ECONOMIC AND ENVIRONMENTAL VIABILITY OF SUBSTITUTING SOYBEANS FOR LUPINS: THE CASE OF DAIRY FARMING IN SOUTHWEST QUEBEC

by

Teklay Messele

Department of Agricultural Economics, McGill University
Montreal, Quebec, Canada

July 1997

A Thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of
Masters of Science

0-612-37149-2

Short Title:

ECONOMIC AND ENVIRONMENTAL VIABILITY
OF SUBSTITUTING LUPINS FOR SOYBEANS

Abstract

The economic feasibility of lupins in a cropping system as a protein supplement for a representative dairy cattle herd in Southwest Quebec (SWQ) to substitute for soybeans was investigated using a single period linear programming (LP) model. At current prices, lupins were not a profitable base case scenario. The gross margin of the dairy farm was $147,918. This resulted in a total soil loss of 3,504 tonnes (t), 50 percent higher than soil tolerance, T (acceptable level of soil loss) of 14 t ha^{-1}, and produced 541 kg of Nitrogen (N). Sale of corn grain (CG) was 442.3 t, constituting about 39 percent of the gross margin but had a negative effect on the soil. The farm purchased 59 t of straw for animal bedding.

When the environmental constraint of soil erosion, 14 t ha^{-1}, was imposed, the gross margin was estimated to be $131,148 while total N and soil loss were 2,454 kg and 1,708 t, respectively. Lupins were produced on 18.3 ha with this soil loss level constraint. The tradeoff between soil loss and gross margin and lupins was observed. The N fixation constraint reduced the gross margin while it increased soil loss. CG sales were reduced from 442 to 244.5 t but milk production increased by 163 hectolitres (HL). Sensitivity analysis on labour supply and farm size indicated that lupins became an alternative to soybeans when farm size and labour supply were larger and fewer respectively.

Lupins would substitute for soybeans if yield is increased by 5 percent; cost of production is reduced by 10 percent and home grown clean lupin seed is

used for 2 or 3 more years or government provides a subsidy of \$328 ha^{-1}. This is approximately equal to the CG subsidy.

Résumé

La faisabilité économique de lupin dans la production agricole comme source supplémentaire de proteine et substitue de soya pour l'elevage de vaches lairiers du Sud Ouest de Quebec (SOQ) a été étudié utilisant, le modéle de programammation livcaire (PL) à une seule période. Aux prix actuels, lupin n'etait pas profitable (ero du semairo de base). La marge brute de la production laitiére était de $147918. Ceci a entrainé 3504 tonnes (t) de tere en sols, 50 pourcent plus élevé que le seul de tolérance (T) qui doit être 14 t /ha et a producit 541 kg d'azote (N). La vente de maïs grain était de 442,3 t constituant environ 39 pourcent de la marge brute maïs auant un effect negatif sur le sol. La ferme ayant acheté 59 t de paille pour la litiére de animaux.

Quand la contrainte de l'érosion, 14 t/ha était imposée, la marge brute était estimée à $131148 alors que l'azote total et les pertes en sols étaient respectivement de 2454 kg et 1708 t. Lupin était produit sur 18.3 ha avec cette contrainte. Le transfert entre les fertes en sols et marge brute. Lupin était observé. La fixation d'azote réduit la marge brute mais reougmentait les perts en sols. Le ventes de maïs-grain étainent reduites de 442 à 244,5 maïs augmentairx de 163 hectolitres (HL) la production laitiére. L'analyse de sensiblité l'offre de la main d'oevire et la taille de la ferme endique que lupin est une alternative pour le soja quand le premiér est petite et le deuxiéme est grand.

Lupin serait un substitue de soja si les rendements augmentaient poucent, le coût de production boissaient de 10 pourcent avec une production locale de semence de lupin pour 2 ou 3 ans ou si le governement subventeome

un hectare de lupin à $328. Ci qui est environ égale à la subvention alloue au maïs-grain

Acknowledgment

I would like to express my thanks to my supervisor, Professor Paul Thomassin, for his patient and skillfull guidance and constructive criticism and support during the study. My thanks are extended to Professor Laurie Baker, my thesis committee member, for his encouragement, sound advice, constructive critisms and suggestions, based on his knowledge of the dairy industry. I thank Professor John Henning, for his assistance in outlining the research procedure and comments on the initial stage of the thesis.

I wish to thank a number of people who have provided assistance during my study: Professor Donald Smith, Department of Plant Science, Macdonald Campus, McGill University, for agronomic information and suggestions on lupins and other field crops, Dr. Yohannes Kebede, Environment Canada, for all his encouragement, selflessness in assisting me during the program and without whom I would not have finished my study, R. Leduce, of MAPAQ, for most of the data for the study and his suggestions, C. Molento, Department of Animal Science, for her advice in dairy nutrition formulation, Dr. R. Martin, J and P Cipolla, P. Cameron, D. Rhyno, T. Berhe and T. Hailue.

I would like to give my appreciation to secretaries, Ms. Janet Broxup and Mrs. Pat Atkinson who always gave me their kindness and useful assistance when I had requests and problems. During my study in the Department of Agricultural Economics, I received help from a number of people. It is difficult to credit each person in turn, but I am extremely grateful. I am indebted to fellow graduate students in the Department of Agricultural Economics, your interaction and suggestions are deeply appreciated and will be remembered, especially E. Kabasele, for his encouragement and suggestions and friendship, J-F. Forrest, G. Lussier, M. El-Helepi, E. Buck, E. Seyoum. Also, I thank A. Bekelle and my friends at Ethiopian Fellowship Church in Montreal for their encouragement and support specially, T. Dinku.

The partial financial support of the Department of Agricultural Economics, MAPAQ and Graduate Research Office is gratefully acknowledged.

Table of Contents

List of Tables

Appendices

Chapter I: INTRODUCTION

1.1 General introduction

Agricultural production in Quebec accounts for 2 percent of provincial GDP (Statistics Canada, 1997). Quebec's dairy production accounts for 33 percent ($1.3 billion) of the provincial agricultural production and supplies 37.9 percent of Canada's dairy production (Reberge et al., 1994). A recent study indicated that a job in the dairy and livestock industry creates 6 and 8 jobs in the rest of the economy and the dairy sector alone employed 5,715 people with a budget of $150 million (UPA, 1994). Strategies to maintain or enhance profit and be environmentally responsible approaches in the dairy sector are important elements of public policy.

Dairy farm inputs are readily available to Quebec farmers. However, successful dairy farming depends not only on the availability of inputs, such as feeds, but also on their prices. The costs of labour, land and capital have generally increased at a faster rate than the price of agricultural products (Rust et al., 1995). Consequently, many inefficient operators have been forced out of business or suffered from reduced farm income (Foltz et al., 1995). A total of 50,234 farms, an average of 1800 farms per year, have left Quebec's dairy industry since 1966 due to rising costs of production (Bertrand and Bourbeau, 1995, Blair and Lister, 1994; Reberge et al., 1994). Higher feed prices reduce flexibility in ration formulation and affect the productivity and profitability of the dairy producer (Odegaar, 1995). The cost of producing dairy products will continue to rise unless less expensive and high quality alternative feeds become available.

Livestock feed accounts for more than 75 percent of total dairy production costs (Gillespie, 1987; Hulme et al., 1986; Pond et al., 1995). Among the principal constituents of a dairy feed ration, protein supplement is the most expensive (Gillespie, 1987). Producers could increase their net farm income from dairying if they replace currently used costly livestock feeds with cheaper but good quality substitutes (Davis et al., 1989). If dairy farmers decide to use a substitute or alternative source of protein supplement, they must decide whether to grow or purchase it.

Dairy farmers are convinced that their income will be safeguarded not by boosting milk production, but by cutting production costs (Brown, 1995a; Carlson, 1995; Herman, 1995; Preston and Zapata, 1995). Production of cheaper high quality feeds is one of the most important factors influencing efficiency, production costs and hence profitability of dairying. Therefore, dairy farmers must focus on alternative sources of protein supplement or feed crops with the objective of maximizing profits (Roy et al., 1977).

