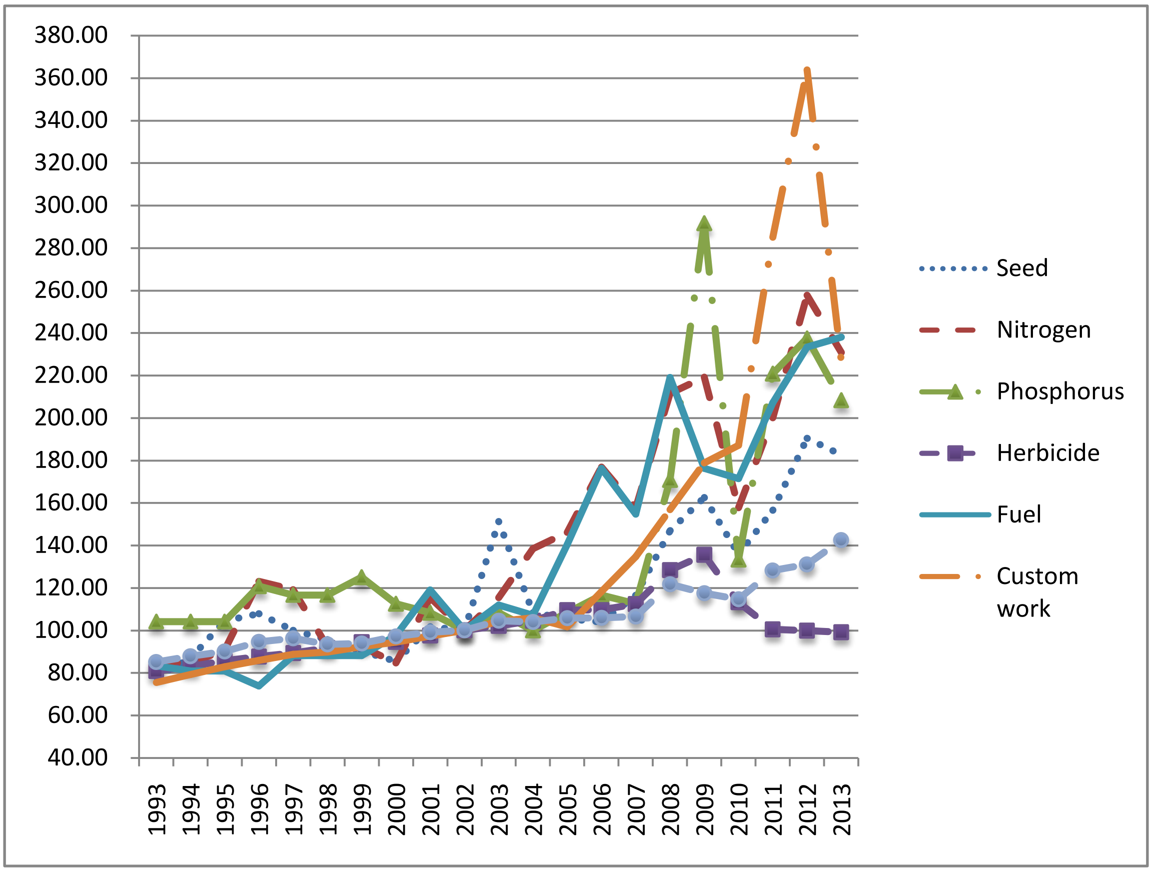


Figure 3.5 Material Category Price Indexes, 1993-2013 (2002 = 100)



3.6 Quantity index

In this section, quantity indexes of inputs applied to grow canola with zero tillage practice in the Dark Brown Soil zone are presented, as one example of other specific crops, to explain trends of input quantity uses over time. The quantity indexes are calculated based on both *ex ante* expenses per acre derived from CPG and price indexes shown in the previous section. Figure 3.6-3.9 demonstrate the four categories of input quantity indexes between 1993 and 2013.

1) In the Capital category, quantities of both M&E (machinery and equipment) and M&E repair have declined significantly after 2005. M&E depreciations quantity index as well as expenses provided by CPG have increased continuously over the 20 years.

2) Quantity indexes of buildings, building repair and building depreciation have shown declining trends between 1993 and 2013.[11] Cropped land quantity index decreased largely in 1999 and stayed relatively stable afterwards. Property tax quantity index have shown the least fluctuations over time.

3) During the 20 years, unpaid labour quantity index gradually decreased by 34.2%. Quantities of paid labour required for the crop production have increased largely from 2005 to 2013, by over 65%.

4) Quantities of seed, herbicides, and utilities applied to canola grown under zero tillage systems have not changed much during the period. Between 2011 and 2013, it can be seen that quantity indexes of custom work, nitrogen and fuel have shown an obvious increase trend.

[11] There was a rapid drop of building repair quantity index observed in 2011-2012 period. Because the *ex ante* expense of building repair significantly decreased by 60%, from $1.25 per acre in 2011 to $0.5 per acre in 2012, meanwhile the price index increased by 4.5%. This is an example to explain that CPG adjusts *ex ante* estimates of few inputs significantly, which may create an obvious (even unreasonable) increase or decrease in a short term. However, there are only a few data like this, which can merely affect measurement of MFP growth rates. Another example is custom work quantity index in 2013, which is exceptionally higher than before.

Figure 3.6 Capital Category Quantity Indexes, 1993-2013 (2002 = 100)

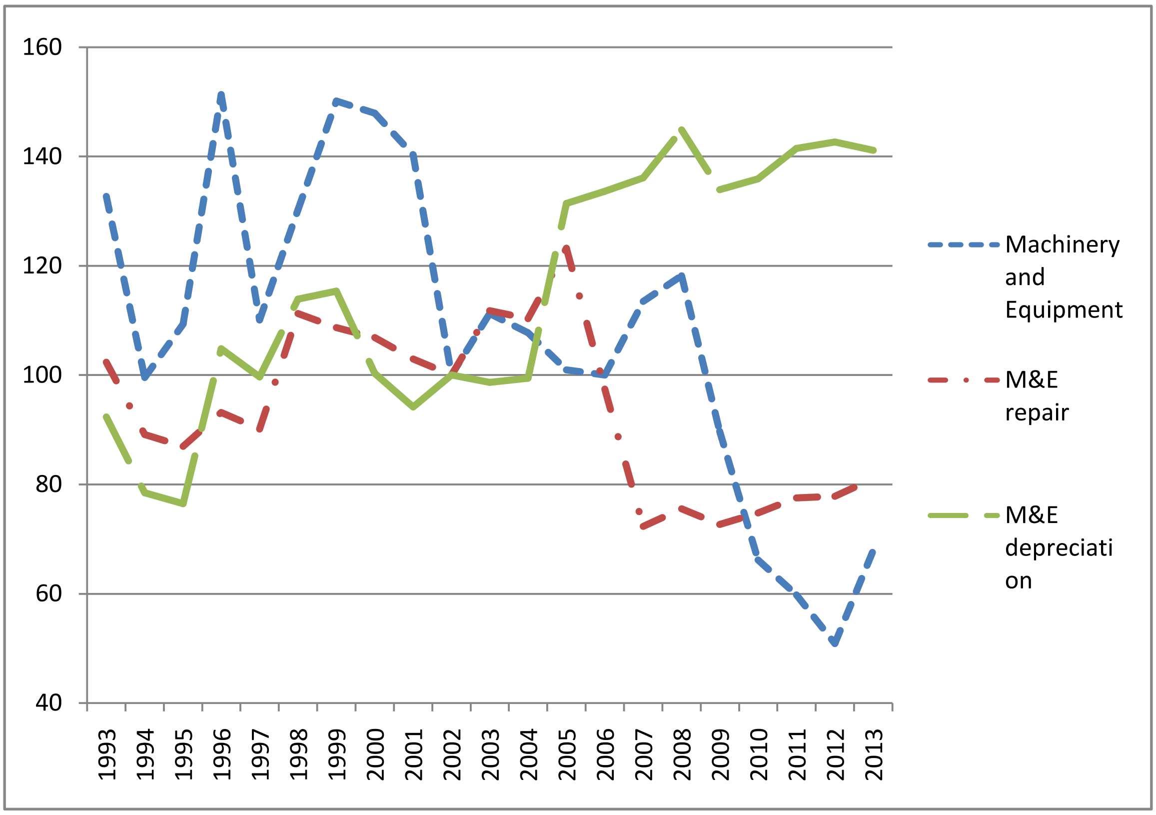


Figure 3.7 Land Category Quantity Indexes, 1993-2013 (2002 = 100)

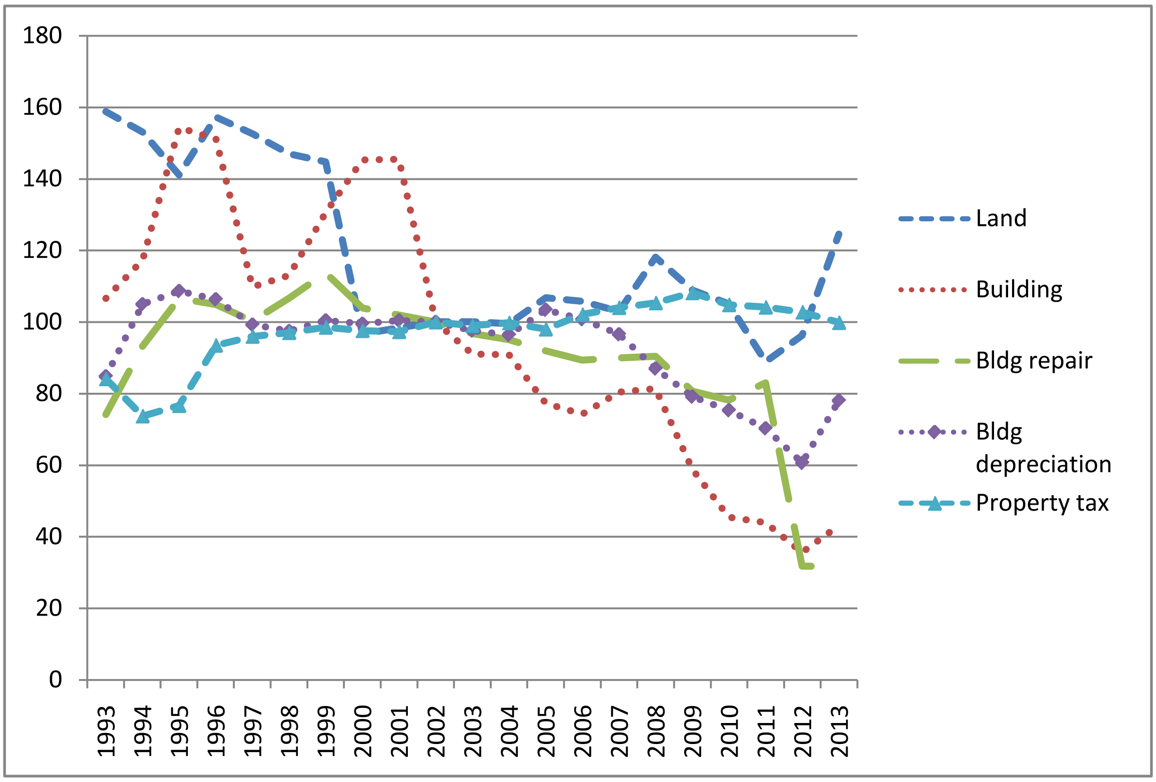


Figure 3.8 Labour Category Quantity Indexes, 1993-2013 (2002 = 100)

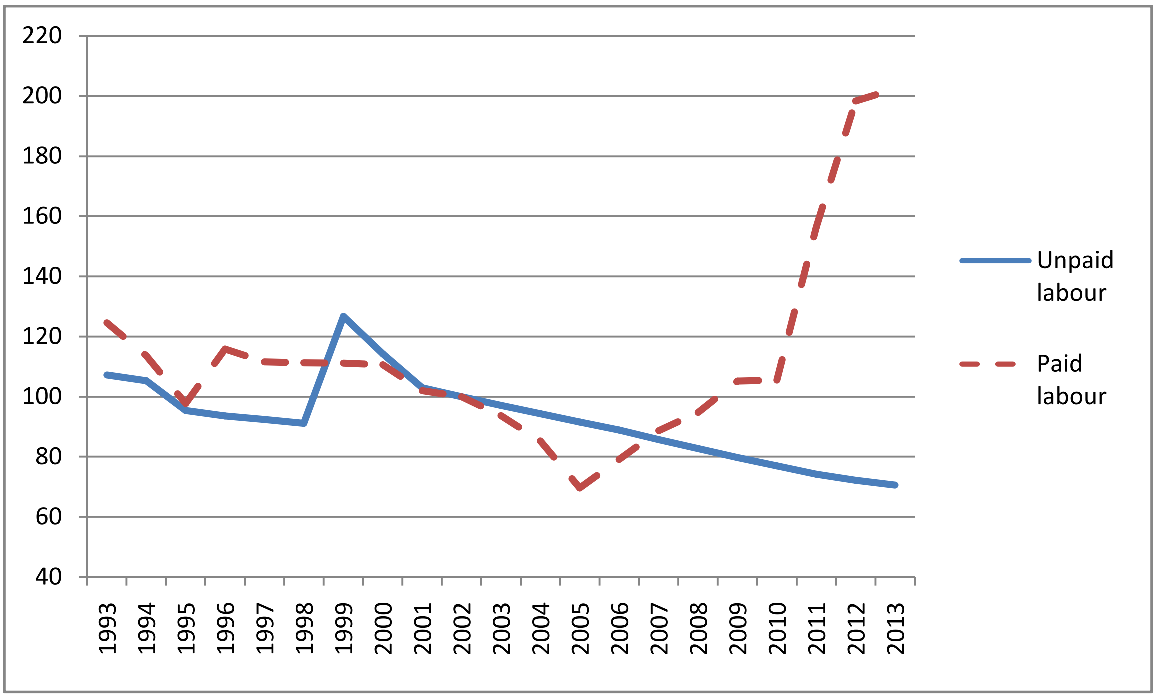
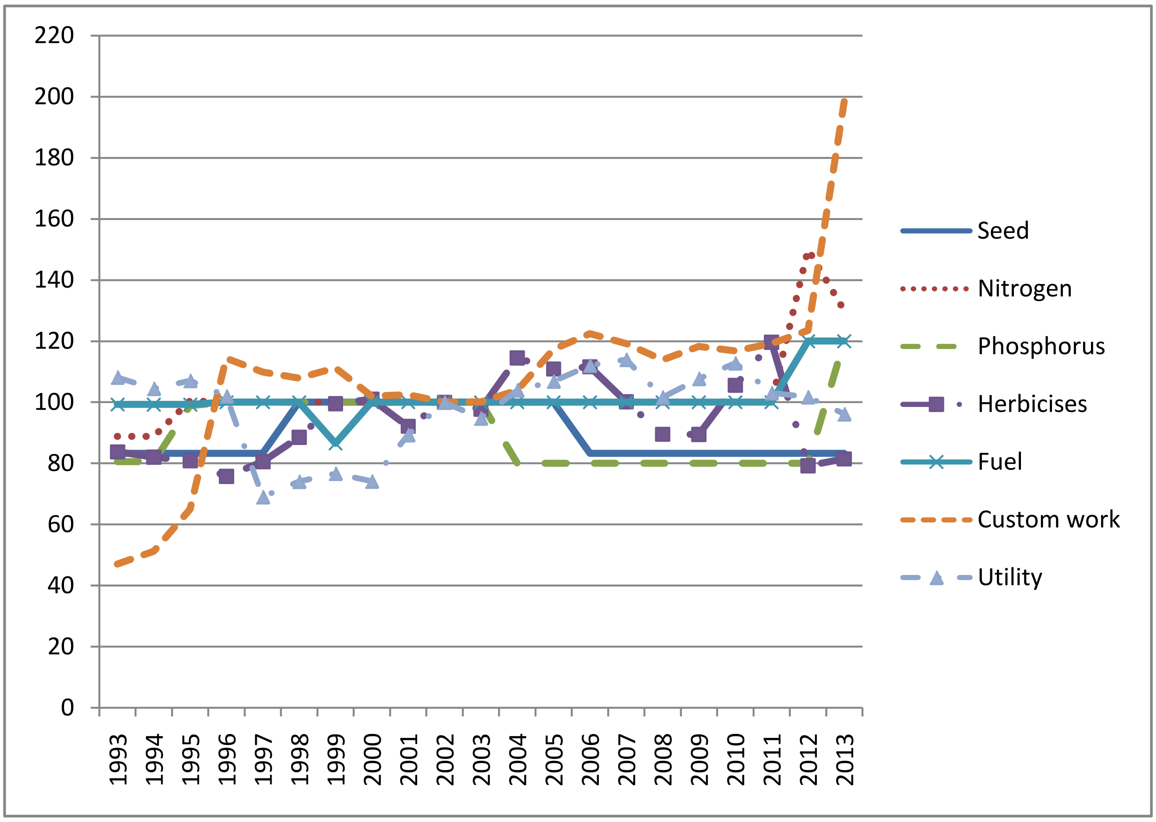


Figure 3.9 Material Category Quantity Indexes, 1993-2013 (2002 = 100)



CHAPTER 4: EMPIRICAL RESULTS OF PRODUCTIVITY PERFORMANCE: CROP SPECIES

4.1 Introduction

As described in Chapter 1, the goal of this thesis is to use partial budgets from the Crop Planning Guide to estimate MFP growth rates for various crops, soil zones and cropping systems within the Saskatchewan crop sector. In Chapter 2 the theory and general methodologies used for MFP analysis were outlined. In Chapter 3, the data and the specific methodology used in this study were described. This chapter reports the MFP research findings at the most disaggregated level by reporting the MFP for each crop in each soil zone and with each cropping system. The MFP aggregated to the level of each crop using the Törnqvist-Theil index procedures and acres for each sub-group are also reported and discussed in this chapter. In Chapter 5, MFP estimates are used to compare wheat and canola growth rates over time as a case study and demonstration of how crop specific MFP estimates can be used.

