Impact of Switching from Fall to Spring Fertilizer Application: "An economic analysis of N_2O reducing seeding systems in Saskatchewan"

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ABSTRACT

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Nitrogen (N) fertilizer applied in the fall has been shown to increase emissions of N_2O a GHG (Nyborg et al. 1997). Applying N fertilizer in the spring is a management technique Saskatchewan grain and oilseed producers can use to reduce N_2O emissions.

The hypothesis of this thesis is that fall application of N fertilizer is more profitable than spring application. Factors to consider in the timing of fertilizer application include, the level of information available, input cost, input efficiency, and application cost.

The key objective of this thesis is to determine the financial impact of switching to spring N application from fall N application. Stochastic variables include fall subsoil moisture, winter precipitation, growing season precipitation, input costs, and output prices. Expected utility theory for two representative farms at two locations is used to determine optimal N fertilizer rates and the value of spring subsoil moisture information and the value of spring output price forecasts. The fixed and variable operating costs are calculated for three seeding systems.

The results show that it is optimum for producers to purchase N fertilizer in the fall and apply N fertilizer in the spring. Spring subsoil moisture information, and spring output price forecasts have little value to producers committed to continuous cropping. One pass (seed and fertilize in the spring) seeding systems have lower variable and

fixed costs than two pass seeding systems for producers applying large amounts of fertilizer.

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CHAPTER 1

INTRODUCTION

> **"***Nitrous Oxide is potentially agriculture's greatest contributor to the Green House Gas Problem. Reduced emissions could be accomplished through optimal application, timing and placement of fertilizer and through improved handling and storage of manure***"** **(**Agriculture and Agri-Food Canada (2000), pg 18.)

1.1 Background

The production of greenhouse gases (GHG) is associated with various environmental concerns such as a general warming of the earth, the melting of the polar ice cap, changes in ocean currents and extreme weather events (IPCC 2001). The three most important GHG for agriculture are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

N_2O emissions have high Global Warming Potential[1] (GWP) and contribute to ozone depletion. Agriculture and Agri-Food Canada (1998) report that N_2O emissions have 170 to 280 times more

---

[1] GWP is a simple way to compare the potency of various green house gases taking into account the gases ability to absorb and remit radiation but also how long the effects last. For a further discussion see Agriculture and Agri-Food Canada (1998).

GWP than does CO_2 depending upon the time horizon, and N_2O released into the atmosphere breaks down ozone.

N_2O can come from anthropogenic and non-anthropogenic sources. N_2O emissions from natural sources are about twice those from anthropogenic sources (Kulshreshthla et al. 1999). Anthropogenic N_2O sources include nitrogen-based fertilizers, soils, crop residues, industrial processes, biomass burning and animal production. Natural N_2O sources include oceans and tropical forest soils.

There have been several international meetings to set GHG emission levels. The meeting in Kyoto Japan in 1997 is important to Canada. “Canada has committed to reduce its average annual emissions of greenhouse gases for the 2008-2012 period to a level 6% below its greenhouse gas emissions in 1990 (Agriculture and Agri-Food Canada 2002).”

Identifying the sources of GHG emissions are important when developing policies to meet the GHG reduction commitments. On a national scale, N_2O contributions are a small portion of total GHG emissions, but agriculture is a significant source of Canadian N_2O emission. Agriculture and Agri-Food Canada (2002) reports primary agriculture is responsible for about 10% of Canada's greenhouse gases which, does not include transportation input costs, or agri food processing. Primary agriculture in Canada is responsible for 61% of the Nation’s N_2O emissions, 38% of the Nation’s CH_4 emissions, and less than 1% of the Nation’s CO_2 emissions. Policies must be developed that economically and efficiently reduce GHG emissions.

Using data presented in Kulshreshthla et al. (1999), Saskatchewan's 1994 GHG emissions[2] were 12245.8-kilotonnes CO_2 equivalents, representing 20 per cent of the Canadian agricultural GHG emissions. Canadian annual N_2O emissions were 45.4-kilo tonnes. Saskatchewan's estimated annual N_2O emissions were 14.4 kilo tonnes representing 32% of the nation's N_2O emissions. Saskatchewan GHG emissions from agricultural activities are presented in Table 1.1. Application of fertilizer is the second highest source of N_2O emissions from agriculture in Saskatchewan.

Table 1.1: 1994 Saskatchewan Agriculture Emissions of Greenhouse Gases (CO_2, CH_4, and N_2O) (CO_2E^1/year)

Activity	CO_2 [1]	CH_4 [1]	N_2O [1]	CO_2 E [1]
CROP PRODUCTION				
Biomass Burning	0	0	56.49	56.49
Crop Residues	0	0	3077.28	3077.28
Fertilizer	0	0	556.74	556.74
Fossil fuel	2708.35	0	73.92	2782.27
Chemicals	22.72	0	0	22.72
Nitrogen Fixing Crops	0	0	463.23	463.23
Soil Organic Matter	3007.85	0	0	3007.85
CROP TOTAL	5738.92	0	4268.38	10007.3
LIVESTOCK PRODUCTION				
Raising Livestock	0	1096.94	0	1096.94
Livestock Management	142.68	0	0	142.68
Animal Excrement/Wastes	0	1506.75	192.08	1698.83
LIVESTOCK TOTAL	142.68	2603.99	192.08	2938.45
GRAND TOTAL	5881.6	2603.99	4455.46	12945.75

Source: adapted from Kulshreshthla et al. 1999 pg E-3.

1. Carbon Dioxide CO_2, Methane CH_4, Nitrous Oxide N_2O, Carbon Dioxide Equivalents CO_2E. Using GWP the emissions of N_2O and CH_4 are converted into CO_2 equivalents.

1.2 Problem

Traditional wheat-fallow crop rotations are becoming less common in Saskatchewan. New herbicides, better seeding equipment, and expired patents on some chemicals enable producers to extend their crop rotation and reduce the amount of

---

[2] Using GWP the emissions of N_2O and CH_4 are converted into CO_2 equivalents.

fallow. These extended cropping rotations require additional inputs of nitrogen (N) in the form of N fertilizer to attain profitable yields. N fertilizers used by agricultural producers in Saskatchewan include urea, ammonium nitrate, anhydrous ammonia and urea-ammonium nitrate. Nitrogen fertilizer consumption has increased rapidly. N fertilizer use at the end of the 1990s was almost double (183 per cent) of what was used at the start of the decade (Saskatchewan Agriculture and Food Statistics Handbook, Various Years). The amount of fertilizer consumption in Saskatchewan for the 1990s is presented in Table 1.2.

Management and environmental factors influence GHG emissions from applied fertilizer. Management practices influencing GHG emissions from fertilizer include application rate, application technique, application timing, tillage practices, the use of other chemicals, irrigation, residual nitrogen and carbon from crops and fertilizer. Environmental factors influencing GHG emissions from fertilizer include temperature, precipitation, soil moisture content, soil texture, soil nitrogen content, organic carbon content, oxygen availability, porosity, pH, freeze and thaw cycle annual variation and microorganisms (Kulshreshthla et al. 1999).

Table 1.3 lists the relative proportion of N_2O-emissions produced as percent of N in the fertilizer from the various forms of fertilizer. There are two main ways to estimate the N_2O emissions associated with fertilizer use. The first approach is a weighted average using a factor for the percent of N_2O evolved multiplied by the aggregate use of that type of fertilizer. The second method is much more complex using not only the previous approach but also a factor that considers the type of crop upon which the nitrogen is applied. Greene and Salt (1993) suggest that regardless of the method used, the estimates of GHG emissions from fertilizer are not very accurate.

Table 1.2 Saskatchewan Nitrogen Fertilizer Consumption by Type 1989-1990 to1998-1999 in tonnes

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	
						Fertilizer nutrient sold tonnes					
NITROGEN[1]											Average
82-0-0	85,020	73,295	95,857	103,734	123,498	138,563	167,103	204,254	151,046	160,091	130,246
46-0-0	117,830	107,040	138,857	141,819	181,376	202,764	230,602	256,410	243,291	208,717	182,871
34-0-0	12,261	10,142	12,289	12,173	16,926	15,796	19,570	24,024	20,935	15,964	16,008
20/21-0-0-24	9,435	9,717	11,423	13,085	17,066	14,793	13,325	19,905	24,774	28,832	16,235
28-0-0	2,733	2,957	2,871	3,824	1,398	3,208	4,451	8,325	17,763	19,742	6,727
Total	227,279	203,151	261,298	274,634	340,264	375,124	435,050	512,918	457,809	433,345	352,087
						Nitrogen based fertilizer nutrient use by form					
NITROGEN[1]											Average
82-0-0	37%	36%	37%	38%	36%	37%	38%	40%	33%	37%	37%
46-0-0	52%	53%	53%	52%	53%	54%	53%	50%	53%	48%	52%
34-0-0	5%	5%	5%	4%	5%	4%	4%	5%	5%	4%	5%
20/21-0-0-24	4%	5%	4%	5%	5%	4%	3%	4%	5%	7%	5%
28-0-0	1%	1%	1%	1%	0%	1%	1%	2%	4%	5%	2%

Source: Saskatchewan Agriculture and Food, Statistics Handbook, Various Years

1. 82-0-0 Anhydrous Ammonia, 46-0-0 Urea, 34-0-0 Ammonium Nitrate, 20/21-0-0-24 Ammonium Sulfate, 28-0-0 Nitrogen Solutions

.

The type of fertilizer used, method and timing of application can influence Nitrogen Use Efficiency (NUE) and the profitability of the farm operation. NUE is a ratio of the amount of N taken up by the crop to the amount of N applied (Gauer et al. 1992). A high NUE value means the N applied is used for the growth of the crop. In general, spring fertilizer application results in higher NUE than fall application, and banding results in a higher NUE than broadcasting.

A farmer can reduce input costs by the timing of the fertilizer purchase. N fertilizer is often more expensive in the spring than in the fall. Cash flow, tax implications and storage availability also influence the timing of fertilizer purchases. Producers may have low cash flow in the fall reducing their ability to purchase fertilizer in the fall. Producers operating on a cash accounting basis may choose to reduce taxes payable by purchasing fertilizer in the fall. If on farm fertilizer storage is not available in the fall the purchase may have to be postponed.

Table 1.3: Fertilizer N_20 Emissions Produced as a Percent of N in the Fertilizer, for Different Fertilizer Types

Fertilizer Type	N_2O-N produced	N_2O-N produced
	(Median) %	(Range) %
Anhydrous ammonia and aqua ammonia	1.63	0.86-6.84
Ammonium Nitrate	0.26	0.004-1.71
Ammonium sulfate nitrate		
Calcium ammonium nitrate		
Ammonium type	0.12	0.002-1.5
Ammonium sulfate		
Ammonium phosphate		
Urea	0.11	0.07-1.5
Nitrate	0.03	0.001-1.5
Calcium nitrate		
Potassium nitrate		
Sodium nitrate		
Other nitrogen fertilizers	0.1	0.001-6.84
Other complex fertilizers	0.11	0.001-6.84

Source: Greene and Salt (1993) (pg. 259) who sourced from OECD (1991)

Society has a vested interest in the environment. In the case of N_2O emissions from nitrogen fertilizer use, society can be affected in several ways. Policy options like taxes and subsidies may be beneficial in changing farming practices to encourage N fertilizer use that reduces the level of N_2O emissions. Taxing nitrogen fertilizer consumption may lead to a decrease in the use of fertilizer or an increase in the amount of fallow. An increase in fallow acreage may lead to other environmental problems like soil erosion and the release of stored soil carbon possibly increasing GHG emissions. Subsidies for the implementation of environmentally friendly management practices may lead to increased fertilizer input use, and possibly N_2O emissions.

The adoption of N_20 reducing technologies by Saskatchewan grain and oilseed producers will occur if the technology can be seen as beneficial. The benefits of the new technology can be increased production, cost savings, reduction of risk or other benefits that leave the manager better off than continuing the use of the current technology. Incentives and disincentives can be developed to affect the farm manager's decision concerning the adoption of a new technology.

1.3 Study Hypothesis

Fall application of Nitrogen fertilizer is more profitable than spring application.

1.4 Objectives

The specific objectives of this thesis are:

1) To determine the benefits and costs of the fertilizer application decision for the farmer.

    i) The value of spring subsoil moisture information.
    ii) The value of output price expectations in fertilizer decisions.
    iii) The effect of N input cost on profitability.
    iv) The direct cost of various seeding systems.

2) To describe the N_2O cycle relating Saskatchewan agronomic practices to environmental concerns.

3) To perform a literature review on risk, uncertainty and new technology investment as it pertains to farm management.

1.5 Methodology

A polynomial function is used to model a producer's N fertilizer choice. The producer has two time frames, fall and spring, in which to make a fertilizer decision with different levels of information. Stochastic variables include fall subsoil moisture, winter precipitation, growing season precipitation, input costs, and output prices. Stochastic variables are generated using historical data for Saskatchewan.

The producer's risk preference and soil type influence the calculated optimum N fertilizer application for representative Saskatchewan locations. Net present value and certainty equivalents are calculated for each scenario to determine the optimal N fertilizer decision strategy. The value of information is calculated using differences in expected utility for the most profitable level of N fertilizer application for each strategy. The fixed and variable operating costs are calculated for the seeding systems to correspond with the producer's direct and indirect costs.

1.6 Scope of the Study

The study focuses on the value of subsoil moisture and price information in choosing the optimum amount of fertilizer to apply in a continuous crop rotation in the Dark Brown and Black soil zones in Saskatchewan. Moisture is highly variable in Saskatchewan and the timing of precipitation is also variable. The stage of plant growth when moisture is received can be more important than the amount received. However, the examination of the timing of moisture is beyond the scope of this thesis. The model assumes precipitation received through the growing season has the same yield influence regardless of which month it is received.

This study assumes that spring nitrogen fertilizer application will result in lower N_2O emissions than fall fertilizer application. However, there are several soil biotic and abiotic factors that affect N_2O emissions from applied nitrogen fertilizers (Beauchamp 1997).

1.7 Organization of Thesis

This thesis examines how producer risk preferences affect the value of information on spring subsoil moisture conditions and the expected output price and consequently the timing of fertilizer application. The second chapter provides a literature review of the two major components relating to this study. The first part is a literature review of the agriculture N cycle and factors that affect N_2O emissions. The second part is a literature review concerns agricultural decision-making. Chapter 3 examines methods for analyzing production and investment decisions under certainty and uncertainty. Chapter 3 includes a discussion on determining the value of information. Chapter 4 provides the methodology used to determine the optimal N fertilizer choice, the value of information, and seeding system operating cost. Chapter 5 provides the assumptions associated with the parameter values required for the methodology described in Chapter 4. The optimal N fertilizer choice, value of information and direct operating cost results are presented in Chapter 6. Chapter 7 contains the summary and conclusions of the thesis and suggests areas for future research.

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

Two different areas of investigation are required to determine the most profitable seeding system that reduces N_2O emissions. The first area of investigation is to examine nitrogen (N) use in agriculture to understand the N cycle and management practices that limit N_2O emissions. The second area of investigation examines farm management decision-making.

2.1 Nitrogen Use in Agriculture.

There are numerous sources available that discuss the N cycle and agriculture including Troeh and Thompson (1993), and Singer and Munns (1996). There are stocks and flows in the N cycle. Stocks represent the accumulated level of material and flows represent the movement of material into and out of the stock. Internal transformations affect the form of N in the system.

Additions of N to the agriculture system come from four sources: electrical fixation, symbiotic nitrogen fixation, nonsymbiotic nitrogen fixation, and industrial fixation. Electrical fixation occurs when lightning reacts with N_2 in the air. Free living bacteria in the soil carry out non-symbiotic fixation. Electrical and non-symbiotic fixation contribute relatively little N to agricultural systems. Symbiotic N fixation and industrial fixation are significant N contributors to the soil system. Symbiotic N fixation occurs when legume crops have been inoculated with the appropriate

Rhizobium bacterial species. Industrial fixation is the application of commercial fertilizer, which requires significant amounts of energy to convert atmospheric N to ammonia (NH_3).

Losses of N from an agriculture system include harvesting of plant material, burning of straw, denitrification, volatile losses, erosion and leaching. Harvesting of plant material involves the transport of N embodied in the plant tissue as protein to the market place. The burning of straw releases the N in straw to the atmosphere. Volatile loss occurs when ammonium based fertilizers are applied and the ammonia embodied in the fertilizer evaporates. Denitrification is a biological process carried out under anaerobic conditions where nitrate is converted to N_2 gas. Erosion is due to wind or water moving soil (common with tilled soil). Leaching is the process of nitrate being washed below the plant rooting zone.

The internal transformations of soil N include immobilization, mineralization and ammonium fixation. Immobilization describes the process during which, soil microbes feeding on nitrogen poor organic materials tie up the N, making it unavailable to plants. Mineralization is the biological process of converting organic N into inorganic N (ammonification, nitrification) for plant use. Ammonium fixation involves the adsorption reactions between negatively charged clay particles and positively charged ammonium ions where the ammonium becomes fixed to the clay surface.

2.2 N_2O Emission Processes

Soil microbial processes are primarily responsible for soil N_2O emissions. Beauchamp (1997), reports that climate, soil characteristics, cropping practices and their interactions affect the nitrification and denitrification processes and hence the production and emission of N_2O. Hutchinson (1995) reports that nitrifiers produce most of the NO and dentitrifiers produce most of the N_2O. Figure 2.1 displays the various biotic and abiotic factors that influence the denitrification of NO_3^-. Figure 2.2 displays the factors affecting the nitrification cycle.

Nitrification is the process of converting atmospheric N_2 into NO_3^-. Equation 2.1 shows the oxidative nitrification chemical process. Soil Nitrification is accomplished by genra of aerobic chemoautotrophic bacteria (Nitrosamonas and Nitrosospira ($NH_4^+ \rightarrow NO_2^-$) and Nitrobacter ($NO_2^- \rightarrow NO_3^-$)).

$$\begin{array}{l} NH_4^+ \rightarrow NH_2OH \rightarrow (\text{e.g. } H_2N_2O_2) \rightarrow NO_2^- \rightarrow NO_3^- \\ \qquad\qquad\qquad\qquad\quad \downarrow \\ \qquad\qquad\qquad\qquad\quad N_2O \end{array} \qquad (2.1)$$

Denitrification is the process of converting plant available NO_3^- into N_2 gas. Certain aerobic bacteria carry out denitrification when O_2 becomes limiting. These bacteria have the ability to reduce N oxides depending upon the availability of a suitable reductant (usually organic C), and the presence of N oxides (NO_3^-, NO_2^-, NO, or N_2O) (Hutchinson 1995).

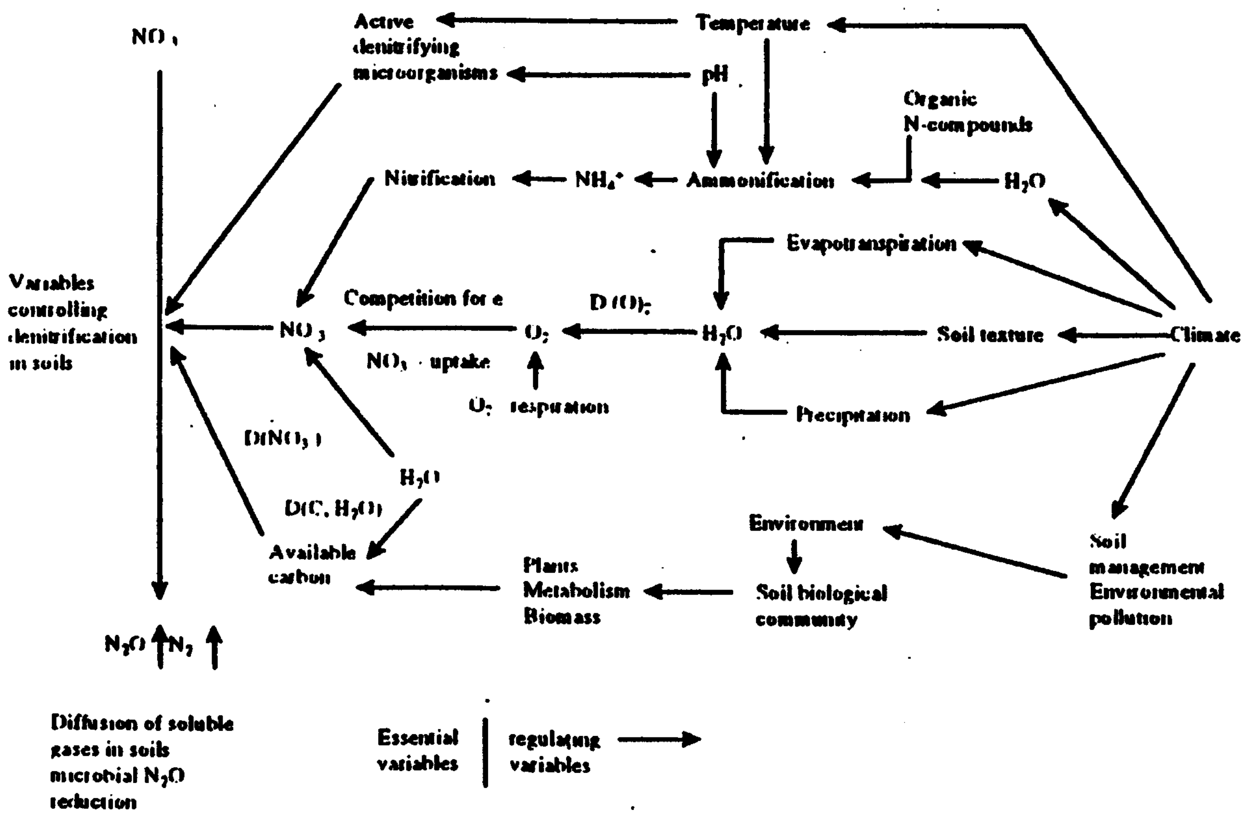


Figure 2.1 Variables regulating the denitrification process in agroecosystems. D (O_2), D (NO_3^-) and D (CH_2O indicate diffusion of O_2, NO_3^- and water soluble C, respectively

Source: Beauchamp (1997) pg 117 sourced Benckiser (1995)

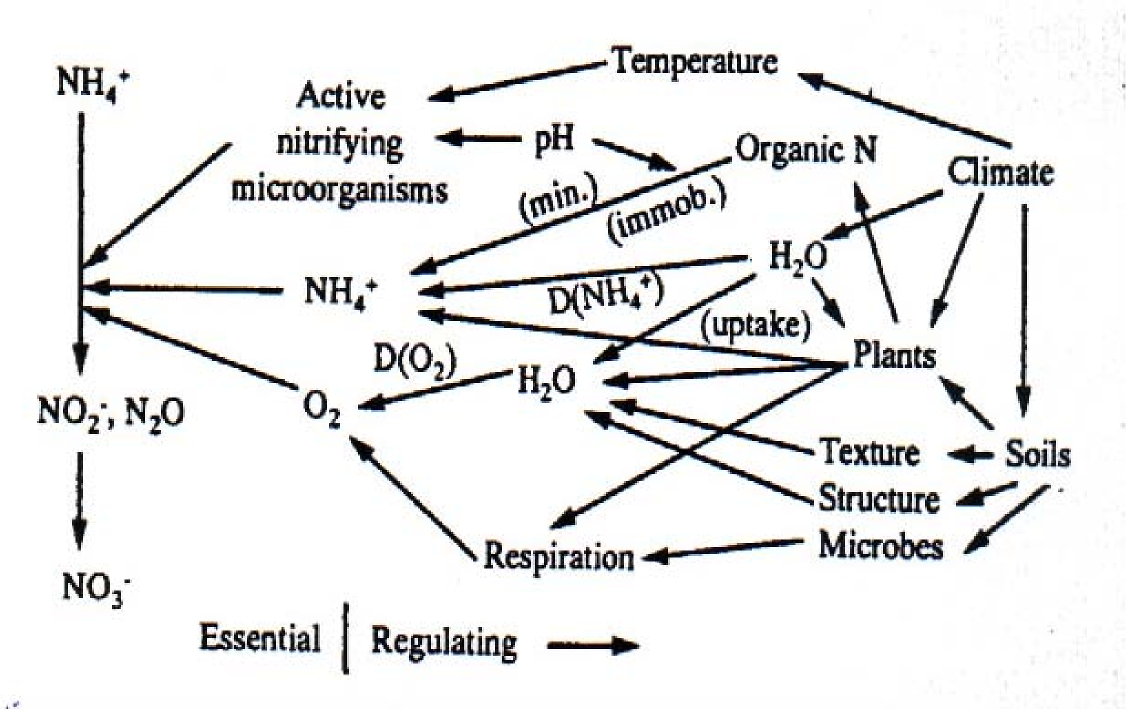


Figure 2.2 Variables Regulating the Nitrification Process in Agroecosystems.