Soybeans are widely used as a source of protein in dairy production. However, legumes such as lupins are believed to be less expensive to produce compared to soybeans (Bell, 1991). Lal (1995) estimated that row-crops, such as soybeans, require about 10.3 litres of gasoline per hectare for seedbed preparation or cultivation by farm machinery. Lupins require less cultivation and gasoline compared to traditional crops such as soybeans (Bell, 1991). Lupins fix more nitrogen compared to other legumes, thus reducing expenditures for inorganic fertilizer. Lupins also reduce soil and water erosion. Lupins contribute to reduce pollution of surface and ground waters from run-offs because they consume less inorganic fertilizers per hectare compared to other crops. Furthermore, lupins are an important source of protein supplement for dairy cattle (Johnson et al., 1986; Hale and Miller, 1985; May et al., 1990). Despite these economic and environmental advantages, few studies have examined the economics of producing lupins. The present study attempts to examine the profitability of adopting lupins by dairy farmers of Southwest Quebec.

1.2 Problem statement

The goal of most dairy producers is to maximize profits. However, environmental conservation must be incorporated into the objective of the dairy industry to attain sustainable productivity. Farmers may consider the reduction of soil erosion and nitrate leaching as competitive objectives (Xu et al., 1995; Straw, et al., 1991). Government may influence farmers' decisions to comply with policies that directly or indirectly affect long-term cropland productivity through measures that minimize soil erosion, contamination of ground water and fish kills caused by leaching of chemicals from farm lands (Gum et al., 1982; Richardson and Ray, 1979).

The major environmental concerns with dairy farming include soil erosion, contamination of ground and surface waters due to nitrate leaching and liquid wastes, soil compaction and increased consumption of gasoline because of intensive use of farm machinery and the deterioration in the physical and chemical structure of soils. Environmentally sustainable dairy farming has to rely on inputs that use less energy or fossil fuel, reduce soil erosion and contamination of water and yet maximize farm income.

Legumes, including lupins, present an option to move toward sustainable dairy farming. Cropping plans based on the inclusion of legumes, such as lupins, have been shown to be an effective means of maintaining soil fertility, especially nitrogen (McLaughlin and Mineau, 1995). Crop plans that include legumes contribute to reduced infestation of weeds, insects and diseases and improve soil fertility. Lupins can be produced at low cost, are found to be rich in protein and fix nitrogen into the soil. Lupins can reduce the expenditure on inorganic fertilizer while reducing pollution because of reduced soil erosion and fertilizer use (Higgs et al., 1990).

Lupins have been grown by some dairy farmers in Southwest Quebec (SWQ). However, little is known about the economic viability of lupins in a cropping plan as a potential source of protein supplement for dairy cows. The goal of the present study is to investigate whether or not growing lupins in a cropping plan, as a source of protein supplement for dairy cows, is profitable for dairy farmers in SWQ. The study will provide an estimate of soil saved from reduced erosion and nitrogen fixed (cost saved) from incorporating lupins in a dairy producer's cropping plan.

1.3 Objectives and Hypotheses

1.3.1 Objectives

The objectives of this study are:

(i) To examine the profitability of substituting lupins for soybeans in a cropping plan, as source of protein supplement, in a dairy operation;

(ii) To determine the level of subsidy required to make lupins competitive with soybeans;

(iii) To identify a cropping plan that maximizes gross margin and provides the greatest reduction in soil erosion below an a proiri determined maximum acceptable level, and

(iv) To examine the sensitivity of gross margin and optimal cropping plan to changes in selected resource constraints (e.g., labour, land, etc.)

1.3.2 Hypotheses

The present study uses mathematical programming to investigate the problems discussed above. Results obtained from the optimal cropping plan will be compared with the conventional situation (not including lupins) to evaluate the hypotheses. The present study hypothesizes that:

(i) dairy farmers in SWQ will profit from adopting a cropping plan that includes lupins;

(ii) the price of lupins will become competitive when the level of subsidy is equal to that of soybeans; and

(iii) there is a tradeoff between profit maximization and decreased soil erosion and increased N-fixation.

1.4. Definitions

For the purpose of this study a "cropping plan" is defined as the inclusion of crops in any given production period, with either the same or a different sequence of crop grown in each field in successive cropping plans (Hunter and Keller, 1983; Katz, 1985).

Sustainable agriculture refers to the integration of resource-efficient crop and animal production strategies that reduce agricultural pollution, conserve energy, avoid dependence on expensive and uncertain sources of petrochemical based fertilizers and pesticides, preserve the family farm, enhance economic viability (providing an acceptable level of profit to producers) and reduces soil erosion and compaction (American Society of Agronomy, 1989; Cooper, 1990; Elmore, 1996, Hesterman and Thorburn, 1994; Keenely, 1989; Parr et al., 1992).

1. 5 Organization of the study

The study is organized in the following order. Chapter 2 provides a review of the literature related to the agronomic and economic aspect of cropping plans and the use of lupins as a potential dairy cattle feed.

Chapter 3 examines the method used to conduct the analysis in the study. It includes a detailed description of the linear programming method used, identifies the nutritional requirements of dairy cattle and the constraints affecting dairy production. The model also accounts for the environmental effect of the cropping plan. This includes the quantity of soil lost and the contribution of N2 from the legume crops used in the cropping plan.

Chapter 4 presents the results and analysis of the study. A sensitivity analysis is conducted to determine the effect of changes in the key parameters.

These key parameters include the price of lupin seed, a change in lupin yield, and the introduction of a government program (subsidy) for lupins.

Chapter 5 summarizes the results and presents conclusions. Also, some suggestions for further research in this area are presented. Detailed operating budgets, labour and other inputs used in the model are presented in the appendices.

Chapter II

Review of Literature

2.1. Introduction

The purpose of this chapter is to review the agronomic and economic studies evaluating different cropping systems. The first section reviews the agronomic benefits of cropping systems. The second, reviews the economic studies that have evaluated cropping systems designed to reduce soil erosion and the consumption of nitrogen fertilizer, and provide a source for livestock feed. Effect of government programs on adoption of livestock feed crops is examined in the next section. This is followed by a discussion of methods used to evaluate agricultural production problems and the justification for the use of a single period LP model for the study. In the last part of this chapter, conclusions of the review are presented.

2.2 Cropping plan

2.2.1 Agronomic benefits of cropping plan

Generally, in a cropping plan, crops are planted in different sequence in order to reduce the incidence of crop pests, insects and weeds or increase or maintain soil organic matter (Huang and Uri, 1992; Hunter and Keller, 1983). Farmers use farm plans to improve soil physical condition, enhance soil nutrient use, improve long-term nitrogen status of the soil, increase crop production by reducing soil erosion, and increase water use (Lockie et al., 1995; Lopez-Bellido and Fuentes, 1990; Martin and Leonard, 1967; McLaughlin and Mineau, 1995). Farmers may benefit from sound cropping plans since machinery and labour requirements may be distributed over several crops. In addition, risks associated with yield and price fluctuations are diversified (Bell, 1991).

Cropping plans can be used to limit the build up of weed population and prevent major shifts in the composition of weed species (Liebman and Janke, 1990). The growth and reproduction of weed species can be disrupted by the growing sequences of crops that differ in planting dates, harvest schedules, competitive characteristics and soil management (Kingwell, 1996). Therefore, sound cropping plans by reducing weed population and species lessen dependence on fertilizers or pesticides.