This chapter begins with a brief description of the methodology used to calculate compound annual growth rates. Section 4.3 reports MFP growth estimates for each crop-soil zone-seeding practice activity. Section 4.4 reports MFP growth estimates aggregated to the crop level for each of the six crops. Section 4.5 provides a more detailed reporting and discussion of MFP changes over time for each crop. Section 4.6 concludes the chapter.

4.2 Compound Annual Growth Rate

In the study, MFP growth rates are calculated in terms of compound annual growth rate (CAGR). It is an assumed value that describes the rate at which a number would have grown, under the assumption that growth rate is steady over the period. The expression of CAGR can be written as follows:

$$\mathrm{r} = \left(\frac{V_t}{V_0}\right)^{\left(\frac{1}{Y}\right)} - 1 \qquad (3.1)$$

where V_t is ending value, V_0 is beginning value and *Y* is numbers of years over the period. The calculation of CAGR means that V_0 has increased or decreased to V_t at a constant growth rate of *r* during the period of *Y* years.

For the remainder of the thesis the CAGR formula reported above is used to describe MFP, output and input growth rates. It is important to note that CAGR is can be very sensitive to the choice of beginning and end points. This implies that any variation in trend over time may not be fully represented by CAGR which just compares beginning and ending values. Often a regression time trend or other approaches are used to fit the data. Given the relatively smooth output from *ex ante* estimates, the data end points were used to impute growth rates. The imputed compound growth rates are able to indicate a general tendency over a long time period. For the sake of completeness the figures showing annual changes in MFP, outputs and inputs are presented in Figures 4.4 to 4.9 to provide further insights into productivity performance.

4.3 Activity Level MFP Growth Rates

In Sector 4.3 and 4.4, the primary results of MFP performance in individual Saskatchewan crops are fully displayed in the figures, at both disaggregated and aggregate levels. Facing the abundant number of results, a detailed discussion is necessary. This sector points out the most significant findings based on the results at a disaggregated level. Moreover, Sector 4.4 reports how individual crops have grown in productivity related to soil zone types and cropping systems by individually providing a detailed discussion for each crop sector.

4.3.1 Overview of Disaggregated MFP Growth Rates

Figure 4.1 illustrates MFP compound annual growth rates of all 45 sub-groups which contain six crops in three different soil zones and with three different technologies. There are three categories based on the following soil zones: Brown, Dark Brown and Black. Each soil zone category is comprised of three farming practices: summer-fallow, conventional tillage and zero tillage. According to various colours of crop names shown in the figure title, results of each specific crop with each sub-group can be matched correspondingly.

Overall, MFP growth rates of all sub-groups distribute in the range between 1.16% and 5.62%. It is apparent that most crops' productivity has grown at more than 2% per annum over time. The fastest growth rates are higher than 4.5% and are found in feed peas, lentils and canola sectors. Peas and canola, using conventional tillage in the Dark Brown Soil zones, have grown in MFP by about 5.5% each year. By contrast, spring wheat and lentils with summer-fallow seeding in the Dark Brown Soil zone have shown the lowest annual growth rates, at less than 1.3%.

4.3.2 The Impact of Soil Zone

The soil environment is a vital factor of agricultural production, which also reflects long term climatic differences. In Southern Saskatchewan there are three main soil types including the Brown, Dark Brown and Black Soil zones. The Brown Soil zone is the most arid, and the Black Soil zone is the most humid. Comparing productivity gains of crops among three soil zones, the study results show that no soil zone has appeared an advantage or disadvantage in MFP growth rates. Nevertheless, to a certain extent, differences of the productivity performance among soil zones are expressed differently for different crops.

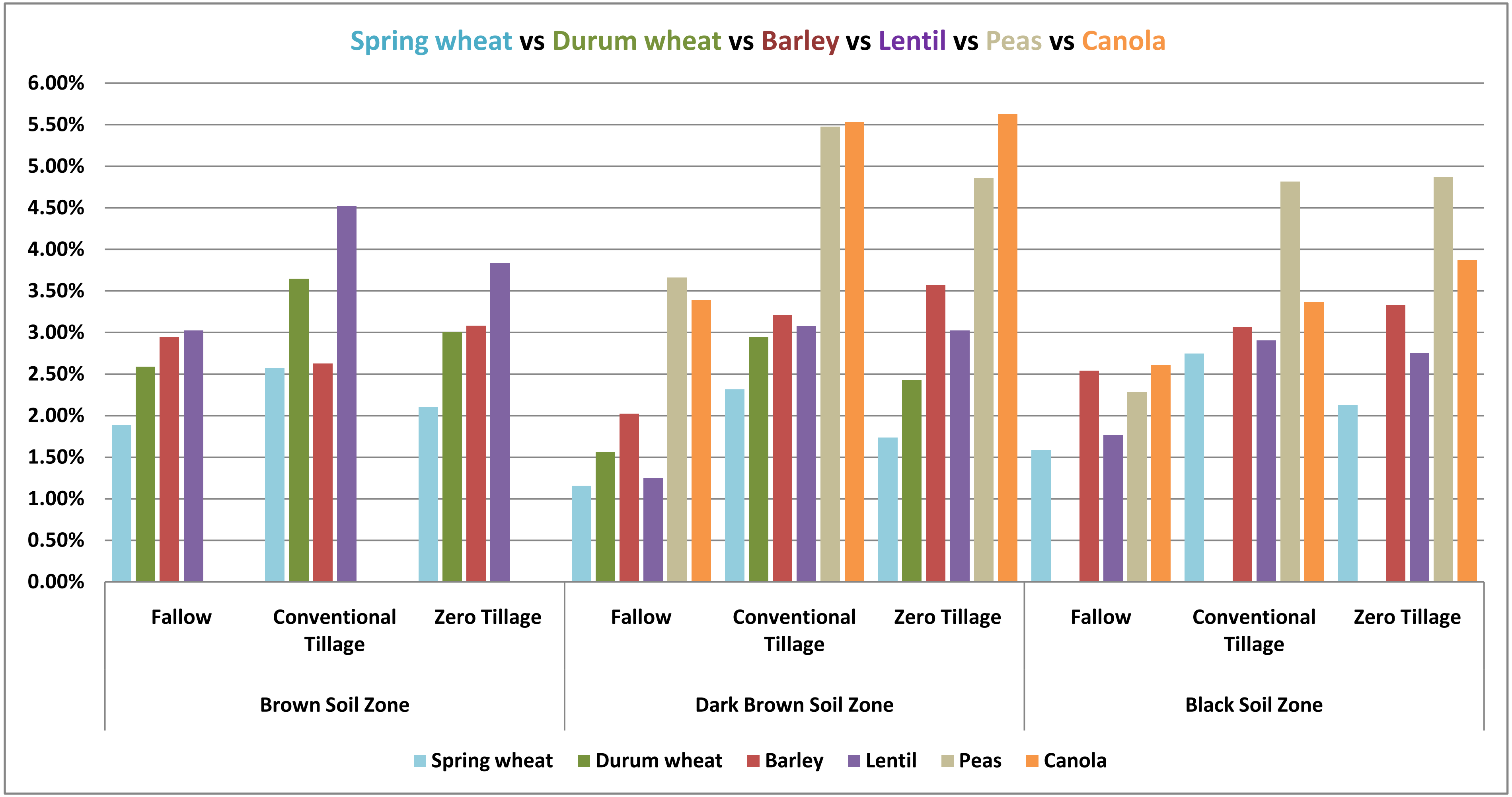
Spring wheat and barley are examples that demonstrate that crop's productivity did not vary in different soil zones over time. For durum wheat and lentils, crops in the Brown Soil zone showed modestly higher productivity growth rates than other soil zones. The productivity growth rates of peas and canola in the Dark Brown Soil zone turns out to be higher than the ones in the Black Soil zone.

4.3.3 The Impact of Cropping Systems

The mainstream of cropping system has shifted away from summer-fallow toward conventional and zero tillage practices. In Saskatchewan, summer-fallow acres accounted for less than 6% of total farming acres in 2011, decreasing from 21.2% in 1991. In 2011, remaining shares of farming acres were divided equally by acres under conventional tillage and acres under zero tillage (Statistics Canada, 2013a). Given this background, it is useful to compare MFP growth rates among cropping systems in order to reveal how productivity performances of crops using different farming practices have changed.

Based on the results, summer-fallow crops exhibited the lowest productivity growth rates lagging overall growth rates, observed in all soil zones. The only exception is found in barley using summer-fallow in the Brown Soil zone which has a MFP growth rate slightly higher than barley grown using with conventional tillage seeding in the same soil zone. With conventional and zero tillage practices, all crops have experienced more than 2% annual increase in productivity, with the exception of spring wheat under zero tillage practice in the Dark Brown Soil zone which shows only 1.73% growth rate.

Figure 4.1 Annual MFP Growth Rates, Crops in Saskatchewan, 1993-2013



4.4 Provincial Level MFP Growth Rates

In this sub-section, the productivity performance of individual crops in Saskatchewan during the 1993-2013 period are presented in forms of compound annual MFP growth rates, as shown in Figure 4.2. Figure 4.3 demonstrates output and input annual growth rates over the same time period.

4.4.1 Overview

According to Figure 4.2, all six crops have increased rates in the range of 2.56% to 4.68%. Specifically, feed peas and canola have grown in productivity at annual rates of over 4% (4.68% and 4.01%, respectively). Durum wheat's productivity has increased at 3.66% per year. The remaining crops (spring wheat, barley, and lentils) kept similar paces in the MFP gains, growing at around 2.60% per year.

The implication of MFP indexes represent not only how fast the productivity has grown, but also how much more productive the production has become over time. For spring wheat, barley and lentils, which have an annual growth rate of 2.6% during the 1993-2013 period, MFP indexes indicate that the productivity in the ending year was approximately 1.66 times more than in the beginning year. Durum wheat, with the growth rate of 3.66% per annum, has shown to be 2.05 times more productive than 20 years before. In the canola sector, it was 2.2 times more productive. With the fastest productivity growth among six crops, feed peas in 2012 were 2.38 more productive than in 1993.

In Figure 4.3, output and input growth rates of six crops are presented individually. Briefly speaking, it can be observed that production of durum, lentils, feed peas and canola has increased considerably in 20 years while spring wheat and barley production has decreased by approximately 20% and 10%, respectively. In addition, inputs of both the spring wheat and barley sectors have experienced dramatic reductions due to fewer cultivated acres over the years. Durum wheat also showed a slight negative growth rate of input, while its production has risen. By contrast, inputs used to grow lentils and canola have increased by over 2.5% annually, still much slower than output growth. Additionally, the most obvious difference between input and output growth rates is found in the feed peas sector, which displays only 0.28% of input annual increase rate but 5.12% of output growth rate.

Figure 4.2 Annual MFP Growth in Saskatchewan Crops, 1993-2013

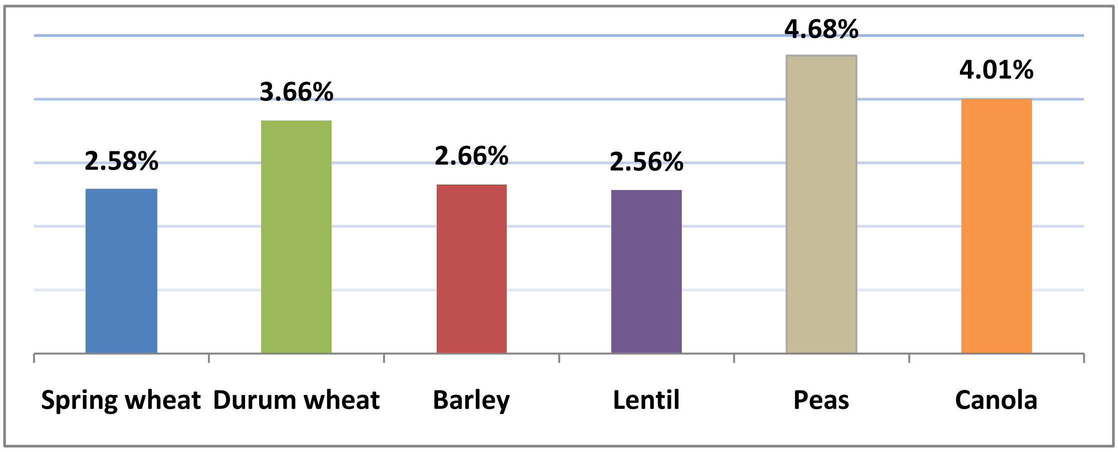
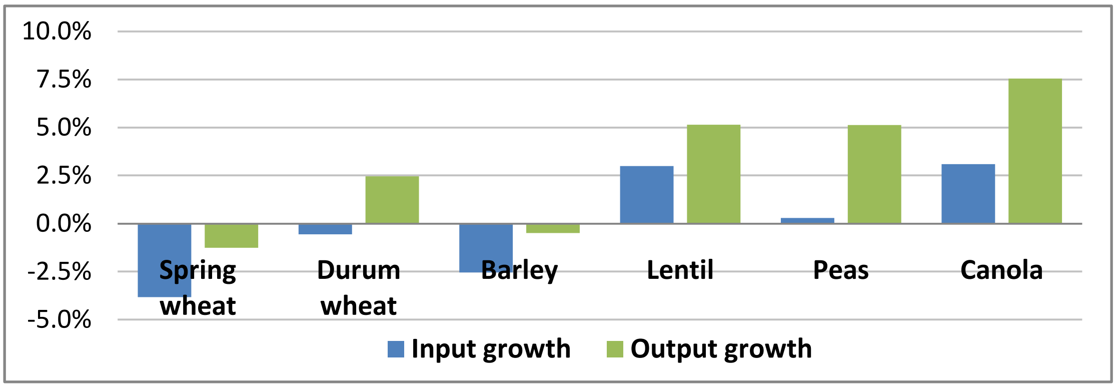


Figure 4.3 Output and Input Growth in Saskatchewan Crops, 1993-2013



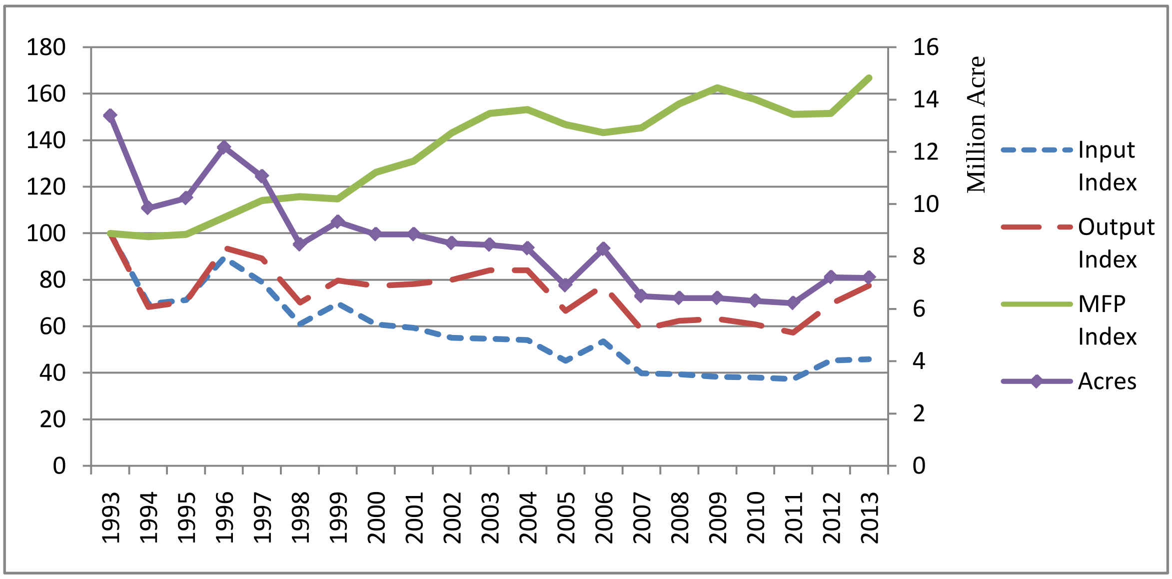
4.5 Productivity Performance: Individual Crop Sectors

The more disaggregated levels of productivity performance in the Saskatchewan crop sector are demonstrated in this section, by illustrating how output, input, acres and MFP indexes have changed over time for individual crops. It contains comparisons between soil zones and cropping systems in each crop sector in order to reveal more insights into crop productivity gains.

4.5.1 Spring Wheat

Spring wheat appears to be one of the slowest MFP growth crops in Saskatchewan. Overall, the MFP index of spring wheat has risen by nearly 67% between 1991 and 2013. Among various sub-groups of spring wheat, crops using summer-fallow procedure were found to be slowing down the overall productivity growth. In all three soil zones, the annual growth rates of summer-fallow spring wheat are under 2%, including the lowest rate of 1.16% in the Dark Brown Soil zone. Conventional tillage spring wheat showed the best productivity growth tendency, increasing modestly faster than spring wheat using other seeding practices. Comparing across soil zones, there is no considerable differences found, excluding that productivity of spring wheat in the Dark Brown Soil zones appears to grow more slowly than other soil zones.