Source: Beauchamp (1997) pg 118.

The microbial conversion of reductive denitrification is displayed in Equation 2.2.

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O\uparrow \rightarrow N_2\uparrow \quad (2.2)$$

2.3 The Soil Microbial Environment

Soil microbes have various physical environmental requirements to grow and function. Soil porosity, aeration, water availability, substrate availability, temperature, and soil pH, influence which soil microorganisms are active and the level of microbial activity (Troeh and Thompson (1993), Singer and Munns (1996))

A certain amount of water and air is required for the soil microorganisms to function. Soil porosity or the volume of soil that is not “earthen material” can be shared between soil moisture and air. The more porous a soil is, the more air and water are available. Soil water content and air content can influence the rates of diffusion of various gasses and solute and substrate transport. Too much or too little water or air can influence the types of microorganisms that are active.

Organic C and N substrate availability influences microbial activity. Organic C content significantly influences microbial growth by providing an energy source to the microbes. Certain levels of organic N are required to maintain basic levels of biological activity.

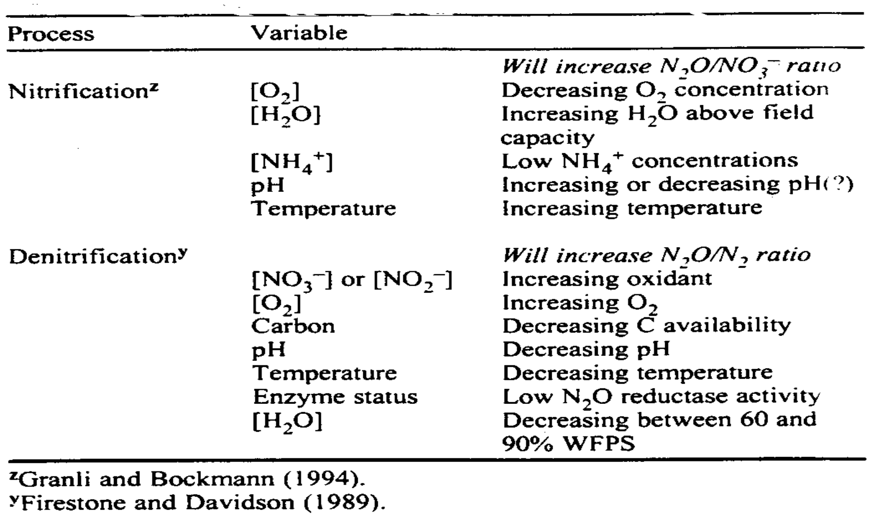
Soil temperature affects microbial activity. Soil microbial activity generally increases as soil temperature increases. Soil temperature and atmospheric temperature can influence the rates of gaseous transfer and solute transport of nitrogen gases.

Freeze thaw cycles affect annual N_2O emissions. Nyborg et al. (1997), report that in a normally well drained soil the spring thaw impeded drainage, and correspondingly the N_2O flux was higher during the spring thaw, compared to the rest of the year.

The pH of the soil environment can affect the type of organisms that are biologically active and the availability of nutrients in the soil.

Management practices that influence the aforementioned variables will influence N_2O emissions from the soil microbial processes of nitrification and denitrification. Table 2.1 displays the variables that influence product ratios of denitrification and nitrification.

Table 2.1 Soil Abiotic Variables that affect Nitrification and Denitrification



Process	Variable	
		Will increase N_2O/NO_3^- ratio
Nitrification[z]	$[O_2]$	Decreasing O_2 concentration
	$[H_2O]$	Increasing H_2O above field capacity
	$[NH_4^+]$	Low NH_4^+ concentrations
	pH	Increasing or decreasing pH(?)
	Temperature	Increasing temperature
Denitrification[y]		*Will increase N_2O/N_2 ratio*
	$[NO_3^-]$ or $[NO_2^-]$	Increasing oxidant
	$[O_2]$	Increasing O_2
	Carbon	Decreasing C availability
	pH	Decreasing pH
	Temperature	Decreasing temperature
	Enzyme status	Low N_2O reductase activity
	$[H_2O]$	Decreasing between 60 and 90% WFPS

[z] Granli and Bockmann (1994).
[y] Firestone and Davidson (1989).

Source: Beauchamp (1997) pg 119.

2.4 N_2O Emission Reducing Management Techniques

In order to reduce N_2O emissions from crop production activities, it is important to focus on managerial techniques. Managerial techniques that affect N_2O emissions include, tillage technology, tillage techniques and tillage timing, crop rotations, method and timing of fertilizer application, and type of N applied. Fertilizer applied in the fall is subject to spring thaw environmental conditions. Fertilizer applied after the spring thaw will not be subject to the spring thaw environmental conditions there by generally reducing N_2O emissions from fertilizer N (Nyborg et al. 1997).

Mosier et al. (1996) suggest management practices that optimize the crop's ability to uptake N as it becomes available will reduce N_2O emissions from mineral and organic N. N use efficiency (NUE) examines a crops N uptake, relative to the amount of N applied. Strategies that increase NUE can also reduce N losses. Gauer et al. (1992) reports that NUE is generally the greatest with low levels of applied N and decreases as the amount of N applied increases. Improved moisture conditions increase NUE through increased yield potential and improvement of N mobility in the soil.

Mosier et al. (1996) (pg 104) gives the following strategies to reduce N_2O emissions:

1) Match N supply with crop demand
    a) Use soil/plant testing to determine fertilizer N needs
    b) Minimize fallow periods to limit mineral nitrate accumulation
    c) Optimized split application schemes
    d) Match N application to reduced production goals in regions of crop over production

2) Close N flow cycles
    a) Integrate animal and crop production systems in terms of manure reuse and plant production
    b) Maintain plant residue N on the production site

3) Use advanced fertilization techniques
    a) Controlled release fertilizers
    b) Place fertilizers below the soil surface
    c) Foliar application of fertilizers
    d) Use nitrification inhibitors
    e) Match fertilizer amount and type to seasonal precipitation

4) Optimize tillage, irrigation and drainage

2.5 Nitrogen Fertilizer Application Options

There are several methods available for adding commercial N to the soil. Prairie Agriculture Machinery Institute (2000) and Thavarajah (2001) provide detailed discussions of fertilizer application methods for the Prairie Provinces. Producers can broadcast, broadcast and incorporate, deep-band, seed place, mid-row band, or side-row band. Some methods of fertilizer placement are more effective than others, with respect to yield response, and N uptake. However, depending upon the resources available to the farm manager, the less effective methods of fertilizer placement may be more profitable than more effective N placement alternatives.

Surface broadcasted fertilizer allows for significant amounts of N to be added however, the N may not be used as efficiently. Broadcasting followed by tillage incorporation allows for significant amounts of N to be added and the efficiency is generally improved compared to surface broadcasting.

Deep-banding fertilizer application involves applying and incorporating fertilizer in one pass. Deep-band fertilizer application allows for large amounts of N to be applied without injury to the seedlings, but requires an additional operation prior to seeding.

A seed-placed fertilizer application technique involves placing the fertilizer with the seed. Amounts of seed-placed fertilizer are limited due to ammonium toxicity with the seed. The amount of fertilizer that can safely be placed with the seed is dependent upon the type of fertilizer used, the seed row spacing, seedbed disturbance and the type of crop. Producers applying large amounts of fertilizer may need to use another fertilizer application technique in conjunction with seed-placed fertilizer to safely apply large amounts of fertilizer.

Side-row banding fertilizer allows for separation of seed and fertilizer by a distance of one inch (2.5 cm) to the side and one inch below. Side-row banding generally allows for significant amounts of N to be safely added without reducing yield. Side-row banding is a one pass operation and can save producers time, labor and fuel. Side-row banding requires double-shoot seeding system technology which is a separate delivery channel for seed and fertilizer.

Mid-row banding fertilizer places the fertilizer between the seed rows with a separate opener. There is significant seed and fertilizer separation and large amounts of fertilizer can be applied. N fertilizer is highly mobile in soil and will eventually be taken up by plant roots. However, other nutrients (phosphorus, sulfur, potassium etc.) are not as mobile and may be inaccessible if applied in the mid-row band. Mid-row banding requires double-shoot seeding system technology.

Broadcasting fertilizer is generally viewed as the least effective method of applying fertilizer measured for N uptake and yield increase. Generally, yields will increase the closer the fertilizer can be placed to the seed without causing injury. However, yield differences may not be significant. Thavarajah (2001) reports that the position of the fertilizer band (side vs. mid-row) and N form (urea vs. anhydrous ammonia) appears to be less agronomically important, when natural soil fertility is high compared to low soil fertility.

Nitrification inhibitors and controlled release fertilizer are options for applying large amounts of N fertilizer with the seed. Inhibitors allow the N to be slowly released to the soil. Slow release fertilizers allow large amounts of seed and fertilizer to be placed together without causing seedling injury. Field trials suggest crop establishment is unaffected with large applications of controlled release N, and performed similar to side-banded urea (Fleury 2000). Mosier et al. (1996) reviewed several papers and reports using nitrification inhibitors does not always result in increased crop yields, but a number of field studies indicate that nitrification inhibitors do limit N_2O emissions from ammonium based fertilizers.

Harapiak (1996) reports on the influence of farm size and location on choice of fertilizer application technique in the Prairie Provinces. There is an increased preference for band applications of N and decreased preference for broadcasting as farm size increases. The preference for application of fertilizer at the time of seeding increases as farm size increases. Fall application of N fertilizer is most common for producers that apply large amounts of N, for high rainfall areas like the Black soil zone.

Part II Economic Literature Review

2.6 Decision Making

Economic theory assumes that economic agents maximize their objective functions subject to constraints. Farm managers may choose to maximize profit or they may choose to avoid large fluctuations in their net income by utilizing risk-reducing practices. The farm manager examines production, financial and marketing, and accounting issues to implement the best practices to achieve his/her goals (Osburn and Schneeberger 1983).

There are two time frames or planning horizons over which farm managers make decisions, the short run and the long run. Short run decisions are made based upon the reality that some of the farm's resources are fixed like land and machinery, and some inputs are variable like fertilizer, seed, and chemical. Long run decisions are made with all inputs being variable including land and machinery.

The farm manager makes decisions based on stochastic and non-stochastic variables. The non-stochastic variables can be viewed as given conditions that the decision-maker may face. The decision-maker will examine the stochastic variable's expected value and distribution to determine the optimal amount of the choice variable to meet the decision-maker's goals.

"Expected Utility maximization is one of the most common decision criteria in agriculture decision analysis" (Qi Dai et al. 1993 pg 378). The expected utility approach needs a utility function to be specified. The expected utility function allows for the examination of the optimum input use given a set of observations and a probability distribution for a stochastic process. The first order conditions are satisfied where the expected marginal value product of a variable input equals the marginal cost of the variable input plus a risk adjustment factor[3] (Zentner et al.1992). SriRamaratnam et al. (1993), and Qi Dai et al. (1993) use nitrogen fertilizer as the choice variable while soil moisture and available nitrogen at seeding are non stochastic with stochastic rainfall.

The Von Neuman-Morgenstern (VNM) utility index ranks outcomes and can aid in decision analysis. Katz and Rosen (1994) define the VNM utility function, as a utility function where the utility associated with some uncertain event is the expected value of the utilities of each of the possible outcomes. Economic agents maximize the expected value of utility and not the utility of the expected gamble. The utility index treats utilities as numerically measurable quantities (Von Neuman and Morgenstern 1947). Katz and Rosen (1994) suggest four steps for using decision trees and VNM utility functions to break up complex problems into simple components.

1) Sketch a decision tree identifying each time a decision has to be made and place branches for each outcome, and identify the probability associated with each.
2) Determine the utility associated with each outcome.
3) Calculate the expected utility considering the utility of each outcome and its associated probability.

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[3] The risk adjustment factor is dependent upon the nature of the Probability Distribution Function and the nature of the risk preferences of producers determined by the Arrow Pratt coefficient of Absolute Risk Aversion.

4) Compare the associated utilities and choose the option with the highest expected utility.

2. 7 Information and Decision Making

Information is an economic input. Agricultural businesses are decision making units with the capacity to make use of their own experience and knowledge, as well as take advantage of externally sourced information. Information needs for decision making include prediction of prices, supply and demand estimates, and information about the performance of alternative technologies, discussion and strategic advice as to implications of regulations and trade policies, and information about changing dietary patterns and retail trends (Just et al. 2002). Katz and Rosen (1994) suggest if information has no effect on the firm’s actions then the information has no economic value.

2.7.1 Information and the Production Decision

The arrival of information has been shown to have value to the farm manager. Decision makers may be better off waiting until stochastic variables are known with certainty. If stochastic production variables are known with certainty decision makers will be able to make more advantageous decisions with respect to other inputs. For grain producers in southern Saskatchewan moisture is a stochastic variable in the determination of grain yields. Zentner and Read. (1977) report producers using spring subsoil information can make more accurate estimates of final yields and fertilizer strategies that result in more efficient use of inputs and higher probabilities of economic success. Zentner et al. (1992) suggest producers who use distributions of growing season precipitation, to determine the amount of fertilizer application will maximize expected utility of profit, subject to their risk preferences. Zentner et al. (1993) studied the use of soil moisture information in the stubble cropping decision. Waiting for moisture information beyond the end of May would results in higher probabilities of stubble crop success and profitability. However, waiting for arrival of information may not be practical if field operations are subject to time constraints.

2.7.2 Information and the Investment Decision

The adoption of new technologies for farm operations usually begins with managers seeking information either actively or passively about the benefits and drawbacks of available products. Kalaitzandonakes and Boggess. (1993) provide definitions of active and passive learning. Active learning requires the firm to invest in new technology and the firm's stock of knowledge increases through experience. Passive learning on the other hand implies that increases in the firm's stock of knowledge with respect to the new technology does not require any investment, and occur through external sources of information or contact with prior adopters.

As producers acquire more knowledge about the technology their expectations are altered. Hiebert (1974) suggests the probability distribution of the production function of new or unfamiliar technological parameters would shift because learning and experience will increase the net income expectations of farmers. Net income probabilities will be redistributed from lower to higher payoffs, inducing farmers to increase their use of the new technology. Kislev and Shchori-Bachrach (1973) suggest a new technology's production function incorporates an efficiency factor positively related to the level of knowledge.

Monchuck (1999) citing Hart (1942) discusses the relevance of learning in some situations and not learning in others. The relevance of learning depends upon the flexibility of an investment. Learning is irrelevant if an investment is completely flexible meaning, it can be upgraded or downgraded costlessly for example there are no additional transaction or sunk costs incurred. Learning is irrelevant when an investment is completely inflexible meaning once the investment is made it can not be reversed or upgraded. Learning is relevant for an investment where the timing of the investment depends not only on the current period but also future periods.

The producer's optimal level of information is influenced by the size of the operation, the producer's age, education, social environment, and the cost of acquiring information (Saha et al. 1994). The value of information is not determined until the information has been obtained and implemented. Feder and Slade. (1984) report that large farmers will allocate more resources to information gathering.

Saha et al. (1994) reports the producer's subjective assessment of the new technology's yield plays a crucial role in the decision to adopt. Adoption is chosen only if the perceived net benefit of adoption outweighs its cost. Kalaitzandonakes and Boggess. (1993) report the optimal adoption path of the competitive firm is directly influenced by the firm's risk preferences and learning ability, the original beliefs of the variance of the new technology performance, the adjustment costs, the discount rate and the technical coefficients.

Adoption choices involving investment are not dichotomous in time, but rather exist on a continuum. Adoption choices are not only influenced by production logistics, but also environmental policy, asset specificity and resale values. Purvis et al. (1995) report that an investment decision is complicated by cost and performance uncertainty of new technologies, evolving environmental regulations, irreversibility, asset fixity, and low salvage value. The option to postpone an investment under such uncertainty may have value.

Adoption is further complicated because technologies or inputs are divisible or non-divisible in nature. Divisible inputs can easily be used in fractions or percentages of product amongst enterprises, like fertilizer. Non divisible technologies are lumpy in nature as they are only available in integer values examples include tractors and harvesters. Divisible input levels can be changed throughout the growing season taking into account their product specifications and will probably require additions to working capital. Non divisible products are inputs for the long-term production horizon and are likely to require large amounts of capital investment. New technologies may exchange production risk and uncertainty with financial risk and uncertainty. New seed varieties, fertilizers, and herbicides may require producers to increase their working capital requirements. New machinery and fixed equipment may necessitate large increases in short or long term debt. Therefore, farm managers face a trade-off between production uncertainty and investment uncertainty.

2.8 Risk and Uncertainty

States of knowledge that affect production and investment decisions include certainty, risk or uncertainty (Knight 1921, Castle et al. 1972). Certainty implies that there is no variability as input cost, output price and quantities etc. are known. Risk implies that while there is variability, the distributions can be determined either a priori or statistically. A priori risk means that all possible outcomes and their associated probabilities are known. Statistical risk uses previous outcomes to determine a distribution of possible outcomes. Uncertainty implies that some or all outcomes and their associated probabilities are unknown. The use of subjective probabilities is needed to make decisions under uncertainty.

Pratt (1964) presents the ideas of risk aversion and utility functions, relative risk aversion, risk premiums, and certainty equivalents.

Three possibilities for a decision-maker's risk preferences are depicted in Figure 2.3. Risk preference options include risk averse (concave curve b), risk neutral (line a) and risk loving (convex curve c). Risk neutral decision-makers have a linear utility function and are profit maximizers (decisions are made based on the highest expected return) and are not influenced by the variability of returns. Risk averse decision-makers have a concave utility function that is $U'(x) \geq 0$, $U''(x) \leq 0$. Decision-makers with risk averse preferences have a tradeoff between the expected profits and the variability of returns. Risk averse decision-makers are willing to forgo some income to have a lower variability of returns. Risk loving individuals have a convex utility function $U'(x) \geq 0$, $U''(x) \geq 0$ and are assumed to be irrational. Risk lovers perceive themselves better off by having a higher variability in income (they expect to receive the higher income while heavily discounting the possibility of a loss) (Schoney 1999a).

No risk analysis would be complete without a discussion of the Arrow-Pratt absolute risk aversion coefficient. The Arrow Pratt risk aversion coefficient examines the first and second derivatives of the utility of income and can be interpreted as the percent change in marginal utility per unit of outcome space[4] (Raskin and Cochran 1986). The absolute risk aversion co-efficient (r) is the ratio of the negative second

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[4] Suppose outcome measured in r dollars is elicited as 0.001 it indicates that near the outcome level at which the elicitation was made, the decision maker's marginal utility is dropping at a rate of 0.01%per dollar. (Raskin and Cochran 1986)

derivative to the first derivative (Eq 2.3). The Arrow Pratt coefficient gives only a local measure of risk aversion as it may change with different levels of wealth. The absolute risk aversion coefficient can be positive, negative, or zero. A positive coefficient of risk aversion represents risk averse preferences, a negative coefficient of risk aversion represents risk lover preferences. The Arrow Pratt risk aversion co-efficient influences the shape of the utility function.

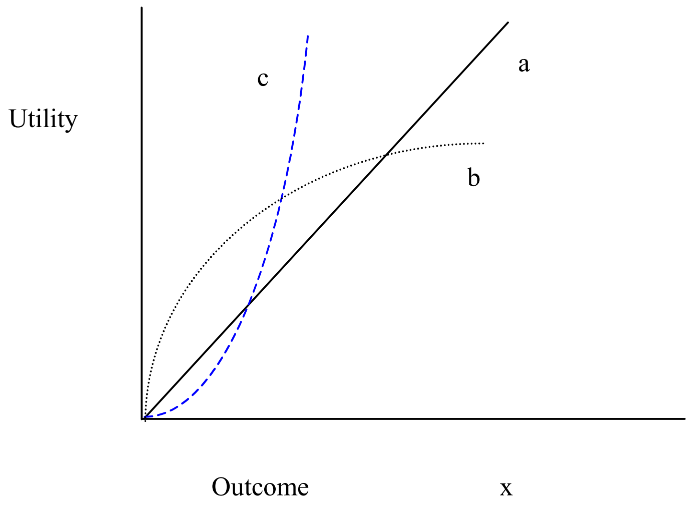

Figure 2.3 Utility functions representing Decision Maker Risk Preferences

$$r = \frac{-u''}{u'} \qquad (2.3)$$

The Von Neuman-Morgenstern (VNM) utility index can be used to study risk preferences over a domain of wealth. The VNM examines whether the Arrow-Pratt risk aversion factor stays constant, decreases, or increases with an increase in wealth. Decreasing absolute risk aversion reflects the idea that an individual becomes less averse to taking small risks as their income increases. Constant risk aversion means the individual's perception of risk is not influenced by their level of wealth. Increasing risk aversion means the individual becomes less willing to take small risks as their income increases. Decreasing absolute risk aversion is a more plausible assumption than the other two (Jehle and Reny1998).

For risk averse decision-makers with concave utility functions a certainty equivalent (CE) can be determined. A CE depends upon the shape of the decision-maker's utility function (the utility function represents the decision maker's risk preferences defined by the Arrow Pratt risk aversion co-efficient). Suppose an investor has an income distribution for possible outcomes of the investment i.e. return. Each possible return value measured on the x-axis will give a certain level of utility measured on the Y-axis. In Figure 2.4 the decision maker is aware of the minimum value F and maximum value Z. The decision-maker assigns probability values to all observations and determines the expected value of the investment G. The decision maker expects utility of G, E(U(G)) but is willing to accept utility U(CE) to forgo the dispersion in outcome values of the investment. The certainty equivalent is the outcome that leaves the investor indifferent between the risk (dispersion) of returns and a certain value (Levy and Sarnat 1994). The difference on the x-axis between D and G is the risk premium.