2.2.2 Land use and its environmental impact

Improved farm management practices are necessary to ensure soil resources are not over utilized (Cransberg and McFarlane, 1994). Soil erosion by water from Canadian soils has been recognized as one of the causes for reduced economic returns to producers (Senate of Canada, 1984). The problem of soil erosion in some parts of Quebec is as serious as the potato fields of Prince Edward Island and the corn-belt of southern Ontario where soil loss may exceed 100 t ha^{-1} (Coote et al., 1981). It is reported that most of the soil in Quebec is acidic and the estimated average depth of the topsoil is about 15 cm (Stonehouse, 1995). An average of 24 t ha^{-1} y^{-1} of fertile soil is removed from Quebec farms due to the cumulative effect of snowmelt, rainfall and farming practices (Cao et al., 1993). Unless measures to maintain soil productivity are taken, its complete loss may occur in about 60 years resulting in severe yield loss and environmental problems (Baffoe et al., 1986; Stonehouse, 1995).

Sanderson and Macleod (1994) estimated that for every kilogram of food consumed, about 15 kg of soil or approximately 5 t y^{-1} per person of soil is lost. Soil loss in excess of the tolerance level may result in substantial yield reduction (Chisholm, 1992). Several studies have confirmed that soil loss above a tolerance level of 11.2 t ha^{-1} y^{-1} is considered as a serious threat to human well-being (Hudson, 1995; Sinner, 1990; Troeh et al., 1991; Vocke and Heady, 1992).

2.2.3 Impact of cropping plan on production

Despite the threat of land degradation, producers may continue practicing erosive farming practices to obtain short-term profits at the expense of long-run loss of soil productivity (Brubaker and Castle, 1982; Heady, 1982; McConnel, 1983; Orazem and Miranowski, 1994; Renard et al., 1978). Some farmers may assume that loss of agricultural production due to land degradation is relatively small compared to increases in productivity from technological innovations and improved management skills (Chisholm, 1992). Erosion increases production costs and reduces water infiltration by altering the physical properties of the soil that result in poorer crop establishment and root penetration (Lal, 1987; Stocking, 1984; Walker and Young, 1986; Xu et al., 1995). These effects contribute to lower crop productivity (Hwang et al., 1994; Kirby and Mehuys, 1987; Painter et al., 1995; Science Council of Canada, 1994). On-site soil erosion (loss in crop and land productivity) reduces current and future revenues to producers while off-site soil erosion (contamination of water by run-off) may result in environmental problems (Fuglie and Bosch, 1995). Careful selection of crops in a cropping plan can reduce loss of topsoil and increase the economic returns to farming (Easter and Cotner, 1982; Fox et al., 1991; Sarawakoon and Abeygunawaradena, 1995).

2.3 Legume crops in a cropping plan

Optimum soil and crop productivity may be achieved by incorporating legumes in a crop plan. It is argued that soil erosion from a cropping system with legume crops is less than without legumes (Hesterman, 1988). Moreover, legumes in a crop plan may reduce the rate of decline in organic matter following cultivation (Molina et al., 1985). Therefore, inclusion of legumes in a cropping plan may not only reduce N fertilizer requirement for crops but also provide the potential to reduce soil erosion and increase land productivity (Allison and Otto, 1987; Hesterman, 1988; Lory et al., 1995; Mooso, 1990; Papendick et al., 1985; Peoples et al., 1995; Vanotti and Bundy, 1995).

It is estimated that there are more than 12,000 species of legume plants but less than 50 have been exploited for agricultural purposes. About 7 species, including lupins, are reported to be used regularly in agriculture (Postegate, 1987). The present study examines the economic feasibility of lupins in a cropping plan.

2.3.1 Lupins in crop plan

2.3.1.1 Introduction

Lupin (*Lupinus spp.*) is a legume crop that is composed of several cultivated and wild species (Aguilera and Trier; 1978; Gladestone, 1970, 1990; Haq, 1993). Lupins have been used as a source of livestock feed and as a green manure in cropping systems for centuries (May, et al., 1990). However, its extensive cultivation as a commercial crop dates back only a few decades. For example, lupin production in Australia and Europe increased by 15% from 1975 to 1994, from a few thousand tonnes to millions of tonnes (Croker et al., 1994; Siddique et al., 1995; Unkovich et al., 1995).

Lupins are moderately drought-resistant, well adapted to acidic sandy soils and to a cool growing season (Zahradnik, 1984). Relative to soybeans, lupins are frost-tolerant, early maturing, grow well on soils unsuitable for soybeans, grow on soils that are low in nutrients and organic matter (Aniszewski, 1993a, 1993b; Gladestone, 1970; Kaplan, 1988). These characteristics of lupins make them an alternative legume to soybeans for low-cost production systems.

2.3.1.2 Soil conservation, N fixation and crop yield

Crop residues or straw may benefit farmers through i) shielding surface soil from raindrop impact, ii) producing larger particulate organic matter that reduces soil erosion, iii) increasing stability of soil aggregates and iv) increasing of organic carbon (Malinda, 1995). For lupins to reap these benefits, an estimated 3 t ha^{-1} (90 percent soil cover) of stubble must be retained in the soil annually (Bell, 1991; Bhagat et al., 1994; Frey, 1989; Frye et al., 1985; Lees, 1978; Lindstorm, 1986). Some studies have confirmed that the amount of residues needed to control soil loss below the tolerance level of 11 t ha^{-1} y^{-1} is about 2 t ha^{-1} (Lindstorm, 1986; Unger and McCalla, 1980).

Lupins cover the ground faster and may protect the soil better than other legumes (Zobisch et al. 1995; Larney et al., 1995). The quantity of stubble produced from lupins is estimated to be 3 to 5 tonnes ha y^{-1}. Studies have shown that about 40 percent (1.5 t ha^{-1}) of the stubble covering the soil may be adequate to reduce the risk of soil erosion (Croker et al., 1994).

Lupins rank among the top legumes with respect to fixing N. Lupins not only have effective nitrogen symbiotic fixing bacteria, but also have symbiotic root fungi that make soil phosphate available to plants (Hill, 1977a; 1977b). Lupins can meet almost all of their nitrogen requirements from fixation and leave substantial amounts of nitrogen behind for successive crops (Bowen and Danson, 1987; Herbek et al., 1987; Unkovich et al., 1994). Thus, growing lupins may be used as a strategy to reduce expenditures on inorganic nitrogen or commercial fertilizer.

Lupins can fix 265 - 327 kg N ha^{-1} depending the type of cultivar and the cultural practices used (Sanderson and MacLeod, 1994; Unkovich et al., 1995). The amount of N transferred from lupins to subsequent crops through residues may range from 50 - 180 kg ha^{-1} (Evans et al.; 1991; Hill, 1977b; Herridge, 1982; Herridge and Dano, 1995; Heenan and Taylor, 1995; Hunt et. al., 1985; King, 1984).

Agronomic studies that examined the benefit of lupins in cropping systems have shown a yield increase of subsequent non-legume crops by 0.5 to 3 t per ha (an increase of more than 350 percent over cereal-cereal cropping sequences) (Peoples et al., 1995; Wilson and Hamblin, 1990). Lopez-Bellido and Fuentez (1986) and Reeves et al., (1984) found a 30 to 100 percent increase in the yield of wheat following lupins. Studies examining nine years of continuous wheat production indicated an annual average yield of 2.87 t ha^{-1} y^{-1} while the average wheat yield on which lupins had been planted earlier was 4.05 t ha^{-1} y^{-1} (Reeves, 1984; Rowland et al., 1988; Rowland et al., 1989; Santos et al., 1990). Other studies have found that 30 percent more lupins can be produced following cereal crops than following legumes (Cheam and Gill, 1992; Unkovich et al., 1994).

Crop yield can also increase because of the ability of lupins to reduce the incidence of pests, disease and weeds. Lupins in a cropping system may prevent root rot diseases and suppress weed infestation and insects (Chantel and Rowland, 1982; Gaudencio et al., 1988; Kingwell, 1996). This characteristic of lupins contributes to reduced pesticide requirement.