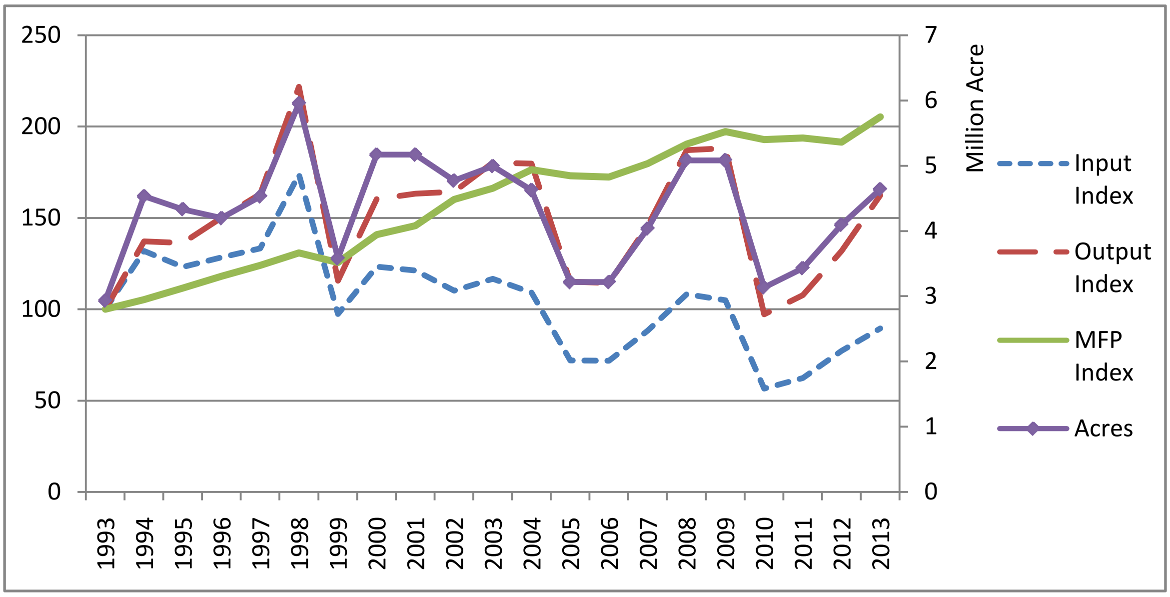
Figure 4.4 Spring Wheat Acres, Output Index, Input Index, MFP Index, 1993-2013



4.5.2 Durum Wheat

The MFP index of durum wheat has doubled since 1991, growing at 3.66% per annum. Comparing durum wheat in the Brown and Dark Brown Soil zones, the former category generally showed approximately 50% higher productivity growth rates than the latter one. Similar to what happened in the spring wheat sector in terms of comparisons of technologies, conventional stubble seeding turns out to be the seeding method that has the fastest productivity growing performance, helping durum wheat grow in productivity by 2.95% to 3.64% per year. Additionally, summer-fallow durum wheat has the slowest growth rate in productivity.

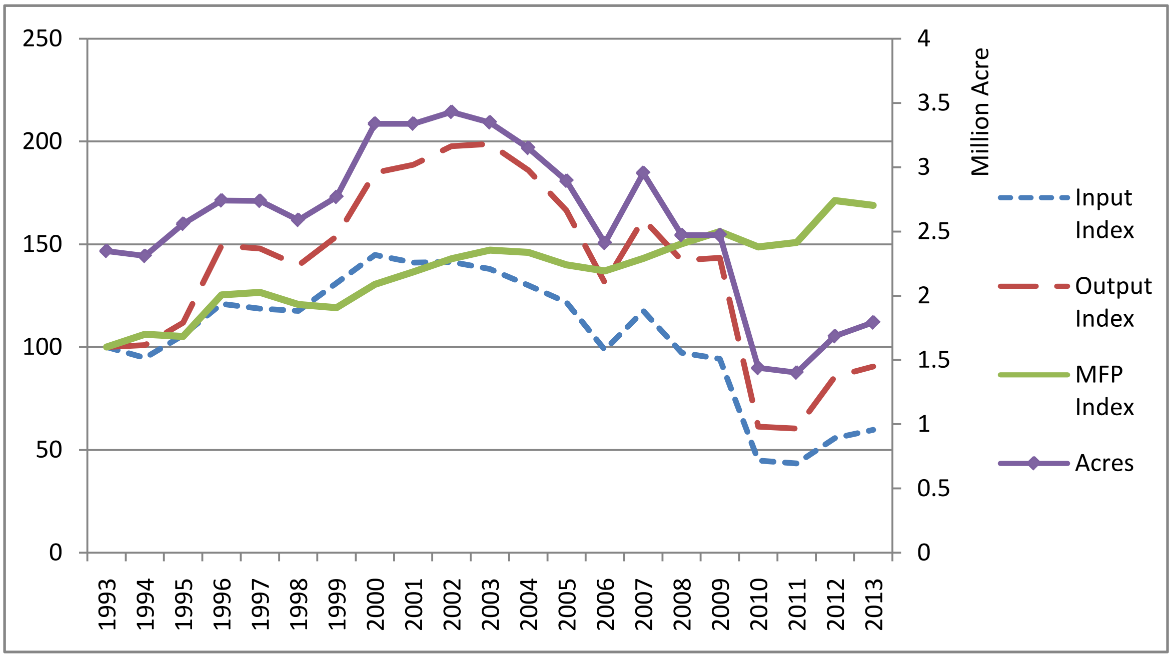
Figure 4.5 Durum Wheat Acres, Output Index, Input Index, MFP Index, 1993-2013



4.5.3 Feed Barley

During the study period, the barley productivity index has risen by nearly 70%. Barley using direct seeding has grown in productivity slightly faster than barley with other technologies, across all soil zones. Crops in different soil zones do not show distinct gaps of productivity growth. Among all nine sub-groups of barley, the average annual growth rate is around 2.9%. Both the highest and lowest figures are observed in the Dark Brown Soil zone: 'zero tillage' has 3.6% and 'fallow' has 2%. In addition, one phenomenon found inthe Brown Soil zone is that summer-fallow barley has experienced a faster growth rate than conventional tillage barley, which is opposite to the other two soil zones.

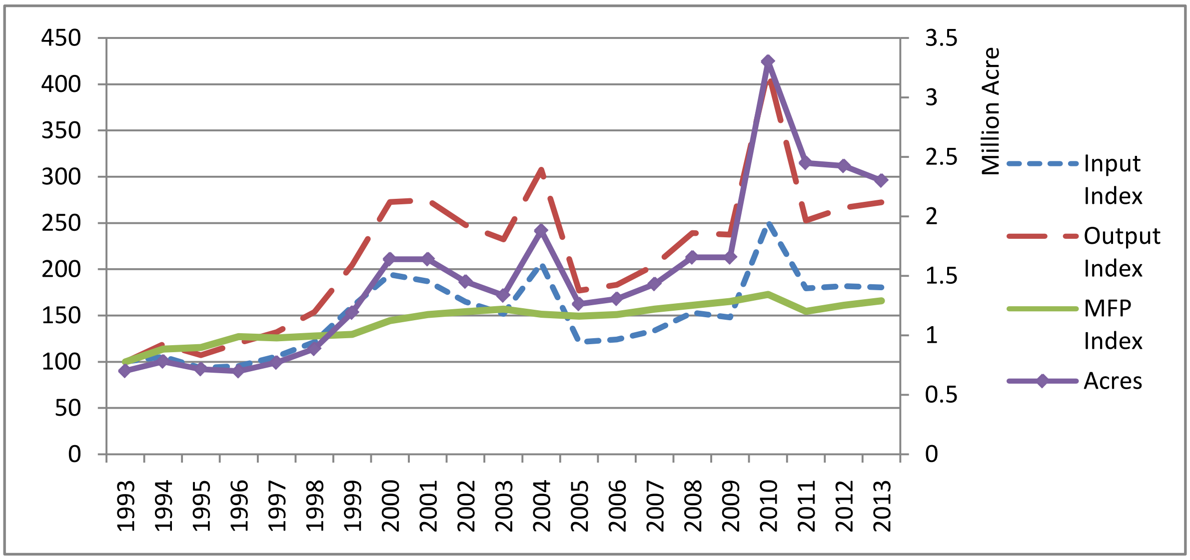
Figure 4.6 Feed Barley Acres, Output Index, Input Index, MFP Index, 1993-2013



4.5.4 Large Green Lentils

Regardless of dramatic changes in production, the productivity of large green lentils has increased by 2.56% per year, the slowest productivity growth compared to other field crops in Saskatchewan. Based on Figure 4.1, it is apparent that lentil productivity growth rates in the Brown Soil zones generally have better performances than the other two soil zones. Lentils grown using conventional tillage in all soil zones have shown higher growth rates of MFP than lentils with other seeding practices. The most outstanding example is presented by lentils using conventional tillage in the Brown Soil zone which has grown in productivity by 4.5% annually.

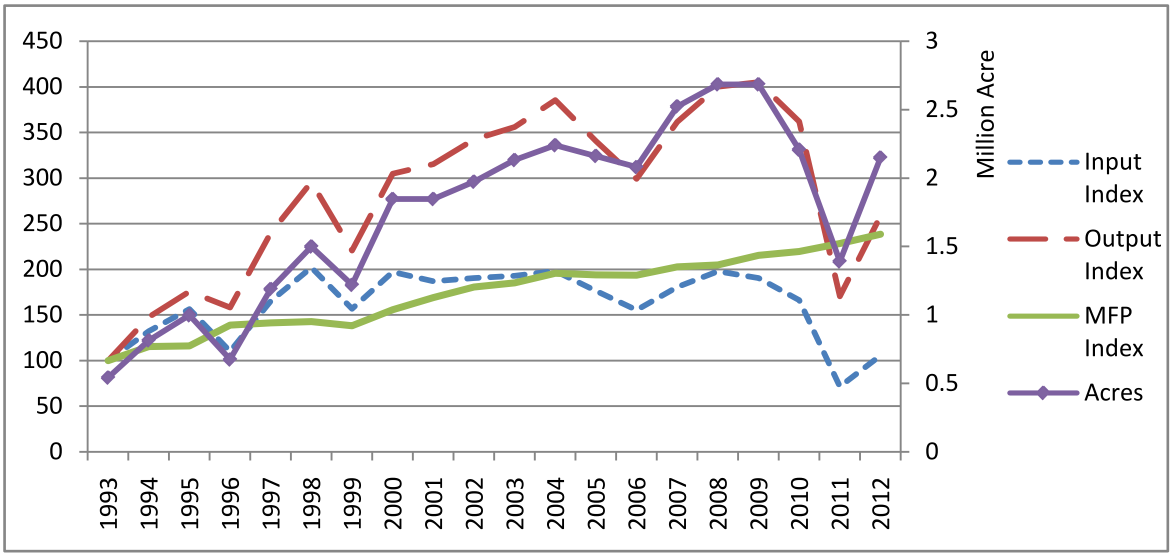
Figure 4.7 Large Green Lentils Acres, Output Index, Input Index, MFP Index, 1993-2013



4.5.5 Feed Peas

Feed peas exhibited the fastest productivity growth in the Saskatchewan crop sector, growing at 4.68% per year. For individual sub-groups of peas examined in this study, most of them had remarkable productivity performances. Peas produced under conventional tillage and zero tillage showed around 5% annual growth rates in productivity. For summer-fallow peas, the MFP increased by nearly 3.7% per year in the Dark Brown Soil zone and 2.3% in the Black Soil zone. Comparing productivity performance between soil zones, feed peas in the Black soil zone grew more slowly.

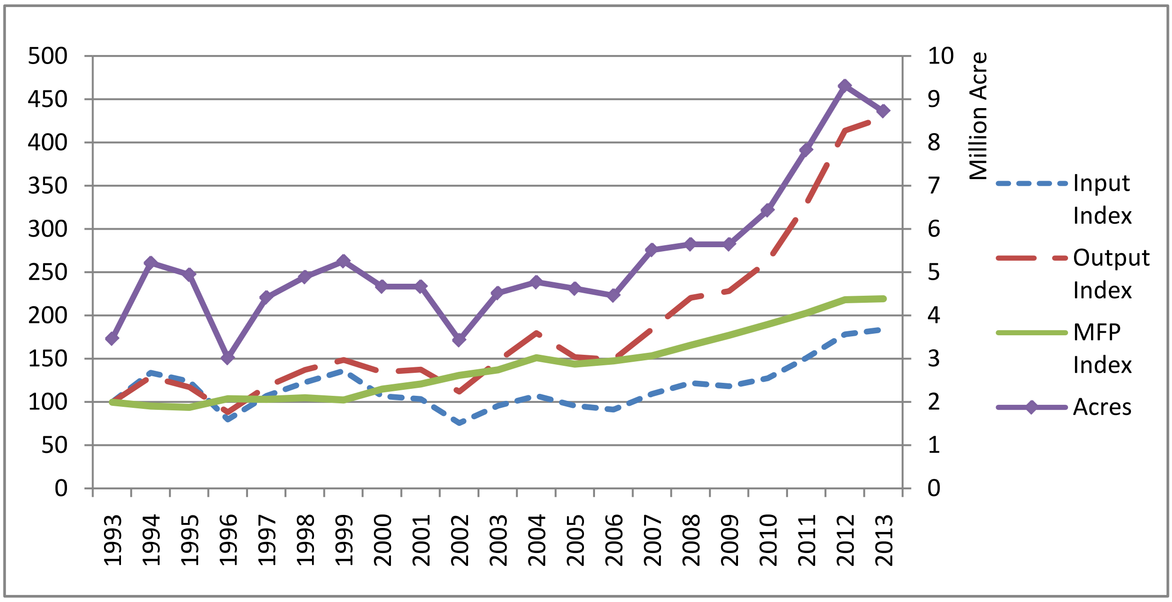
Figure 4.8 Feed Peas Acres, Output Index, Input Index, MFP Index, 1993-2012



4.5.6 Canola

The MFP of canola increased at a rate of 4% each year, which indicates its productivity has doubled in 20 years. Canola in the Dark Brown Soil zone performed well in productivity, showing higher growth rates than the Black Soil zone. Conventional tillage and zero tillage canola inthe Dark Brown Soil zone had annual growth rates of over 5.5%. Summer-fallow canola showed the slowest growth of MFP in both soil zones.

Figure 4.9 Canola Acres, Output Index, Input Index, MFP Index, 1993-2013



4.6 Conclusion

The past twenty years have witnessed an overall progress in productivity of Saskatchewan crops. Feed peas and canola have shown the fastest ongoing growth of production and productivity. As opposed to this, spring wheat and barley have suffered a reduction in production and have shown relatively slower productivity growth. For durum wheat, fewer inputs were used and more production was shown than 20 years ago, generating important productivity gains. Lastly, even the production of large greenlentils has increased dramatically, though the amount still accounted for a small portion of total production of the six Saskatchewan crops. Its productivity grew at a relatively slower rate at the same time.

In the comparison of cropping systems, the most significant finding is that summer-fallow crops' productivity has shown limited potential, while conventional tillage and zero tillage practices were increasingly adopted and showed rapid productivity gains. This conclusion applies for almost all of the sub-groups measured in this study. As an example, the most striking growth rates can be seen in canola using the zero tillage system in the Dark Brown Soil zone. Additionally, the empirical results related to the comparisons of soil zones indicate that the Brown Soil zone was the most beneficial to productivity gains in the durum wheat and large green lentils sectors; the Dark Brown Soil zone was found most beneficial in peas and canola sectors; and no particular soil zone was found beneficial in spring wheat and barley sectors.

CHAPTER 5: CASE STUDY - SPRING WHEAT VS. CANOLA

5.1 Introduction

As mentioned in Chapter 4, spring wheat production has lessened significantly over the last 20 years while canola production has continuously increased. In 2013, the production shares of both spring wheat and canola have each accounted for approximately 30% of the six crops' total production. In this chapter, a discussion about the comparison between two crops' MFP gains is presented to offer insights into the productivity performance of the two major crops in Saskatchewan at disaggregated levels of soil zones and cropping systems.

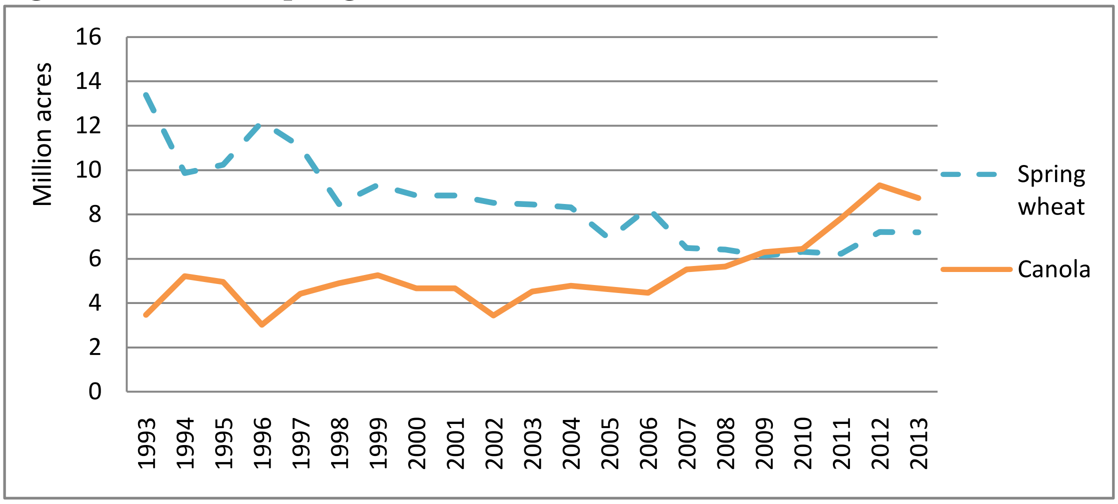
In Chapter 5, MFP estimates are used to compare wheat and canola growth rates over time as a case study and demonstration of how crop specific MFP estimates can be used. The background of spring wheat and canola is introduced in terms of the changes in cultivated acres. A detailed discussion on the comparison of productivity gains between the two crops is also undertaken. After understanding how MFP estimates can be applied in the case study of spring wheat versus canola, other possible comparisons in this crop productivity study will be briefly suggested in Chapter 6 for further research interests.

5.2 Background

Variation in cultivated areas of various crops over the years can be considered as a reflection of the changes in crops' popularity due to multiple factors such as market, environment, technology improvement, etc. This section exhibits the areas of spring wheat and canola cultivated in Saskatchewan from 1993 to 2013, on a basis of aggregate crop sector. The situation of crop acres at disaggregated levels of both soil zones and cropping systems is explained in the following sub-sections. The data for acres is derived from the Prairie Crop Energy Model (Nagy, 2001).