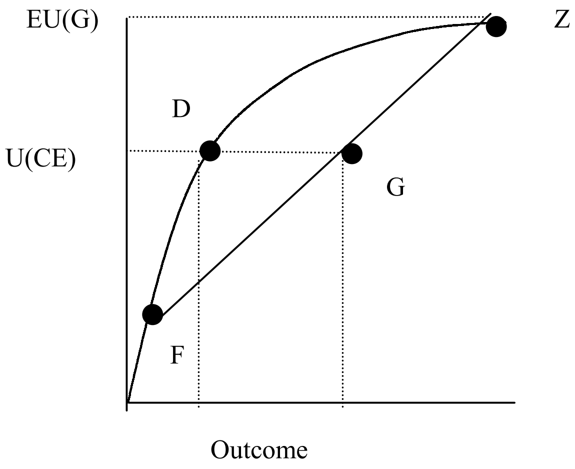

Figure 2.4 Certainty Equivalent

2.9 Government Policy and Decision Making

Policies developed by government and other organizations to encourage adoption of new technology in an industry must be congruent with adoption behavior. Research efforts should be directed at understanding and relaxing constraints to adoption (Purvis et al. 1995). Policy instruments are used as incentives or penalties to reach the desired goal of the policy maker. These incentives and disincentives need to be evaluated carefully for their direct and indirect effects. In the case of incentives that increase output price or reduce cost, resource misallocation may occur leaving society worse off. Administrative and enforcement costs also have to be considered in policy development.

2.10 Summary

Sections 2.1 to 2.3 of this chapter present information concerning the agriculture N cycle and management techniques that can increase the effectiveness of N fertilizer application and reduce N_2O emissions. From section 2.3 it is concluded that management techniques involving the timing of N fertilizer can lead to reductions in N_2O emissions. Section 2.5 presented fertilizer application techniques available to Saskatchewan farmers. Section 2.6 to 2.9 presented information concerning factors that influence farm managers production and investment decisions including risk and uncertainty and government policy. Section 2.7 suggests that producers will adopt new technologies if there is a perceived benefit. The adoption of nitrous oxide reducing technologies by grain and oilseed producers of Saskatchewan will occur if the technology can be seen as beneficial. Section 2.9 suggested external (government, social influence) incentives and disincentives must be developed carefully to affect the farm manager's decision concerning the adoption of a new technology.

CHAPTER III

DECISION MAKING, RISK AND UNCERTAINTY, PRODUCTION ECONOMICS, INVESTMENT ANALYSIS, AND INFORMATION VALUE

3.0 Introduction

Issues related to the modeling of the production decision a firm faces are presented in this chapter. Production decisions under both certainty and risk are discussed. The effect of production decisions with certainty and risk on investment value is presented. Methods for determining the value of information in production decisions are included in this chapter.

3.1 Production Economics

> *"Production economics is concerned with the choice among alternative production processes, namely, enterprise selection and resource allocation. How much and what to produce and the optimal combination of resources are key issues in any production problem, whether at the level of an individual firm, an entire industry, or society. Production economics concerns not only production choices but, more importantly, how choices are influenced by changes in technical and economic circumstances."*
> (Beattie and Taylor (1985), pg. 1.)

This section includes a discussion on production functions and profit functions. A brief discussion of profit maximizing conditions, and how they are influenced by technical, and economic circumstances and the effect of risk on production choices is included.

3.1.1 The Production Function

The production function represents the maximum output given the inputs used. The simplest scenario to study the production function is the case of one output (Y) and one variable input (x_1) Eq 3.1. Equation 3.1 is also known as the total physical product.

$$Y = f(x_1 / x_2) \tag{3.1}$$

The total physical product can be manipulated to provide other economically interesting equations like the average product and the marginal physical product. The marginal physical product represents the change in output for a change in input Eq 3.2.

$$MPP = \frac{dy}{dx_1} = Y' \tag{3.2}$$

3.1.2The Profit Function

In neo-classical economics[5] the goal of all perfectly competitive firms is profit maximization. Profit[6] is the difference between total revenue (TR) and total costs (TC) Eq 3.3. TR is total production (Y) multiplied by output price (P) Eq 3.4. Marginal Revenue (MR) is the change in revenue for a change in output Eq 3.5. TC is total variable costs plus total fixed cost Eq 3.6. Marginal cost (MC) is the change in cost for a change in output Eq 3.7. Value Marginal Product (VMP) is the marginal physical product (MPP) multiplied by MR (Eq 3.8). If a firm is a price taker then they will choose the profit maximizing level of output. If there is only one variable input the firm

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[5] There are four fundamental assumptions for neo-classical perfect competition 1) sellers are price takers, 2) sellers do behave strategically 3) no barriers to entry or exit exist 4) buyers are price takers

[6] $\Pi = P * Y - (z * x + FC)$

where

P is price of output

Y is output determined by a production function

Z is the cost of input x

FC are fixed costs

will maximize profits with respect to that input. That condition is satisfied where VMP equals MC (Eq 3.9). The profit maximizing condition z equals the VMP for the choice variable x is shown in Figure 3.1.

$$\Pi = TR - TC \tag{3.3}$$

$$TR = P * Y \tag{3.4}$$

$$MR = \frac{dTR}{dY} = P \tag{3.5}$$

$$TC = TVC + TFC \tag{3.6}$$

$$MC = \frac{dTC}{dY} = z \tag{3.7}$$

$$VMP = MP * MR \tag{3.8}$$

$$\begin{aligned} VMP &= MC \\ MP * MR &= z \end{aligned} \tag{3.9}$$

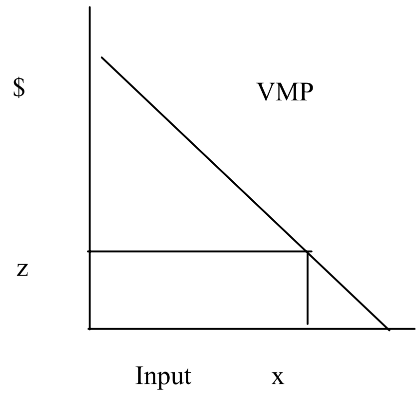

Figure 3. 1 Value Marginal Product (VMP) Profit Maximizing Condition for Production with one Single Variable Input

3.1.3 Sources of Uncertainty in the Profit Function

There are three sources of uncertainty to be considered when determining the optimum output (a) output price, (b) input costs and (c) production function (yield) (Gray 2000). The optimum output is displayed by the output supply function and is dependent on input costs and output price. The output supply function is determined by the production function.

A profit-maximizing firm given a certain price will produce where price equals the marginal cost (MC) of production. Often firms choose production levels prior to the sale period with the output price unknown. If the price of output is unknown at the time of production the firm will produce where the MC is less than the expected price, and the quantity of output under uncertainty will be less than the quantity of output under certainty (McCall 1967, Sandmo 1971). In Figure 3.2 the profit maximizing production level is output q' but under risk aversion the firm only produces q. The new choice of input use for the firm with a one variable production function is x displayed in Figure 3.3. The marginal cost plus some risk value λ equals the VMP (Eq 3.10), resulting in less input usage and consequently less output. As the degree of risk aversion increases the risk premium increases (the difference between the price and MC) and subsequently the output drops.

$$MVP = MC + \lambda \qquad (3.10)$$

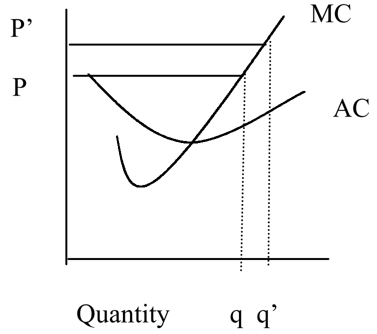

Figure 3.2 Profit Maximizing Output Choice without certainty

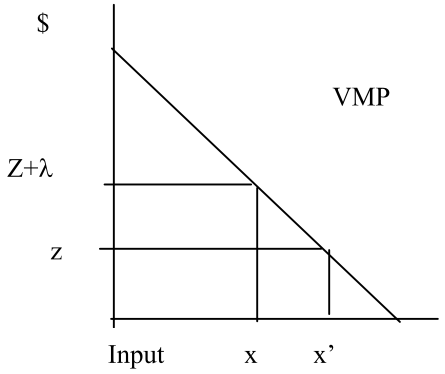

Figure 3.3 Value Marginal Product (VMP) Profit Maximizing Condition for Production with one Single Variable Input without Certainty

Within the production function inputs can be risk increasing or risk reducing. An input's effect within the production function will fall into one of three categories additive risk, multiplicative risk or linear risk (Gray 2000). Additive risk means the level of input use does not affect the degree of yield variability the producer is exposed to. Multiplicative risk means the more the input is used the more yield variability the producer faces. Linear risk means the input contributes to both expected yield and yield variability. In the case of fertilizer the general notion is that nitrogen fertilizer is risk increasing at all levels of use however, in a study by SriRamaratnam et al. (1987) most producers of grain sorghum considered nitrogen fertilizer to reduce yield risk.

3.2 Investment with Certainty

A method to evaluate a firm's investment decisions is needed. The decision may be financial investment in new technology or different strategies to determine production levels. Net Present Value (NPV) is the standard approach to evaluating investments if returns are known with certainty. The NPV approach uses a desired discount factor to value a future stream of profits. The discount factor provides the present value of future profits (Eq 3.11). The sum of the present value of future profits is the NPV.

$$DF=1/(1+r)^t \qquad (3.11)$$

Where: DF= discount factor
r= the desired discount rate[7] or required rate of return,
t= the time in years starting at t=0.

In the case of a single investment alternative the investment will occur if the NPV is positive. For the case where investment alternatives exist the decision-maker will choose to invest in the most profitable alternative.

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[7] Akin to the discussion of a discount factor is the concept of the time value of money. The time value of money is made up of three components; A-the alternative uses or the pure time value of money, R-a premium for risk associated with uncertainty, and I- a premium or discount for inflation. T=A+R+I. In the case of 3.11 the risk premium would be 0 so the discount factor would be A+I.

3.3 Investment Analysis with Risk/Uncertainty

A simple net present value analysis is often not the most effective method for evaluating a firm's investment options. Some investments will have a variety of possible outcomes each with a probability of occurring. In such instances expected returns can be calculated from the probability sets of the estimated returns.

3.3.1 A Priori

Expected profits give an alternative measure for discovering the value of an investment. Expected NPV of profit is simply the weighted average of all the possible NPV of profit outcomes for the investment (a priori) (Eq 3.12). The expected value of an investment provides the decision-maker with a number value for the investment with no measure of variability (risk).

$$E(x) = \sum_{i=1}^{n} \Pr_i x_i \qquad (3.12)$$

Where:
E(x)=expected value of the project,
x_i = i th possible NPV of profit outcome,
$\Pr_i$= probability of obtaining the i th outcome x_i,
N= number of possible outcomes.

The variance or standard deviation can be used to measure the riskiness of an investment. The variance provides information about the dispersion of possible NPV of profits around the mean. It should be noted that the variance of x is reported in dollars squared, which has no economic meaning. The larger the variance the more risk is associated with the project. The standard deviation term, which is the square root of the variance (Eq 3.13), gives a measure of dispersion in dollars.

$$\sigma^2(x) = \sum \Pr_i (x_i - E(x_i))^2 \qquad (3.13)$$

Where:
$\sigma^2(x)$= variance of x,
and the other parameters are the same as previously described.

3.3.2 Statistical Analysis

A project is dependent upon several stochastic variables. Output not only happens at low, medium, or high levels but rather an infinite number of values between the highest and lowest. The same can be said for output price or costs. Decision-makers can use simulation analysis (statistical risk) to examine a project beyond a low, medium, or high scenario.

A simulation analysis for NPV is like a project summary based upon output as shown in Figure 3.7 (output price, cost etc.). Decision makers need to identify stochastic and non-stochastic factors, that can affect the NPV and assess the probability distributions associated with the variables. In this manner the calculated NPV distribution reflects the factors that influence NPV.

When generating observations for simulation analysis it is important to recognize that the observations are only as good as the model used to generate the observations. The observations generated are intended to reflect real world events.

A method available to generate future prices for a price taker is the random walk method. A random walk method does not attempt to explain the factors affecting the price; it only tries to forecast possible prices. The random walk method in the simplest form suggests that this year's price can be determined from last year's price Y_{t-1} plus some white noise u_t (Eq 3.14).

$$Y_t = d * Y_{t-1} + u_t \tag{3.14}$$

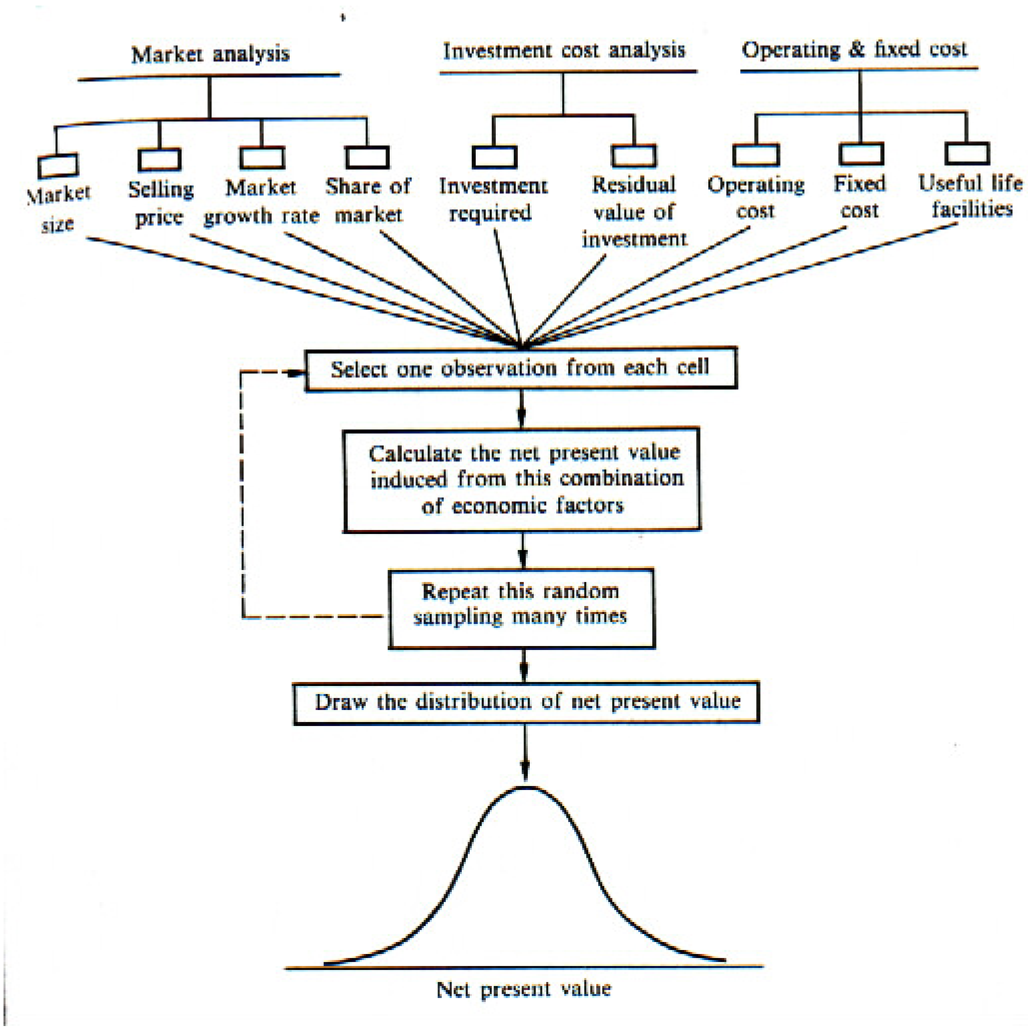

Figure 3.7 Net Present Value Simulation Analysis
Source: Levy and Sarnat (1994) pg. 275.

3.4 The E-V Model

The mean variance or E-V model is a tool for decision-makers to use in evaluating risky alternatives. The investment alternatives are evaluated on the basis of their expected returns and variance. The underlying assumptions of the E-V model are (adapted from Schoney 1999a):

1. There is a functional linear trade off between income and variance where;

    a) the utility function can adequately be described by the first and second moments, or
    b) the utility function is quadratic.
2. The decision-maker is a price taker.

The first assumption is perhaps the most restrictive. A quadratic utility function implies that decision-makers view the trade off between income and variance as a linear function. The linear function means that decision-makers are not influenced by higher moments in the investment probability distribution like skewness or peakedness. Yassour et al. (1981) suggest yield data distributions often are non-normal and are better defined by a gamma distribution.

The criteria used to choose between investment A and investment B is as follows (adapted from Levy and Sarnat 1994):

1. The expected return of A exceeds or is equal to the expected return of B and the variance of A is less than the variance of B, or
2. The expected return of A exceeds that of B and the variance of A is less than or equal to that of B.

A graphical representation of an E-V efficient frontier is displayed in Figure 3.5. The E-V frontier represents the loci of the minimum variance for a given level of expected returns. The decision-maker will choose the investment where the utility function is tangent to the E-V frontier.

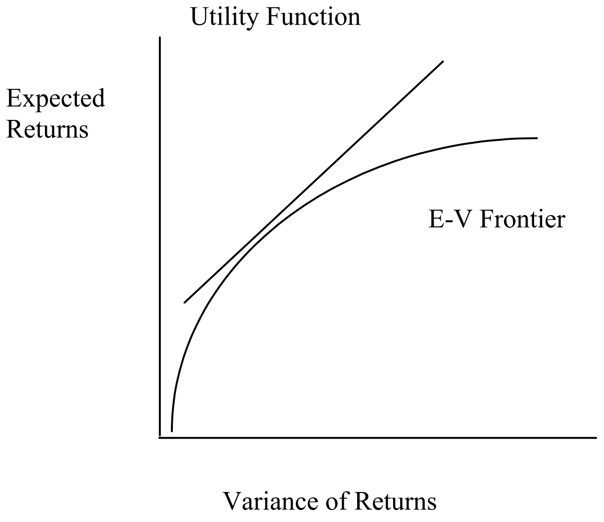

Figure 3.5 E-V efficient criteria

While the E-V analysis provides a simple and interesting way to evaluate investment alternatives it ignores the time value of money. To correct for the lack of time in the analysis, expected NPV can be substituted for expected profits.

3.5 Stochastic Dominance

Stochastic dominance is the least restrictive tool for analyzing investment decisions. Stochastic dominance does not require a normal distribution or utility functions to be specified. A cumulative distribution is used to determine the probability that a random variable X will be less than some number *x* (Eq 3.15).

$$F(x) = P_r(X \leq x) \tag{3.15}$$

First Degree Stochastic Dominance (FSD) is determined by the following criteria. Any investment B is preferable to investment A if $F_B(x) \leq F_A(x)$, for all values of x (and a strict inequality holds for some value x), i.e., if the cumulative probability distribution of B lies to the right of A (Figure 3.6). The FSD is set out in terms of monetary probabilities instead of utilities. Investment B has a higher probability of receiving greater returns at any given level and is therefore preferred to investment A. (Levy and Sarnat 1994).

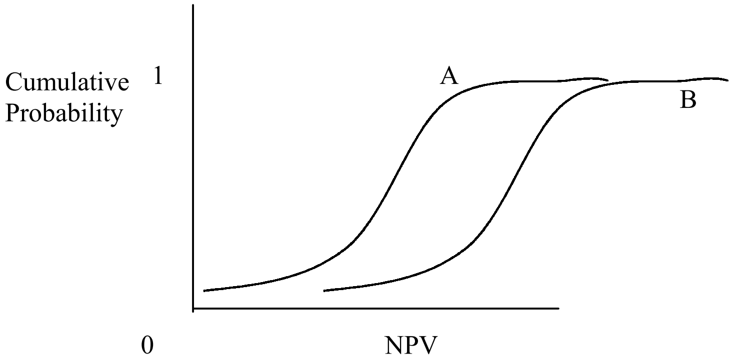

Figure 3.6. First Degree Stochastic Dominance

In many cases the choice between two or more investments are not as obvious as the case in Figure 3.6. Often the investment alternatives' cumulative density functions (CDF) cross, in which case the FSD criterion does not provide an answer. In such cases Second Degree Stochastic Dominance (SSD) provides a criteria to evaluate the investment alternative.

The SSD criteria provided by Levy and Sarnat (1994) are as follows. Any investment B is preferable to investment A if $F_B(x)<F_A(x)$, for all values of x and strict inequality holds for some value x, i.e., if the cumulative probability distribution of B lies to the right of A (integral of B is greater than the integral of A. The SSD criteria essentially amounts to choosing the investment that has a larger portion of its cumulative distribution to right of the other. In Figure 3.7 the area a is greater than the area in b and as such investment B is preferred to A.

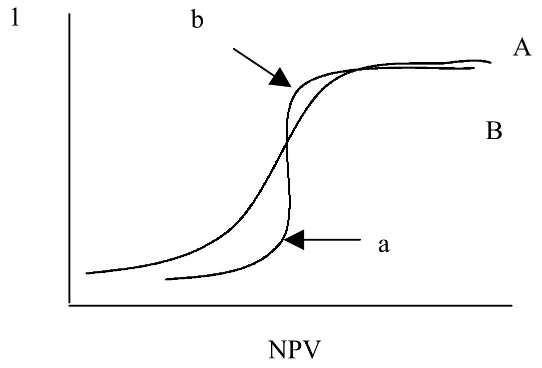

Figure 3.7 Second Degree Stochastic Dominance

A third type of stochastic dominance is Generalized Stochastic Dominance (GSD). GSD requires the decision maker's utility function to be specified and can be used to rank distributions that SSD or FSD fail to rank (Meyer 1977). The Arrow Pratt risk aversion co-efficient is incorporated in the decision maker's utility function. The decision maker's Arrow Pratt risk aversion co-efficient affects the utility associated with each distribution. Investment $F_A(x)$ is preferred to $F_B(x)$ if the utility of $F_A(x)$ CDF is greater than utility of $F_B(x)$ CDF (Eq 3.16).

$$\int_0^1 u(x)dF_A(x) \geq \int_0^1 u(x)dF_B(x) \qquad (3.16)$$

3.6 Exponential Utility Moment Generating Function

The exponential utility moment generating function (EUMGF) is another alternative for examining risk. The EUMGF may be used with all distributions that have a moment generating function. The EUMGF assumes Constant Absolute Risk Aversion (CARA), which under certain criteria, technology choices made by EUMGF approach decisions made under Decreasing Absolute Risk Aversion (DARA) (Yassour et al.1981). Yassour et al. (1981) used EUMGF to compare two alternative technologies each with deterministic variable costs and stochastic yield. The alternative with the highest expected utility of profits is chosen. Using an exponential utility function takes into account the Arrow Pratt measure of risk aversion (r) and profit (R). The function is displayed in Eq 3.17.

$$U(R)= -e^{-rR} \tag{3.17}$$

The EUMGF can be used in very general cases where uncertainty exists in both yield and price and the total revenue distribution is not known (Yassour et al. 1981). The alternative with the highest E (U(R)) will be chosen.