2.4 Lupins in dairy farming

Depending on the type of lupin cultivar, crude protein and lipid (oil) content may be as high as 50 and 14 percent respectively (Guilluame et al., 1987; Godfrey 1982; Haq, 1993). Lupin cultivars that contain about 50 percent crude protein are considered to be potential substitutes for meat meal. The high protein and oil content of lupins facilitates cost effective ration formulation, thus encouraging the expansion of beef, sheep, pig, broilers, turkeys and horse enterprises (Croker et al., 1994; Sathe et al., 1982; Taverner et al., 1984; Watkins and Mirosh, 1987).

Lupins are an important source of supplemental protein for dairy cows. Furthermore, the stubble from lupins reduces grazing requirements for livestock in late summer (Gardiner, 1975 and Croker et al., 1979). An estimated 300 to 400 kg ha^{-1} of lupin seed is lost during harvest. These fallen seeds make excellent grazing feed for livestock dairy cattle (Croker et al., 1994).

There is considerable variation in biomass, grain yield and N production of lupins. The average grain yield of lupins ranges from 1,000 to 2,700 kg ha^{-1} (Aniszewski, 1993c; Batte et al., 1993; Hill, 1977b). Shoot dry matter varies from 2.02 to 14.33 tonne ha^{-1} (Unkovich et al., 1994). Lupins have been found to produce 45 to 322 kg ha^{-1} of shoot nitrogen (Aniszewski, 1993b; Unkovich et al., 1994; Evans et al., 1989). Moreover, lupins have been found to provide up to 120 tonnes ha^{-1} of silage for cattle feeding in winter (Frey, 1989).

In Nova Scotia, lupins provide 6.0 to 8.1 t ha^{-1} of dry matter (DM). Lupins planted with a small grain crop provided 6.0 to 9.5 t ha^{-1} DM (Jannasch, 1994). In addition, silage made from lupins intercropped with small grains has superior feeding quality compared to silage from lupins alone (Jannasch, 1994).

2.5 Technical and economic comparison of lupins and soybeans

Soybean is the grain legume preferred by Quebec dairy farmers as a protein supplement but grows only in a few areas. However, the high cost of producing and transporting soybeans from the Midwestern U.S. has shifted interest from soybeans to lupins as a source of protein supplement.

Crops planted following soybeans have been shown to require less nitrogen than crops planted following non-leguminous crops (Heichel and Barnes, 1984). The amount of N fixed by soybeans range from 64 to 118 kg N ha^{-1} y^{-1} (Nelson and Weaver, 1980). During harvest, however, 50 to 80 percent of the N fixed is removed while the remaining N is retained in the soil (Smith et al., 1988). Other studies have found that soybeans removed more N than it fixed and might consume an additional soil N of up to 80 kg ha^{-1} (Heichel and Barnes, 1984; Parr et al., 1992). However, lupins fix as much as 327 kg of N ha^{-1} (Unkovich et al., 1994)

Lupins grow well on a land where soybeans perform poorly (Zahradnik, 1984). Delayed planting substantially reduces yields of soybeans (Schmersal, 1996). More organic matter is produce and soil erosion is minimal following lupins compared to soybeans (Fisher, 1982). In fact, field data have shown that soil erosion is almost twice as severe after growing soybeans than after corn (Brusko, 1985; Fahad et al., 1982; Francis and King, 1988; Van Doren et al., 1984).

Prices of lupin seed are higher due to fewer certified lupin cultivars. If farmers produce high quality lupin seed on the farm, it might be possible to avoid purchases from outside sources and spread the initial investment in seed over two or more years (Olson and Putnam, 1991). Furthermore, the higher seed cost of lupins may be compensated by low labour, machinery and fertilizer requirements of growing lupins compared to growing soybeans on the farm.

2.6 Economics of livestock feed and cropping system

2.6.1 Introduction

It is generally assumed that farmers are price-takers (Lockie et al., 1995). In any production year the future selling price for a crop is uncertain (Duffy and Taylor, 1993). The producer's main objective is be to maximize net profit. In dairy farming, feed cost is an important factor in determining or gross margin. Low-cost feeds enable dairy farmers to maximize their revenue by minimizing their costs of labour, machinery, fuel, fertilizer and other inputs per kilo of feed produced (Apland et al., 1994; Ess et al., 1994).

Efficiency in dairying can be achieved by either increasing returns or reducing the cost of production. Since the price of milk is predetermined and the quantity of milk that can be produced is set by a quota system (supply management), dairy farmers can maximize profit through reducing the cost of production (Ostergaard et al., 1996). Lupins could offer an alternative to soybeans as a source of protein for dairy cows.

Crop-mix decisions appear to be fairly sensitive to relative prices (Heady, 1982). The objective of selecting a specific production system or crop-mix is to maximize the net value of outputs obtained from the land (Baffoe, 1982). By choosing a specific crop-mix, producers could maximize their gross margin over the period.

2.6.2 Production of low-input feeds for dairy production

The gross margin from dairying is influenced by the cost of feed ingredients used in ration formulations, the quality of feed ingredients and feeding balanced ration at the proper time (Mason, 1995; McCullough, 1973). Mason (1995) states that offering less feed or reducing the level of high cost feed ingredients might lower feed costs. However, underfeeding protein may cost more than overfeeding (Erba and Knoblauch, 1995; Epplin and Heady, 1984; Van Soest, 1994).

More than seventy five percent of the production cost of dairy farms is accounted for by feed. Thus, strategies to reduce feed costs may directly increase net income per unit of dairy products produced (Gempesaw et al., 1992; Hulme et al., 1986; Pond et al., 1995). Furthermore, strategies that reduce the cost of feed, hence the cost of producing a litre of milk, may enable dairy farmers to gain greater financial benefits and increase their ability to compete in domestic and international markets. Long-term profitability and survival of modern dairy farm operations requires that the farm operators have an understanding of the biological factors influencing milk production, knowledge of production economics and management skills. Nonetheless, appropriate use of such knowledge and information by itself is not sufficient, but a necessary condition for successful dairy farming (Kalter and Skidmore, 1991).

Increases in the prices of fuel, inorganic fertilizer and chemicals as well as costs associated with continuous monocropping (e.g., decline in crop yield and losses in fertility) have created a situation where the marginal costs are increasing more rapidly than marginal returns of farmer producers (Reganold et al., 1987).

Increased reliance on non-renewable resources, such as fossil fuel based agrochemicals contributes to vulnerability of dairy farm income, to disruptions in the supply of crude oil or prices of fertilizer (Lal, 1995; Peterson et al., 1990). Therefore, adoption of alternative livestock feed crops that consume less N fertilizer and require few field operations may increase net returns to dairy producers (Hough, 1979; Lal, 1992; Solbrig and Solbrig, 1994).

2.6.3 Prices and substitutability of feeds in dairy production

Feed grains and oilseed meals exhibit a high degree of substitutability (Motha et al., 1972). The substitutability of feed crops may depend on relative price, growth rate of the consuming animal and the ability of the feed to meet the nutritional requirement of the animal (Motha et al., 1972). To maximize returns from dairying, farmers must search for the least expensive ration formulation (Heady et al., 1976). This may depend upon the substitution of high for low cost feeds and the marginal rate of substitution between the various classes of feeds (Heady et al., 1976).

There is a potential for using lupins as a source of protein supplement, especially in dairy production (Hale and Miller, 1985). May et.al. (1990) reported that feeding lupins as a protein supplement to lactating cows produced the same amount of milk to that produced by cows supplemented with soybean meal. The same result was found by dairy farmers in Minnesota who substituted lupins for 100 percent soybean meal in their ration (Zahradnik, 1984).

Guillaume et. al. (1987) showed that cows fed lupins consumed less dry matter than those fed soybean meal and observed no significant difference in the level of milk produced. Furthermore, the performance of dairy animals fed on lupins was found similar to animals fed on soybeans (Broqua et al., 1984; Hawthorne and Fromm, 1978; Kung et al., 1991).