In Saskatchewan, the cultivated area of spring wheat has been reduced by 46%, from 13.4 to 7.2 million acres during the period between 1993 and 2013. Meanwhile, the acres of canola have increased significantly by nearly 150%, from 3.5 to 8.7 million. According to Figure 5.1, it can be observed that from 1996, there was a continuous decrease in the cultivation of spring wheat until 2006 when a rebound was seen. On the other hand, canola cultivation area increased rapidly from 2002 to 2012. As a result, the cultivated area of canola has overtaken area of spring wheat since 2010.

Figure 5.1 Acres of Spring Wheat and Canola in Saskatchewan, 1993-2013[12]



5.2.1 Acres of Soil Zones

Figures 5.2-5.4 provide changes in acres of spring wheat and canola in the various Saskatchewan soil zones from 1993 to 2013. In all the soil zones, the spring wheat's cultivated area reduced from 1993 to 2006 and then retained a relatively stable level, from 2007 to 2010. During the last three years of the study period, more acres were cultivated to grow spring wheat in the Dark Brown and Black Soil zone, but fewer acres in the Brown Soil zone. For canola, the tendency of increasing production can be observed in all three soil zones. Between 2002 and 2012, the area of canola has quintupled in the Brown Soil zone, tripled in the Dark Brown Soil zone and doubled in the Black Soil zone.

In regards to each soil zone's share of total crop area, spring wheat and canola have both common and different features. On the one hand, both crops' acres in the Dark

[12] Total area includes the Brown, Dark Brown and Black Soil zones in Saskatchewan.

Brown Soil zone have steadily accounted for approximately 37% of the total acres over the period. On the other hand, spring wheat and canola have different situations related to the shifts of area shares between the Brown and Black Soil zones. For spring wheat, its share of the Brown Soil zone has decreased from 28% in 1993 to 15% in 2013 while the Black Soil zone share has experienced an increase from 34% to 47%. The shares of the Brown and Black Soil Zones in the canola sector have shown an upward trend: in 1993, Brown vs. Black was 6% vs. 66%; in 2013, Brown vs. Black was 14% vs. 47%.

In summary, the area of spring wheat has generally reduced over time but a rebound was experienced during the 2011-2013 period in the Dark and Black Soil zones. A considerable increase in canola’s cultivated acres can be observed in all soil zones, even in the Brown Soil zone where over one million acres of canola has been grown annually since 2011.

Figure 5.2 Acres in Brown Soil Zone in Saskatchewan, 1993-2013

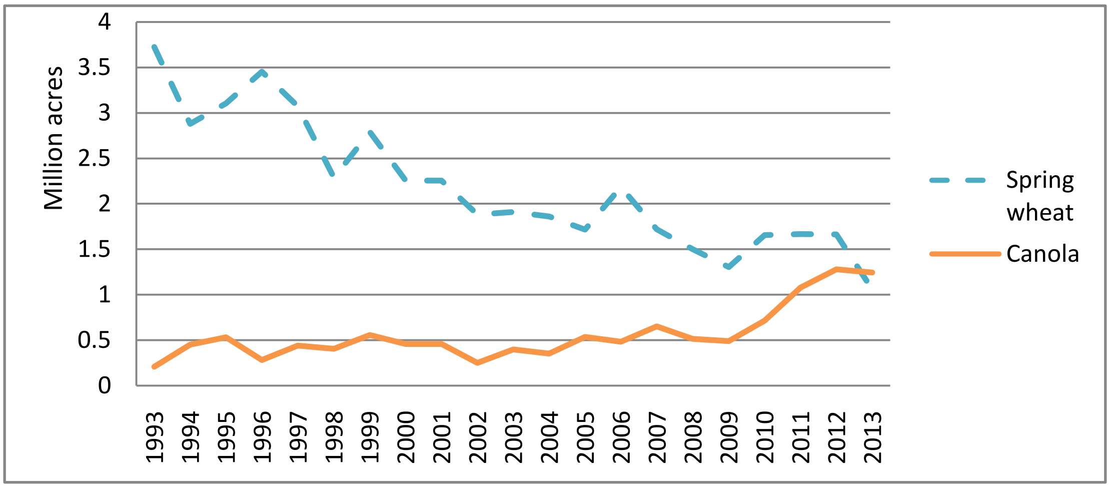


Figure 5.3 Acres in Dark Brown Soil Zone in Saskatchewan, 1993-2013

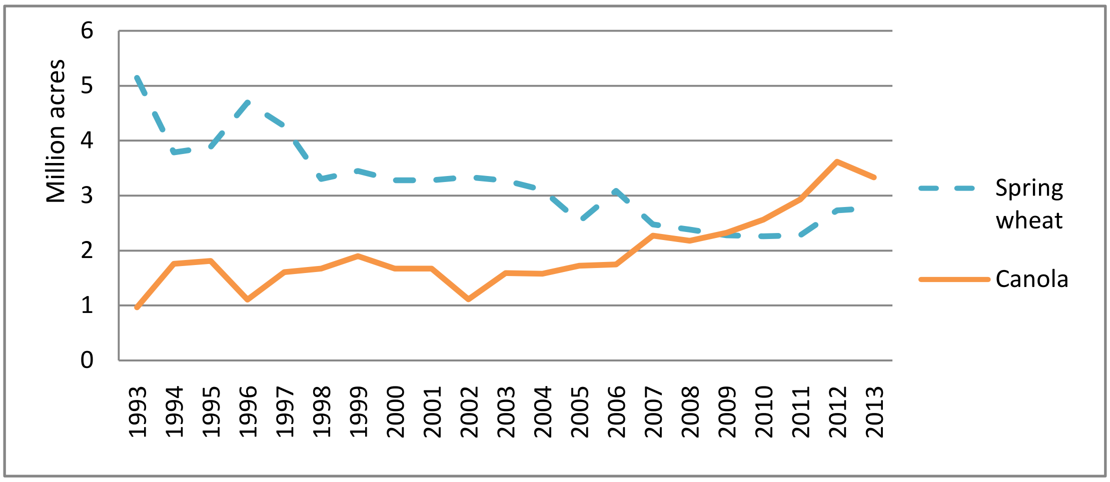
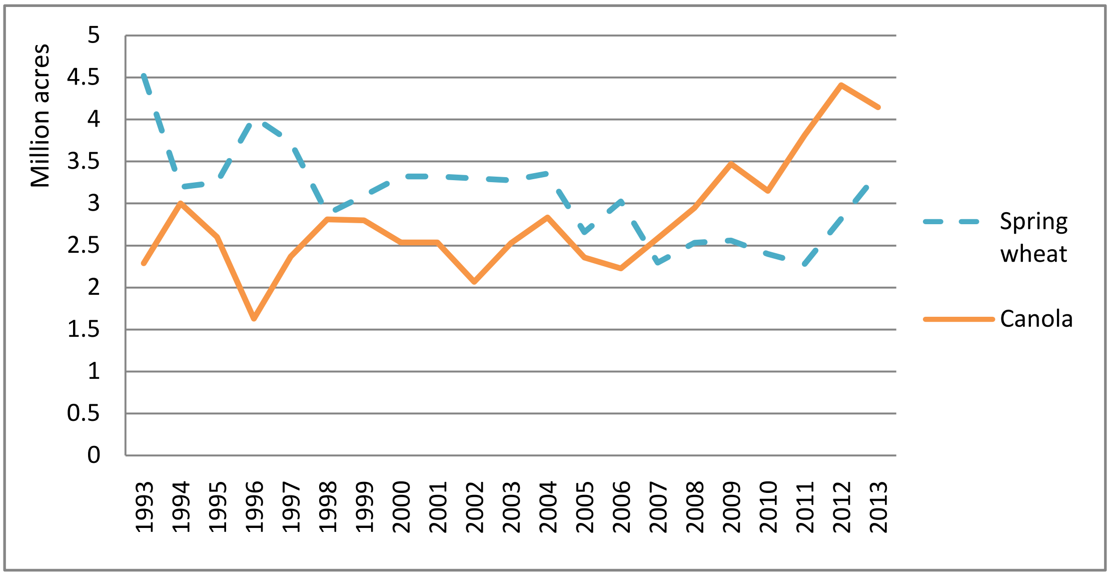


Figure 5.4 Acres in Black Soil Zone in Saskatchewan, 1993-2013



5.2.2 Acres of Technologies

This subsection presents a graphical comparison based on the use of various cropping systems between spring wheat and canola (see Figure 5.5-5.7). First, summer-fallow acres have reduced dramatically in both spring wheat and canola sectors. The summer-fallow spring wheat area dropped enormously from nearly 7 million to 300 thousand acres. For canola, the summer-fallow acres showed a 60% reduction, from 3.5 to 1.4 million. Secondly, the land area of spring wheat applying conventional tillage has decreased at a rapid rate over the 20 years period. Since 2006 the conventional stubble seeding practice has been increasingly adopted by farmers when growing canola, becoming twice that of 1993. Finally, according to Figure 5.9, it is obvious that zero tillage has become the most popular cropping system among spring wheat and canola growers. The acres of both spring wheat and canola with zero tillage have reached5 million by 2013, from 1.5 million and 590 thousand acres in 1993, respectively. Spring wheat production was the first to experience an increase in the adoption of zero tillage technology (since 1995), but the growth rate seemed to slow down between 1998 and 2013. By contrast, the acres of zero tillage canola rose in 2002, showing a much faster increase rate than spring wheat afterwards.

For the spring wheat and canola sectors, the popular cropping system has significantly changed from summer-fallow to zero tillage over the past two decades. In 1993, summer-fallow lands accounted for over half of total acres in each crop sector. In 2013, the figures dropped to only 4.5% of total spring wheat area and 16% of total canola area. Consequently, zero tillage has been increasingly adopted to grow crops. The zero tillage acre share of spring wheat increased from 12% to 70%; and as for canola, the cultivated acres increased from 8% to 58%. In terms of conventional tillage practice, its percentage share in the spring wheat sector has decreased from 37% to 26%. In the canola sector, it has not changed and retained around 24% over years.

In summary, it is obvious that zero tillage has been increasingly adopted for both spring wheat and canola production when compared to summer-fallow. For spring wheat, given the total cultivated area was deceasing, there were more acres cultivated by zero tillage and less by other cropping systems. Canola growers have applied conventional tillage and zero tillage more frequently than summer-fallow. In particular, the acre share of zero tillage canola has accounted for nearly 60% of the total canola acres in 2013.

Figure 5.5 Acres of Summer-fallow in Saskatchewan, 1993-2013

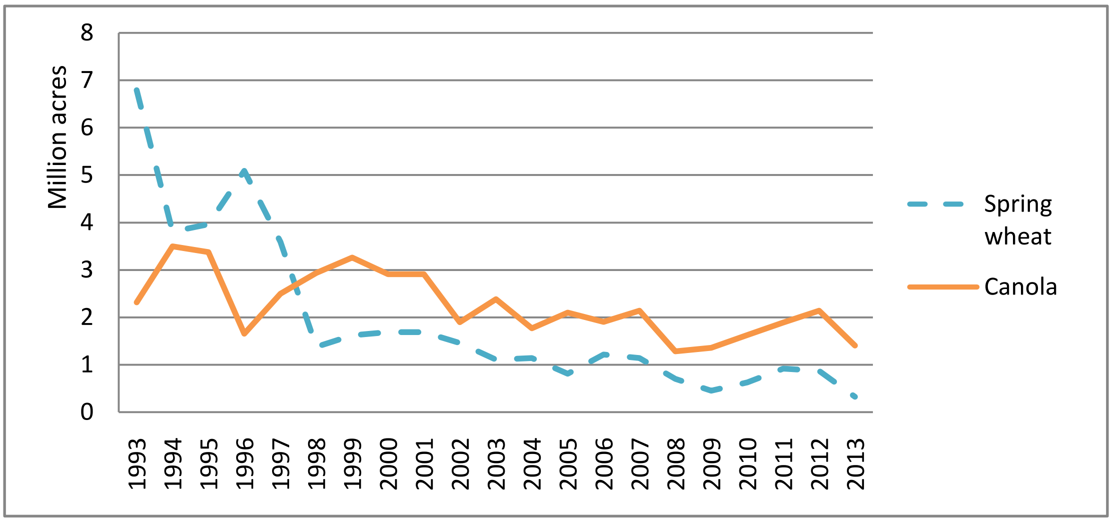


Figure 5.6 Acres of Conventional Tillage in Saskatchewan, 1993-2013

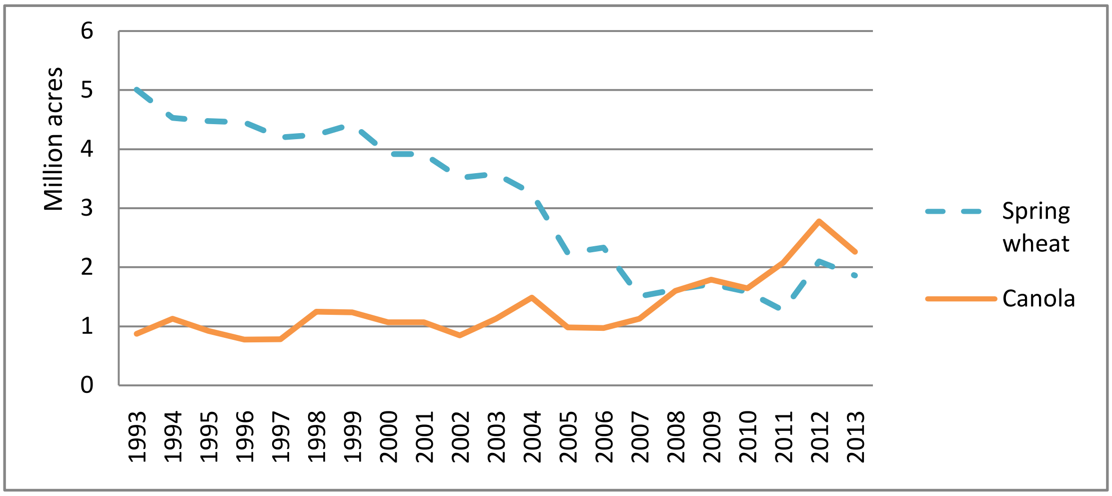
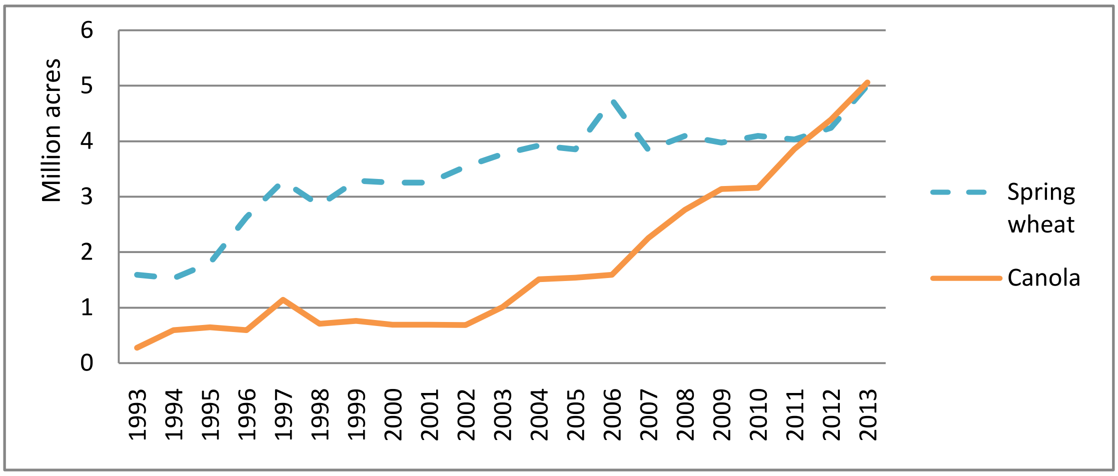


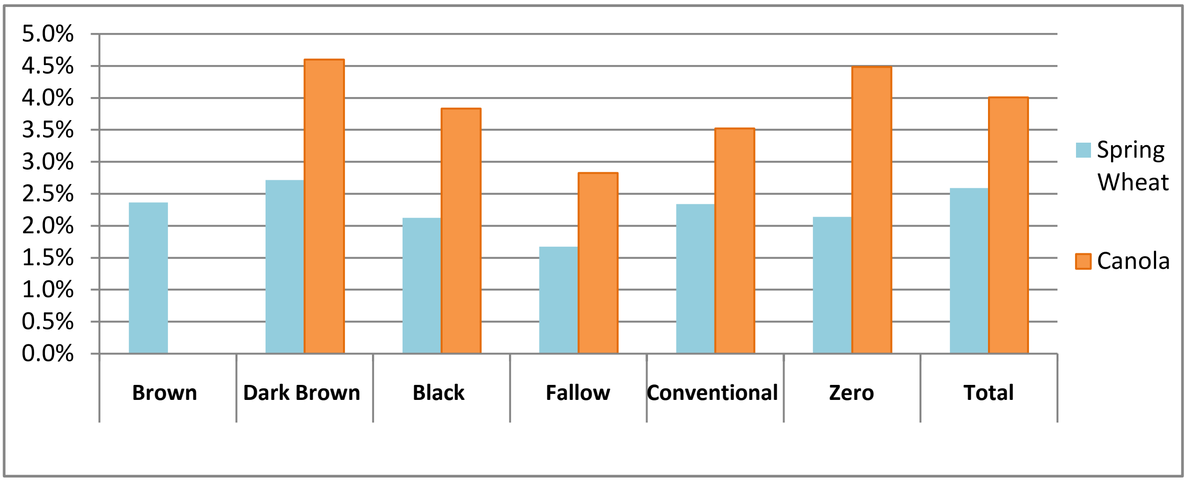
Figure 5.7 Acres of Zero Tillage in Saskatchewan, 1993-2013



5.3 Overview

Figure 5.8 shows the productivity gains of both spring wheat and canola. The empirical results of the MFP compound annual growth rates are classified into three groups: soil zone, technology and total (i.e., aggregated crop sector). The following sub-sections explain findings based on the different group comparisons.