3.7 Certainty Equivalent NPV

For an investment that has an expected return it is possible to determine a certainty equivalent NPV given the decision makers utility function and risk preference (defined by the Arrow Pratt risk aversion co-efficient). This method requires the certainty equivalent of each of the future returns to be calculated then discounted using a risk free discount rate. The certainty equivalent NPV provides a risk adjusted NPV (Levy and Sarnat 1994)

3.8 Determining the Value of Information

Thomas and Bontems (1998) used a multistage crop production process for corn, where weather information at each stage was examined. The value of the information was based on whether the farmer could use the information. Thomas and Bontems (1998) used a utility function with constant absolute risk aversion (CARA), to determine the value of information. The difference between maximizing the expected utility of profits by varying nitrogen application timing and the expected maximum utility of the profits based on the optimum timing sequence is calculated (Eq 3.18). So the information value is the dollar amount (D) that would leave the decision-maker indifferent between making the decision prior to waiting for the arrival of weather information and waiting for the arrival of the information.

$$D = \max E(U(\Pi)) - E \max U(\Pi) \tag{3.18}$$

Bosch and Eidman (1987) employed simulated net income and GSD to estimate the value of information under uncertainty. Distributions of net income were simulated for various levels of information. The value of information estimated with GSD is that amount by which each element of a net income distribution generated with information can be lowered before it no longer dominates a net income distribution generated without information and is dependent upon a decision maker's risk preferences (defined by the Arrow Pratt risk aversion co-efficient).

The original income distribution is generated with information F (X) and is compared to the net income distribution without information G (X), to see if it dominates when V_i is equal to zero. Setting V_i equal to zero implies that the information leading to F_i (X) is available at no cost. If F_i (X) dominates G (X), V_i is augmented by Y until the inequalities Eq 3.19 and Eq 3.20 are satisfied.

$$\int_0^1 G(X) - F_i(X - V_i)U'(X)Dn > 0 \tag{3.19}$$

$$\int_0^1 G(X) - F_i(X - V_i - Y)U'(X)Dx > 0 \tag{3.20}$$

Where:
X represents net income,

$G(X)$ net income distribution without information,
$F(X)$ net income distribution with information,
V_i is the value of information that generates F_i using decision rule i,
U is a von Neumann- Morgenstern utility,
Y is a small positive amount.

Byerlee and Anderson (1982) examined the value of information by determining the difference in utilities associated with profits generated by choosing variable inputs from a probability distribution function (PDF) and a function with a prediction for the upcoming period's stochastic events (Eq 3.21). The value of information is dependent upon the Arrow Pratt risk aversion co-efficient used.

$$\iint U(\Pi(\theta , X^*(k)) - V_z) g(\theta / k) f(k) d\theta dk - \iint U(\Pi(\theta , X_o^*)) g(\theta / k(f(k) d\theta dk) = 0 \tag{3.21}$$

Where:
U is a von Neumann Morgenstern utility function,
π is profit,
θ a random disturbance,
X^* a choice variable,
$X^*{}_k$ a choice variable with a predictor
$g(\theta | k)$ the probability of observing the random variable θ,
f(k) the probability of generating prediction k,
V_z is the ex ante value of information, includes uncertainty about the actual prediction as well as uncertainty about the true value of the random variable given the prediction.
(adapted from Bosch and Eidman 1987)

3.9 Summary

This chapter has provided the theoretical concepts required in examining risk, and uncertainty affects on production/investment decisions and how to calculate the value of information.

Production decisions under certainty can be solved with a simple mathematical optimization. A risk averse producer's production decisions with stochastic variables are more complicated. In general input usage and production decrease as risk aversion increases.

Simulation analysis to calculate a project's NPV, requires decision makers to identify stochastic and non-stochastic variables. CENPV is useful in determining an investments value for risk averse decision makers.

The value of information in decision making can be calculated by determining the value that leaves the decision maker indifferent between the expected utility with information and the expected utility without information.

CHAPTER IV

METHODOLOGY

4.0 Introduction

The key objective of this thesis is to determine the producer impact of switching to spring N application from fall N application assuming spring application is less profitable. The reason for switching to spring fertilization is to reduce the N_2O emissions from nitrogen based fertilizer. The assumption is, the most controllable producer method to limit the amount of nitrogen available in the soil during the freeze thaw periods, is to apply nitrogen in the spring. Methodology to determine the optimum N fertilizer choice, and value of information is included in this chapter. The methodology used to determine the costs of three seeding systems is delivered in this chapter.

4.1 Model

This chapter outlines the methods employed in determining the costs and benefits associated with three types of seeding systems. The three seeding systems are: a two pass system (single-shoot technology) fall band and spring seed, and a spring band and spring seed system, and a one pass seed and side-band (double-shoot technology) system. The three factors to be studied with respect to the seeding systems are the risk efficient N fertilizer strategy, the value of information, and actual costs associated with the seeding system. For the purpose of this study the strategy that produces the highest NPV under profit maximization or highest CE under risk aversion will be chosen.

4.1.1 Risk Neutral

The farmer's objective is to maximize expected profit by choosing the amount of fertilizer nitrogen to apply. Annual income is determined from simulation analysis. Revenue is price multiplied by yield. Actual levels of growing season precipitation (GSP) and total nitrogen will be used to determine yield. Final prices are generated to determine total revenue.

Selles (2002) provides a yield response function for wheat (Equation 4.1).[8] The yield response function was developed from fertilizer experiments for crops grown on fallow and stubble with various amounts of N applied at seeding conducted from 1998 to 2001. This equation allows for optimal N application to be determined based upon fertilizer N plus soil NO_3-N to 60 cm depth and available water.

$$Yield = (a + bN + cN^2 + dW + fNW) \qquad (4.1)$$

$$Yield = (-559 + 11.29N + -0.0072N^2 + 73W + .04NW) \qquad R^2 = .075$$

Where:

N is the available Nitrogen (sum of applied fertilizer (N_1), and soil N (N_2) to 60cm), and
W is the available water (soil available water to 120cm in spring plus GSP).

The total revenue[9] less the cost of production (variable cost, machine and building costs) will leave the annual return to labour, management, and land Eq (4.2). The nitrogen input demand function is shown in equation 4.4

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[8] It should be noted that the use of a polynomial function consistently over estimates the maximum yield and the optimal fertilizer recommendations. This leads to excessive use of fertilzers, which is both a waste of scarce resources and unnecessarily pollutes the environment, Ackello-Ogutu et al. (1985).

[9] Crop insurance premiums and revenues are not analyzed in this model.

$$\Pi = P(a + b(N_1 + N_2) + c(N_1 + N_2)^2 + dW + f(N_1 + N_2)W) - zN_1 - FC \quad (4.2)$$

Where:

P is the output price,
z is the input cost
FC is fixed cost

The first derivative of Eq (4.2) is shown in Eq (4.3)

$$\frac{\partial \Pi}{\partial N_1} = P(b + 2c(N_1 + N_2) + fW) - z \qquad (4.3)$$

Setting Eq (4.3) equal to 0 and solving for N gives the input demand function Eq (4.4).

$$N_1 = \frac{P(b + 2cN_2 + fW) - z}{-2Pc} \qquad (4.4)$$

Annual returns are discounted to determine the present value for each of 100 possible yearly outcomes. The risk neutral producer will choose the strategy that provides the highest NPV of returns to land, labour, and management for a 30 year period. The six fertilizer decision strategies are presented in Table 4.1[10]. The key factors used to determine the rate and timing of N fertilization are, the level of actual precipitation, expected precipitation, output price either Canadian Wheat Board (CWB) final payment or CWB pool return outlook (PRO), and input cost. The N input demand functions for the various strategies are presented in Figures 4.1 and 4.2.

---

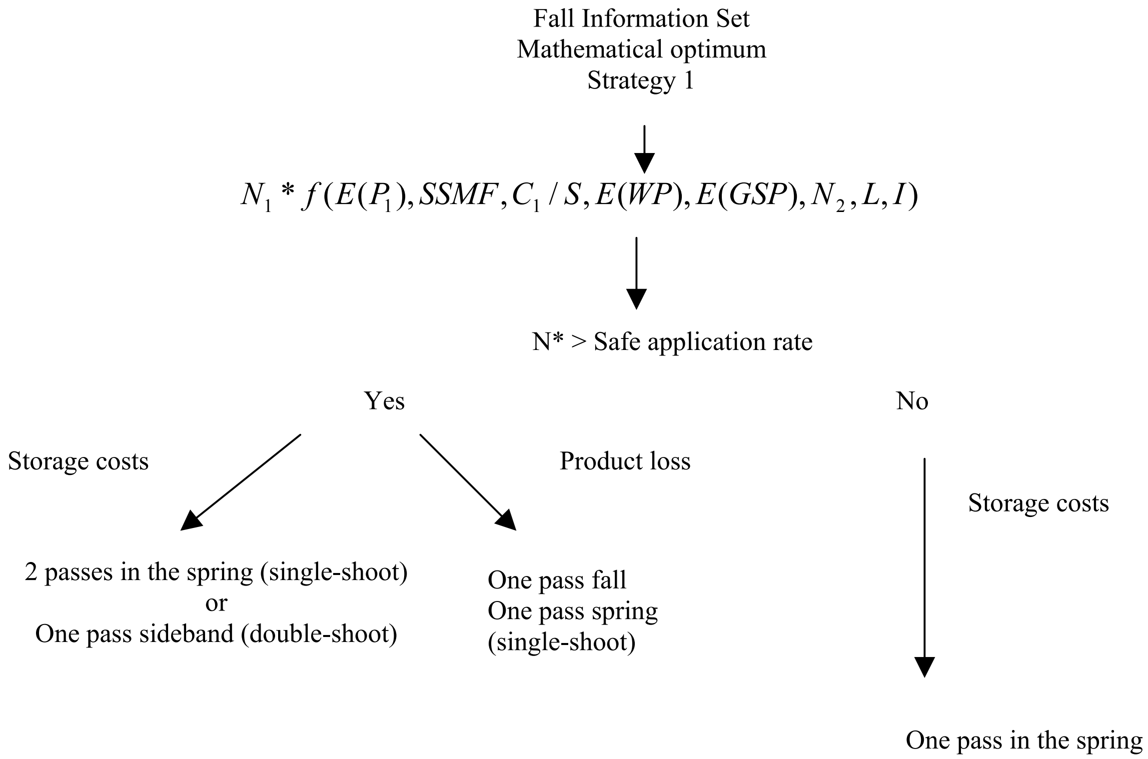
[10] The author recognizes that the producer may apply fertilizer in the fall and also increase his/her fertilizer application in the spring. This fact does not negate the benefit of waiting to discover a new level of information. Especially if the producer wished to reduce the amount of fertilizer based upon the level of information. The author recognizes that multiple pass seeding systems may lead to more moisture loss and reduced yields compared to single pass seeding systems.

Table 4.1 Fertilizer Application Decision Strategies based on Time, and Information Levels

Strategy Number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for interest charge

Source: Author

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

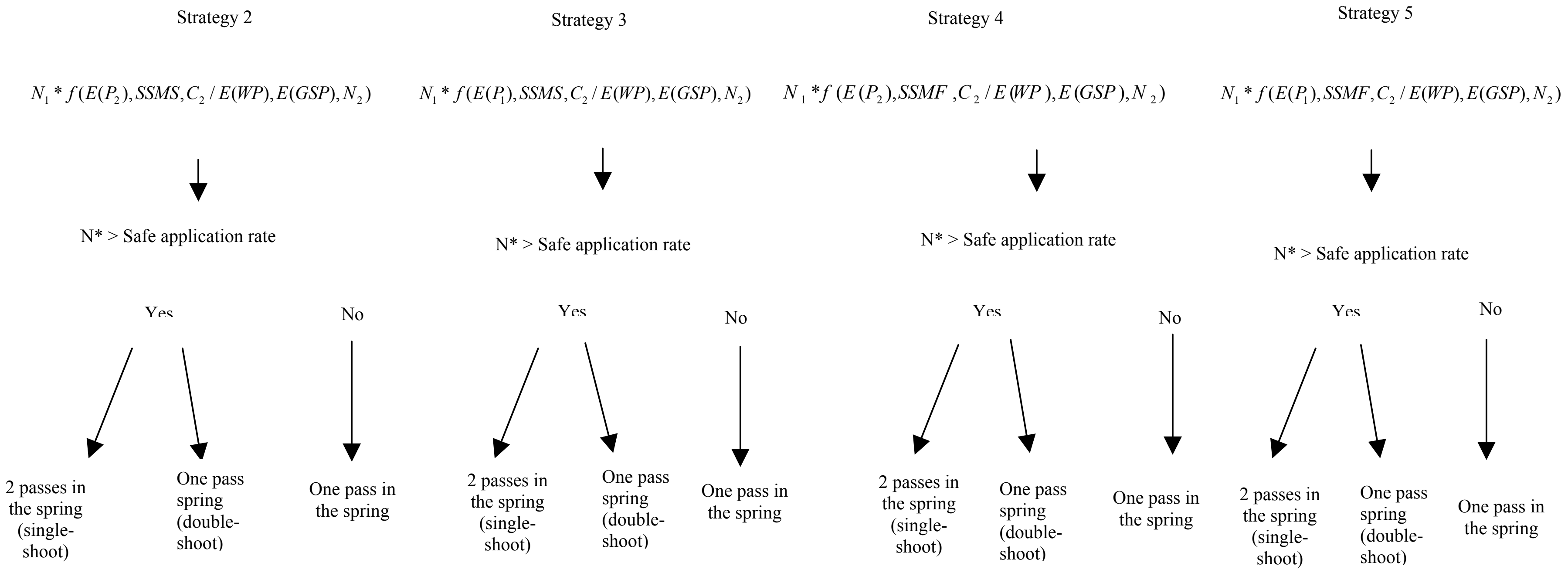


Where:

P_1= Final Wheat Price
P_2=Pool Return Outlook
SSMF=Fall subsoil moisture
SSMS=Spring subsoil moisture
WP=Winter Precipitation
GSP=Growing Season Precipitation
C_1=Fall fertilizer price
S=Storage cost
L=over winter product loss
I=Interest cost
N*=Optimum N application

Figure 4.1 Fall Fertilizer Decision Information Sets (Mathematical) and Application Options

Source: Author



Where:

P_1= Final Wheat Price
P_2=Pool Return Outlook
SSMF=Fall subsoil moisture
SSMS=Spring subsoil moisture
WP=Winter Precipitation
GSP=Growing Season Precipitation
C_2=Spring fertilizer price
N*=Optimum N application

Figure 4.2 Spring Fertilizer Decision Information Sets (Mathematical) and Application Options

Source: Author

The VMP is shown in Eq 4.5 and Figure 4.3. The first part of the equation represents the intercept term and the second part of the equation represents the slope of the VMP. Changes in the level of soil and water will result in a shift in (reduction in water or increase in soil N) or out (decreases in soil N or increase in water) of the VMP line. A change in price affects both the intercept and slope. An increase in price makes the VMP more inelastic while a decrease in price makes the curve more elastic.

$$VMP = P(b + 2cN_2 + fW) + 2cPN_1 \tag{4.5}$$

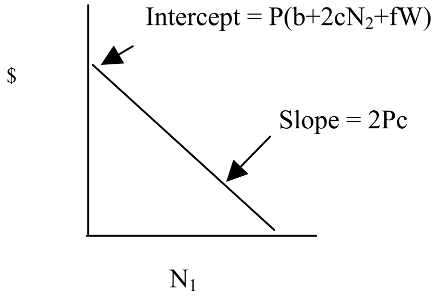


Figure 4.3 Value Marginal Product for Model Used

For fall fertilization, where spoil N losses occur over winter the MPP and VMP have to be altered to reflect this loss (Eq 4.6). The amount of applied N available is a fraction g of what is applied (Eq 4.7). A change in the loss rate will affect both the intercept and the slope. An increase in the loss rate will make the VMP curve more elastic. A decrease in the loss rate will make the VMP curve more inelastc.

$$VMP = P(bg + 2g^2cN_1 + 2gN_2 + gfW) \tag{4.6}$$

$$g = (1 - lossrate) \tag{4.7}$$

The effective fall fertilizer price also has to be adjusted to account for interest charges i. The effective fall price is shown in Equation 4.8.

$$fallprice = z(1+i) \tag{4.8}$$

4.1.2 Risk Aversion

The risk averse producer is concerned with both the expected income and the dispersion of that income. Certainty equivalents (CE) are useful in analyzing the value of an income distribution. To determine a CE for an expected future a utility function has to be specified. The exponential utility function in Equation 4.9 is used. The Arrow Pratt risk aversion coefficient influences the shape of the utility function.

$$U = 1 - \exp^{-rw} \tag{4.9}$$

Where:

r is the Arrow Pratt risk aversion coefficient,
w is the annual income.

Exponential utility functions have positive marginal utility with respect to wealth U'>0, negative second derivative with respect to wealth U''<0, and exhibit constant absolute risk aversion. In order to determine certainty equivalents risk aversion coefficients (r) and the utility of the expected income (U(E(W)) are required as shown in Equation 4.10. The Arrow Pratt risk aversion coefficient is used.

$$CE = \frac{\ln(1 - U(E(W))}{-r} \tag{4.10}$$

The CE based on the expected net annual income is calculated and discounted to determine the CE NPV.

4.1.3 Optimum Fertilizer Rates given Risk and Uncertainty

The mathematical optimum fertilizer rate determined using Equation 4.4 might not be the rate that provides the highest certainty equivalent. Some risk averse farmers may not choose to apply this profit maximizing level of N. Fertilizer rates will be varied as a percentage of the profit maximizing rate to determine the application rate with the highest NPV CE.

4.2 The Value of Information

The value of information is measured on a per hectare basis. This thesis examines the value of information to determine the optimum nitrogen fertilizer application for wheat. The expected price E(P) and level of spring available moisture are stochastic variables that affect the amount of applied nitrogen. The value to the decision maker of waiting for six months to gain market information (E(P)), and the level of spring subsoil moisture is determined.

The value of information may vary depending upon the decision-maker's risk attitudes. The simulation analysis will be based on 100 possible 30 year futures. The 3000 outcomes should provide a large enough distribution for the simulation analysis. To examine the value of information, 200 net income outcomes from the optimal fertilizer application level for the specified risk preference will be selected from 3000 possible outcomes for each scenario (200 outcomes should be sufficient to represent the expected utility distribution). The 200 outcomes will be selected from the same co-ordinates, thereby allowing for a side by side comparison. In the profit maximizing scenario the difference between the simple means of the selected outcomes are compared. For risk averse individuals the value of information will be calculated by examining the net income distribution of the different strategies. The expected utility for each strategy will be calculated using Eq 4.11. The value of information D is the amount the net income distribution with information can be augmented so that there is no difference in the expected utility of the net income distribution (Eq 4.12).

$$E(U) = \frac{1}{n}\sum_{i=1}^{n} U(NI_s) \tag{4.11}$$

$$E(U(NI_{si} - D) = E(U(NI_{is})) \tag{4.12}$$

Comparison of strategy 1 to 6, 3 to 5, and 2 to 4 will provide the value of spring moisture information with different input costs and output prices. Comparison of strategy 2 to 3 and 4 to 5, will provide the value of the PRO. Comparison of strategy 1 to 2 will determine the total benefit to making the decision with spring information.

4.3 Timeliness Concerns and Machinery Costs

For those farms that do not have a one pass seeding system and choose to wait until the spring to make their fertilizer decision, they may require larger equipment to perform both operations or be subject to timeliness losses. The timeliness losses represent reduced yield and quality that may occur if seeding operations are delayed.

Annual fixed and variable machinery costs are calculated. Fixed costs are those costs that do not vary with the amount of use and include depreciation, interest on investment, housing, and insurance costs. Variable costs are those costs that vary with the amount of use and include fuel, repairs, lube, and labour.

4.3.1 Timeliness Concerns

For the purpose of this study timeliness costs associated with seeding are incorporated in the machinery costs, for the three seeding systems. The working width of equipment, horsepower requirement and field efficiency will vary for the three systems. The seeding complement[11] is sized so as to not exceed the minimum number of workdays for the May 1 to May 30 period at the 90% certainty level.

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[11] The implement size in this thesis may be smaller than actually required if labour is needed for other spring field activities like pesticide application.

4.3.2 Fixed Cost

Depreciation costs represent the reduction in market value of the machine due to age and obsolescence (Brown 1994). There are several methods available to estimate depreciation; the straight-line method, the declining balance method and the sum of the years digits. To calculate annual depreciation, estimates of useful life and salvage value are required. This study will use salvage values determined by TopMan[12] coefficients (Schoney 1997).

Interest on investment is the charge for the use of the capital invested in the machine.

The capital recovery method takes into account both depreciation and the interest on investment costs using the time value of money concept. The capital recover charge (CRC) displayed in Equation 4.5 is the annual cost associated with owning the machinery.

$$CRC = (PP - SV) * (i/(1-(1/(1+i)^n)) + (SV * i) \qquad (4.5)$$

Where:

i is the desired interest rate,
N is the number of years,
PP is purchase price, and
SV is salvage value.

4.3.3 Variable costs

Variable costs include the operating costs of labour, fuel, lube, oil, grease and electricity. The fuel use per hour is calculated by multiplying kilowatt hours per litre by the percentage of the maximum kilowatts used.[13]

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[12] TopMan is a stochastic simulation program for farm business management, developed by Dr. R.A. Schoney at the University of Saskatchewan.

[13] $\frac{L}{hr} = \frac{kw\text{-}Hrs}{L} \mathbf{*\ \%HP*} \text{Max HP}$

The American Society of Agricultural Engineers (2002) and TopMan software provide methods for estimating repair and maintenance cost for machines based on age and use. Repair costs however can vary drastically from one identical machine to another for various explainable and unexplainable reasons. For this reason the study will examine the general maintenance costs for machinery use. Tractor maintenance costs will be per hour and machine maintenance costs will be per hour meter.

4.4 Summary

This chapter has outlined the economic methodology that is used to determine the optimum N fertilizer choice, the value of information, and the direct operating costs of the seeding systems. The next chapter will provide the parameter values to be used in the model.

CHAPTER V

PARAMETER VALUES

5.0 Introduction

To determine the value of information, timeliness costs and actual field costs for the three seeding systems various parameters must be collected or estimated. These values include future input/output prices, precipitation values, representative farm size, farm equipment size and use. The choice in these and other values are contained in this chapter. Monetary values generated are in real terms and are not adjusted for inflation likewise there are no adjustments for increases in farm size or farm productivity.

5.1 Precipitation Values

Precipitation in Saskatchewan can be highly variable and unpredictable.

"*For the province as a whole about eleven years out of twenty have rainfalls less than the yearly average. This is because a few years with exceptionally heavy rainfalls raise the average value somewhat higher than the observed values for one-half of the years…. Examination of the climatic data for Saskatchewan has failed to show that the rainfall of the growing season is preceded by particular types of weather. Wet summers occur as frequently as dry after a fall with frequent fogs, after a fall or winter with heavy precipitation, and after a winter with lower than normal temperatures.*" (University of Saskatchewan (1945), pg 4.)