Snapp and Jolliff (1988) stated that dependence on relatively few feed crop varieties and purchased feed may increase the vulnerability of dairy farmers to environmental and economic fluctuations. Dairy farmers import a large volume of supplemental protein from the U.S. It is reported that the price of feeds in the U.S. are near a 15-year high (House, 1996). Milk to feed ratio is expected to be considerably lower in the years ahead prompting producers to be more conservative in the type and amount of concentrate they feed to their cows (Muirhead, 1996). Increases in the price of feed in the U.S. may be passed to Canadian producers if imports of supplemental protein continue to rise. To promote self-sustaining dairy production, therefore, Canadian farmers should explore alternative low cost feeds that would meet the nutritional requirement of dairy cows (Hooge, 1996; Johnson et al., 1992).

2.7 Effect of government programs on adoption of livestock feed crops

Low-input agricultural systems have not been financially competitive with traditional production systems largely because of relatively lower prices received for legumes and other low-input systems (Hoag and Jack, 1990). It is reported that commodity programs do not provide incentives to farmers to adopt sound crop production practices, restrict the possibility of more sustainable crop rotations and penalize those who try them (Lyman et al., 1990; Young and Goldstein, 1988). On the other hand, low or zero subsidies may be a major economic barrier to the adoption of alternative agricultural systems (Diebel et al., 1995).

Adoption of an alternative cropping system may arise out of the need to reduce environmental degradation, sever soil erosion and depletion of natural resources and concern for the future of family farms (Madden, 1989). Yield uncertainties, lack of established markets, volatile market prices, agronomic problems and fear of losing farm program benefits may discourage them from adopting alternative low-cost feed crops (Lockie et al., 1995; Painter et al., 1995).

Painter et al. (1995) reported that increases in adoption of an environmentally sound and economically viable alternative crop systems might demand multifaceted efforts of policy reform, research and education. To reduce soil vulnerability to water erosion, farm programs should be designed to include soil-building crops and cropping practices that increase organic matter in eroded soils.

Government support programs, by reducing farm risks, may have contributed to the continuous use of conventional production methods that do not contribute to soil conservation. Higher commodity prices in the absence of government support programs may increase farmers' incentive to protect soil from degradation (Painter et al., 1995; McNeely, 1988). Other studies have argued that increases in agricultural commodity prices may lead to greater soil degradation as the land is cultivated more intensively (Innes and Ardila, 1994; LaFrance, 1992).

Canada intends to phase out subsidies to industrial milk by the year 2002 (Leger, 1996). Quebec dairy producers will be affected by this phase-out of government support. It is estimated that Quebec dairy producers will lose a total of

$76 million in direct payment, as a result of phasing-out of subsidies (Leger, 1996). This phase-out will also affect subsidized crops such as soybeans. This trend in the withdrawal of government support may create a favourable situation for lupins to become an alternative low cost crop to substitute for soybeans

2.8 Methods of evaluating agricultural production problems

2.8.1 Introduction

Farmers must make decisions regarding the types of crops to grow, quantities to produce, methods of production and timing of the production plan. Decisions have to be made subject to physical and financial constraints. Analytical approaches used to examine farm management decisions include inventory/descriptive studies, predictive (statistical studies), normative allocation or use of partial budgeting and whole farm planning, input-output modelling, simulation and mathematical programming (Heady and Vocke, 1992; Hazell and Norton, 1986). Each of these models has their advantages and disadvantages (Heady and Dillon, 1961). Various categories exist within each analytical approach. For example, mathematical programming includes single or multi-period linear, dynamic, integer, separable, stochastic and non-linear programming. Commonly used analytical approaches to examine agricultural production problems will be reviewed below.

2.8.2 Partial Budgeting and whole farm planning

Partial budgeting is useful for analyzing and comparing alternatives where the proposed change affects only a small part of the total farming operation (Kay, 1986). Partial budgeting examines the impact of changing a specific activity on net farm income, holding all other factors constant. In other words, this approach does not examine the impacts of introducing or removing an activity on the long-term viability of the farm. It examines only the receipts and expenses that are expected to change with a change in a farming operation and compares only a few activities (Osburn and Schneeberger, 1983). It doesn't require preparing a complete budget and can not be used to develop a plan for an entire farm. However, it is useful for checking the feasibility of decisions such as adoption (produced or purchased) of substitutes of currently used inputs. It can assist in the development of a whole farm plan (Kay, 1986; Osburn and Schneeberger, 1983).

Whole farm planning is a systematic planning procedure that works by selecting enterprises with the highest return per unit of the most limiting resource used to achieve the profit-maximizing plan (Kay, 1986). Whole farm financial analysis can be undertaken to examine the feasibility of different farming systems, such as rotations and the sensitivity of feasible farm plans to input and output prices and government support program (Leddy, 1987).

Govindasamy and Huffman (1993) employed marginal analysis of land value to examine yield potential of different management practices. They found that conservation tillage increased yield on most soil types compared to traditional practices. Furthermore, rotations increased yield and reduced soil erosion compared to monocropping. Govindasamy and Huffman (1993) have also analyzed the effect of controlling soil erosion on net income of representative farms in Iowa. They restricted cropping activities to limit the amount of soil loss to less than or equal to a tolerance level of 20 t ha^{-1} y^{-1}. This study indicated that farmers lost between $0.60 to $6.06 for every tonne of reduction in the tolerance level. However, the marginal cost of controlling soil erosion is not the same for each tonne of soil saved. As more soil conservation measures are employed, the cost of these measures increase rapidly (Govindasamy and Huffman, 1993). However, Sinner (1990) stated that there are considerable debates about the value of the tolerance level and how it is determined. Sensitivity analysis of plus or minus 25 percent showed that a cropping system (e.g., rotation) would be profitable when the tolerance level is set at 20 t ha^{-1} but less profitable when the tolerance level is reduced to 15 t ha^{-1} (Sinner, 1990).

Diebel et al. (1995) used whole-farm analysis to compare conventional and alternative cropping systems. They found that the latter showed lower cost of production compared to the former system. Johnson (1979) used budgeting to identify the rotation that gives the maximum return to the farm. A similar study was conducted by Culver et al. (1985). The findings suggest that rotations that involve legumes maximized net farm income.

Olson and Putnam (1991) used a whole farm budget for lupins and soybeans. They found that lupins did not have an economic advantage over soybeans when grown as a cash crop in regions suitable for soybean production. Using benefit-cost analysis in a whole farm setting Olson and Putnam found that soybeans gave greater net revenue (about $57.06 ha^{-1}) compared to lupins. This was attributed to higher soybean prices and high seed prices or cost of production of lupins. However, farmers in the Midwest of the U.S. have grown lupins for less than

$100 per tonne, compared to $225 to $230 per tonne for soybeans (Bell, 1991; Zahradnik, 1984). These differences in cost of production may be due to differences in management strategies followed by farmers (Mayer et al., 1996).

2.8.3 Production Functions (Econometric tools)

The production function relates inputs to outputs with the objective of identifying the structure of production that maximizes gross margin. Details regarding various farm applications of production functions are found in Heady and Dillon (1961) and Dillon (1976). Classic production functions have several drawbacks such as the assumption of continuity of the same production function over an indefinite time (assume that all resources are perfectly exhausted, strict concavity), ignores existence of local optima and the inability of incorporating detailed technical coefficients in to the structure of the production function.

2.8.4 Linear programming

2.8.4.1 Introduction

Linear programming (LP) can handle specific production structures and restrictions or constraints. LP makes provisions for discontinuity in production functions, uncertainty and non-exhaustion of resources. Most studies that have examined farm decision or allocation problems have used LP tool. Single period (short-term) and multi-period (long-term) linear programming methods have been widely used in applied farm decision problems (Agrawal and Heady, 1972; Heady and Candler, 1958).