Figure 5.8 MFP Growth Rates of Spring Wheat and Canola in Saskatchewan, 1993-2013



5.3.1 The Impact of Soil Zone

From the left side of the above bar chart, the first part shows the MFP growth rates of spring wheat and canola in various soil zones. Canola has grown in productivity twice as much as spring wheat in each soil zone. The productivity of spring wheat has grown by more than 2% in all soil zones: the highest growth rate of over 2.7% was observed in the Dark Brown Soil zone, the second highest growth rate (2.37%) was found in the Brown Soil zone and the slowest growth rate (2.12%) was found in the Black Soil zone. Canola's MFP growth rate was 4.6% per year in the Dark Brown Soil zone and it was 3.8% in the Black Soil zone. The similarity between these two crops is that they both have higher productivity growth rates in the Dark Brown Soil zone than in the Black Soil zone.

In the Dark Brown Soil zone, the productivity growth of spring wheat and canola kept a consistent pace during the first decade of the period. Since then, canola started to exhibit a faster growth rate than spring wheat. By 2013, the canola MFP index was 44.1% higher than the spring wheat MFP index. In the Black Soil zone, spring wheat's growth of productivity slightly overtook canola in 1997 until the two growth paces overlapped in 2004. Between 2005 and 2013, canola has increased in productivity by over 50% while spring wheat has barely improved.

Overall, the following two figures indicate that in both soil zones the productivity growth of canola has overtaken spring wheat. Spring wheat has almost flattened out since 2003, while canola consistently showed a stable increasing rate of productivity gains over the last two decades. In both crop sectors, crops in the Dark Brown Soil zone showed modestly higher productivity growth rates than the Black Soil zone, which to some extent was caused by the better soil environment (e.g., moisture) in the Dark Brown Soil zone than the Black Soil zone.

Figure 5.9 MFP Index of Crops in Dark Brown Soil Zone, 1993-2013

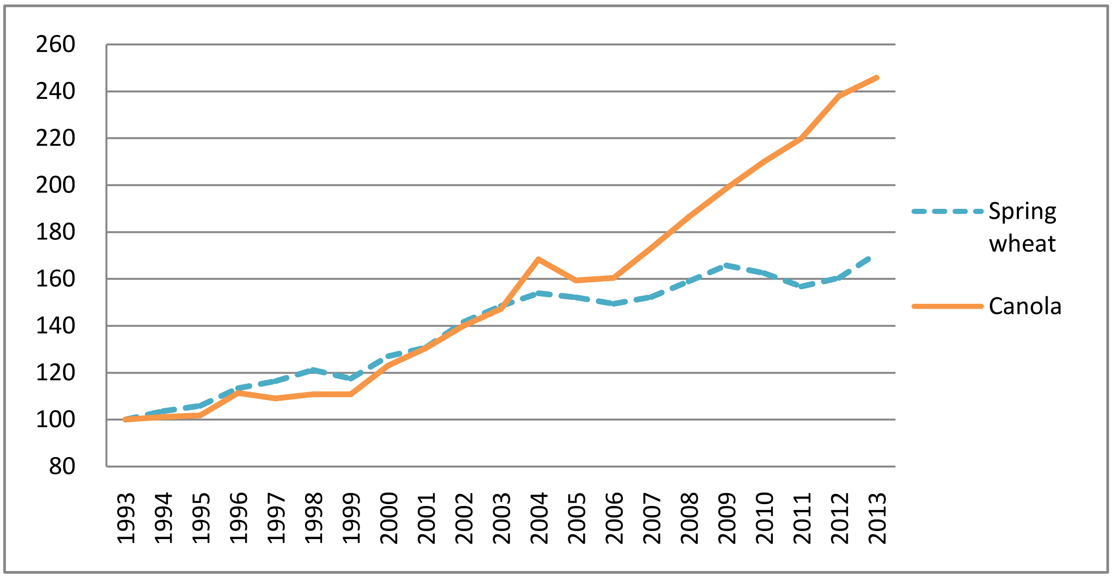
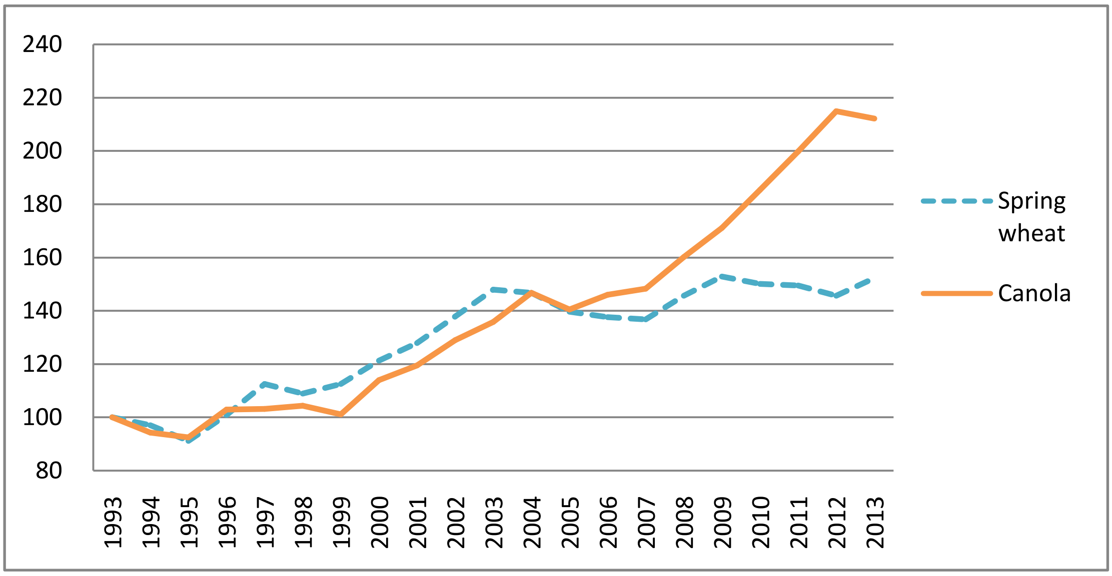


Figure 5.10 MFP Index of Crops in Black Soil Zone, 1993-2013



5.3.2 The Impact of Cropping Systems

The group located in the middle of Figure 5.8 shows the productivity gains of spring wheat and canola by applying three different types of cropping systems. In this comparison group, it can be seen that the MFP growth rates of canola were overwhelmingly higher than spring wheat. For crops seeded by zero tillage, the gap of the productivity growth rates between two crops was the largest: 2.14% of spring wheat vs. 4.48% of canola. Additionally, the cropping system that had the highest growth rate of productivity over the past two decades was conventional tillage for spring wheat (2.34%), and zero tillage for canola (4.48%).

For summer-fallow crops, the productivity has not grown as significantly as crops using conservation tillage practice, but both crops have shown a relatively consistent increasing tendency. Canola using summer-fallow has grown faster in productivity than summer-fallow spring wheat since 2003. Conventional tillage canola surpassed conventional tillage spring wheat in terms of MFP growth in 1998. For zero tillage crops, canola overtook spring wheat in 1996, showing a much faster growth. As Figure 5.13 shows, the divergence of growth rate has expanded since 2005 with a faster growth for canola and a flat growth for spring wheat.

Zero tillage has become the most popular seeding procedure for both crops, particularly canola. It is worthwhile to note that the productivity growth of spring wheat with using zero tillage has not improved over the last five years. On the other hand, even though MFP of summer-fallow spring wheat has not grown as rapidly as zero tillage spring wheat, its productivity was still steadily growing by 2012.

For a long time, summer-fallow has been considered as a belief system which is the best farming practice for crop production in terms of managing soil moisture and controlling weeds, while its damage to the soil quality being not fully realized by farmers. The results of this study suggest that MFP growth rates of crops under zero tillage system were generally faster than summer-fallow crops over the past two decades.

Figure 5.11 MFP Index of Summer-fallow Crops, 1993-2013

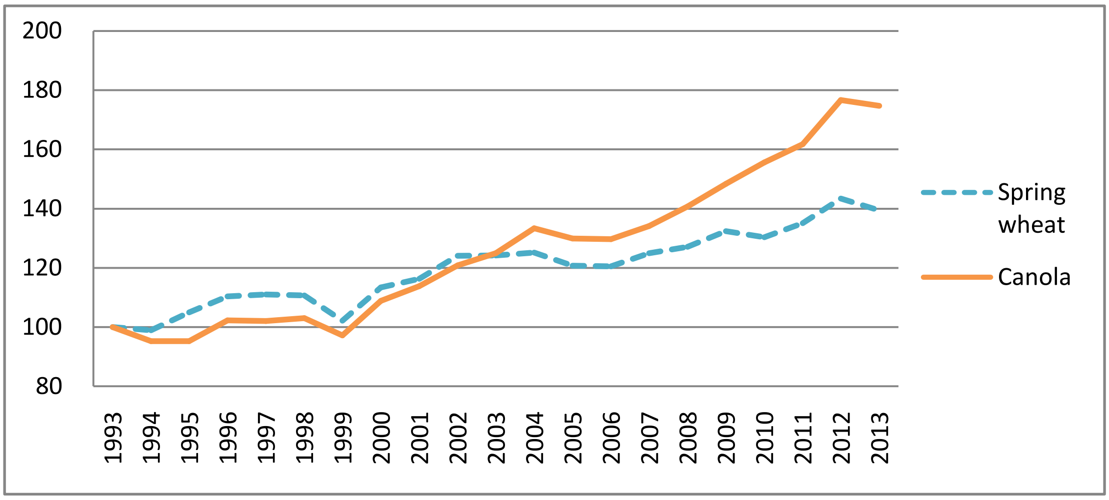


Figure 5.12 MFP Index of Conventional Tillage Crops, 1993-2013

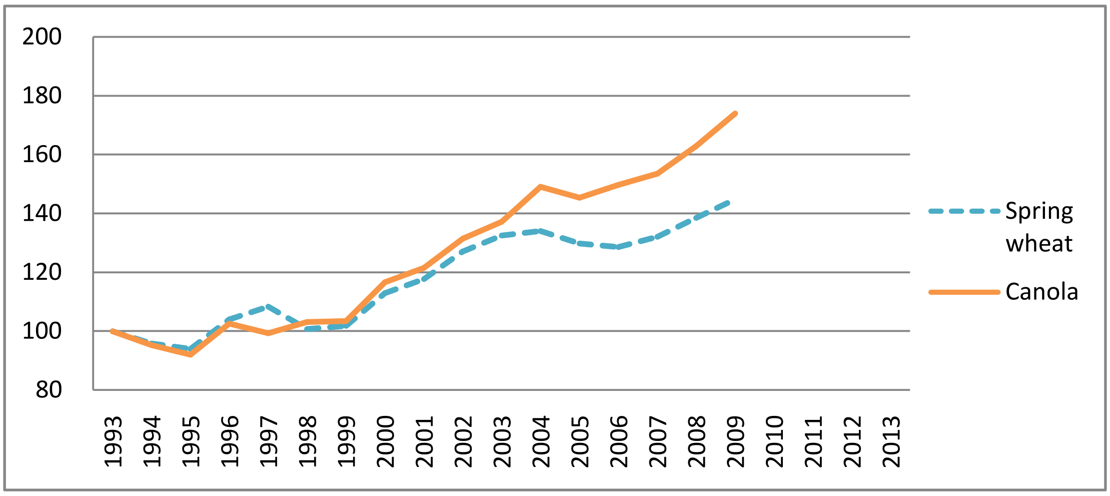
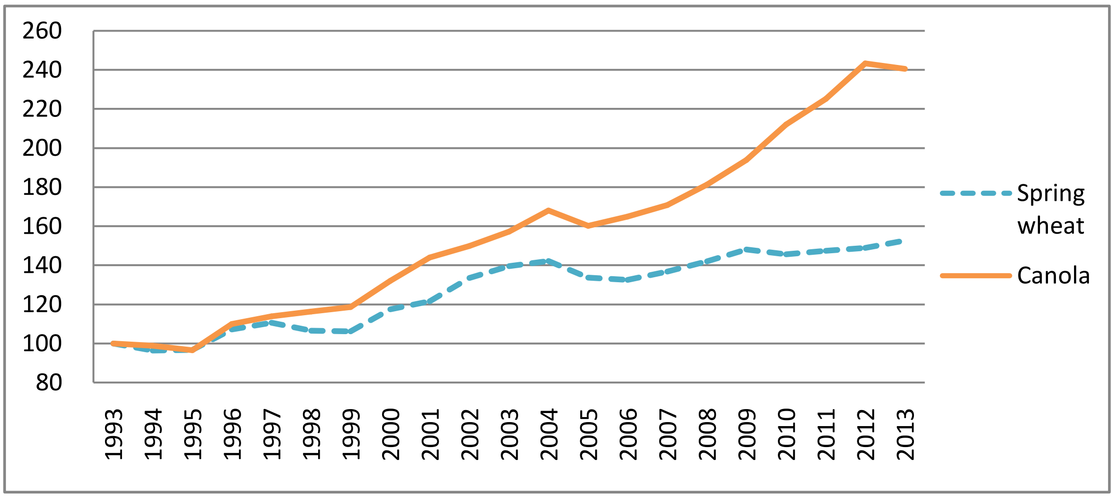


Figure 5.13 MFP Index of Zero Tillage Crops, 1993-2013



5.4 Conclusion

In recent years, cultivated acres of canola have outnumbered spring wheat. Canola is increasingly grown in all soil zones, including the Brown Soil zone where there were few canola crops 20 years ago. Zero tillage technology has been applied in about half of canola farmlands in Saskatchewan since 2008. A different situation happened in the spring wheat sector. The areas of farmland committed to spring wheat cultivation have generally reduced in each soil zones, though during the last three years the Dark Brown and Black Soil zones have experienced an increased trend in cultivation of spring wheat. Farming practices adopted in Saskatchewan spring wheat cultivation have evolved in the last two decades, where zero tillage technology has significantly been substituted for summer-fallow and conventional tillage.

When comparing productivity gains of the two crops in various soil zones, one important finding is that the 2003-2005 period is a milestone that indicates that canola's productivity growth rate started to surpass that of spring wheat's. Furthermore, in the comparison of cropping systems, the time point when canola's productivity growth speed passes spring wheat's, varies with different technology categories, with the following sequence: zero tillage (1995-1996), conventional tillage (1997-1998) and summer-fallow (2002-2003).

Allocative effects in spring wheat and canola sectors were found in the study results. Acres of spring wheat using zero tillage between 1993 and 1997 increased dramatically, however, the productivity gains flattened out at the same time. As a result, the acres dropped in 1998 and then increased more slowly than before. By contrast, canola's productivity has appeared to increase significantly between 2005 and 2006, as mentioned in Section 5.3.1. Perhaps as a result of this, an increase in acres of canola has occurred since 2006. In summary, the results indicate that more acres are cultivated because the more productive crop variety is increasingly adopted by growers.

CHAPTER 6: CONCLUSION AND POLICY IMPLICATIONS

6.1 Introduction

The study is summarized in this chapter. Then, several conclusions and policy implications based on the empirical results are provided. Finally, an explanation of study limitations and an introduction of further possible research topics are given.

6.2 Study Summary

The objective of the study is to provide insights into the disaggregated levels of productivity gains in the six major Saskatchewan crops during the 1993-2013 period, by comparing across crop sectors, soil zones and cropping systems. The productivity gains are measured by multi-factor productivity growth rates with employing the Törnqvist-Theil index procedures. The data are derived from 1) the partial budget of the Saskatchewan Crop Planning Guide, 2) measurements of acres based on the Prairie Crop Energy Model, and 3) farm input price indexes from Statistics Canada database.

Based on the study results, among the six major crops in Saskatchewan feed peas and canola had the fastest growth rates in productivity, and then durum, feed barley, spring wheat and lastly large green lentils. The differences of productivity gains between soil zones were not apparent in all the crop sectors. In the comparison of cropping systems, zero tillage technology has become increasingly dominant, while summer-fallow cropping has almost been eliminated. Not surprisingly, these adoption patterns reflect a move toward cropping systems with higher productivity growth rates.

The comparison between the productivity performances of spring wheat and canola shows how the two major crops in Saskatchewan have changed in productivity at disaggregated levels of soil zones and cropping systems. Three meaningful findings are concluded. First, canola's productivity growth rate has exceeded spring wheat's since 2006. Second, zero tillage has become the most popular seeding procedure to grow spring wheat and canola. Especially in the canola sector, crops employing zero tillage have the highest productivity growth rate in comparison with other cropping systems. Third, both spring wheat and canola in the Dark Brown Soil zone, where growing fewer acres than the Black Soil zone, found faster growth rates of productivity.

6.3 Conclusions

There are several factors that contribute to growing productivity in the Saskatchewan crop sector. In this section, conclusions are outlined as sub-sections from the perspectives of the following four factors: genetic improvement and potential, technological change, appropriate soil environment and allocative effects. These factors have joint effects on crop productivity performance.

6.3.1 Genetic Improvement and Potential

The genetic quality of a variety is a critical factor to crop's productivity performance. Feed peas, canola and spring wheat set great examples in this case. As better varieties have been introduced and increasingly adopted, feed peas and canola experienced the fastest productivity growth in crops over the 20 years. Between 1999 and 2006, research trial yields of canola and peas have shown increases of about 37% and 14%, respectively (Veeman and Gray, 2010). New high-yield varieties have had a positive impact on rotation and cropping diversity, generating more crop production in a certain amount of farmland. By contrast, the genetic potential of spring wheat seems limited, generating the lowest productivity growth rate among the six crops estimated in this study. Spring wheat's research trial yield has increased by only 5.8% during the same period of time (Veeman and Gray, 2010).