The yield function in the model requires estimates of available moisture. Available moisture is the sum of spring available subsoil moisture and growing season precipitation (GSP). Spring available subsoil moisture is the sum of fall available subsoil moisture plus a percentage of winter precipitation. GSP is defined as May, June, July precipitation.

5.1.1 Winter Precipitation and Growing Season Precipitation

The two locations being studied are Melfort and Regina. Data provided by the Prairie Farm Rehabilitation Administration (various years) for the November 1951 to April 2001 period is used in calculating the GSP, and winter precipitation distributions. A general distribution is used to generate the precipitation values in the @Risk software package. General distributions enable a maximum and a minimum value to be specified and are useful for approximation of irregular probability distributions. The minimum and maximum values used are presented in Table 5.1. Determination of the minimum and maximum values was made subjectively by examining the actual minimum and maximum values experienced in the last fifty years at both locations.

Table 5.1 Min and Max values for Precipitation Distributions (mm).

		Melfort	Regina
Growing Season Precipitation	Minimum	0	25
	Maximum	370	360
	Mean	202.7	195.61
Half of winter Precipitation	Minimum	15	10
	Maximum	125	100
	Mean	70.59	56.95

Source: Author, Means from Prairie Farm Rehabilitation Administration (Various years)

5.1.2 Fall subsoil moisture

There exists 17 years of fall subsoil moisture conditions for the Province of Saskatchewan collected by the University of Saskatchewan and Saskatchewan Agriculture and Food. A general distribution was used with the @Risk software to produce the possible fall subsoil moisture amounts. The fall subsoil moisture conditions can range from dry to saturated. Water holding capacity depends upon the soil texture. Light soils hold less moisture than heavy soils. Light soils like sandy loams will hold about 31.25 mm per 30 cm of soil, heavy soils like clay will hold 50 mm per 30 cm of soil (Soil Subsoil Moisture Map, Nov 1998 Saskatchewan Agriculture and Food). For a 120 cm depth, plant available moisture in light soils is 125 mm and in heavy soils 200 mm.

5.2 Input Cost and Output Price

The intent of the price simulation is not to predict nor to explain what effects independent variables have on prices. The intent of the price simulation is to generate possible values for wheat and fertilizer. Prices are in 2001 constant dollars. These prices are used to determine the optimal input usage in the objective function.

5.2.1 Fertilizer Prices

Annual fertilizer prices are generated using a random walk model. Table 5.2 displays urea and anhydrous ammonia (NH_3) prices between the fall of 1985 and the spring of 2002. The residuals generated by the regression of the previous year's fall fertilizer price on the current year's fall fertilizer price have a normal distribution and standard deviation of 40.49. Using @Risk software 10,000 possible residuals were generated and used in the random walk process to generate the fall urea prices. The starting price was $0.608/kg N. The prices generated were constrained to lie between $0.326/kg N and $1.087/kg N.

The fall fertilizer price (FP) used in the model needs to be adjusted for nitrogen losses and interest charges to provide the effective price the decision maker faces (FFP). Schoenau (2002) suggested that the expected nitrogen losses for nitrogen applied in the fall average 5% and range from 0 to 10% depending on soil environmental conditions for Saskatchewan. An average of 5% is used in this study. A 3% interest cost is used on fall-applied fertilizer. The effective fall nitrogen price is shown in Eq. 5.1.

$$FFP = FP * \frac{1}{1 - loss} * (1 + rate) \tag{5.1}$$

Table 5.2 Anhydrous Ammonia and Urea Spring and Fall Nitrogen Fertilizer Prices

	Spring Price $/tonne		Fall Price $/tonne		NH_3 increase in Price Spring-Previous Fall	Urea increase in Price Spring-Previous Fall
Year	NH_3[1]	Urea	NH_3	Urea	NH_3	Urea
2002		$280.00				
2001	$ 580.00	$ 412.00		$ 272.00		$ 8.00
2000	$ 358.00	$ 267.00	$ 387.00	$ 281.00	$ 193.00	$ 131.00
1999	$ 321.00	$ 238.75	$ 309.00	$ 241.50	$ 49.00	$ 25.50
1998	$ 353.00	$ 250.00	$ 291.00	$ 229.50	$ 30.00	$ 9.25
1997	$ 417.50	$ 310.00	$ 367.50	$ 228.00	$ (14.50)	$ 22.00
1996	$ 442.00	$ 347.00	$ 383.00	$ 286.00	$ 34.50	$ 24.00
1995	$ 405.00	$ 332.00	$ 374.00	$ 290.00	$ 68.00	$ 57.00
1994	$ 273.00	$ 243.00	$ 296.50	$ 233.00	$ 108.50	$ 99.00
1993		$ 215.00	$ 235.00	$ 200.00	$ 38.00	$ 43.00
1992		$ 205.00		$ 243.00	$ -	$ (28.00)
1991		245.35		$ 240.00	$ -	$ (35.00)
1990	$ 337.40	$ 223.61		$ 254.00		$ (8.65)
1989	$ 408.56	$ 252.73	$ 361.69	$ 201.04		$ 22.57
1988	$ 404.50	$ 235.00	$ 399.29	$ 229.10		$ 23.63
1987	$ 448.33	$ 234.09	$ 402.43	$ 214.76		$ 20.24
1986	$ 469.76	$ 275.37	$ 442.95	$ 237.17		$ (3.08)
1985			$ 464.81	$ 260.21		$ 15.16
Average	$ 387.43	$ 274.06	$ 330.38	$ 249.83	$ 63.31	$ 25.04
Standard Deviation					62.93	41.13

1 NH_3 Anhydrous Ammonia

Source: 1985- 1990 Saskatchewan Agriculture and Food Agriculture Statistics (Various years), 1991-1994 Saskatchewan Wheat Pool (Date Unknown), 1994-2001 Pilger 2001, 2002 Saskatchewan Agriculture and Food (2002).

The increase in the price of fertilizer from fall to spring over the 17 years of data averaged $25.04 with a 41.13 standard deviation. Using @Risk software 10,000 possible price changes were generated with a mean of 0 and a standard deviation of 41.13. The price change and a drift value of $25.04 were added to the previous fall's fertilizer price to create a spring price for urea.

5.2.2 Output Price

The output in the model is assumed to be straight grade number 1 Canada Western Red Spring Wheat (CWRS). No attention is given to the protein level due to the complexity of predicting protein levels and a lack of price information (Protein premiums have only recently been paid). Final wheat prices are generated using a modified random walk method for the final realized price[14] for 1971-72 to 200-01. The farm gate prices were acquired from various years of Canada Grains Council, and Saskatchewan Agriculture and Food statistics. The regression of last year's final price on this year's final price is shown in Eq. 5.2. The standard deviation of the errors is 75.8.

$$\underset{}{Y_t = \underset{(19.24)}{0.9516}\, Y_{t-1}} \qquad R^2=0.64 \text{ adj. } R^2=0.603 \qquad (5.2)$$

Instead of using the errors from the first order autoregressive (AR1) function the errors from an AR1 AR2 and AR4 are employed. Prices in the current time period are dependent upon last years price, the price from two years ago and the price from four years ago (Eq 5.3). This function has a higher R^2 and a smaller standard deviation 35.82 and all of the co-efficients are significant at the 95% confidence level. Using Microsoft Excel's random number generator 10,000 possible errors were created. Future prices using these errors started at $130.00/tonne and ranged between $100 to $270/tonne.

$$Y_t = \underset{(6.20)}{1.0350}\, Y_{t-1} \underset{(-2.32)}{-0.3799} Y_{t-2} \underset{(3.43)}{+0.2692}\, Y_{t-4} \qquad R^2=0.84 \text{ adj. } R^2=0.832 \qquad (5.3)$$

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[14] The realized price is the farm gate price. The value received after freight and handling charges are deducted.

Spring PRO values are generated using the same method that was used to generate spring fertilizer prices. The CWB has produced April PRO's since 1992-93. The real price spread, between the previous crop year's final price and the spring PRO, averaged ($10.52)/tonne with a standard deviation of 23.14. Using Microsoft Excel’s random number generator, 10,000 errors were generated with a mean of zero and a standard deviation of 23.14, to work in the random walk price model. The generated errors were added to the previous crop year’s final price, and adjusted down $10.52/tonne to a minimum PRO of $75.00/tonne.

5.3 Farm Size

In general, farms are larger in the semi-arid Brown soil zone with large amounts of fallow and smaller farms in the more humid Black/ Grey soil zone with smaller percentages of fallow (Agriculture and Agri-Food Canada 2000). Mechanization has made possible the increase in farm size over time. The value of implements and machinery in Saskatchewan has increased from $4,526,433,000 in 1972 to $8,437,649,000 in 2000 (2000 constant dollars) (Saskatchewan Agriculture and Food Handbook 2000). The size of farms has been increasing in Saskatchewan since 1906 while the number of farms has been decreasing since 1936. In 1996 the average size of a farm was 1152 ac compared to 845 ac in 1971(Saskatchewan Agriculture and Food Agriculture Statistics 2000).

The problem with using simple averages is it provides no information concerning the distribution, which it represents. In Saskatchewan 35% of farms produced almost 80% of total provincial farm receipts (Statistics Canada 2002).

In this study, two medium-sized farms, one in the Dark Brown soil zone (Regina) and one in the Black soil zone (Melfort) are examined. A 2560 acre (1036 ha) operation is used in this study.

5.4 Machinery Size

The size of machinery used in this study varies depending upon the type of soil and the type of seeding system. Machines were sized so that most of the working days available in the May1- May 30 period would be used. A working day is considered to be 12 hours of field time. Field efficiency varies depending upon the size of the machine and the amount of seed and/or fertilizer being applied. The size of machines for the various systems and soil type are given in Table 5.3. The machine sizes may be smaller than what is normally used because it is assumed that all field time is devoted to seeding and ignores other field operations such as spraying that may also be performed during the time frame.

Table 5.3 Machinery Complements and Available Working Days

	Soil type					
	Light			Heavy		
Seeding System	Double-shoot	Single-shoot Fall	Single-shoot Spring	Double-shoot	Single-shoot Fall	Single-shoot Spring
Width ft	29.5	29.5	41	34	34	54
Air Cart	250	250	250	250	250	250
Seeder Price	$105,828	$102,808	$110,819	$111,000	$104,000	$156,287
Draft PTO hp	147	147	194	167	167	247
Tractor size PTO hp	170	170	215	170	170	270
Tractor Price	$142,759	$142,759	$170,000	$142,759	$142,759	$183,314
Field Efficiency	70%	72%	75%	72%	72%	77%
Working days	Melfort	22.5		Melfort	16.8	
	Regina	21.6		Regina	17.1	

Sources: Author, Moody's (2001 and 2002), Dyer et al. (1978).

To calculate the variable and fixed costs associated with the various seeding systems, estimates are needed for the cost of fuel, maintenance, and life (years) for equipment. Fuel use generally varies from 2.75-3.15 kwh/l (Schoney and Nagy (1999b)). An average fuel use is calculated at 3.15 kwh/l in this study. The price of fuel is $0.4364/l for diesel fuel, which is net of all fuel tax rebates (Saskatchewan Agriculture and Food Farm Input Survey 2002). Labour costs are valued at $12/hour.

The lifespans of machinery are calculated according to their half-lives. Half-lives are estimates of half the life span of a machine. It is assumed that at the half-life a major overhaul is required to keep the machine operational. The half-life of a seeding implement is 1500 hours of use (Schoney and Nagy 1999b). The half-life of a tractor is 6,000 hours use (Schoney and Nagy 1999b).

The model calculates the annual use associated with each seeding system. The seeding operation is the only field operation and all tractor fixed costs are born by the seeding operation.

The assumptions used in calculating the maintenance costs for tractors and seeding implements are displayed in Table 5.4. Prices were obtained from local dealerships (Red Head Equipment 2002). Maintenance frequencies and quantities required were estimated by specifications for different sized tractors.

Table 5.4 Tractor and Seeding Implement Maintenance Costs

Low horsepower less than 275

Maintenance	Frequency (hours)	Quantity	Price	Total	$/hr
Oil change	200	30	$ 1.69	$ 50.70	$ 0.25
Oil filter	200	1	$ 32.26	$ 32.26	$ 0.16
Air Filter	400	1	$ 100.00	$ 100.00	$ 0.25
Transmission filter	500	1	$ 85.00	$ 85.00	$ 0.17
Transmission oil	1000	150	$ 1.81	$ 271.50	$ 0.27
Water filter	750	1	$ 10.00	$ 10.00	$ 0.01
Coolant	750	25	$ 2.00	$ 50.00	$ 0.07
Replace tires	5000	8	$1,000.00	$8,000.00	$ 1.60
Total per hour					$ 2.79

High horsepower more than 275

Maintenance	Frequency (hours)	Quantity	Price	Total	$/hr
Oil change	200	55	$ 1.69	$ 92.95	$ 0.46
Oil filter	200	1	$ 32.26	$ 32.26	$ 0.16
Air Filter	400	1	$ 100.00	$ 100.00	$ 0.25
Transmission filter	500	1	$ 85.00	$ 85.00	$ 0.17
Transmission oil	1000	225	$ 1.81	$ 407.25	$ 0.41
Water filter	750	1	$ 10.00	$ 10.00	$ 0.01
Coolant	750	40	$ 2.00	$ 80.00	$ 0.11
Replace tires	5000	8	$1,200.00	$9,600.00	$ 1.92
Total per hour					$ 3.49

Machine costs

Personal experience approximately $500 per year for general maintenance for a 30 foot cultivator used for 115 hrs per year equates to 14.5 cents per hour foot

Sources: Author, Red Head Equipment (2002)

5.5 Crop Rotation and Budget

The farm is continuously cropped with a four-year rotation consisting of a cereal/pulse/cereal/oilseed. Crop rotations with different plant families are useful for weed, disease, and pest control, staggering farm operations particularly at harvest and for diversifying farm income (Saskatchewan Agriculture and Food 1997). For the purpose of this study budgets for wheat production at Melfort and Regina are required. The budget is presented in Table 5.5. The budget assumptions are as follows:

- Seed is sown at 84 kg/ha valued at last years final wheat price,
- 34 kg/ha of P_2O_5 @ \$.53. /kg,
- Nitrogen cost is stochastic,
- Half of the area is sprayed for wild oats, 100% for broadleaf weeds and all receive a pre-seed burn off,
- Fuel, Repairs, Custom work, Utilities costs are from 2001 Census data and
- Capital Recovery Charge (CRC) is estimated from Schoney and Nagy (1999b) average of medium sized conventional and zero tillage farms.

Table 5.5 Regina and Melfort Wheat Crop Production budget \$/ha

Crop Production budget for wheat

Cash Costs/ acre	Regina	Melfort
Phosphorus	$ 18.53	$ 18.53
Pesticides	$ 33.77	33.77
Utilities and misc.	$ 8.72	$ 10.62
Building repair	$ 4.03	$ 7.29
Total cash costs	$ 176.07	$ 194.51
Interest on cash costs	$ 5.28	$ 5.84
Total Cash Costs and interest	$ 181.35	$ 200.35
Capital Recovery Charge	$ 84.97	$ 84.97
Total cost	$ 266.32	$ 285.32

Source: Author

5.6 Risk Coefficients

Raskin and Cochran (1986) examined commonly used risk aversion coefficients. They noticed that most of the coefficients are based on certainty equivalents. They proceed to discuss the limitations of using assumed risk aversion coefficients. They caution using risk coefficients that involve a change in spatial or temporal dimension of the outcomes. They provide two examples of such cases examining risk on a per area basis and risk applied to returns examined on a ten-year NPV basis.

> *"A way around the scaling problems is to elicit directly the aversion to per acre or ten year NPV risk. Such a procedure would stray from the typical after-tax net farm income questioning commonly used in the past and focus directly on preferences for per acre (or ten-year) returns before taxes and unrelated fixed expenses. Some interesting empirical question could potentially be answered concomitantly. How do attitudes towards risk change (if at all) as the time horizon is varied (but the time origin remains fixed)? Do we become less prone to risk taking as wealth rather than short-term income is at stake? Are our attitudes toward risk identical for each crop in a multi crop farm? Or can we even correctly measure risk for a single crop without the knowledge of the other income sources? Little work has been carried out to answer the above questions."*
> (Raskin and Cochran (1986), pg 208.)

Eliciting Arrow Pratt risk aversion co-efficient values is a difficult time consuming prospect. Schoney (1999a) provides r values for net annual income for Saskatchewan farmers. However, net returns per hectare is being studied in this paper. Zentner et al. (1992) scaled coefficients from literature to allow analysis on a per hectare basis. The values are 0 for risk neutral 0-.0075 for low risk aversion, .0075-.0225 for medium risk aversion and .0225-.05 for high risk aversion.

5.7 Discount Rate

To conduct NPV analysis discount rates are required. A 2% time value of money and a real rate of return of 3% is assumed. This leads to an opportunity cost of capital of 5%. Schoney and Nagy (1999b) and Zentner et al. (1993) used and opportunity cost of capital of 5%.

5.8 Soil Nitrogen

Two levels of indigenous soil N are used. A high level of soil N is 55 kg/ha (Saskatchewan Soil Testing Laboratory 1990, Edgar 1998), and a low level of soil N 35 kg/ha. The amount of indigenous soil N is non-stochastic unless there was unused fertilizer from the year before in which case a 50% carryover is modeled (Schoenau 2002).

5.9 Safe Nitrogen Application Rates

The amount of nitrogen that can be safely applied with the seed depends upon seed bed utilization. The seed bed utilization is a ratio of the amount of disturbance caused by the opener divided by the distance between openers. The amount that can safely be applied influences the number of operations required to complete seeding. Soil texture and crop also influence the safe amount of seed-placed nitrogen. Table 5.6 shows the safe level of Nitrogen (urea plus N contained in phosphorus fertilizer) for this study.

Table 5.6 Safe rates of Nitrogen (kg/ha) Application with Wheat and Canola based on Soil Texture.

Crop	**Soil Texture**	
	Heavy	**Light**
Wheat	58	41
Canola	25	30

Source: Author, Saskatchewan Agriculture and Food (1998)

5.10 Fertilizer Storage Costs

It is assumed that fertilizer bins can be used for grain storage in the fall. The additional fixed costs (epoxy coating to prevent corrosion by fertilizer) will be charged to fertilizer storage. Fertilizer storage costs are calculated using the CRC of the difference between fixed costs of storage for grain bins and fertilizer bins.[15] Storage costs are $65.10 per 100 tonne bin required to store fertilizer over winter. Fertilizer storage is needed for all systems, if the optimum fertilizer decision does not exceed the safe rate of N application with seed, than fertilizer will be applied in the spring with the seed.

5.11 Spring Fertilizer Price

For a storable commodity like fertilizer the price from period A to period B should be the purchase price in period A plus interest and storage costs. Fertilizer plants have large warehouses and the cost of storage would seem to be small. In the absence of economic shocks like large increases in natural gas costs for the production nitrogen fertilizer issues like fertilizer plant production capacities may explain historical price fluctuations exceeding storage and interest cost. There is a large demand for fertilizer in the spring and fertilizer plants may not have the capacity to produce the fertilizer demanded within the spring period. Fertilizer companies may reduce the price of fertilizer in the fall to reduce storage requirements to improve profits.

5.12 Summary

This chapter has delivered the assumptions made in determining the parameter values for the study. Precipitation values are generated using historical data and a general distribution. Actual output price received in the model is generated using a random walk model with AR1, AR2, and AR4 regression residuals. PRO estimates are created using generated values based on the average and standard deviation of the real

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[15] The cost of a new epoxy coated 100 ton fertilizer bin is $7910 and an uncoated bin is $6950 (Saskatchewan Wheat Pool 2002). Assume a 30 year lifespan 5% charge for capital and a 0 salvage value

price spread between the previous years final price and the spring PRO. Fall fertilizer prices are generated using a random walk model. The change in fertilizer price from fall to spring is generated with a random walk using historical average and standard deviation of fall to spring price changes. The study farms are 1036 cultivated ha located at Regina and Melfort Saskatchewan. Machines were sized so most of the working days available in the May 1 to May 31 period would be used. Maintenance costs are \$2.79/hr, \$3.49/hr, and \$0.145/(hr*ft) for power units under 275 hp, over 275 hp and tillage implements respectively. The total cost of production for wheat in Regina is \$266.32/ha and \$285.32/ha in Melfort. The risk coefficients are 0 risk neutral, 0.0075 low risk aversion, 0.0225 medium risk aversion, 0.05 high risk aversion. Opportunity cost of capital is 5%. Indigenous soil N is non stochastic at 55kg/ha and 35 kg/ha. Fertilizer storage costs are \$65.00 per 100 tonne unit annually.

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the CRC is \$65.10/year.

CHAPTER VI

RESULTS

6.0 Introduction

The results of the study are presented in this chapter. The optimum use of fertilizer and factors that affect the optimum use of fertilizer are presented. The values of spring subsoil moisture information, and price information are calculated. The influence of the cost of fertilizer on profitability is presented. The direct operating costs of three seeding systems and presented.

6.1 Optimal Fertilizer use

The optimal use of fertilizer for each of the six strategies is calculated. The mathematical optimum amount of fertilizer is determined where the Value of Marginal Product (VMP) equals the Marginal Factor Cost (MFC). The amount of applied fertilizer in each case is dependent on the expected prices, expected precipitation, the amount of indigenous soil N, soil type, and the over winter loss[16] of product. The actual amount of nitrogen applied ranges from 6 kg/ha to over 140 kg /ha depending upon the strategy used. The average amount of fertilizer applied for the locations and strategies is presented in Table 6.1 for two levels of indigenous soil N.

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[16] Over winter loss includes leaching, volatilization, and denitrification.

Table 6.1 Average Mathematical Optimum Nitrogen Fertilizer Application Rate (Kg/ha)

55 kg Indigenous Soil N

Strategy[1]	Regina Light[2]	Regina Heavy[2]	Melfort Light[2]	Melfort Heavy[2]
1	76	87	76	83
2	65	75	64	71
3	68	78	67	74
4	65	75	65	71
5	68	78	68	74
6	77	88	76	84

35 kg Indigenous Soil N

Strategy[1]	Regina Light[2]	Regina Heavy[2]	Melfort Light[2]	Melfort Heavy[2]
1	97	107	97	103
2	84	95	84	91
3	88	98	87	94
4	85	95	85	91
5	88	98	88	94
6	98	108	97	104

Source: Author

1

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winte loss and interest charge

1 GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.
2 Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion while heavy soils have more clay particles.

In general, higher rates of recommended N are applied to the heavy soil as compared to the lighter soil. This is due to the higher moisture holding capacity of heavier soils. The heavier soils in years of high winter precipitation will have higher levels of spring soil moisture a factor used in calculating the yield.