Linear programming is a mathematical technique in which an optimal mix of production methods and crops is derived by allocating limited resources (such as land, labour, and capital) among various production activities to achieve the highest net farm return. It is a logical and operational framework that optimally organizes the amount of complex information for farm decision problems (Agrawal and Heady, 1972; Hazell and Norton, 1986; Johnson et al., 1993). It involves the maximization or minimization of a linear function (profit or cost) subject to linear inequalities (Heady and Candler, 1958). Solutions to a linear program indicate when and how an optimal plan will change due to a change in the use of input (such as pesticides) or a change in market price (Lazarus and White, 1983).

Linear programming methods help answer questions frequently asked by farmers such as how much area to allocate for pasture (fodder crops), conserve for hay and silage, whether or not to purchase the adjoining farm, raise own heifer replacements or buy them and how much additional capital can be profitably invested in the business (Olney and Standing, 1989). Restrictions such as land, labour, and building capacities limit the alternatives available to the farmer. Linear programming can handle the interactions of complex farming systems that other techniques such as partial budgeting can not. The ease with which complex computational problems can be handled makes LP an extremely powerful technique capable of solving problems with thousands of variables and constraints as well as multiple objectives, risks and planning over time (McCarl and Nuthall, 1982; Nevo and Podmore, 1994). LP is an efficient means of answering economic questions concerning farm planning, livestock feed formulation and product mix (Agrawal and Heady, 1972; Hazell and Norton, 1986; Kay, 1986; McCarl and Nuthall, 1982; Osburn and Schneeberger, 1983).

With limited resources, a farmer must identify production inputs that provide the highest return per dollar invested and make allocative decisions taking into account these alternatives (Munson and Doll, 1959). Most farmers frequently develop farm plans with the assumption that only land, without considering the supply and demand of other inputs, is the limiting factor in crop production. However, in livestock production, a farmer must also consider factors such as the nutritional requirements of dairy cattle, storage and barn capacity. Formulation of least-cost and balanced rations for dairy cows is an important strategy of a successful whole farm plan. Producers have to employ a tool that can effectively determine the effects of an inadequate supply of a particular resource given all relevant data. The tool should select the optimal farm plan with the highest net return from all feasible alternatives.

2.8.4.2 Single-period linear programming

Mayer et al. (1996) used different optimization methods in multi-dimensional dairy models and found that LP is a more useful tool than other models. LP modelling and its extensions are employed to assist in the economic decision processes of crop planning. The advantage of LP over other farm management tools include i) many activities and restrictions can be considered at the same time, ii) explicit and efficient optimum seeking procedure is provided, iii) results from changing variables can be computed easily once the model is formulated and iv) enables incorporation of new production techniques (Nevo and Podmore, 1994; Wossink et al., 1992).

Single-period linear programming has been used to analyze cropping systems (Narayanan et al., 1983; Swanson, 1956). The single-linear programming model requires:

i) farm activities, units of measurement, resource requirements and constraints on their production;

ii) fixed resource constraints of the farm; and

iii) activity returns net of variable costs or gross margins;

Let X_j represent the land allocated to the jth farm activity (where j = 1..., n),

C_j represent gross margin of a unit of the jth farm activity (\$ ha^{-1}),

a_{ij} is the quantity of the jth resource required to produce a unit of the jth activity for i=1 to m, and

b_i is the amount of the ith resource available to the farm.

The LP model (deterministic single-period) can be written as:

$$\text{Max } Z = \sum_{j=1}^{n} C_j X_j \quad \text{for all } j=1 \text{ to } n$$

Subject to

$$\sum_{I=1}^{m} a_{ij} X_j <= b_i, \text{ for all } i=1 \text{ to } m$$

and $X_j >= 0$,

This simple model assumes (I) optimization (an objective function maximized), (ii) non-zero right hand side coefficient (fixedness), (iii) finite number of activities and constraints (finiteness), (iv) all Cj, aij and bi coefficients assumed to be known (determinism), (v) resources can be used and activities produced in quantities that are fractional units (continuity), (vi) all units of the same resource are identical (homogeneity), (vii) activities are additive and no interaction effects between activities are permitted (additivity), and (viii) gross margin and resource requirements per unit of activity are assumed to be constant regardless of the level of the activity used (proportionality).

Madden (1989) employed LP model to study the feasibility of conventional and organic agriculture. The study was conducted to identify the profitability of a transition scheme from conventional to organic farming. Profitability of organic, conventional and no till systems were examined using a LP models in Pennsylvania by Domanico et al. (1989) and Domanico et al. (1986). These studies found that net income increased as small grains were dropped from rotation. Dobbs et al. (1987) examined different production sequences of conventional, minimum till and no-till systems. They found that the conventional system, grown under different alternative management practices, provided 5 to 9.5 percent higher than no-till net farm return (Dobbs et al., 1987).

Berglund and Michalson (1981) found that farm income in Idaho was reduced by 8 percent when farms used different soil loss control strategies. Johnson and Ali (1982) found that fallowing reduced income risk and generated higher expected net returns under price support conditions. Short and Heady (1983) reported that when commodity prices are higher, farmers may find it profitable to control soil erosion to a level where future commodity prices equal the cost of present soil control.

El-Nazer and McCarl (1986) used LP to solve profit maximizing and risk-averting decisions. They found that the choice of a rotation plan that maximizes profit was different when risk was included in the model. Pannell and Falconer (1988) studied the value of nitrogen fixed and applied on a dryland crop-livestock farm in Australia. They found that the total benefits of legumes for cereals exceed those from nitrogen fertilization. They also reported that the benefit of lupins was better than other legume crops (Pannell, 1995; Pannell and Falconer, 1988). Some studies estimated that, lupins when integrated into a farming system would increase net return by about $11,000 per year (Erwing et al., 1987).

Lazarus and White (1983) studied the return to farm operator labour and management for different cropping systems on dairy farms. They found that continuous cropping systems produced lower yields. A similar model was used by Crowder et al (1985) to choose a farm plan that maximizes net farm income subject to specific economic and environmental constraints. Heady and Vocke (1992) used an inter-regional programming model to calculate the impacts of soil erosion and nitrogen run-off. A cropping plan that incorporates legumes was found to produce the maximum profit (Crowder et al., 1985).

Berentsen et al (1991) used an LP model to maximize labour income. The model examined the effects of institutional, technical and price changes on the farm plan, profitability and nutrient loss. They found that the negative economic impacts on the environment could be compensated by positive environmental improvements in the long run.

Utter and Justus (1961) employed an LP model to determine the maximum net return from different cropping systems. The feasibility of a rotation included in the analysis was based on a soil loss of 12 t ha^{-1} or more than 5 t $acre^{-1}$. They found that a rotation on terraced land showed the maximum profit while keeping soil erosion below 5 t $acre^{-1}$ y^{-1}

An LP model was used by Pope et al. (1983) to identify a farm plan that maximized net return from the use of conservation tillage by a representative farm in Iowa. They compared soil losses from the different management practices and crop rotations. Their findings suggested that sound crop rotations could be an economically viable means to reduce soil erosion. Similarly, Doster et al. (1983) noted that farmers could afford to reduce soil loss below the tolerance level without sacrificing yields by adopting less intensive crop rotations.

Most applications of LP do not assume growth. That is, they assume no change in the technological coefficients over time. Most LP models are single-period and assume a certain economic environment (that is perfect knowledge of prices, yield etc.). While complex LP includes risk and uncertainty however, most studies use sensitivity analysis to capture some aspects of the uncertain environment.

2.8.4.3 Multi-period linear programming (MPLP)

Single-period optimization models are often used to analyze short-term economic profitability (Heady and Candler, 1958). However, two level decision making processes, short and long run, represent the economic behaviour of agricultural producers. Farmers make decisions in the short-run regarding types of output to be produced (type and allocation of acreage), variable inputs assuming technology and existing physical capital as given (Antle and Capalbo, 1991). However, decision problems that extend over more than one cropping year and involve many crops can be examined using multi-period linear programming (MPLP). For long-run plans, MPLP is considered the best tool for solving these complex farm problems (Antle, 1983; Mayer et al., 1996; Nevo and Podmore, 1994).