6.3.2 Technological Change

One most significant technological change in agriculture over the past two decades is zero tillage, which had been well adapted and increasingly adopted since the 1970s. In 2011, zero-tillage acres accounted for 63.3% of total farmland in Saskatchewan

(Statistics Canada, 2014). The innovation of zero tillage has brought numerous benefits for crop productivity and soil quality.

Zero tillage is an innovative agricultural practice that avoids negative effects to soil quality caused by tillage farming. As a result, the features of zero tillage include the capacities of reducing soil erosion, improving organic matter, conserving soil moisture, increasing water efficiency and so on. Eventually, soil quality under zero tillage practice is well preserved and improved, contributing to higher crop yields.

Studies have indicated that zero tillage can be more profitable than tillage farming when farming operations and environment are appropriate (Beck, et al., 1998; Dumanski, et al., 2006; Zentner, et al., 2002). The combination of specialized seeding equipment and herbicides save labour, machinery, fuel and irrigation expenses considerably. With the help of zero-tillage farmers are able to practice more crop rotations due to less fallow of the soil and more water content. Besides, the capability of carbon sequestration and reducing agricultural greenhouse gas emissions make a significant contribution to sustainable agriculture (Lafondet al., 2011). Overall, the combined effect of zero tillage's various advantages can positively impact crop productivity.

6.3.3 Appropriate Soil Environment

In Saskatchewan, a large proportion of crop land under conventional and zero tillage operations is concentrated in the Dark Brown and Black Soil zones because of appropriate soil moisture (particularly the Dark Brown Soil zone which is neither too dry nor too moist). In this study, peas and canola in the Dark Brown Soil zones showed outstanding productivity growth rates, especially for crops using conventional and zero tillage practices. Less soil disturbance preserves and improves soil quality over time, which plays a critical role in driving productivity growth.

6.3.4 Allocative Effects

Adoption of more productive farming activities (e.g., using better seed varieties and technologies) creates positive allocative effects on productivity growth. Farmers' education enhances allocative efficiency, heavily depending on the relationship between technical change and the value of information (Khaldi, 1975). The results presented in this study suggest shifts from an activity with a relative lower productivity growth rate to one with a higher productivity growth (see Chapter 5). In the current technically dynamic environment, the effect of allocative efficiency of farmer information plays an increasingly important role within the productivity function.

6.4 Policy Implications

This study's finding provides several implications for the interests of agricultural policy. For policy makers, the knowledge of crops' productivity growth is important to improve the competitiveness and diversification of agricultural production. Understanding the productivity performance of specific crops can lead to another level of perspective when developing policies.

6.4.1 Research and Development

The research and development (R&D) investments on both basic and applied science in the agricultural industry are necessary to carry on with the objective of promoting crop productivity and agricultural sustainability. Leveling off in the R&D expenditures cannot be a healthy strategy in the long term to pursue growing productivity. Nevertheless, real R&D investments for crops declined between 1996 and 2004 (Gray, 2008). Veeman and Gray (2010) point out that declining growth in R&D expenditures has adversely affected crops' productivity growth in Canada. From an overall perspective, increased funding on agriculture would be a positive causal factor of productivity growth.

The estimates of specific crop productivity presented in this study provide helpful information for developing research programs and policy for crops. Canola and peas are found to drive the overall increase in crop productivity, with spring wheat, barley and lentils lagging. Based on this knowledge, productivity and comparative advantage of crop sector can be enhanced by both optimizing research programs on crops with fast productivity growth (e.g. canola and peas) and increasing funding on crops with slower productivity growth (e.g., spring wheat).[13]

6.4.2 Zero Tillage System

Considering that zero tillage technology has led to an increasingly productive seeding practice, its significant potential should attract the direction of R&D investments in the future. Awada (2014) found extremely high rates of return of zero tillage research, development and extension (RD&E) investments, and that farmers gain most of the research benefits through reduction in costs and increase in production. The high rates of return suggest that RD&E investments on zero tillage are still insufficient. Consistent and increasing investments from both public and private sectors can promote the extent of benefits of zero tillage technology. It is fundamentally important that farmers, policy makers and the public fully recognize the high existing and potential benefits of this new farming practice.

This study indicates spring wheat, durum wheat and lentils using zero tillage have slower productivity growth than these crops with conventional tillage. The finding implies that further studies in terms of both agronomy and economics are required to examine effects of zero tillage on those crops' productivity, with the objective to pursuing a ripe zero tillage system which benefits various crops. One recent agronomic study (Lafond et al., 2011), which observed effects of zero tillage on soil properties and crop productivity, has proved that "no tillage combined with continuous cropping and proper fertility represents a path to sustaining the global soil resource".

6.4.3 Productivity Growth Estimates

More productivity growth estimates at disaggregated levels in crops are needed. The composition of the Saskatchewan crop output has changed significantly over the

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[13] Based on the Gray's study (2008) the most apparent reduction of R&D expenditures is found in wheat sector, where has a limited extent of variety improvement. By contrast, canola and peas varieties are improved remarkably, since private sector playing a major role of R&D investments. The changes of R&D expenditures for crops can explain that canola and peas grew much faster than spring wheat in productivity, founding this study.

past two decades. Expanding and extending agricultural productivity growth estimates at disaggregated levels can be valuable to project and promote future agricultural production. A better understanding of individual crops' productivity also can base the structure of R&D funding in the crop sector.

6.5 Study Limitations

The primary limitations of this study are due to the availability of data. First, the partial budget used in the study involves only partial production factors. It implies that if more factors are considered, more accurate results of productivity gains would be generated. Second, data of the partial budget is *ex ante* yield and input expenses. Thus, it is not totally consistent with actual experience in some periods of time. Third, data of crops area in various soil zones and with various cropping systems is estimated with the help of a theoretical model because relevant statistics are unavailable. Consequently, differences may exist could occur when applying the imputed data rather than statistics data. Lastly, the study period is from 1993 to 2013. The study with a period of 20 years hardly can be considered as a long term economic study, which results in another limitation of the study.

6.6 Further Research

Further research is discussed in this section. More aggregated levels of productivity gains are practical to study by applying the dataset of this thesis. On the other hand, further study with broader research interests could be conducted when the study limitations are overcome in the future.

6.6.1 More Aggregations

The case study of spring wheat and canola can be used as an example to present how disaggregated levels in this productivity study indicate different insights. Thus, this section introduces other possibilities of aggregations for developing more research interests, including: 1) comparisons across crops, or crop sectors such as cereal vs. pulse; 2) comparisons between soil zones and technologies in each crop sector; 3) comparisons across aggregate levels of soil zones and technologies.

6.6.2 More Inputs, Regions and Years

The study of crop productivity should adopt more factors including interest expenses, climate/weather, and investment of research and development when related data are available. This study can be replicated for other regions, for example, Manitoba where the agricultural department also offers a similar partial budget as the Crop Planning Guide. Additionally, further research that involves more years can be developed as time goes on.

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APPENDIX A: DATA

Table A- 1 Saskatchewan Spring Wheat in Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	90.76	95.74	104.99	90.55	95.94	105.39	92.53	95.94	103.41
1995	81.75	95.74	115.41	85.86	95.94	110.84	87.59	95.94	108.93
1996	87.65	106.38	119.90	91.87	100.00	107.78	93.49	100.00	106.20
1997	85.49	104.96	121.26	89.68	99.49	109.81	90.30	99.49	109.29
1998	88.37	105.32	117.59	94.59	101.52	106.03	95.00	101.52	105.83
1999	91.77	108.51	116.62	97.61	106.09	107.42	98.04	106.09	107.21
2000	84.98	109.93	126.77	92.00	110.15	117.71	92.52	110.15	117.34
2001	84.47	112.06	129.99	91.24	111.17	119.76	91.76	111.17	119.39
2002	81.62	115.60	138.48	89.13	119.29	131.28	88.97	119.29	131.75
2003	82.02	118.79	141.63	90.08	125.89	137.14	89.62	125.89	138.07
2004	83.28	118.79	139.45	92.00	125.89	134.23	91.67	125.89	134.92
2005	83.91	116.31	135.49	92.39	125.89	133.65	95.25	125.89	129.64
2006	84.43	114.54	132.58	93.23	125.38	131.89	95.92	125.38	128.20
2007	82.81	117.02	137.99	92.12	131.98	140.40	94.11	131.98	137.37
2008	82.18	119.86	142.40	91.70	136.55	145.90	93.80	136.55	142.58
2009	78.93	119.50	147.60	89.03	136.55	150.16	91.10	136.55	146.68
2010	78.67	117.38	145.47				91.41	135.03	144.56
2011	77.42	118.44	149.10				91.50	138.58	148.21
2012	82.08	125.89	149.49				97.56	151.27	151.97
2013	85.72	128.01	145.40				101.49	156.85	151.46

Table A- 2 Saskatchewan Spring Wheat in Dark Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	94.49	92.36	97.87	95.14	92.24	97.10	97.04	92.24	95.20
1995	92.53	92.36	99.89	95.93	92.24	96.29	97.71	92.24	94.54
1996	101.76	106.98	105.74	102.01	106.47	105.05	103.68	106.47	103.34
1997	99.32	106.31	107.62	102.00	106.90	105.48	102.50	106.90	104.94
1998	102.33	109.97	108.07	106.96	108.62	102.05	107.38	108.62	101.64
1999	109.68	111.96	102.26	113.16	115.09	102.21	113.61	115.09	101.79
2000	97.97	110.96	112.27	103.63	115.52	111.20	104.33	115.52	110.49
2001	94.70	109.63	114.67	100.60	115.52	114.45	101.18	115.52	113.82
2002	91.11	110.30	119.71	97.91	120.69	122.63	97.76	120.69	122.76
2003	90.55	111.30	121.52	97.59	125.00	127.41	97.20	125.00	127.86
2004	90.77	112.96	123.05	98.16	131.47	133.27	97.85	131.47	133.61
2005	91.14	110.96	120.38	98.26	129.74	131.37	100.94	129.74	127.64
2006	91.18	108.97	118.16	99.10	129.74	130.26	100.89	129.74	127.71
2007	89.89	109.30	120.19	97.54	132.33	134.90	99.97	132.33	131.41
2008	90.86	111.96	121.82	98.38	136.64	138.14	100.39	136.64	135.14
2009	87.47	111.96	126.36	95.59	138.79	144.23	97.59	138.79	141.05
2010	87.66	110.96	124.96				98.49	137.93	138.87
2011	86.36	111.96	127.93				98.68	140.52	141.20
2012	90.97	115.95	125.66				107.51	147.41	135.50
2013	92.14	117.61	125.86				106.56	152.16	141.05

Table A- 3 Saskatchewan Spring Wheat in Black Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	98.99	95.60	96.60	100.46	95.93	95.48	104.84	95.93	91.09
1995	98.44	95.60	97.14	104.61	95.93	91.53	108.84	95.93	87.62
1996	108.94	112.58	104.04	113.11	124.39	111.24	117.92	124.39	106.30
1997	106.58	112.89	106.59	110.41	126.02	115.36	112.98	126.02	112.14
1998	109.40	112.58	103.46	115.34	127.64	111.69	117.32	127.64	109.28
1999	115.77	114.47	99.17	120.85	131.71	109.91	120.71	131.71	109.61
2000	103.40	114.47	109.77	111.24	134.15	120.69	109.99	134.15	121.37
2001	99.98	114.47	113.41	107.45	137.40	127.73	107.25	137.40	127.33
2002	95.69	116.98	120.76	103.85	144.72	138.80	103.57	144.72	138.48
2003	95.55	119.50	123.54	104.25	151.22	144.51	103.76	151.22	144.46
2004	94.97	118.87	123.63	103.79	151.22	145.14	103.36	151.22	145.01
2005	95.19	114.47	118.77	103.76	145.53	139.73	106.11	145.53	135.70
2006	94.90	115.09	119.78	103.54	146.34	140.81	105.70	146.34	136.97
2007	93.56	116.04	122.46	102.60	147.97	143.65	104.16	147.97	140.49
2008	94.32	119.50	125.11	103.34	152.44	146.96	105.03	152.44	143.57
2009	90.58	120.75	131.40	100.16	155.28	154.22	101.83	155.28	150.62
2010	90.44	120.44	131.24				102.40	155.69	150.18
2011	88.41	123.27	137.28				101.56	159.35	154.93
2012	90.07	131.45	143.81				106.20	169.92	158.14
2013	94.38	131.45	136.93				110.09	169.92	152.33

Table A- 4 Saskatchewan Durum Wheat in Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	92.38	93.48	101.10	92.61	93.58	100.97	92.76	93.58	100.82
1995	82.71	93.48	111.68	85.65	93.58	108.57	85.63	93.58	108.57
1996	88.61	106.88	119.73	91.52	100.00	108.56	91.29	100.00	108.84
1997	85.30	105.07	122.18	88.49	99.47	111.57	87.33	99.47	112.98
1998	88.04	107.97	121.61	93.18	102.67	109.27	91.72	102.67	110.95
1999	91.50	111.59	120.92	96.18	109.63	113.15	94.67	109.63	114.89
2000	84.67	114.86	133.48	90.65	116.04	126.28	89.35	116.04	128.07
2001	84.20	118.12	138.02	89.93	118.72	130.19	88.64	118.72	132.04
2002	81.20	122.46	148.01	87.82	127.81	143.21	85.85	127.81	146.31
2003	81.64	126.45	152.03	88.79	135.83	150.62	86.57	135.83	154.26
2004	82.79	131.88	156.41	90.63	142.25	154.61	88.50	142.25	158.11
2005	83.49	128.62	151.23	91.03	143.32	155.09	91.97	143.32	153.09
2006	83.68	127.17	149.18	91.25	142.25	153.56	92.00	142.25	151.91
2007	82.03	131.88	157.64	90.16	151.34	165.21	90.25	151.34	164.50
2008	81.48	136.23	163.90	89.81	158.29	173.43	90.02	158.29	172.48
2009	78.25	135.51	169.53	87.21	157.22	177.28	87.45	157.22	176.24
2010	77.92	134.42	168.88				87.69	156.15	174.56
2011	76.81	135.51	172.65				87.87	160.96	179.58
2012	81.44	144.57	173.79				93.66	173.26	181.47
2013	85.14	145.29	166.76				97.49	179.68	180.78

Table A- 5 Saskatchewan Durum Wheat in Dark Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	95.73	89.88	94.15	97.25	89.84	92.59	97.43	89.84	92.41
1995	94.60	89.88	95.26	95.68	89.84	94.09	95.72	89.84	94.03
1996	103.72	106.44	103.63	101.59	106.91	106.15	101.44	106.91	106.28
1997	99.14	105.21	107.01	100.46	107.72	108.14	99.15	107.72	109.49
1998	104.05	103.07	99.53	105.16	110.16	105.53	103.69	110.16	106.96
1999	109.52	106.13	97.26	111.17	113.01	102.22	109.62	113.01	103.60
2000	98.55	106.75	107.56	101.82	115.04	112.66	100.67	115.04	113.92
2001	94.71	106.44	111.44	98.88	116.67	117.51	97.67	116.67	118.93
2002	91.51	107.67	116.49	96.19	122.36	126.43	94.33	122.36	128.79
2003	90.07	108.90	119.66	95.94	127.24	131.80	93.85	127.24	134.59
2004	90.62	115.64	126.34	96.43	139.43	143.76	94.41	139.43	146.68
2005	90.94	112.88	122.88	96.55	138.21	142.32	97.41	138.21	140.74
2006	90.06	111.04	122.06	95.70	138.21	143.58	96.36	138.21	142.26
2007	88.98	110.43	122.86	94.88	139.43	146.07	95.48	139.43	144.81
2008	91.94	115.34	124.23	95.79	145.93	151.49	95.97	145.93	150.81
2009	86.75	115.34	131.24	93.07	149.19	159.17	93.29	149.19	158.40
2010	86.93	114.42	129.92				94.07	149.59	157.50
2011	85.58	115.64	133.33				94.36	152.85	160.44
2012	90.28	123.01	134.50				102.86	163.01	156.66
2013	91.15	125.77	136.23				102.03	166.67	161.43

Table A- 6 Saskatchewan Feed Barley in Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	90.93	103.06	112.13	90.33	102.37	112.04	85.96	102.37	116.42
1995	82.62	103.06	122.38	85.55	102.37	117.97	81.22	102.37	122.83
1996	88.48	114.35	127.11	91.35	108.14	116.62	87.07	108.14	120.89
1997	86.01	112.71	128.82	89.95	106.10	116.21	85.90	106.10	120.25
1998	88.95	112.24	123.88	94.82	109.15	113.26	90.42	109.15	117.37
1999	92.50	114.82	121.79	97.94	112.20	112.69	93.44	112.20	116.74
2000	85.64	117.41	133.58	92.41	115.93	122.80	88.06	115.93	127.34
2001	85.13	120.24	137.59	91.63	118.98	127.08	87.37	118.98	131.68
2002	82.20	123.06	145.55	89.67	125.42	136.66	84.79	125.42	142.70
2003	82.57	125.88	148.24	90.56	131.53	141.96	85.40	131.53	148.62
2004	83.74	125.41	145.58	92.46	127.46	134.59	87.33	127.46	140.67
2005	84.48	121.88	140.20	92.92	127.46	133.92	90.88	127.46	134.95
2006	84.14	119.76	138.32	92.34	125.76	132.98	90.11	125.76	134.30
2007	82.49	123.76	145.65	91.27	133.90	143.12	88.41	133.90	145.52
2008	81.98	127.29	150.71	91.00	138.98	148.99	88.26	138.98	151.29
2009	78.59	125.18	154.43	88.21	136.95	151.36	85.60	136.95	153.64
2010	78.24	122.59	151.94				85.82	135.25	151.34
2011	76.99	124.24	156.40				85.88	138.64	155.03
2012	83.68	158.82	186.35				94.47	179.66	185.39
2013	87.13	158.82	178.67				97.81	184.07	183.38