Reducing the amount of indigenous soil N by 20 kg/ha resulted in the mathematical optimum rates increasing by approximately 20 kg/ha. This can be explained by examining the profit maximizing conditions in Eq 6.1. The total amount of N required to maximize profits is not influenced by the amount of indigenous N. However, reduced indigenous N will increase input costs.

$$g(N_1) + N_2 = \frac{Pb + PfW - z}{-2Pc} \tag{6.1}$$

Increased information about the level of subsoil moisture did not significantly affect the average fertilizer application rates (6 vs. 1, 2 vs. 4, 3 vs. 5). Overall, it may be that while precipitation is variable the variability may be seasonal instead of annual. That is, if the producer expects 350 mm of precipitation for the year, it will be received either equally throughout the year, or with moist winters and dry summers, or dry winters and moist summers. This model is limited because it does not account for the impacts of the timing of precipitation on plant growth.

The use of the final payment for wheat in estimating fertilizer rates resulted in marginally higher average rates over using the PRO (2 vs. 3, 4 vs. 5). This increase in rates is likely due to the PRO being on average less than the previous year's final payment in the simulation analysis. In Equation 6.2 as output price P increases the third term on the right hand side becomes smaller increasing the amount of nitrogen required.

The most influential component that determines the use of fertilizer is the cost of fertilizer. In Equation 6.2 the only negative coefficient is c. Thus the last term on the right hand side is negative. If output price is unchanged then the higher the input cost z the lower will be the total amount of applied nitrogen. The fall price of fertilizer is about 8% less than spring price. The use of fall prices resulted in an increased application rate of approximately 10 kg/ha.

$$g(N_1) + N_2 = \frac{Pb}{-2Pc} + \frac{PfW}{-2Pc} - \frac{z}{-2Pc} \qquad (6.2)$$

6.2 Net Present Value and Certainty Equivalent Net Present Value Maximizing level of Fertilization.

The profit-maximizing rate of fertilizer may not be the best choice to maximize NPV or the Certainty Equivalent NPV (CENPV). Other factors like output price and precipitation variability, and a producer's risk aversion can affect the amount of applied fertilizer. There is likely a difference between the expected VMP and the actual VMP. The fertilizer rates that maximize NPV or CENPV by location, soil type, strategy, level of soil N, and risk preference are presented in Appendix A1.

A risk neutral producer's optimal strategy is to apply 90-100% of the mathematical optimum rate at all locations for both high and low levels of indigenous soil N. Lower levels of indigenous soil N lead to higher percentages of the mathematical optimum fertilizer being applied, which is more pronounced at higher levels of risk aversion. In such instances the risk premium associated with the purchase of fertilizer does not change between high or low levels of soil N. However, the VMP curve shifts out (VMP H to VMP L) resulting in a higher percentage of fertilizer being applied (N'/N")>(N_o/N_o') (Figure 6.1).

The average fertilizer rates for the Regina heavy soil location for high and low soil N are displayed in Figures 6.2 and 6.3 respectively. The actual amount of fertilizer applied declines as risk aversion increases. There is not much variability in average application rates when using spring fertilizer prices. The difference between the average amount of fertilizer applied for strategy 6 and strategy 1 decreases as risk aversion increases. This suggests that at low input cost receiving information about spring subsoil moisture brings risk averse individuals closer to risk neutrality.

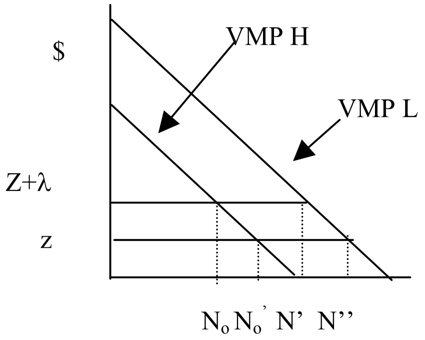

Figure 6.1 Effect of Soil N and Risk Premium on the level of Nitrogen Applied

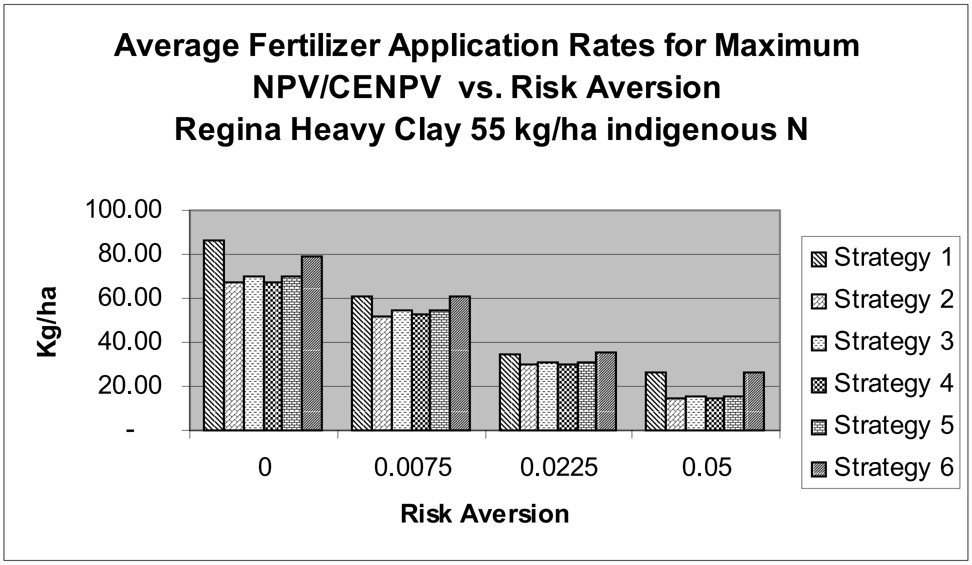

Figure 6.2 Average Nitrogen Fertilizer Application Rates (Kg/ha) for Regina Heavy[3] high Soil Nitrogen

Source: Author[2,3,4]

2

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winter loss and interest charge

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

[3] Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion whereas heavy soils have more clay.

[4] As the coefficient of risk aversion r increases so does the producers distaste for risk. A coefficient of 0 represents profit maximization and 0.05 represents high risk aversion.

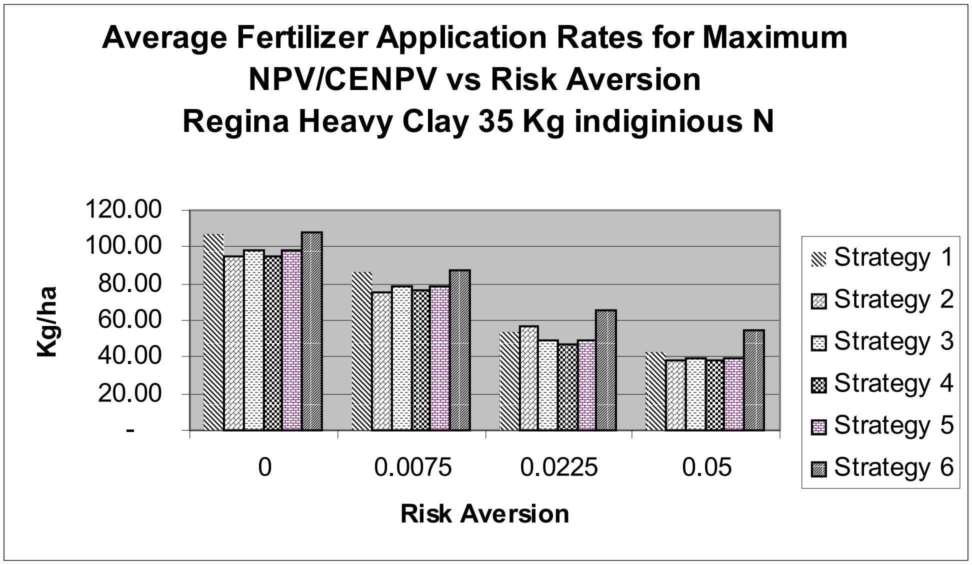

Figure 6.3 Average Nitrogen Fertilizer Application Rates (Kg/ha) for Regina Heavy low Soil Nitrogen

Source: Author[2,3,4]

[2]

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winte and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winte and GSP	Fall subsoil and assume average winte and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winte loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winte loss and interest charge

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

[3] Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion whereas heavy soils have more clay.

[4] As the coefficient of risk aversion r increases so does the producers distaste for risk. A coefficient of 0 represents profit maximization and 0.05 represents high risk aversion.

6.3 Maximum Net Present Value and Certainty Equivalent Net Present Value

The values presented in Table 6.2 represent returns to labour, management and land. The NPV less a proxy for labour and management would provide a value per ha of land. If labour and management are the same across soil types then heavier textured land will sell at a premium to lighter textured land. A negative CE means that the risk averse producer would have to be subsidized or gifted the land in order for them to take the gamble of farming.

The maximum NPV or CENPV are higher at the heavier textured site than the lighter textured site. The Regina site had a higher NPV than the Melfort site due to lower production costs. The lower levels of indigenous soil N resulted in lower profits due to increased cost as the profit maximizing yield is independent of the amount of soil N. The variable costs are negatively correlated with soil N and profit level is positively correlated with indigenous soil N.

The benefit of learning spring subsoil moisture was more pronounced on heavier soils than on lighter soils at the same location.

Table 6.2 Returns to Land Labour and Management Max NPV or NPV CE achieved Based on percent of Profit Maximizing Nitrogen Applied

55 kg

r=0	Regina Light	Regina Heavy	Melfort Light	Melfort Heavy
1	$ 2,782.18	$ 3,596.60	$ 2,586.52	$ 3,101.41
2	$ 2,650.19	$ 3,449.06	$ 2,445.67	$ 2,950.12
3	$ 2,647.62	$ 3,448.25	$ 2,445.72	$ 2,949.24
4	$ 2,645.04	$ 3,445.88	$ 2,444.41	$ 2,948.74
5	$ 2,641.83	$ 3,444.38	$ 2,443.26	$ 2,948.01
6	$ 2,823.68	$ 3,644.71	$ 2,623.37	$ 3,142.81
r=.0075				
1	$ 779.86	$ 1,444.95	$ 618.95	$ 994.21
2	$ 700.15	$ 1,352.49	$ 529.54	$ 896.21
3	$ 699.24	$ 1,355.03	$ 532.32	$ 901.52
4	$ 695.86	$ 1,346.76	$ 527.02	$ 893.56
5	$ 695.90	$ 1,347.57	$ 528.81	$ 898.42
6	$ 807.27	$ 1,479.96	$ 645.63	$ 1,023.69
r=0.0225				
1	$ (657.99)	$ (280.56)	$ (804.47)	$ (608.11)
2	$ (698.44)	$ (322.37)	$ (852.41)	$ (655.67)
3	$ (701.05)	$ (322.58)	$ (852.43)	$ (655.22)
4	$ (699.89)	$ (325.49)	$ (855.26)	$ (658.36)
5	$ (704.28)	$ (327.90)	$ (853.77)	$ (656.82)
6	$ (642.30)	$ (262.15)	$ (786.69)	$ (589.73)
r=0.05				
1	$ (1,572.40)	$ (1,377.24)	$ (1,685.71)	$ (1,607.06)
2	$ (1,598.84)	$ (1,401.64)	$ (1,716.83)	$ (1,632.62)
3	$ (1,602.16)	$ (1,400.94)	$ (1,714.88)	$ (1,632.75)
4	$ (1,600.02)	$ (1,401.43)	$ (1,717.92)	$ (1,632.42)
5	$ (1,602.99)	$ (1,402.29)	$ (1,716.07)	$ (1,634.01)
6	$ (1,562.01)	$ (1,365.18)	$ (1,672.45)	$ (1,594.17)

Table 6.2
continued
35 kg

r=0	Regina Light	Regina Heavy	Melfort Light	Melfort Heavy
1	$ 2,570.20	$ 3,385.00	$ 2,374.38	$ 2,889.51
2	$ 2,397.40	$ 3,195.07	$ 2,192.74	$ 2,697.28
3	$ 2,395.23	$ 3,192.97	$ 2,193.33	$ 2,696.66
4	$ 2,392.22	$ 3,190.47	$ 2,191.57	$ 2,696.07
5	$ 2,389.44	$ 3,189.40	$ 2,190.87	$ 2,694.65
6	$ 2,620.91	$ 3,442.72	$ 2,420.08	$ 2,940.14
r=.0075				
1	$ 558.89	$ 1,221.98	$ 398.46	$ 774.19
2	$ 438.16	$ 1,090.53	$ 268.41	$ 635.68
3	$ 441.39	$ 1,092.10	$ 272.34	$ 641.32
4	$ 433.06	$ 1,082.92	$ 265.15	$ 632.23
5	$ 437.78	$ 1,083.87	$ 270.77	$ 637.20
6	$ 599.02	$ 1,265.80	$ 434.89	$ 811.72
r=0.0225				
1	$ (879.22)	$ (512.07)	$ (1,026.44)	$ (832.06)
2	$ (955.80)	$ (591.76)	$ (1,113.23)	$ (916.26)
3	$ (958.46)	$ (590.41)	$ (1,110.81)	$ (913.48)
4	$ (959.59)	$ (597.93)	$ (1,115.39)	$ (919.10)
5	$ (960.40)	$ (594.58)	$ (1,112.94)	$ (916.42)
6	$ (850.94)	$ (481.36)	$ (998.68)	$ (803.46)
r=0.05				
1	$ (1,788.52)	$ (1,613.15)	$ (1,910.67)	$ (1,830.55)
2	$ (1,850.46)	$ (1,677.15)	$ (1,977.44)	$ (1,886.28)
3	$ (1,854.26)	$ (1,674.53)	$ (1,973.40)	$ (1,885.95)
4	$ (1,852.54)	$ (1,677.44)	$ (1,978.82)	$ (1,887.85)
5	$ (1,855.54)	$ (1,676.83)	$ (1,974.80)	$ (1,887.81)
6	$ (1,766.31)	$ (1,591.40)	$ (1,888.53)	$ (1,807.88)

Source: Author[2,3,4]

[2]

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winte loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winte loss and interest charge

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

[3] Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion whereas heavy soils have more clay.

[4] As the coefficient of risk aversion r increases so does the producers distaste for risk. A coefficient of 0 represents profit maximization and 0.05 represents high risk aversion.

6.4 Value of Output Price, And Moisture Information and Seasonal Fertilizer Price change

The four factors that affect the amount of N fertilizer applied are expected moisture (spring subsoil moisture and growing season precipitation (GSP)), expected output price, input cost, and producer risk aversion. The NPV of the strategies are presented in Table 6.3. The value of expected moisture and expected output price information is quantified. Also, the effect of a change in input cost on profit is calculated. A discussion explaining what the strategy comparisons are and the findings follows.

The value of output price, spring soil moisture and the value of seasonal fertilizer price change information are presented in Table 6.3 and Table 6.4. The value of information for a producer who is risk neutral (r=0) is the difference in the means of the 200 selected outcomes. The value of information for an individual who is risk averse is the amount the net income distributions would have to be decreased so that the two strategies have the same expected utilities.

Comparison of strategy 1 to strategy 6 represents the value of spring subsoil moisture information using the cost of fertilizer adjusted for interest costs. The values of comparing strategy 1 to 6 are all positive indicating that there is some value to using spring subsoil moisture levels in determining optimal fertilizer rates using the cost of fertilizer in the fall. The value of information is greater with lower levels of soil nitrogen than with high levels of soil nitrogen in all but one instance. The information is more valuable at lower levels of soil N if high N application levels are optimal when using fall input prices. The value of information decreases as the level of risk aversion increases due to correspondingly lower levels of actual N that are applied at higher levels of risk aversion.

Comparison of strategy 2 to strategy 3, and strategy 4 to strategy 5 represents the value of output price information using spring fertilizer prices with either spring or fall subsoil moisture information. The values were between \$0.21 and -\$1.35 per ha suggesting that the difference in value between the two sources of information is not very large in most years. This finding is likely due to the manner in which output prices where generated. Adding an error term to the last year’s final payment generated PRO values. In the model PRO values and final prices are highly positively correlated (correlation coefficient 0.8058). It may be that for most years there may not be much difference in using final payment or PRO’s in determining production, but there may be specific instances where shocks occur and the final payment will not capture that information.

Comparing strategy 1 to strategy 2 provides the total difference in annual returns between making a decision with fall information and fall input cost or a decision using spring information and spring input cost. A risk neutral or slightly risk averse, or moderately risk averse producer will incur a significant reduction in profits by waiting for spring moisture and price information. The reduction in profits is even more pronounced at lower levels of soil N. The cause of the reduction in profits is the higher input cost in the spring dominating the value of spring time output price information.

Comparisons of strategy 2 with strategy 4, and strategy 3 with strategy 5 estimates the value of spring subsoil moisture using either the final payment for wheat or the spring PRO as price estimates. The value of spring information is less than \$1.00/ha for risk neutral producers except for the Melfort light textured low soil nitrogen scenario, which is -$0.30/ha. As risk aversion increases the value of information is less than plus or minus $1.00/ha.

Table 6.3 Information Value at high levels of soil Nitrogen $/ha by Location, Soil Texture and Producer Risk Preference

Regina Heavy 55 kg per ha						
r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	3.47	(0.14)	(11.52)	0.45	0.48	(0.11)
0.0075	2.53	(0.28)	(8.00)	0.02	0.30	(0.28)
0.0225	1.31	(0.70)	(4.98)	0.07	0.08	(0.68)
0.05	0.59	(0.36)	(4.29)	(0.18)	(0.15)	(0.33)
Regina Light 55 kg per ha						
r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	2.67	(0.01)	(10.37)	0.52	0.47	(0.06)
0.0075	2.01	0.11	(5.76)	0.31	0.31	0.11
0.0225	1.27	0.07	(2.48)	0.40	0.51	0.19
0.05	0.79	(0.01)	0.46	0.80	0.46	(0.35)
Melfort Light 55 kg per ha						
r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	2.84	(0.30)	(11.41)	0.42	0.51	(0.21)
0.0075	1.51	(0.57)	(6.53)	-	0.11	(0.31)
0.0225	0.88	(0.41)	(2.14)	(0.03)	(0.06)	(0.44)
0.05	0.36	0.12	(1.26)	(0.30)	0.38	0.09
Melfort Heavy 55 kg per ha						
r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	2.81	(0.13)	(12.00)	0.24	0.37	(0.10)
0.0075	1.85	(0.67)	(7.07)	-	-	(0.67)
0.0225	1.10	(0.34)	(2.03)	0.36	0.01	(0.68)
0.05	0.70	0.01	(0.05)	(0.19)	(0.05)	0.13

Source: Author calculations[2,3,4]

[2]

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winte loss and interest charge

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

[3] Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion whereas heavy soils have more clay.

[4] As the coefficient of risk aversion r increases so does the producers distaste for risk. A coefficient of 0 represents profit maximization and 0.05 represents high risk aversion.

Table 6.4 Information Value at low levels of soil Nitrogen $/ha by Location, Soil Texture and Producer Risk Preference

Regina Heavy 35 kg per ha

r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	2.94	0.15	(14.67)	0.49	0.54	0.20
0.0075	3.11	0.16	(11.01)	0.31	0.11	(0.18)
0.0225	3.94	0.21	(7.09)	1.60	0.00	(1.35)
0.05	2.74	(0.74)	(6.76)	(0.22)	(0.14)	(0.66)

Regina Light 35 kg per ha

r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	3.51	(0.01)	(13.48)	0.46	0.47	(0.07)
0.0075	2.90	0.11	(8.68)	0.71	0.31	0.00
0.0225	2.10	0.04	(5.73)	0.66	0.38	(0.24)
0.05	0.99	(0.22)	(4.32)	0.26	0.69	0.22

Melfort Light 35 kg per ha

r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	3.41	(0.31)	(14.52)	(0.30)	0.00	0.09
0.0075	2.46	(0.69)	(9.28)	0.01	(0.11)	(1.07)
0.0225	1.66	(0.78)	(3.93)	0.15	0.44	(0.48)
0.05	1.04	(0.10)	(0.64)	(0.04)	0.64	0.57

Melfort Heavy 35 kg per ha

r	1 vs. 6	2 vs. 3	1 vs. 2	2 vs. 4	3 vs. 5	4 vs. 5
0	3.73	(0.15)	(15.15)	0.33	0.37	(0.11)
0.0075	2.40	(0.71)	(9.77)	0.11	0.00	(0.96)
0.0225	1.60	(0.44)	(3.60)	0.28	0.16	(0.55)
0.05	1.04	0.20	(0.54)	0.12	0.10	0.17

Source: Author calculations[2,3,4]

[2]

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winter loss and interest charge

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

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3 Light and heavy refer to soil texture. Light soils have a higher portion of sand in their composition whereas heavy soils have more clay.

4 As the coefficient of risk aversion r increases so does the producers distaste for risk. A coefficient of 0 represents profit maximization and 0.05 represents high risk aversion.

6.5 Direct Operating Costs

The three seeding systems are a fall band and spring seed (single-shoot technology), spring band and spring seed (single-shoot technology), and a one pass side-band system (double-shoot technology). Total variable costs are the sum of the fuel cost, machine maintenance cost, tractor maintenance, and labour cost. Total fixed costs include the CRC for the seeding implement and the power unit. Fall single-shoot system costs are calculated using strategy 1[17] decision criteria. Spring single-shoot system costs are calculated using strategy 2[17] decision criteria. A break down of the direct operating costs of the three seeding systems is located in Appendix A2.

The seeding system direct costs including fertilizer storage associated with location, soil type, risk aversion, and indigenous soil N are presented in Tables 6.5 and 6.6. In general the fall single-shoot system required more operations than the spring single-shoot system due to higher rates of fertilizer being applied for a given risk preference.

Light soils have lower limits for safe seed-placed N and are more costly to seed compared to heavy soils using a fall single-shoot seeding system (Saskatchewan

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[17]

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winter loss and interest charge

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

Agriculture and Food 1998). The higher the level of soil N the lower the N applied lowering the expected number of passes and the expected seed cost. The double-shoot (side-band) system is most valuable for farms with light soils, low soil N and low risk aversion which results in higher levels of applied N. Farms with heavy soils, high soil N levels, and high risk aversion have lower seeding cost with single-shoot seeding systems. Single-shoot seeding systems are the lowest cost alternatives for producers with high risk aversion and high levels of soil N.

Table 6.5 Total Seeding system costs for 35kg/ha Soil N By Location, Soil Texture and Producer Risk Preference

Risk Aversion	System	Regina Light	Regina Heavy	Melfort Heavy	Melfort Light
r=0	FSS	$ 38,923.67	$ 35,907.48	$ 35,862.94	$ 38,922.18
	SSS	$ 36,023.42	$ 38,773.48	$ 38,716.37	$ 36,003.12
	SDS	$ 29,944.03	$ 28,880.86	$ 28,880.86	$ 29,944.03
	SDSS	$ 8,979.64	$ 7,026.62	$ 6,982.08	$ 8,978.15
r=0.0075	FSS	$ 38,258.65	$ 35,843.55	$ 35,718.70	$ 38,934.34
	SSS	$ 36,077.70	$ 38,699.85	$ 38,586.66	$ 36,055.65
	SDS	$ 30,139.33	$ 29,076.16	$ 29,076.16	$ 30,139.33
	SDSS	$ 8,119.32	$ 6,767.39	$ 6,642.54	$ 8,795.01
r=0.0225	FSS	$ 38,110.98	$ 32,112.06	$ 34,408.68	$ 38,099.08
	SSS	$ 35,636.82	$ 35,903.14	$ 35,684.86	$ 35,648.27
	SDS	$ 30,074.23	$ 29,011.06	$ 29,011.06	$ 30,074.23
	SDSS	$ 8,036.75	$ 3,101.00	$ 5,397.62	$ 8,024.85
r=0.05	FSS	$ 30,932.98	$ 28,061.59	$ 30,867.89	$ 37,747.30
	SSS	$ 29,288.15	$ 31,323.58	$ 33,046.73	$ 34,158.01
	SDS	$ 30,074.23	$ 29,011.06	$ 29,011.06	$ 30,074.23
	SDSS	$ 858.75	$ (949.47)	$ 1,856.83	$ 7,673.06

Source: Author calculations [2,3,4,5]

2

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winte loss and interest charge

1 GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board

3 Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion whereas heavy soils have more clay.