The MPLP for t number of years can be given as:

$$\text{Max}\quad \Sigma\Sigma C_{jt}\,(1+r)^{-t}\,X_{jt} - \Sigma\Sigma E_{jt}\,(1+r)^{-t}\,X_{jt} + TV_{DA} + ATVL_{L}$$

Subject to

$$\Sigma\Sigma\Sigma a_{ijt}\,X_{jt} <= b_{t}$$

$$X_{jt} >= 0$$

where: Cjt is gross revenue from jth activity in the t^{th} year,

$(1+r)^{-t}$ states for the present value interest factor at r discount rate and for the t^{th} year,

X_{jt} is the X^{th} activity in the t^{th} year,

E_{jt} is total cost of the j_{th} activity in the K^{th} year,

TV_{DA} is terminal value of depreciable asset,

ATV_L is adjusted terminal value of land,

a_{ij} is input-output coefficient; and

b_i denotes quantity of the ith resource available

In agriculture, sound planning requires the recognition of the annual risks and returns associated with various farm enterprises (Johnson et al., 1993). Planning becomes even more complicated when the dynamic aspects of many agricultural processes are considered. In any given year, the ultimate selling price for a crop is generally unknown and prices are largely beyond any individual farmer's control (Duffy and Taylor, 1993). However, prices of products under quota are fixed taking into account the cost of production. Yields will vary with farming practices. Some cultural practices, such as rotation management, add another dynamic aspect to the agricultural environment. Crop choices made in one period may have a residual impact on yields in one or more subsequent periods. Sound farm planning must account for these dynamic effects.

Multi-period linear programming (MPLP) models are used to optimize net returns over several production cycles. In building MPLP, it is necessary to decide on the number of periods (planning horizon), assign terminal values to investments that extend beyond the planning horizon selected and ensure that the model reflects farmers initial starting investments. Fox et al. (1991) summarized studies that have estimated the costs and benefits of short or long run cropping plans in controlling soil erosion through the adoption of different production systems using MPLP. Costs of reducing erosion to a tolerance level were found to be greater than their benefits (Fox et al., 1991). Depending on the erodibility of the soil, the type and duration of rotation, it is estimated that income from farming may be less profitable when soil control measures are incorporated in the model.

Miranowski and Hammes (1984) employed MPLP to choose a farm model that will maximize the net present value of crop production. They found that if farmers recognize the productivity impact of soil loss and maximize long-run net returns, they would adjust their crop management practices in response to the more significant productivity losses associated with soil erosion.

Dabbert and Madden (1986) used a MPLP model to study the profitability of livestock and crop production in Pennsylvania undertaking a transition from conventional to organic farming. They found that net income from organic farming was less than conventional farming. Heady and Vocke (1979) used MPLP to evaluate the impact of controlling soil erosion on net farm income. They found that net farm income declined by more than 7.4 percent. Hence, without government support, a substantial increase in food prices is required to compensate the income loss to producers.

MPLP was used to incorporate the time element of multi-year production process and long-term investment, (Baffoe, 1982; Irwin, 1968). Baffoe (1982) examined the costs and benefits of cropping systems in the presence of soil erosion constraints. The study was used to identify a cropping plan that maximizes the present value of net return (Baffoe et al., 1986; Forest, 1992; Fox et al., 1991; Kurtz et al., 1984). Baffoe et al. (1986) found that cereal based cropping systems could be more profitable but induced a higher rate of erosion compared to legume based cropping plans. Stonehouse et al. (1988) used MPLP to examine the profitability of different cropping plans under different yield trend scenarios (Stonehouse et al., 1987). They found that corn-soybean-winter wheat was more profitable than a corn-soybean cropping plan. Other studies used dynamic programming and risk programming to examine multi-period farm planning problems (Katz, 1985).

2.9 Justification for use of single period LP

The present study investigates the producer's single period decision regarding i) profit maximization; ii) the impact of an erosion constraint, and iii) the impact of a nitrogen constraint. One of the reasons often given by producers for not adopting sustainable practices is the negative impact these practices have on the short-term profit of the farm. Previous agronomic research indicates that lupins can provide environmental benefits, with regards to soil erosion and nitrogen fixation. This study will investigate the impact of lupins on the short term gross margin of a dairy producer and account for the environment benefits. This study will use a single period LP to estimate these short-term impacts on a crop of an average year within a crop rotation.

2.10 Conclusions

Agronomic and economic aspects of legumes or feed crops and lupins have been reviewed. In general, the literature and available evidence seems to suggest that the competitiveness of the dairy industry could be enhanced through reduced cost of production without reducing the quality of milk produced. One strategy to reduce the cost of production is to search for livestock feeds that are low-cost and high in nutrient content. Compared to legumes such as soybeans, lupins seem to be a promising source of livestock feed.

Various descriptive, statistical and mathematical tools have been used to examine the feasibility of introducing an alternative cropping system or crop into an existing farming system. These methods include partial budgeting, whole-farm planning, production function analysis and mathematical programming. Each of these methods is applicable in different situations or to investigate different farm planning decisions.

The present study intends to examine the feasibility of incorporating lupins in a cropping plan as a source of protein supplement to dairy cows. Although the problem is multi-period, the present study will examine the feasibility of incorporating lupins in a cropping plan as a single-period farm planning decision. Uncertainty regarding future values of important parameters such as government programs (subsidies), prices, etc. and scarcity of data necessiated the use of a single-period optimization method. However, several activities, and mixes of crops and livestock enterprise will be examined.

Chapter III

Method of Analysis

3. 1 Introduction

This chapter provides i) the framework to analyze the problem identified in chapter I; ii) describes the typical dairy farm in Southwest Quebec; iii) describes the model, and iv) includes the objective function and constraints.

3.2 Study area and representative or typical dairy farm

The study area is Napierville, in Southwest Quebec, about 30 km south of Montreal. Dairy production is the major enterprise in this region. The climate in the region is suitable for growing pasture and other fodder crops for dairy ration formulation. The farming system to be modeled has an average growing season that covers the months of May to October.

The representative farm in this study is based on the average dairy farm in the region from the 1994 census of agriculture (Isabelle et al., 1995). The farm contains 122 ha of land. A sole proprietorship business is assumed with a husband and wife partnership. The farmer can choose the combination of crops in order to maximize gross margin. The land and soil type is suitable for any temperate zone crop. The crops considered on the farm include grain corn, corn silage, barley, oats, alfalfa hay, alfalfa silage and sorghum silage. In addition, soybean and lupin can be grown as protein supplements.

The typical dairy farm is assumed to own 42 head of Holstein milking cows, 30 heifers of which 16 are open heifers and 14 bred heifers and 12 calves. The model assumes that the average weight of a Holstein cow is 650 kg and produces 67.57 hectolitres of milk/year (Isabelle et al., 1995) that contains 3.75 percent milkfat. These figures are average values taken from GREPA but the model will select the number of animals in each group that will maximize the gross margin. The lactation length is 44 weeks (305 day) which is divided into two periods: the first 10 weeks and the second 34 weeks. The remaining 8 weeks is the dry period.

In order to maintain the number of milking cows constant during the study period, the farmer is assumed to replace dead and culled cows. The reason for maintaining the number of cows at a predetermined level is because raising cows at less than the optimal number is assumed to decrease the gross margins.