Table A- 7 Saskatchewan Feed Barley in Dark Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	94.76	101.66	106.90	95.02	101.23	106.21	92.04	101.23	109.19
1995	93.78	101.66	108.00	95.88	101.23	105.25	91.89	101.23	109.37
1996	103.08	117.22	113.82	101.75	118.77	117.04	97.84	118.77	121.24
1997	99.73	115.98	116.32	101.85	116.31	114.50	98.19	116.31	118.29
1998	102.85	112.86	109.55	107.11	118.46	110.71	102.91	118.46	114.79
1999	110.35	113.90	102.58	113.37	128.00	113.15	109.00	128.00	117.24
2000	98.55	114.11	113.73	104.03	131.08	125.19	99.88	131.08	129.87
2001	95.15	114.11	117.65	100.85	134.15	131.96	96.84	134.15	136.88
2002	91.67	114.73	122.60	98.46	138.77	139.63	93.85	138.77	145.81
2003	90.98	113.69	122.41	97.90	140.92	142.58	93.07	140.92	149.28
2004	91.07	113.69	122.29	98.34	147.08	148.18	93.57	147.08	155.00
2005	91.50	110.37	118.14	98.51	144.62	145.43	96.67	144.62	147.28
2006	90.82	108.30	116.80	97.64	143.08	145.17	95.61	143.08	147.31
2007	89.55	109.96	120.22	96.85	149.23	152.59	94.23	149.23	155.78
2008	90.74	112.45	121.35	97.89	155.38	157.24	95.37	155.38	160.32
2009	87.17	111.62	125.23	94.96	159.08	165.69	92.55	159.08	168.87
2010	87.76	111.20	123.92				94.10	160.00	167.02
2011	86.10	112.03	127.18				93.74	163.69	171.52
2012	94.99	139.21	144.91				105.37	205.85	194.40
2013	92.86	140.25	149.24				102.59	208.00	201.57

Table A- 8 Saskatchewan Feed Barley in Black Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	99.35	103.58	104.23	100.45	102.97	102.53	99.51	102.97	103.46
1995	99.87	103.58	103.68	104.74	102.97	98.14	103.54	102.97	99.27
1996	110.40	124.21	113.40	112.99	147.03	132.40	111.49	147.03	134.12
1997	106.41	124.84	118.08	109.24	148.11	137.77	108.12	148.11	139.16
1998	109.01	124.21	114.60	113.94	148.92	132.59	112.32	148.92	134.52
1999	115.57	124.63	108.09	119.71	152.16	128.76	115.70	152.16	133.40
2000	102.23	123.79	119.83	108.76	153.24	141.47	105.14	153.24	146.52
2001	99.45	124.00	123.30	106.02	156.22	147.76	101.99	156.22	153.76
2002	95.63	126.32	130.34	103.31	161.89	156.91	99.31	161.89	163.38
2003	95.41	130.11	134.55	103.54	167.03	161.53	99.32	167.03	168.54
2004	94.69	126.53	131.86	102.94	162.43	158.04	98.80	162.43	164.80
2005	94.98	120.84	125.54	103.00	155.14	150.85	101.60	155.14	152.73
2006	94.04	121.26	127.21	101.87	155.68	153.03	100.30	155.68	155.21
2007	92.75	122.53	130.28	101.03	157.30	155.87	98.91	157.30	158.98
2008	93.78	124.21	130.62	102.06	159.46	156.44	100.03	159.46	159.37
2009	89.87	124.63	136.51	98.77	160.00	162.01	96.83	160.00	164.99
2010	89.59	124.00	136.25				97.26	159.19	163.43
2011	87.79	128.00	143.37				96.78	164.32	169.51
2012	91.28	162.11	175.88				103.91	208.11	202.18
2013	95.24	159.16	165.05				106.96	204.32	192.57

Table A- 9 Saskatchewan Large Green Lentils in Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	90.97	93.65	102.68	91.15	104.64	113.49	91.16	104.64	113.48
1995	83.29	93.65	111.35	85.92	104.64	120.00	85.78	104.64	120.18
1996	87.29	107.20	122.11	88.76	121.11	134.92	88.90	121.11	134.71
1997	87.02	106.03	121.15	88.83	119.46	132.98	90.94	119.46	129.80
1998	86.90	115.87	132.57	90.47	119.55	130.63	90.79	119.55	130.11
1999	89.84	117.14	129.54	92.08	125.39	134.69	92.43	125.39	134.12
2000	81.68	119.37	143.76	84.04	131.50	153.00	84.24	131.50	152.54
2001	80.12	122.48	150.25	81.79	132.66	158.46	81.99	132.66	157.95
2002	79.47	127.49	157.62	82.73	144.34	170.59	82.46	144.34	170.95
2003	79.85	131.75	162.12	83.49	154.49	181.01	83.04	154.49	181.77
2004	81.37	129.59	156.40	85.70	153.05	174.53	84.29	153.05	177.34
2005	79.87	124.55	153.20	83.03	150.45	177.01	84.05	150.45	174.83
2006	79.37	120.95	149.73	82.26	147.66	175.36	83.11	147.66	173.56
2007	78.05	129.90	163.31	81.44	159.97	191.74	81.43	159.97	191.52
2008	77.19	134.92	171.41	80.59	166.98	202.13	80.69	166.98	201.64
2009	74.10	131.53	173.97	77.89	161.98	202.83	78.06	161.98	202.20
2010	75.14	129.78	169.20				79.86	160.60	195.81
2011	76.37	133.27	170.99				81.28	167.16	200.31
2012							82.77	178.65	210.42
2013							86.37	187.90	212.17

Table A- 10 Saskatchewan Large Green Lentils in Dark Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	93.88	91.11	97.22	94.51	106.03	111.52	94.59	106.03	111.44
1995	91.44	91.11	99.75	93.20	106.03	113.06	93.20	106.03	113.07
1996	98.21	104.32	106.84	97.27	125.03	128.39	97.57	125.03	128.04
1997	95.92	106.57	111.63	98.34	126.05	128.03	99.18	126.05	126.97
1998	95.76	107.83	113.14	98.43	129.12	131.04	99.48	129.12	129.68
1999	101.19	110.62	109.65	100.86	134.13	132.87	101.41	134.13	132.19
2000	89.16	112.02	124.08	89.97	135.15	148.24	90.31	135.15	147.68
2001	85.45	113.47	130.84	86.12	135.84	155.33	86.43	135.84	154.76
2002	84.24	114.01	133.32	86.56	138.57	157.65	86.41	138.57	157.90
2003	83.93	101.00	118.59	86.48	138.23	157.41	86.13	138.23	158.02
2004	85.14	99.25	114.83	88.44	135.84	151.12	87.16	135.84	153.41
2005	83.50	96.51	113.87	85.68	131.40	150.90	86.74	131.40	149.14
2006	82.72	96.26	114.65	84.66	131.74	153.09	85.54	131.74	151.59
2007	81.69	97.26	117.26	84.03	131.74	154.23	84.10	131.74	154.14
2008	82.27	98.25	117.63	84.31	134.47	156.92	84.52	134.47	156.57
2009	78.98	99.25	123.53	81.40	134.47	162.33	81.70	134.47	161.79
2010	78.59	110.97	138.72				81.33	149.62	180.76
2011	80.11	102.17	125.04				82.12	139.83	167.15
2012							84.07	161.02	188.52
2013							87.96	162.32	181.33

Table A- 11 Saskatchewan Large Green Lentils in Black Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	95.29	92.60	97.32	95.92	119.27	123.35	98.22	119.27	121.05
1995	94.03	92.60	98.60	97.16	119.27	121.75	99.36	119.27	119.65
1996	101.05	112.62	112.56	100.96	132.16	130.15	103.14	132.16	128.03
1997	99.71	112.33	113.76	100.01	133.20	132.40	102.60	133.20	129.71
1998	99.36	112.03	113.85	99.97	134.01	133.26	102.22	134.01	130.97
1999	105.18	113.02	108.18	103.06	138.59	133.69	103.63	138.59	133.64
2000	91.92	114.40	123.14	91.30	140.31	150.61	91.66	140.31	150.74
2001	89.21	107.73	119.59	87.85	142.24	158.36	88.49	142.19	157.96
2002	87.58	106.67	120.60	87.92	140.83	156.68	86.94	140.83	159.22
2003	87.63	105.21	118.88	88.42	138.91	153.65	88.09	138.91	154.94
2004	88.54	100.39	112.21	90.11	132.55	143.68	88.90	132.55	146.44
2005	86.92	94.08	107.21	87.43	124.22	138.92	88.42	124.22	138.02
2006	85.94	95.86	110.44	86.22	126.56	143.46	87.04	126.56	142.78
2007	84.87	94.18	109.88	85.56	124.35	142.06	85.61	124.35	142.62
2008	85.37	96.84	112.34	85.86	127.86	145.57	86.05	127.86	145.93
2009	81.78	101.58	122.56	82.68	134.11	158.08	82.95	134.11	158.32
2010	81.17	107.10	130.14				82.39	141.41	167.99
2011	80.95	112.43	136.96				80.63	148.44	179.93
2012							83.84	156.72	182.79
2013							87.95	155.10	171.96

Table A- 12 Saskatchewan Feed Peas in Dark Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	92.97	93.56	100.60	93.60	112.87	119.27	83.02	112.87	129.85
1995	90.09	93.56	103.71	91.54	112.87	121.89	86.57	112.87	124.28
1996	100.88	112.45	112.22	100.55	132.16	130.74	98.60	132.16	128.27
1997	96.31	110.73	115.58	97.44	130.99	133.63	95.87	130.99	130.69
1998	96.72	114.16	118.68	98.38	133.92	135.32	96.46	133.92	132.81
1999	103.53	119.31	115.68	102.58	144.44	140.17	100.63	144.44	137.51
2000	91.76	122.32	131.74	92.43	147.37	156.88	90.52	147.37	154.10
2001	87.58	126.61	142.37	87.90	154.39	172.04	86.06	154.39	169.03
2002	85.52	132.19	152.00	87.31	166.08	186.23	84.94	166.08	184.04
2003	85.14	137.34	158.59	87.17	171.35	192.44	84.58	171.35	190.65
2004	84.17	147.21	171.80	85.96	190.06	216.12	83.44	190.06	214.03
2005	84.37	143.35	166.88	85.85	185.38	211.07	86.01	185.38	202.18
2006	84.46	140.77	163.69	86.14	183.63	208.37	86.12	183.63	199.99
2007	83.30	146.35	172.43	85.37	191.81	219.52	84.81	191.81	211.95
2008	84.30	149.36	173.90	86.22	197.08	223.35	85.77	197.08	215.37
2009	80.65	151.07	183.42	82.91	199.42	234.57	82.51	199.42	226.13
2010	81.02	154.08	186.24				83.68	202.92	226.90
2011	79.87	155.79	190.96				83.66	207.60	232.17
2012							81.92	215.79	246.17
2013									

Table A- 13 Saskatchewan Feed Peas in Black Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	95.63	104.58	108.95	96.16	105.06	108.89	96.05	105.06	109.01
1995	94.00	104.58	110.81	96.41	105.06	108.61	96.15	105.06	108.89
1996	104.04	104.93	99.34	104.42	152.81	148.96	103.99	152.81	149.51
1997	101.26	105.63	102.66	101.58	153.93	154.11	101.44	153.93	154.27
1998	101.30	105.63	102.62	102.13	155.06	154.39	101.65	155.06	155.08
1999	108.25	106.34	96.26	106.73	150.00	142.41	104.40	150.00	145.84
2000	94.90	107.75	109.41	95.10	153.37	161.13	92.86	153.37	165.23
2001	90.64	109.86	116.47	90.00	156.74	173.30	87.86	156.74	177.76
2002	88.24	114.08	124.03	89.13	163.48	182.43	86.41	163.48	188.33
2003	88.27	120.42	130.88	89.65	167.42	185.77	86.81	167.42	191.98
2004	87.17	117.96	129.84	88.41	162.08	182.41	85.64	162.08	188.45
2005	87.18	111.27	122.45	88.11	170.79	192.84	87.82	170.79	193.78
2006	87.02	109.15	120.35	88.12	171.91	194.07	87.68	171.91	195.37
2007	85.84	113.03	126.26	87.33	175.84	200.25	86.39	175.84	202.71
2008	86.68	116.55	128.96	88.11	178.65	201.66	87.27	178.65	203.89
2009	82.83	119.72	138.19	84.65	180.90	212.11	83.87	180.90	214.41
2010	83.03	121.83	140.29				84.92	194.38	227.68
2011	79.43	125.00	150.02				81.34	199.44	243.22
2012							84.04	208.99	246.78
2013									

Table A- 14 Saskatchewan Canola in Dark Brown Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	95.02	93.75	98.73	95.47	93.22	97.75	95.38	93.22	97.84
1995	94.02	93.75	99.77	95.30	93.22	97.92	95.03	93.22	98.20
1996	103.84	115.63	112.63	102.01	110.17	108.84	101.14	110.17	109.74
1997	101.09	109.38	109.52	102.62	108.47	106.51	97.22	108.47	112.31
1998	102.44	115.10	113.79	105.10	111.86	107.26	101.40	111.86	110.99
1999	111.25	118.23	107.10	113.38	138.98	124.82	109.00	138.98	129.58
2000	98.74	118.23	119.14	102.94	141.53	138.59	100.40	141.53	142.16
2001	96.02	121.35	125.57	100.80	148.31	148.11	96.67	148.31	154.26
2002	93.10	125.52	133.71	99.20	159.32	161.46	96.14	159.32	166.57
2003	92.71	129.69	138.70	99.11	170.34	172.78	95.81	170.34	178.65
2004	92.26	141.67	152.18	98.70	194.92	198.42	97.06	194.92	202.09
2005	92.38	136.46	146.40	98.45	189.83	193.75	99.23	189.83	192.31
2006	90.14	130.73	143.80	95.37	185.59	195.49	95.92	185.59	194.44
2007	88.53	135.42	151.53	94.02	194.92	208.07	93.71	194.92	208.67
2008	88.91	142.19	158.45	93.93	206.78	220.94	93.56	206.78	221.72
2009	85.48	143.23	165.72	91.13	215.25	236.57	90.72	215.25	237.54
2010	85.79	148.96	171.76				91.35	235.59	258.32
2011	86.41	155.21	177.71				92.07	250.00	272.08
2012	88.72	172.40	192.66				95.57	280.51	294.94
2013	92.63	181.77	194.64				99.61	295.76	298.51

Table A- 15 Saskatchewan Canola in Black Soil Zone Input, Output and MFP Index (1993=100)

Year	Summer-fallow			Conventional Tillage			Zero Tillage		
	Input	Output	MFP	Input	Output	MFP	Input	Output	MFP
1993	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1994	99.55	91.85	92.30	100.74	95.88	95.14	103.17	95.88	92.71
1995	100.04	91.85	91.84	104.02	95.88	92.04	106.13	95.88	90.05
1996	109.79	106.44	97.48	110.95	115.88	105.11	112.19	115.88	103.69
1997	108.03	106.44	99.04	110.54	117.65	107.10	107.43	117.65	109.67
1998	108.82	106.01	97.92	112.37	117.65	105.33	110.85	117.65	106.19
1999	116.64	107.73	92.47	119.94	122.94	102.97	115.78	122.94	106.23
2000	102.65	108.58	104.30	108.16	127.06	116.53	105.76	127.06	118.99
2001	100.45	110.30	108.18	106.36	129.41	120.63	97.76	129.41	130.20
2002	97.14	113.30	114.69	104.40	137.06	129.98	101.11	137.06	133.43
2003	97.18	116.31	117.69	105.00	143.53	135.37	101.00	143.53	139.86
2004	95.99	120.17	123.03	103.67	152.94	145.96	101.72	152.94	148.04
2005	96.00	117.17	119.95	103.34	148.82	142.50	103.68	148.82	141.20
2006	93.64	117.17	122.90	100.13	150.00	148.05	100.27	150.00	146.96
2007	92.02	116.31	124.12	98.76	149.41	149.49	98.10	149.41	149.57
2008	92.32	121.89	129.67	98.72	158.82	158.97	97.99	158.82	159.16
2009	88.55	125.32	138.62	95.57	164.71	169.93	94.82	164.71	170.21
2010	88.55	134.76	149.06				95.19	182.94	188.38
2011	89.17	142.92	157.05				95.24	195.88	201.61
2012	88.10	157.51	174.96				96.48	215.88	219.56
2013	94.57	162.23	167.36				101.93	222.35	213.75