4 As the coefficient of risk aversion r increases so does the producers distaste for risk. 0 represents profit maximization and 0.05 represents high risk aversion.

5 Fall single-shoot (FSS), Spring Single-shoot (SSS), Spring Double-shoot (SDS), Spring Double-shoot Savings (SDSS) (side-band).

Table 6.6 Total Seeding system costs for 55kg/ha Soil N By Location, Soil Texture and Producer Risk Preference

Risk Aversion	System	Regina Light	Regina Heavy	Melfort Heavy	Melfort Light
r=0	FSS	$ 38,188.84	$ 35,719.89	$ 35,465.38	$ 38,181.41
	SSS	$ 35,854.72	$ 37,402.57	$ 37,505.09	$ 35,841.46
	SDS	$ 30,139.33	$ 29,076.16	$ 29,076.16	$ 30,139.33
	SDSS	$ 8,049.51	$ 6,643.73	$ 6,389.22	$ 8,042.07
r=0.0075	FSS	$ 37,757.46	$ 33,368.44	$ 32,750.83	$ 37,745.56
	SSS	$ 34,334.80	$ 35,485.82	$ 34,491.68	$ 34,313.60
	SDS	$ 30,074.23	$ 29,011.06	$ 29,011.06	$ 30,074.23
	SDSS	$ 7,683.23	$ 4,357.38	$ 3,739.77	$ 7,671.33
r=0.0225	FSS	$ 31,576.41	$ 27,702.70	$ 28,094.57	$ 34,875.57
	SSS	$ 29,366.61	$ 31,216.47	$ 31,332.97	$ 31,702.72
	SDS	$ 30,009.13	$ 28,945.96	$ 29,011.06	$ 30,074.23
	SDSS	$ 1,567.28	$ (1,243.26)	$ (916.49)	$ 4,801.34
r=0.05	FSS	$ 29,164.88	$ 27,702.70	$ 27,702.70	$ 31,500.64
	SSS	$ 28,282.73	$ 31,216.47	$ 31,216.47	$ 29,353.97
	SDS	$ 30,009.13	$ 28,945.96	$ 28,945.96	$ 30,009.13
	SDSS	$ (844.25)	$ (1,243.26)	$ (1,243.26)	$ 1,491.51

Source: Author calculations [2,3,4,5]

2

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winte loss and interest charge

1 GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

3 Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion while heavy soils have more clay particles.

4 As the coefficient of risk aversion r increases so does the producers distaste for risk. 0 represents profit maximization and 0.05 represents high risk aversion.

5 Fall single-shoot (FSS), Spring Single-shoot (SSS), Spring Double-shoot (SDS), Spring Double-shoot Savings (SDSS) (side-band).

6.6 The least cost seeding system alternative

In Section 6.2 it was shown that fertilizer cost is important in determining the level of profit reached. Farmers can expect higher NPV by determining their input use with strategy 1[18] (the fall information set) compared to waiting until the spring for the arrival of information about subsoil moisture, strategies 2,3,4,5[18].

Producers who apply large amounts of fertilizer using single-shoot seeding systems had higher costs than a double-shoot system as determined in Section 6.3. Farmers that apply fertilizer in the fall do not incur storage costs but are subject to N product loss and emit GHG.

Farmers, who are risk neutral, slightly risk averse or moderately risk averse would have lower seeding costs using a double-shoot seeding system. The double-shoot seeding system also allows producers flexibility; to incorporate spring soil moisture and output price expectations in their fertilizer decision, to reduce field operations to conserve moisture, add cropping flexibility, and reduce GHG emissions. Producers with high risk aversion and high levels of indigenous soil N may not require a double-shoot system to place the optimal amount of fertilizer with the seed in the spring.

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[18]

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winte and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winte and GSP	Fall subsoil and assume average winte and GSP	Spring available moisture assume average GSP
Wheat Price	Last years final payment	PRO[1]	Last years final payment	PRO	Last years final payment	Last years final payment
Input Cost	Fall fertilizer price adjusted for over winter loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winte loss and interest charge

[1] GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

6.7 Policy Options

The spring side-banding seeding system is the most profitable for producers applying large amounts of fertilizer nitrogen. The spring side-banding seeding system is also the seeding system that produces the least N_2O emissions given the assumptions used in this thesis. However, in reality there may be several constraints facing farmers in changing technologies. Constraints in adopting different technologies may include cash flow to finance the purchase of different technologies, and on farm fertilizer storage. This thesis, proposes three types of policy options to limit fall applied nitrogen, an extension option, an incentive option with the use of investment tax credits, and a disincentive option to using fall fertilizing systems through taxation. In addition a market for carbon credits is mentioned in section 6.7.4.

6.7.1 Extension Programs

The use of an extension program to inform farmers of the benefits and costs associated with two pass seeding systems and one pass seeding systems. The extension program should stress the reduction in operating costs by applying seed and fertilizer in one pass and the importance of on farm fertilizer storage for fall fertilizer purchases. This information could be produced in a pamphlet and distributed through existing organizations like the Prairie Farm Rehabilitation Administration, Saskatchewan Agriculture and Food and Rural Revitalization, and Saskatchewan Soil Conservation Association. Extension programs are likely the cheapest method of promoting the benefits of using a one pass seeding system and purchasing fertilizer in the fall. An extension program does not directly influence the market for seeding systems. Results are unpredictable as to the amount of producers that will change seeding systems especially if cash flow or other constraints exist at the farm level.

6.7.2 Investment Tax Credit

Investment tax credits (ITC) can be used as an incentive to increase the rate of adoption of one pass seeding systems. ITC allow producers to subtract a portion of the purchase of qualifying property or expenditures from income tax owing. ITC provide a financial incentive for producers to invest or upgrade to different technologies. The ITC should be targeted to the purchase or upgrade of machines and equipment related to one pass seeding systems and spring fertilizer application. There is a possibility that the benefits of the ITC to be captured by machine suppliers if demand shifts for new machines and storage capacity and the supply of machines and new storage are perfectly inelastic. ITC will likely have a greater benefit for wealthier and or high net income producers. As with any subsidy trade agreement regulations must be considered.

6.7.3 Fall Applied Fertilizer Tax

A third policy option is a tax on fall applied fertilizer. The tax could be charged on a per kg of applied N/ha to reflect the amount of N_2O emissions evolved or to make the fall applied N cost greater than spring applied N. Taxes would likely be effective at reducing fall applied N. However, there are several drawbacks associated with taxing fall applied N. Producers may reduce the use of N fertilizer, which would reduce production possibly affecting producer profits and consumer prices. There would be substantial costs in monitoring the time of fertilizer application. Over winter fertilizer storage costs may also rise because product normally applied in the fall may be applied in the spring. There may also be a bottleneck in handling and delivering fertilizer in the spring by fertilizer dealers.

6.7.4 Carbon Credit Trading

A fourth option is the use of carbon credits, if a carbon credit trading system is established. Carbon credits could be allocated to fertilizer use. A base scenario would be required to establish credits for producers. A producer's historical use and timing of application should be considered in distributing credits. Those producers who apply N fertilizer in the fall would be required to purchase carbon credits. Producers who apply fertilizer in the spring would have carbon credits for sale. There are several unresolved issues with the development, implementation and governance of carbon credit trading.

CHAPTER VII

SUMMARY AND CONCLUSIONS

7.1 Motivation

Farmers in Saskatchewan can apply their fertilizer in the fall or spring. There are several benefits and costs associated with both fall and spring fertilizer application including cost and efficiency of inputs, information available and application costs to make decisions.

Fertilizer is generally cheaper in the fall compared to spring. However, a certain amount of N fertilizer applied in the fall will be lost due to denitrification reducing nitrogen use efficiency, and some flexibility in production decisions will be lost. Producers who choose to purchase their fertilizer in fall and apply it in the spring will incur storage costs. Waiting until spring to make fertilizer application results in new information about expected prices and available soil moisture.

Producers who are applying more than the recommended safe rate of fertilizer with the seed can spread out their work load by applying fertilizer in the fall. Producers who apply seed and fertilizer in two separate operations in the spring may also dry out the seed bed which may reduce emergence. Producers with double-shoot seeding systems can safely apply the required amount of fertilizer in one pass with the seed in the spring thereby eliminating a field operation, reducing operating costs and saving moisture.

The previous paragraphs mention some of the factors that weigh on the producer in determining the timing of fertilizer application. The timing of fertilizer application can also influence the emissions of the GHG N_2O produced. Nitrogen fertilizer applied in the spring is not subject to freeze thaw conditions, which result in increased amounts of N_2O emissions.

The hypothesis of this study thesis was that fall fertilizer application is more profitable than spring fertilizer application.

The key assumption made in this thesis is that N fertilizer applied in the fall is subject to spring thaw conditions, which result in higher N_2O emissions. This thesis did not attempt to determine the amount or change in the amount of N_2O emissions between fall or spring fertilizer application. This thesis instead focused on the direct and indirect costs and benefits of fall fertilizer application and spring fertilizer application.

7.2 Process of Determining Results

The purpose of this study is to determine the direct and indirect costs associated with applying N fertilizer in the fall versus the spring: specifically, 1) what is the value of spring subsoil moisture and six months of market information in determining the optimal N input usage, 2) the effect of N input seasonal price changes on profitability, and 3) the direct operating costs for seeding.

This study reviewed the economics and finance literature in the areas of production and investment under uncertainty. These criteria are risk averse producer preferences, stochastic input cost, stochastic output prices, and production function variability. When these criteria exist then traditional profit maximization and standard investment models are no longer sufficient to examine the problem.

The theoretical analysis was based on a profit maximizing producer subject to their risk constraints facing stochastic yields, input costs and output prices. A polynomial profit function was used to model a producer's N fertilizer choice. The producer can make the fertilizer application decision in the spring or fall with different information sets. Stochastic variables used in information sets include fall subsoil moisture, winter precipitation, growing season precipitation, input costs, and output prices. Stochastic variables were generated using historical data for Saskatchewan. Scenarios using different combinations of information were used to calculate the value of information.

Precipitation values were generated using historical data and a general distribution. Output prices are generated using a random walk model with AR1, AR2, and AR4 regression residuals. PRO estimates are generated using values based on the average and standard deviation of the real price spread between the previous years final price and the spring PRO. Fall fertilizer prices are generated using a random walk model. The change in fertilizer price from fall to spring is generated with a random walk using historical average and standard deviation of fall to spring price changes. The hypothetical study farms are 1036 cultivated ha located at Regina and Melfort Saskatchewan. Machines were sized so most of the working days available in the May 1 to May 31 period would be used. Maintenance costs were calculated for power units and tillage implements. The risk coefficients are 0 risk neutral, 0.0075 low risk aversion, 0.0225 medium risk aversion, 0.05 high risk aversion. Opportunity cost of capital is 5%.

Producer's risk preference and soil type influenced optimum N fertilizer application. Net present value and certainty equivalents were calculated for each scenario to determine the most profitable N fertilizer decision strategy. The value of information was calculated using differences in expected utility for the most profitable level of N fertilizer application for each strategy. The fixed and variable operating costs were calculated for the seeding systems to correspond with the producer's direct and indirect costs.

The amount of applied fertilizer in each strategy is dependent on the expected prices, expected precipitation, the amount of indigenous soil N, soil type, and the over winter loss[19] of N fertilizer. The cost of N fertilizer is the most influential component that determines the amount of N fertilizer applied. The use of fall prices resulted in an increased N fertilizer application rate of approximately 10 kg/ha across all strategies.

In general, higher rates of recommended N are applied to the heavy soil as compared to lighter soil regardless of location or producer risk preference. The total amount of N required to maximize profits is not influenced by the amount of indigenous soil N. However, reduced indigenous soil N will increase input costs and reduce profits.

There is some value to using spring subsoil moisture levels in determining optimal N fertilizer rates using the cost of N fertilizer in the fall. However, a risk neutral or slightly risk averse, or moderately risk averse producer will incur a

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[19] Over winter loss includes leaching, volatilization, and denitrification.

significant reduction in profits by waiting for spring moisture and price information. The benefit of knowing spring subsoil moisture was more pronounced on heavier soils than on lighter soils at the same location. Generally, the value of information is greater with lower levels of soil N than with high levels of soil N. The value of spring subsoil information decreases[20] as the level of risk aversion increases due to correspondingly lower levels of actual N that are applied.

There may not be much difference in using Canadian Wheat Board final payment or PRO’s in determining production, but there may be specific instances where shocks occur and the final payment will not capture that information.

The seeding system direct costs including fertilizer storage associated with location, soil type, risk aversion, and indigenous soil N are calculated. The double-shoot (side-band) system is most valuable for farms with light soils, low soil N and low risk aversion, which results in higher levels of applied N. The spring side-band seeding system is also the seeding system that produces the least N_2O emissions given the assumptions used in this thesis. Farms with heavy soils, high soil N levels, and high risk aversion have lower cost with single-shoot seeding systems and likely will be able to safely apply desired fertilizer rates with the seed.

Three types of policy options were identified for promoting the adoption of N_2O reducing seeding systems. The extension program should stress the reduction in operating costs by applying seed and fertilizer in one pass and the importance of on farm fertilizer storage for fall fertilizer purchases. The Investment Tax Credit (ITC) should be targeted to the purchase or upgrading machines and equipment related to one

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[20] The exception is Regina Heavy 35 kg where the values increase then decrease as risk aversion increases.

pass seeding systems and spring fertilizer application. A tax on fall applied fertilizer could be charged on a per kg of applied N/ha to reflect the amount of N_2O emissions evolved or to make the fall applied N cost greater than spring applied N. Regardless of which policy is used, trade issues and other externalities must be taken into account to develop an effective and efficient method for promoting the adoption of N_2O reducing seeding systems.

7.3 Key Findings

7.3.1 Direct Operating Costs

A one pass seeding (double-shoot) system has lower variable and fixed costs than a two pass (single-shoot) seeding system. A one pass seeding system is most valuable for light textured soils where savings over a two pass system are more than \$8.00/ha where moderate to high amounts of nitrogen is applied. One pass seeding systems savings are less, for producers who apply moderate amounts of fertilizer on heavy textured soils, but still greater than \$3/ha. As the amount of fertilizer a producer applies increases, so does the savings in variable costs of the one pass seeding system.

7.3.2 Input Cost

Purchasing fertilizer in the fall using the fall information set and storing it on farm as opposed to purchasing fertilizer in the spring can significantly increase producer profits. Purchasing fertilizer in the fall can increase profits for risk neutral producers between \$10.37 to \$15.15/ha depending upon location, soil texture, and indigenous soil N. Purchasing fertilizer in the fall can increase profits for slightly risk averse producers between \$5.76 to \$11.01/ha depending upon location, soil texture, and indigenous soil N. Purchasing fertilizer in the fall can increase profits for moderately risk averse producers between \$2.03 to \$7.09/ha depending upon location, soil texture, and indigenous soil N.

7.3.3 Information Levels.

Producers committed to a continuous cropping system should make their fertilizer purchase in the fall using the CWB final price of the previous crop year, fall available subsoil moisture and assume average growing season precipitation, and winter precipitation. Producers should re-evaluate their fertilizer decision in the spring to take advantage of any market or precipitation information that may be of use.

7.3.4 Government Policy

GHG emissions are reduced by producers applying nitrogen fertilizer in the spring as opposed to the fall. A producer's profitability increases by adopting a one pass seeding system where N fertilizer is applied at the time of seeding. However, there are still farmers who choose to apply N fertilizer in the fall. To encourage the switch from fall application to spring nitrogen fertilizer application government could develop extension services and offer ITC. The extension program would promote the increase in profits of purchasing fertilizer in the fall and reduced cost associated with applying fertilizer in the spring with a one pass seeding system. Farmers may have financial constraints that limit the adoption of one pass seeding system. ITC aimed at the purchase of new one pass seeding systems or upgrading of existing seeding systems to one pass capability may reduce these financial constraints.

7.4 Limitations

The scope of the study used average moisture expectations and did not recognize the timing of precipitation events and consequently yields are directly correlated with precipitation. In addition to precipitation, there are other elements like wind, hail, heat, disease, etc that affect yield, which were not modeled nor considered. One way to account for these externalities, would be to generate residuals from the original yield model, to be added to each of the calculated yields.

Questions exist as to how accurate risk aversion coefficients are in reflecting actual producer risk preferences. Risk aversion coefficients were used to calculate CENPV for various fertilizer decision strategies and to calculate the value of information. However, in this study the savings associated with switching to a one pass seeding system vs. a two pass seeding system are paramount. The policy options of extension, tax credits, and GHG credits require additional assessment regarding their effectiveness.

7.5 Conclusions and Implications

Double-shoot one pass seeding systems have lower variable and fixed costs than single-shoot two pass seeding systems for producers applying large amounts of fertilizer. Double-shoot one pass seeding systems increase producer profits and reduce N_2O emissions from N fertilizer. The cost of N fertilizer has a significant impact on profitability. The availability of on farm fertilizer storage and purchasing fertilizer in the fall when it is generally lower cost will increase producer profitability. Producers who are committed to a continuous cropping system are better off to assume that they will receive normal amounts of winter and growing season precipitation and purchase their fertilizer requirements in the fall. The policy options of extension, ITC, and taxes require additional assessment regarding their effectiveness.

7.6 Recommended areas for Further Research

Calculations determining the actual amount of N_2O reductions associated with switching from fall to spring fertilizer application would be useful in assigning emission credits.

Greater study is needed surrounding the use of slow release fertilizers. Does the investment in double-shoot technology more than compensate for the added input cost of slow release fertilizer for producers with single-shoot technology? If a green house gas emission trading system were established, does the use of slow release fertilizer reduce emissions more than the added input cost associated with it?

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Appendix A1 Percentage of Profit Maximizing Fertilizer Application Level

Appendix A1 Percentage of Profit Maximizing Fertilizer Application Level

Table A1: Percentage of Profit Maximizing Fertilizer Rates by location, strategy, indigenous Nitrogen and risk preference

Indigenous Soil N	55 kg			
r=0	Regina Light	Regina Heavy	Melfort Light	Melfort Heavy
1	100%	100%	100%	100%
2	100%	90%	100%	100%
3	100%	90%	100%	90%
4	100%	90%	100%	100%
5	100%	90%	100%	90%
6	100%	90%	90%	90%
r=.0075				
1	70%	70%	70%	70%
2	70%	70%	70%	70%
3	70%	70%	70%	70%
4	70%	70%	70%	70%
5	60%	70%	70%	70%
6	70%	70%	70%	70%
r=0.0225				
1	40%	40%	50%	50%
2	40%	40%	50%	50%
3	40%	40%	40%	40%
4	40%	40%	50%	50%
5	40%	40%	40%	40%
6	50%	40%	50%	50%
r=0.05				
1	30%	30%	40%	30%
2	30%	20%	40%	30%
3	20%	20%	30%	30%
4	30%	20%	30%	30%
5	20%	20%	30%	30%
6	20%	30%	40%	40%

Table A1
continued
Indigenous Soil N 35 kg

r=0	Regina Light	Regina Heavy	Melfort Light	Melfort Heavy
1	100%	100%	100%	100%
2	100%	100%	100%	100%
3	100%	100%	100%	100%
4	100%	100%	100%	100%
5	100%	100%	100%	100%
6	90%	100%	90%	90%
r=.0075				
1	70%	80%	80%	80%
2	80%	80%	80%	80%
3	70%	80%	80%	80%
4	70%	80%	80%	80%
5	70%	80%	70%	80%
6	70%	80%	70%	80%
r=0.0225				
1	60%	50%	60%	60%
2	60%	60%	60%	60%
3	50%	50%	60%	60%
4	60%	50%	60%	60%
5	50%	50%	50%	50%
6	60%	60%	60%	60%
r=0.05				
1	40%	40%	50%	50%
2	50%	40%	50%	50%
3	40%	40%	50%	50%
4	40%	40%	50%	50%
5	40%	40%	40%	40%
6	50%	50%	50%	50%

Source: Author Calculations[2,3]

2

Strategy number	1	2	3	4	5	6
Decision time	Fall	Spring	Spring	Spring	Spring	Spring
Moisture	Fall subsoil and assume average winter and GSP[1]	Spring available moisture assume average GSP	Spring available moisture assume average GSP	Fall subsoil and assume average winter and GSP	Fall subsoil and assume average winter and GSP	Spring available moisture assume average GSP
Wheat Price	Last year's final payment	PRO[1]	Last year's final payment	PRO	Last year's final payment	Last year's final payment
Input Cost	Fall fertilizer price adjusted for over winte loss and interest charge	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Spring Fertilizer Price	Fall fertilizer price adjusted for over winter loss and interest charge

1 GSP growing season precipitation, PRO pool return outlook released by the Canadian Wheat Board.

3 Light and heavy refer to soil texture. Light soils have a higher portion of sand in their compostion while heavy soils have more clay particles.