Table A- 16 Saskatchewan Spring Wheat Estimated Acres

Year	Brown Soil Zone			Dark Brown Soil Zone			Black Soil Zone		
	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage
1993	2502044.06	714577.81	508733.91	3049234.95	1444562.19	650284.48	1238271.58	2847703.48	433194.82
1994	1696797.70	689137.54	494120.15	1563074.31	1594215.96	627490.86	544278.84	2244569.65	405893.22
1995	1764393.70	751192.42	588855.22	1400782.69	1730916.19	753696.70	792811.69	1994286.93	459816.06
1996	2058065.39	753378.83	640880.74	1655604.23	1917303.38	1123457.97	1374482.86	1781890.59	868292.41
1997	1599504.94	662865.95	812253.83	1366586.49	1480376.12	1415937.36	622972.99	2053424.56	1056688.29
1998	595783.41	935574.78	756817.45	285997.79	1785326.78	1229652.66	492698.74	1520683.78	860785.93
1999	901029.46	940258.60	950774.77	536307.16	1556534.17	1355551.10	182801.21	1922708.59	984258.78
2000	748059.42	680786.33	828089.13	566778.85	1347951.94	1366157.43	371200.68	1885748.14	1062010.56
2001	748058.53	680786.09	828087.89	566776.59	1347951.65	1366157.32	371199.81	1885748.05	1062010.56
2002	564312.39	561665.33	755459.53	481825.21	1312327.17	1542166.81	412837.68	1638637.88	1246334.62
2003	535712.68	573950.67	800736.54	393185.49	1287833.03	1590491.85	179436.68	1716690.04	1376244.25
2004	469729.27	559021.98	832150.40	405803.78	1118767.76	1577521.26	261521.10	1577212.43	1517117.64
2005	421014.68	389660.25	904763.46	206481.90	831622.28	1488833.47	179326.35	1016185.73	1461871.88
2006	523623.94	452274.18	1209382.57	345628.68	857764.21	1882948.54	343763.47	1020138.06	1658412.68
2007	421590.48	302962.66	997164.87	331014.65	574276.94	1570076.82	386082.89	627955.34	1277040.41
2008	267818.34	264708.02	970215.90	223160.94	535651.86	1624557.06	206305.80	821480.52	1501348.87
2009	228904.03	237238.18	839915.12	155506.98	544227.76	1577964.39	66359.54	929054.46	1561233.82
2010	291927.05	298406.88	1067085.82	167487.58	521839.26	1570602.32	167841.39	765379.63	1461301.62
2011	229736.41	279147.04	1158196.83	410458.84	306617.68	1561198.95	278116.04	682484.01	1316875.49
2012	197725.07	473580.86	993688.27	145577.80	846051.21	1741092.98	525319.31	780809.12	1509876.42
2013	58316.49	202536.15	797387.96	58326.47	618833.34	2097600.39	205767.12	1039955.50	2115882.69

Table A- 17 Saskatchewan Durum Wheat Estimated Acres

Year	Brown Soil Zone			Dark Brown Soil Zone			Black Soil Zone		
	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage
1993	1123167.94	322724.32	235090.23	640169.21	218276.23	135722.30	112761.58	112792.60	30040.43
1994	1367702.24	605415.20	413247.77	799072.10	543387.94	275416.23	144131.49	303294.35	77215.20
1995	1350558.52	578727.17	445700.29	705987.98	553251.04	314054.51	134570.94	178333.20	69863.25
1996	1401754.03	503425.38	421298.96	656177.14	483416.43	370281.00	130339.66	128133.87	99145.04
1997	1272965.75	560440.59	650691.71	656285.21	438709.12	544093.05	110022.24	158148.40	135611.52
1998	870338.96	1232280.03	1054696.53	222043.54	1120639.32	866617.22	61756.61	309983.93	213771.99
1999	667540.11	743485.53	734013.47	217026.53	478158.04	479277.08	17751.23	140929.15	98522.44
2000	839063.14	922875.93	993300.96	351252.62	726636.61	807475.94	65071.01	250079.32	210559.18
2001	839063.72	922874.26	993301.37	351250.98	726636.77	807475.23	65070.55	250079.86	210556.87
2002	738657.92	797763.47	1022329.40	262643.60	697962.10	844236.29	38711.56	186479.25	179137.25
2003	752315.91	977821.47	1272003.56	198620.71	623937.80	786554.44	16566.39	182134.43	180803.56
2004	612031.72	835000.61	1162680.96	221866.51	595400.87	836596.92	22196.06	158490.02	180772.37
2005	408123.36	418153.80	962054.42	131437.38	352837.35	688948.22	16960.50	83026.60	152662.39
2006	407544.67	376531.98	1004254.63	137446.83	314442.98	721333.19	8011.36	85372.29	159265.81
2007	556801.68	391024.03	1337290.48	190475.38	347067.85	959068.37	21223.01	72400.43	158412.84
2008	517961.15	504846.65	1865078.36	181234.18	388870.99	1262984.55	16991.22	99256.88	244244.02
2009	468898.76	484075.42	1772027.64	147526.37	364738.68	1148741.36	8662.97	95148.26	221754.22
2010	338559.72	326730.64	1169773.49	86718.96	250286.52	784508.48	7747.08	47069.65	121500.15
2011	353969.13	321016.03	1414257.95	196932.08	157328.23	834469.51	23780.36	26487.29	99317.88
2012	395077.31	653678.00	1419034.03	192720.31	350393.51	827607.43	31368.33	68565.31	154538.13
2013	191880.89	513379.72	1985641.42	42936.91	352905.09	1321901.38	3991.51	49800.77	173177.35

Table A- 18 Saskatchewan Feed Barley Estimated Acres

Year	Brown Soil Zone			Dark Brown Soil Zone			Black Soil Zone		
	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage
1993	0.00	377503.20	82699.21	0.00	634475.54	114295.64	0.00	1030219.67	108727.29
1994	0.00	337798.68	90866.06	0.00	598207.12	137274.41	0.00	1004172.74	140629.23
1995	0.00	323389.04	99961.88	0.00	634037.16	170921.93	0.00	1142585.73	188695.86
1996	0.00	319195.36	104332.06	0.00	650348.06	230601.52	0.00	1111868.76	325150.75
1997	0.00	293631.88	138433.26	0.00	585346.15	322045.48	0.00	1004414.57	394202.76
1998	0.00	256094.47	142225.06	0.00	592153.85	360543.81	0.00	863550.26	375104.11
1999	0.00	282187.06	173778.43	0.00	597107.40	421893.93	0.00	879674.80	414150.30
2000	0.00	315028.43	231123.33	0.00	709577.19	554600.75	0.00	1025498.86	503708.11
2001	0.00	315028.35	231121.75	0.00	709577.42	554600.59	0.00	1025499.42	503708.68
2002	0.00	382937.85	353279.75	0.00	619870.28	598303.23	0.00	901351.63	574905.52
2003	0.00	356923.06	367756.04	0.00	565126.08	611133.89	0.00	833509.01	614970.36
2004	0.00	302265.39	355768.29	0.00	502160.49	611394.03	0.00	736983.02	641614.52
2005	0.00	195638.12	331824.60	0.00	394548.27	655697.42	0.00	574738.37	742363.04
2006	0.00	186689.81	377808.89	0.00	309313.28	598525.66	0.00	387461.59	550089.86
2007	0.00	210597.71	495584.69	0.00	332963.22	739462.33	0.00	479889.39	697151.39
2008	0.00	95156.94	270121.10	0.00	262049.93	673416.21	0.00	461552.07	709967.18
2009	0.00	98442.91	280896.88	0.00	229229.39	587120.53	0.00	413369.42	624505.57
2010	0.00	85416.09	248946.78	0.00	143994.08	388027.51	0.00	211349.27	359100.84
2011	0.00	64164.52	217874.40	0.00	131981.18	391046.08	0.00	237049.50	358504.94
2012	0.00	104381.68	203666.39	0.00	214908.02	406585.23	0.00	321227.76	433564.62
2013	0.00	82318.81	301106.90	0.00	162921.77	530794.62	0.00	252785.96	461550.94

Table A- 19 Saskatchewan Lentils Estimated Acres

Year	Brown Soil Zone			Dark Brown Soil Zone			Black Soil Zone		
	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage
1993	0.00	137232.61	30232.95	0.00	322833.51	62952.92	0.00	129529.83	17066.56
1994	0.00	146967.74	40613.16	0.00	347974.27	83362.91	0.00	137579.65	23075.01
1995	0.00	153086.16	48844.25	0.00	321808.39	93291.59	0.00	79772.40	18341.29
1996	0.00	160538.83	54160.80	0.00	285646.72	108080.79	0.00	65721.28	23589.07
1997	0.00	160324.30	82286.80	0.00	273664.05	161066.83	0.00	61148.28	31636.79
1998	0.00	151793.92	98489.49	0.00	308853.62	206190.26	0.00	77723.94	41991.28
1999	0.00	210694.78	151111.16	0.00	378573.39	285283.47	0.00	103091.59	61148.06
2000	0.00	298240.22	236086.30	0.00	488235.04	403932.48	0.00	129128.58	83920.47
2001	0.00	298242.44	236087.18	0.00	488234.61	403932.52	0.00	129127.72	83919.18
2002	0.00	277548.41	270897.01	0.00	371889.86	370427.63	0.00	88359.24	71732.72
2003	0.00	234183.61	257605.97	0.00	330674.10	363675.56	0.00	77173.23	70678.56
2004	0.00	305908.68	377655.79	0.00	439916.56	538500.17	0.00	106213.16	110339.92
2005	0.00	153461.78	283678.29	0.00	259463.11	432827.96	0.00	51800.47	81514.94
2006	0.00	131380.16	288554.43	0.00	252997.40	490208.36	0.00	51210.53	91732.30
2007	0.00	139398.55	360892.73	0.00	246985.69	560088.40	0.00	39820.11	83377.09
2008	0.00	154575.34	477976.15	0.00	233250.38	628016.62	0.00	51511.78	109106.06
2009	0.00	240145.00	727023.13	0.00	310485.72	846110.80	0.00	66165.46	140007.87
2010	0.00	342647.54	1047422.25	0.00	423246.34	1179379.49	0.00	100514.79	208109.71
2011	0.00	276670.40	996311.25	0.00	240055.31	800280.38	0.00	38120.63	97522.53
2012	0.00	397040.81	847224.53	0.00	342011.77	676323.15	0.00	59157.44	101761.34
2013	0.00	241268.13	890896.27	0.00	231967.14	803899.96	0.00	32347.45	99897.25

Table A- 20 Saskatchewan Feed Peas Estimated Acres

Year	Brown Soil Zone			Dark Brown Soil Zone			Black Soil Zone		
	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage
1993	0.00	37146.40	7722.66	0.00	140482.95	24644.12	0.00	301552.60	30450.57
1994	0.00	56800.72	15084.62	0.00	240796.27	53705.47	0.00	394622.48	52890.58
1995	0.00	77085.40	24068.59	0.00	310914.17	83051.74	0.00	431318.69	70516.85
1996	0.00	50828.45	17316.31	0.00	181087.91	62705.59	0.00	283619.64	78678.50
1997	0.00	107518.13	53109.07	0.00	311530.47	176867.78	0.00	384906.81	154652.80
1998	0.00	141086.04	81950.05	0.00	362409.83	221697.37	0.00	479154.75	213063.65
1999	0.00	145553.62	93723.59	0.00	286579.15	201406.86	0.00	333723.95	158386.54
2000	0.00	251574.23	187799.43	0.00	395073.78	311047.19	0.00	470748.77	230007.69
2001	0.00	251573.39	187799.75	0.00	395072.90	311047.86	0.00	470748.06	230007.03
2002	0.00	269380.82	255092.73	0.00	364982.98	353828.12	0.00	441125.73	287995.68
2003	0.00	324024.82	340430.69	0.00	379308.83	411266.36	0.00	382429.79	293281.10
2004	0.00	327373.05	385043.54	0.00	373797.52	454508.57	0.00	366842.28	331579.80
2005	0.00	291951.02	522778.06	0.00	274780.20	466766.67	0.00	258910.51	345548.38
2006	0.00	289095.96	596577.96	0.00	237514.83	469771.57	0.00	195996.97	290307.98
2007	0.00	319181.55	784700.80	0.00	258163.75	596778.20	0.00	221746.99	341938.06
2008	0.00	291039.84	847524.37	0.00	243018.96	662952.20	0.00	240361.02	398740.82
2009	0.00	263214.69	755348.05	0.00	259509.69	699210.22	0.00	229240.75	390756.04
2010	0.00	221257.56	650421.17	0.00	205346.44	567417.13	0.00	203972.07	358616.36
2011	0.00	138645.01	484112.41	0.00	116341.03	377261.64	0.00	95127.51	179080.37
2012	0.00	305080.98	609442.06	0.00	285051.46	558828.80	0.00	156528.94	233508.78
2013	0.00	236384.14	841449.66	0.00	156450.15	547717.05	0.00	107148.44	219916.96

Table A- 21 Saskatchewan Canola Estimated Acres

Year	Brown Soil Zone			Dark Brown Soil Zone			Black Soil Zone		
	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage	Fallow	Conventional Tillage	Zero Tillage
1993	164542.65	20883.06	22113.28	765126.25	105494.71	98139.89	1387814.72	743350.93	154744.29
1994	326127.99	58482.47	65918.58	1279309.53	239485.10	242391.34	1889845.74	829760.18	281218.69
1995	402679.18	45626.69	83168.17	1297928.49	230198.53	283264.38	1672719.43	645459.85	279992.03
1996	162871.17	67658.71	50975.74	684366.52	196911.81	224597.58	803039.52	508957.68	314629.28
1997	234361.32	105247.60	101006.76	833598.88	294042.02	479688.17	1429819.48	378924.90	559401.40
1998	305768.12	66076.53	31824.29	1260694.56	266477.86	145884.35	1367299.20	912645.75	529878.50
1999	445360.65	72222.46	39904.09	1448154.96	276349.59	174199.30	1366462.27	885162.98	545862.46
2000	367492.95	51928.28	38468.54	1281715.72	230591.81	162216.23	1262069.55	782455.45	488410.02
2001	367492.13	51929.68	38467.47	1281717.19	230593.13	162215.68	1262069.51	782454.75	488411.23
2002	203834.34	23548.01	21743.30	829823.84	151747.33	131023.36	861224.92	670472.68	533755.27
2003	331736.36	31657.00	33581.46	1162074.00	215189.80	213982.49	888544.73	878815.20	760718.88
2004	213485.66	63162.60	76875.29	810139.15	354290.07	417370.23	746328.17	1069044.21	1017421.28
2005	327156.24	75296.91	134248.98	1067432.65	249342.02	411053.22	704348.91	656975.98	992942.58
2006	305179.63	58256.09	120670.33	952856.67	279057.72	516137.69	644541.08	630103.08	952464.71
2007	409185.72	70364.43	173130.12	1007393.28	400501.81	868650.13	720280.17	653659.52	1211179.21
2008	324009.15	48362.56	141914.79	627878.44	452718.92	1101026.60	330734.36	1099280.25	1518077.16
2009	309464.69	45945.55	133900.13	650589.97	485372.97	1188608.80	396862.89	1256070.14	1817230.01
2010	447714.89	67139.33	201353.71	775610.27	503944.21	1288691.78	405605.13	1072408.52	1668979.21
2011	676557.44	88147.41	314506.07	900453.18	535597.12	1494948.52	312575.55	1453655.44	2047307.07
2012	630382.70	208969.25	439844.12	958091.37	921316.20	1740951.67	551938.47	1645702.22	2209444.35
2013	601298.63	133099.44	510323.53	578559.91	664205.67	2093953.72	227241.98	1461546.16	2454287.05

APPENDIX B: CROP PLANNING GUIDE2013: GENERAL ASSUMPTIONS FOR ALL SOIL ZONES

1. Crop prices are based on information obtained as of early December 2012. Prices become outdated very quickly. Producers must continually adjust these figures as seeding approaches.

2. Crop yields are increased by 20 per cent above long-term Saskatchewan Crop Insurance Corporation (SCIC) area yield. Feed barley yields are increased an additional 20 per cent over malt barley yields. Crop yields are increased to reflect a higher level of management and higher input levels.

3. Fertilizer: Nitrogen costs are based on 46-0-0 at $605/tonne or $0.60/lb.; Phosphorus costs are based on 11-52-0 at $713/tonne or $0.50/lb.; Sulphur costs are based on 21-0-0-24 at $487/tonne or $0.40/lb. These prices can vary dramatically as spring approaches and producers are reminded to continually adjust these figures as seeding approaches.

4. Chemicals: Pesticide costs are set using Suggested Retail Price (SRP) costs as well as full rate application. Weeds, insects and diseases being controlled vary significantly from farm to farm and from soil zone to soil zone. The assumptions used are only to create a general cost for the guide. Producers must use their own costs based on the weed, insect and disease pressures they are controlling. Prices can also vary significantly from SRP rates.

5. Machinery operating costs: Fuel costs are based on estimated fuel consumptions for the various farming operations with diesel fuel priced at $1.00/litre. Machinery repair rates are four per cent of machinery investment per year for pulse crops, flax and sunflowers, and three per cent for all other crops.

6. Custom work and hired labour is made up of costs for custom farm operations, such as custom trucking and custom spraying. Skilled labour is assumed to be $20 per hour

for 2013.

7. Crop Insurance premiums are based on the yield levels used at a coverage level of 70 per cent.

8. Utilities are made up of electricity, natural gas, water and telephone. This category has increased by 2.7 per cent for 2013.

9. Interest on variable expenses: Operating interest is calculated on all variable expenses at 4.2 per cent for six months, 18 months for fallow.

10. Building repair rates are two per cent of building investment per acre.

11. Business overhead is made up of legal, accounting, insurance, licenses and miscellaneous. This category is up 1.5 per cent for 2013.

12. Machinery depreciation is calculated at 10 per cent of machinery investment per year on a straight-line basis.

13. Building depreciation is calculated at five per cent per year on a straight line basis of building investment.

14. Machinery investment is calculated at a 3.25 per cent return on investment. It is assumed that a Brown Soil Zone farm has $178.27 per cultivated acre invested in machinery; a Dark Brown Soil Zone farm has $207.21 per cultivated acre invested in machinery; and a Black Soil Zone farm has $238.47 per cultivated acre invested in machinery. Chem-fallow has only a portion of the machinery cost attributed to it. An additional machinery investment of $63 per acre is assumed for pulses and some specialty crops.

15. Building investment cost is calculated at a three per cent return on investment. It is assumed that a Brown Soil Zone farm has $20 per cultivated acre invested in buildings; a Dark Brown Soil Zone farm has $26 per cultivated acre invested in buildings; and a Black Soil Zone farms has $35 per cultivated acre invested in buildings.

16. Land investment cost is calculated at a 4.1 per cent return on investment of $480 per cultivated acre in the Brown Soil Zone; $583 per cultivated acre in the Dark

Brown Soil Zone; and $643 per cultivated acre in the Black Soil Zone.

17. Labour and management: These budgets do not include an estimate for owner/operator labour and management. This value varies greatly and farm managers need to determine their own actual labour and management cost.