Appendix A2 Seeding System Direct Costs

Appendix A2 Seeding System Direct Costs

Table A2.1 Direct operating costs $ for Regina Heavy

	Risk Aversion		0	Risk Aversion		0.0075	Risk Aversion		0.0225	Risk Aversion		0.05
	Soil Nitrogen		35	Soil Nitrogen		35	Soil Nitrogen		35	Soil Nitrogen		35
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,413.39	4,783.93	3,198.49	5,340.00	4,636.78	3,198.49	4,284.50	4,058.50	3,198.49	3,244.56	2,839.19	3,198.49
Machine Maintenance	1,136.35	1,064.71	671.41	1,120.94	1,031.96	671.41	899.38	903.26	671.41	681.08	631.89	671.41
Tractor Maintenance Costs	923.51	689.18	545.65	910.99	667.98	545.65	730.92	584.68	545.65	553.51	409.02	545.65
Labour Cost	3,846.42	2,279.08	2,278.54	3,818.71	2,211.25	2,278.54	3,059.40	1,916.19	2,278.54	2,327.80	1,373.55	2,278.54
Total VC	11,319.67	8,816.90	6,694.08	11,190.64	8,547.97	6,694.08	8,974.20	7,462.63	6,694.08	6,806.96	5,253.65	6,694.08
VC / Acre	4.42	3.44	2.61	4.37	3.34	2.61	3.51	2.92	2.61	2.66	2.05	2.61
VC/ Ha	10.92	8.51	6.46	10.80	8.25	6.46	8.66	7.20	6.46	6.57	5.07	6.46
Seeding CRC	12,859.92	16,669.23	11,839.02	12,859.92	16,669.23	11,839.02	12,167.10	15,433.89	11,839.02	11,096.52	13,598.27	11,839.02
Tractor CRC	11,727.90	13,287.35	10,347.76	11,727.90	13,287.35	10,347.76	10,905.65	12,876.43	10,347.76	10,027.92	12,341.47	10,347.76
											-	-
Total CRC	24,587.81	29,956.58	22,186.78	24,587.81	29,956.58	22,186.78	23,072.76	28,310.32	22,186.78	21,124.43	25,939.73	22,186.78
CRC/Acre	9.60	11.70	8.67	9.60	11.70	8.67	9.01	11.06	8.67	8.25	10.13	8.67
CRC/Ha	23.72	28.90	21.41	23.72	28.90	21.41	22.26	27.32	21.41	20.38	25.03	21.41
Total cost	35,907.48	38,773.48	28,880.86	35,778.45	38,504.55	28,880.86	32,046.96	35,772.94	28,880.86	27,931.39	31,193.38	28,880.86
TC/acre	14.03	15.15	11.28	13.98	15.04	11.28	12.52	13.97	11.28	10.91	12.18	11.28
TC/ ha	34.65	37.41	27.87	34.52	37.15	27.87	30.92	34.52	27.87	26.95	30.10	27.87
Expected passes	1.99	1.93	1.00	1.96	1.87	1.00	1.54	1.61	1.00	1.09	1.01	1.00

1 FSS Fall Single-shoot

2 SSS Spring Single-shoot

3 SDS Spring Double-shoot (Side-Band)

Appendix A2 Seeding System Direct Costs con't

Table A2.2 Direct operating costs $ for Regina Heavy

	Risk Aversion	0		Risk Aversion	0.0075		Risk Aversion	0.0225		Risk Aversion	0.05	
	Soil Nitrogen	55		Soil Nitrogen	55		Soil Nitrogen	55		Soil Nitrogen	55	
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,270.50	4,397.00	3,198.49	4,734.19	3,842.47	3,198.49	3,112.04	2,820.85	3,198.49	3,112.04	2,820.85	3,198.49
Machine Maintenance	1,106.35	978.60	671.41	993.77	855.18	671.41	653.26	627.81	671.41	653.26	627.81	671.41
Tractor Maintenance Costs	899.13	633.44	545.65	807.64	553.56	545.65	530.91	406.38	545.65	530.91	406.38	545.65
Labour Cost	3,791.00	2,106.11	2,278.54	3,314.35	1,794.09	2,278.54	2,216.96	1,356.59	2,278.54	2,216.96	1,356.59	2,278.54
Total VC	11,066.98	8,115.15	6,694.08	9,849.95	7,045.30	6,694.08	6,513.16	5,211.63	6,694.08	6,513.16	5,211.63	6,694.08
VC / Acre	4.32	3.17	2.61	3.85	2.75	2.61	2.54	2.04	2.61	2.54	2.04	2.61
VC/ Ha	10.68	7.83	6.46	9.50	6.80	6.46	6.28	5.03	6.46	6.28	5.03	6.46
Seeding CRC	12,859.92	16,016.19	11,839.02	12,167.10	15,433.89	11,839.02	11,096.52	13,598.27	11,839.02	11,096.52	13,598.27	11,839.02
Tractor CRC	11,727.90	13,075.92	10,347.76	11,286.28	12,876.43	10,347.76	10,027.92	12,341.47	10,347.76	10,027.92	12,341.47	10,347.76
Total CRC	24,587.81	29,092.11	22,186.78	23,453.39	28,310.32	22,186.78	21,124.43	25,939.73	22,186.78	21,124.43	25,939.73	22,186.78
CRC/Acre	9.60	11.36	8.67	9.16	11.06	8.67	8.25	10.13	8.67	8.25	10.13	8.67
CRC/Ha	23.72	28.07	21.41	22.63	27.32	21.41	20.38	25.03	21.41	20.38	25.03	21.41
Total cost	35,654.79	37,207.27	28,880.86	33,303.34	35,355.62	28,880.86	27,637.60	31,151.37	28,880.86	27,637.60	31,151.37	28,880.86
TC/acre	13.93	14.53	11.28	13.01	13.81	11.28	10.80	12.17	11.28	10.80	12.17	11.28
TC/ ha	34.40	35.90	27.87	32.13	34.11	27.87	26.67	30.06	27.87	26.67	30.06	27.87
Expected passes	1.93	1.76	1.00	1.72	1.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00

1 FSS Fall Single-shoot

2 SSS Spring Single-shoot

3 SDS Spring Double-shoot (Side-Band)

Appendix A2 Seeding System Direct Costs con’t

Table A2.3 Direct Operating Costs $ for Regina Light

	Risk Aversion		0	Risk Aversion	0.0075		Risk Aversion	0.0225		Risk Aversion	0.05	
	Soil Nitrogen		35	Soil Nitrogen	35		Soil Nitrogen	35		Soil Nitrogen	35	
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,583.94	5,015.53	3,374.12	5,538.46	4,946.76	3,374.12	5,474.36	4,755.01	3,374.12	3,647.89	3,122.86	3,374.12
Machine Maintenance	1,142.88	1,079.73	690.59	1,133.57	1,064.92	690.59	1,120.45	1,023.64	690.59	746.62	672.28	690.59
Tractor Maintenance Costs	1,080.89	922.84	653.13	1,072.09	910.19	653.13	1,059.68	874.91	653.13	706.13	574.60	653.13
Labour Cost	4,514.89	3,058.59	2,727.36	4,463.29	3,013.81	2,727.36	4,405.24	2,906.33	2,727.36	2,960.48	1,903.22	2,727.36
Total VC	12,322.61	10,076.70	7,445.21	12,207.41	9,935.68	7,445.21	12,059.73	9,559.90	7,445.21	8,061.12	6,272.96	7,445.21
VC / Acre	4.81	3.94	2.91	4.77	3.88	2.91	4.71	3.73	2.91	3.15	2.45	2.91
VC/ Ha	11.89	9.72	7.18	11.78	9.59	7.18	11.64	9.22	7.18	7.78	6.05	7.18
Seeding CRC	13,740.38	12,960.07	11,790.73	13,740.38	12,960.07	11,790.73	13,740.38	12,960.07	11,790.73	12,167.10	10,943.76	11,790.73
Tractor CRC	12,860.68	12,986.65	10,708.09	12,245.76	12,986.65	10,708.09	12,245.76	12,986.65	10,708.09	10,574.56	11,941.22	10,708.09
Total CRC	26,601.07	25,946.72	22,498.82	25,986.14	25,946.72	22,498.82	25,986.14	25,946.72	22,498.82	22,741.67	22,884.98	22,498.82
CRC/Acre	10.39	10.14	8.79	10.15	10.14	8.79	10.15	10.14	8.79	8.88	8.94	8.79
CRC/Ha	25.67	25.03	21.71	25.07	25.03	21.71	25.07	25.03	21.71	21.94	22.08	21.71
Total cost	38,923.67	36,023.42	29,944.03	38,193.55	35,882.40	29,944.03	38,045.88	35,506.62	29,944.03	30,802.78	29,157.95	29,944.03
TC/acre	15.20	14.07	11.70	14.92	14.02	11.70	14.86	13.87	11.70	12.03	11.39	11.70
TC/ ha	37.56	34.76	28.89	36.85	34.62	28.89	36.71	34.26	28.89	29.72	28.13	28.89
Expected passes	2.00	1.96	1.00	1.98	1.94	1.00	1.96	1.86	1.00	1.29	1.14	1.00

1 FSS Fall Single-shoot
2 SSS Spring Single-shoot
3 SDS Spring Double-shoot (Side-band)

Appendix A2 Seeding System Direct Costs con't

Table A2.4 Direct Operating Costs $ Regina Light

	Risk Aversion		0	Risk Aversion		0.0075	Risk Aversion		0.0225	Risk Aversion		0.05
	Soil Nitrogen		55	Soil Nitrogen		55	Soil Nitrogen		55	Soil Nitrogen		55
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,511.60	4,838.61	3,374.12	5,336.85	4,536.53	3,374.12	3,811.73	3,203.06	3,374.12	3,270.73	2,921.64	3,374.12
Machine Maintenance	1,128.07	1,041.64	690.59	1,092.31	976.61	690.59	780.16	689.54	690.59	669.43	628.96	690.59
Tractor Maintenance Costs	1,066.89	890.29	653.13	1,033.06	834.71	653.13	737.84	589.35	653.13	633.12	537.57	653.13
Labour Cost	4,431.04	2,942.16	2,727.36	4,243.99	2,758.55	2,727.36	3,108.82	1,934.57	2,727.36	2,650.88	1,791.27	2,727.36
Total VC	12,137.60	9,712.70	7,445.21	11,706.21	9,106.41	7,445.21	8,438.55	6,416.53	7,445.21	7,224.17	5,879.44	7,445.21
VC / Acre	4.74	3.79	2.91	4.57	3.56	2.91	3.30	2.51	2.91	2.82	2.30	2.91
VC/ Ha	11.71	9.37	7.18	11.29	8.79	7.18	8.14	6.19	7.18	6.97	5.67	7.18
Seeding CRC	13,740.38	12,960.07	11,790.73	13,740.38	12,346.80	11,790.73	12,167.10	10,943.76	11,790.73	11,591.36	10,571.70	11,790.73
Tractor CRC	12,245.76	12,986.65	10,708.09	12,245.76	12,751.39	10,708.09	10,905.65	11,941.22	10,708.09	10,284.25	11,766.49	10,708.09
Total CRC	25,986.14	25,946.72	22,498.82	25,986.14	25,098.19	22,498.82	23,072.76	22,884.98	22,498.82	21,875.61	22,338.19	22,498.82
CRC/Acre	10.15	10.14	8.79	10.15	9.80	8.79	9.01	8.94	8.79	8.55	8.73	8.79
CRC/Ha	25.07	25.03	21.71	25.07	24.22	21.71	22.26	22.08	21.71	21.11	21.55	21.71
Total cost	38,123.74	35,659.42	29,944.03	37,692.36	34,204.60	29,944.03	31,511.31	29,301.51	29,944.03	29,099.78	28,217.63	29,944.03
TC/acre	14.89	13.93	11.70	14.72	13.36	11.70	12.31	11.45	11.70	11.37	11.02	11.70
TC/ ha	36.78	34.41	28.89	36.37	33.00	28.89	30.40	28.27	28.89	28.08	27.23	28.89
Expected passes	1.97	1.89	1.00	1.91	1.77	1.00	1.36	1.20	1.00	1.05	1.00	1.00

1 FSS Fall Single-shoot

2 SSS Spring Single-shoot

3 SDS Spring Double-shoot (Side-band)

Appendix A2 Seeding System Direct Costs con't

Table A2.5 Direct Operating Costs $ for Melfort Light

	Risk Aversion		0	Risk Aversion		0.0075	Risk Aversion		0.0225	Risk Aversion		0.05
	Soil Nitrogen		35	Soil Nitrogen		35	Soil Nitrogen		35	Soil Nitrogen		35
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,582.88	5,013.83	3,374.12	5,563.46	4,947.00	3,374.12	5,465.85	4,750.39	3,374.12	5,301.47	4,464.60	3,374.12
Machine Maintenance	1,142.66	1,079.36	690.59	1,138.69	1,064.97	690.59	1,118.71	1,022.65	690.59	1,085.07	961.12	690.59
Tractor Maintenance Costs	1,080.69	922.53	653.13	1,076.93	910.23	653.13	1,058.03	874.06	653.13	1,026.22	821.47	653.13
Labour Cost	4,514.89	3,040.68	2,727.36	4,489.09	2,991.42	2,727.36	4,405.24	2,924.25	2,727.36	4,218.20	2,682.42	2,727.36
Total VC	12,321.12	10,056.40	7,445.21	12,268.17	9,913.63	7,445.21	12,047.83	9,571.35	7,445.21	11,630.95	8,929.62	7,445.21
VC / Acre	4.81	3.93	2.91	4.79	3.87	2.91	4.71	3.74	2.91	4.54	3.49	2.91
VC/ Ha	11.89	9.70	7.18	11.84	9.57	7.18	11.62	9.23	7.18	11.22	8.62	7.18
Seeding CRC	13,740.38	12,960.07	11,790.73	13,740.38	12,960.07	11,790.73	13,740.38	12,960.07	11,790.73	13,740.38	12,346.80	11,790.73
Tractor CRC	12,860.68	12,986.65	10,708.09	12,860.68	12,986.65	10,708.09	12,245.76	12,986.65	10,708.09	12,245.76	12,751.39	10,708.09
Total CRC	26,601.07	25,946.72	22,498.82	26,601.07	25,946.72	22,498.82	25,986.14	25,946.72	22,498.82	25,986.14	25,098.19	22,498.82
CRC/Acre	10.39	10.14	8.79	10.39	10.14	8.79	10.15	10.14	8.79	10.15	9.80	8.79
CRC/Ha	25.67	25.03	21.71	25.67	25.03	21.71	25.07	25.03	21.71	25.07	24.22	21.71
Total cost	38,922.18	36,003.12	29,944.03	38,869.24	35,860.35	29,944.03	38,033.98	35,518.07	29,944.03	37,617.10	34,027.81	29,944.03
TC/acre	15.20	14.06	11.70	15.18	14.01	11.70	14.86	13.87	11.70	14.69	13.29	11.70
TC/ ha	37.55	34.74	28.89	37.50	34.60	28.89	36.70	34.27	28.89	36.29	32.83	28.89
Expected passes	2.00	1.96	1.00	1.99	1.94	1.00	1.96	1.86	1.00	1.90	1.75	1.00

1 FSS Fall Single-shoot
2 SSS Spring Single-shoot
3 SDS Spring Double-shoot (Side-band)

Appendix A2 Seeding System Direct Costs con’t

Table A2.6 Direct Operating Costs $ for Melfort Light

	Risk Aversion		0	Risk Aversion		0.0075	Risk Aversion		0.0225	Risk Aversion		0.05
	Soil Nitrogen		55	Soil Nitrogen		55	Soil Nitrogen		55	Soil Nitrogen		55
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,506.28	4,829.13	3,374.12	5,328.34	4,527.78	3,374.12	4,654.08	3,722.89	3,374.12	3,794.44	3,197.23	3,374.12
Machine Maintenance	1,126.98	1,039.60	690.59	1,090.57	974.73	690.59	952.56	801.45	690.59	776.62	688.29	690.59
Tractor Maintenance Costs	1,065.86	888.55	653.13	1,031.42	833.10	653.13	900.90	685.00	653.13	734.50	588.28	653.13
Labour Cost	4,431.04	2,942.16	2,727.36	4,243.99	2,749.60	2,727.36	3,715.11	2,221.17	2,727.36	3,057.22	1,930.09	2,727.36
Total VC	12,130.16	9,699.44	7,445.21	11,694.31	9,085.21	7,445.21	10,222.65	7,430.51	7,445.21	8,362.78	6,403.89	7,445.21
VC / Acre	4.74	3.79	2.91	4.57	3.55	2.91	3.99	2.90	2.91	3.27	2.50	2.91
VC/ Ha	11.70	9.36	7.18	11.28	8.77	7.18	9.86	7.17	7.18	8.07	6.18	7.18
Seeding CRC	13,740.38	12,960.07	11,790.73	13,740.38	12,346.80	11,790.73	12,859.92	11,819.71	11,790.73	12,167.10	10,943.76	11,790.73
Tractor CRC	12,245.76	12,986.65	10,708.09	12,245.76	12,751.39	10,708.09	11,727.90	12,322.30	10,708.09	10,905.65	11,941.22	10,708.09
Total CRC	25,986.14	25,946.72	22,498.82	25,986.14	25,098.19	22,498.82	24,587.81	24,142.01	22,498.82	23,072.76	22,884.98	22,498.82
CRC/Acre	10.15	10.14	8.79	10.15	9.80	8.79	9.60	9.43	8.79	9.01	8.94	8.79
CRC/Ha	25.07	25.03	21.71	25.07	24.22	21.71	23.72	23.29	21.71	22.26	22.08	21.71
Total cost	38,116.31	35,646.16	29,944.03	37,680.46	34,183.40	29,944.03	34,810.47	31,572.52	29,944.03	31,435.54	29,288.87	29,944.03
TC/acre	14.89	13.92	11.70	14.72	13.35	11.70	13.60	12.33	11.70	12.28	11.44	11.70
TC/ ha	36.78	34.39	28.89	36.36	32.98	28.89	33.59	30.46	28.89	30.33	28.26	28.89
Expected passes	1.97	1.89	1.00	1.91	1.76	1.00	1.67	1.44	1.00	1.35	1.19	1.00

1 FSS Fall Single-shoot
2 SSS Spring Single-shoot
3 SDS Spring Double-shoot (Side-band)

Appendix A2 Seeding System Direct Costs con’t

Table A2.7 Direct Operating Costs $ Melfort Heavy

	Risk Aversion	0		Risk Aversion	0.0075		Risk Aversion	0.0225		Risk Aversion	0.05	
	Soil Nitrogen	35		Soil Nitrogen	35		Soil Nitrogen	35		Soil Nitrogen	35	
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,401.20	4,754.55	3,198.49	5,305.77	4,568.84	3,198.49	4,865.41	3,940.97	3,198.49	4,085.33	3,254.56	3,198.49
Machine Maintenance	1,133.79	1,058.17	671.41	1,113.76	1,016.84	671.41	1,021.32	877.10	671.41	857.57	724.34	671.41
Tractor Maintenance Costs	921.43	684.95	545.65	905.15	658.20	545.65	830.03	567.74	545.65	696.95	468.86	545.65
Labour Cost	3,818.71	2,262.12	2,278.54	3,741.11	2,190.90	2,278.54	3,480.62	1,858.53	2,278.54	2,931.92	1,526.17	2,278.54
Total VC	11,275.13	8,759.79	6,694.08	11,065.79	8,434.78	6,694.08	10,197.38	7,244.34	6,694.08	8,571.77	5,973.92	6,694.08
VC / Acre	4.40	3.42	2.61	4.32	3.29	2.61	3.98	2.83	2.61	3.35	2.33	2.61
VC/ Ha	10.88	8.45	6.46	10.68	8.14	6.46	9.84	6.99	6.46	8.27	5.76	6.46
Seeding CRC	12,859.92	16,669.23	11,839.02	12,859.92	16,669.23	11,839.02	12,859.92	15,433.89	11,839.02	11,591.36	14,432.69	11,839.02
Tractor CRC	11,727.90	13,287.35	10,347.76	11,727.90	13,287.35	10,347.76	11,286.28	12,876.43	10,347.76	10,574.56	12,509.92	10,347.76
Total CRC	24,587.81	29,956.58	22,186.78	24,587.81	29,956.58	22,186.78	24,146.20	28,310.32	22,186.78	22,165.92	26,942.61	22,186.78
CRC/Acre	9.60	11.70	8.67	9.60	11.70	8.67	9.43	11.06	8.67	8.66	10.52	8.67
CRC/Ha	23.72	28.90	21.41	23.72	28.90	21.41	23.30	27.32	21.41	21.39	26.00	21.41
Total cost	35,862.94	38,716.37	28,880.86	35,653.60	38,391.36	28,880.86	34,343.58	35,554.66	28,880.86	30,737.69	32,916.53	28,880.86
TC/acre	14.01	15.12	11.28	13.93	15.00	11.28	13.42	13.89	11.28	12.01	12.86	11.28
TC/ ha	34.60	37.36	27.87	34.40	37.04	27.87	33.14	34.30	27.87	29.66	31.76	27.87
Expected passes	1.98	1.92	1.00	1.95	1.84	1.00	1.77	1.56	1.00	1.46	1.24	1.00

1 FSS Fall Single-shoot
2 SSS Spring Single-shoot
3 SDS Spring Double-shoot (Side-band)

Appendix A2 Seeding System Direct Costs con't

Table A2.8 Direct Operating Costs $ Melfort Heavy

	Risk Aversion	0		Risk Aversion	0.0075		Risk Aversion	0.0225		Risk Aversion	0.05	
	Soil Nitrogen	55		Soil Nitrogen	55		Soil Nitrogen	55		Soil Nitrogen	55	
	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]	FSS[1]	SSS[2]	SDS[3]
Fuel Cost	5,210.59	4,444.72	3,198.49	4,578.59	3,688.97	3,198.49	3,307.58	2,858.46	3,198.49	3,112.04	2,820.85	3,198.49
Machine Maintenance	1,093.78	989.22	671.41	961.11	821.02	671.41	694.31	636.18	671.41	653.26	627.81	671.41
Tractor Maintenance Costs	888.91	640.32	545.65	781.09	531.44	545.65	564.26	411.80	545.65	530.91	406.38	545.65
Labour Cost	3,619.18	2,143.42	2,278.54	3,292.18	1,722.87	2,278.54	2,338.89	1,356.59	2,278.54	2,216.96	1,356.59	2,278.54
Total VC	10,812.46	8,217.67	6,694.08	9,612.97	6,764.30	6,694.08	6,905.04	5,263.03	6,694.08	6,513.16	5,211.63	6,694.08
VC / Acre	4.22	3.21	2.61	3.76	2.64	2.61	2.70	2.06	2.61	2.54	2.04	2.61
VC/ Ha	10.43	7.93	6.46	9.28	6.53	6.46	6.66	5.08	6.46	6.28	5.03	6.46
Seeding CRC	12,859.92	16,016.19	11,839.02	12,167.10	14,909.17	11,839.02	11,096.52	13,598.27	11,839.02	11,096.52	13,598.27	11,839.02
Tractor CRC	11,727.90	13,075.92	10,347.76	10,905.65	12,688.01	10,347.76	10,027.92	12,341.47	10,347.76	10,027.92	12,341.47	10,347.76
Total CRC	24,587.81	29,092.11	22,186.78	23,072.76	27,597.18	22,186.78	21,124.43	25,939.73	22,186.78	21,124.43	25,939.73	22,186.78
CRC/Acre	9.60	11.36	8.67	9.01	10.78	8.67	8.25	10.13	8.67	8.25	10.13	8.67
CRC/Ha	23.72	28.07	21.41	22.26	26.63	21.41	20.38	25.03	21.41	20.38	25.03	21.41
Total cost	35,400.28	37,309.79	28,880.86	32,685.73	34,361.48	28,880.86	28,029.47	31,202.77	28,880.86	27,637.60	31,151.37	28,880.86
TC/acre	13.83	14.57	11.28	12.77	13.42	11.28	10.95	12.19	11.28	10.80	12.17	11.28
TC/ ha	34.16	36.00	27.87	31.54	33.15	27.87	27.04	30.11	27.87	26.67	30.06	27.87
Expected passes	1.91	1.78	1.00	1.65	1.44	1.00	1.11	1.03	1.00	1.00	1.00	1.00

1 FSS Fall Single-shoot
2 SSS Spring Single-shoot
3 SDS Spring Double-shoot (Side-band)