For planning and management purposes, the replacement dairy heifers are divided into three age groups. These are: i) calves (1 week-6 month old); ii) open heifers (7-15 months old) and iii) bred heifers (16-24 months old). These age groups are proportional with the number of mature cows. Therefore, proportionality exists between each group and the number of mature cows. The coefficient of each group is expressed as a fraction of a young animal to a cow. Forest (1992) calculated that the animal equivalent of calf, open heifer and bred heifer to a cow is 0.375, 0.368 and 0.335 respectively. The number of deaths and culled cows are expressed as a function of animal equivalents per year. Birth and culling rates are taken into account in determining the size of the herd and the number of animals in each group.

The mortality and culling rate of the mature cows is 2 and 32 percent respectively. This is typical for Quebec dairy farms (Fcrest, 1992). It is assumed that farmers keep a fixed number of animals in each group, and that the dairy herd replacement rate is equivalent to the number of cows dead or culled each year.

Regarding unproductive cows, it is assumed that cows not kept are replaced with two year old heifers. Of the live calves, 50 percent are assumed to be bull calves and are sold as soon as they weigh 90 pounds. Mortality rate of calves is 10 percent while that of open and bred heifers is 2 percent (Forest, 1992). The breeding period for heifers is 15 months and their first milking begins nine months later. Therefore, heifers will start milking at the age of two years. Failure to conceive is assumed to be 8 percent. Heifers unable to conceive are culled immediately and weigh 550 kg (Forest, 1992). Both the mortality and culling rates of heifers are taken as a percentage of the mature cows. The meat selling activity is excluded from the study.

Information from MAPAQ publications and consultation with experts in the region were used to determine the crops grown for livestock feed and cash in this region. Crop plans that are commonly practiced by dairy producers in SWQ were chosen as a base case. These plans include lupins as a potential substitute for soybeans. The reason for the choice of lupins as a substitute for soybeans is its adaptability to the region's climate, its high nutritive value for livestock and its potential for soil conservation.

3.3 An Overview of the Model

The model building procedure in the present study follows that of Forest (1992) and Nevo and Podmore (1994). The procedure includes model construction and documentation, quantification of model coefficients from published data, field trails, surveys, market reports and private communication.

The objective function is to maximize gross margin subject to physical and non-physical constraints. The model is expected to minimize feed by choosing a cropping system based on the ability of the farm to meet the nutrient requirements of its dairy herd. The principal activities included in the model are production, buying (straw for animal bedding) and selling of crops (corn grain, barley, oats, soybeans, and straw), nutrient requirements for the animals and milk production.

The present study will undertake a single-period optimizing scheme that incorporates lupins into a crop plan of a typical dairy producer. Land is characterized as fixed and allocable. The model will generate an optimal farm plan assuming that farm policies, technologies, prices, etc. remain unchanged. While it is possible to explore changes in optimal farm plans as a result of changes in these parameters, the current study is restricted to undertaking a sensitivity analysis on the provision of subsidies to lupin growers. This was done so that the latter can effectively compete with soybeans.

Linear programming has long been used to determine least-cost and optimal rations based on the nutrient requirements of cattle and nutrient availability of feedstuffs (Henery et al., 1995; Martin and Touchton, 1983). The optimal cropping system will be based on the feed value of forage and other crops produced on the dairy farm. A system of equations is used to design a farm plan that maximizes gross margin and environmental benefit (decreased levels of soil erosion and nitrogen fixed).

3.4 Description of the Model

3.4.1 Assumptions

Linear programming problems require several assumptions regarding the relationship of the various activities, the nature of the data and the products to be produced (Bradley et al., 1977; Utpton, 1996). The present study utilizes a single-period LP model. However, to minimize uncertainties regarding the reliability of the results, the following assumptions are made

(i) Revenue from milk sales depends on the amount of milk produced and the price received for it. It is assumed that herds with good management can achieve the same level of milk production per cow as the average achieved by herds on PATLQ (Programme d'Analyse des Troupeaux Laitiers du Quebec) test.

(ii)The cost of an average dairy farm includes the cost of producing feeds on the farm, purchased feeds and a wide range of expenses, such as maintenance of field equipment, family and hired labour, cost of seed, fertilizer, fuel and other expenses associated with feed production. These costs are assumed to remain constant during the study period.

(iii) Milking cows of a given weight and breed producing the same amount of milk require the same amount of dry matter.

(iv) There is no adoption of new technologies, and

(v) The quantity of feed consumed and the concentration of nutrients in animal diet varies seasonally and across animal type. It is assumed that the animals are raised in confinement in order to minimize the variation in feed consumption. Pasture grazing is excluded to avoid variations in feed intake by an animal in the same category.

The general framework of the model is presented in Table 3.1 on next page.

3.4.2 Objective Function

The objective function maximizes the gross margin of a representative dairy farm in Southwest Quebec from the sale of milk and crops in excess of the nutritional requirements of the herd, taking into account the storage capacity on the farm.

In mathematical terms, the objective function is summarized as follows:

$$\text{Max } Z = \sum_{j=1}^{n} C_j X_j \text{ for all } j = 1 \text{ to } n \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\text{Subject to } \sum_{i=1}^{m} a_{ij} X_j \leq b_i, \text{ for all } i=1 \text{ to } m$$

and $X_j \geq 0$,

Where,

Z, is variable gross margin of the dairy farm,

C_i, return of the activity i;

X_j, level of activity j;

a_{ij}, technical requirement of activity j for resource i;

b_i, level of resource i available.

3.4.3 Constraints

There are four sets of constraints. The first set of constraints are land, labour and building capacity. The second set of constraints are the crop plan practices, which limit cropping plan alternatives. The third set of restrictions are the nutritional needs of the cows, heifers and calves. The final set of restrictions are the transfers of crops produced to either feeding and/or selling activities.

The LP model will select the most economical type of cropping system that includes either lupins or soybeans, as a protein supplement, and meet all the nutritional requirements for the dairy cows. To do so, crop budgets have to be constructed for each crop. The main production activities are dairy cows, raising replacement heifers and crop production. Feeding activities include corn grain, corn silage, barley, oats, alfalfa hay, alfalfa silage, sorghum silage, lupins and soybeans. Sales activities include corn, barley, oats and soybeans. Sale prices reflect handling losses, transportation costs and other transfer costs (Table 3.2). The cost variables include seeds, fertilizers, herbicides, field operation, farm transport, machinery repair and maintenance, hired labour, harvest insurance, interest on capital and miscellaneous (Appendix 1-9). Dietary requirements are formulated

Table 3.1 Framework for linear programming model of a representative dairy farm in Southwest Quebec

Row Identification	Production feeds (1-9)	Crop sales (10-17)	Crop nutrient (18-26)	Dairy feeding (27-32)	Milk sale (33-34)	RHS
Objective Row (1)	-x	x			x	Max
Labour Availability (2)	x				x	≤ b1
Land Availability (3)	x					≤ b2
Crop yield (4-12)	x	-x				≤ b3
Dairy nutrition (13-90)			x	-x		≤ b4
Proportion of animals (91-96)					-x	≤ b5
Milk production (97)					x	≤ b6
Soil loss (98)	x					≤ b7
Nitrogen fixation	x					≥ b8

Table 3.2 Crop production and sale activities

	Production activity									Sale activities				
	CG	CS	BA	OT	ALH	ALS	SG	LPN	SB	SCG	SBA	SOT	SSB	RHS
OBJ	-512.07	-728.43	-337.43	-253.9	-369	-454.09	-539.8	517.74	-322.89	192.36	187.09	203.15	326.38	MAX
LAND	1	1	1	1	1	1	1	1	1	1				≤122
LABOUR	7.2	20.84	9	8	3.6	3.6	16.32	9.68	7.2					≤6000
YCG	6020									-1				≥0
YCS		12000												≥0
YBA			3080								-1			≥0
YOT				2464								-1		≥0
YALH					5251									≥0
YALS						5320								≥0
YSG							8000							≥0
YLPN								2610						≥0
YSB									2420				-1	≥0
TOTER	29.77	41.03	32.99	32.99	1.61	1.61	41.03	1.61	37.01					≤1708
TOTN					30	30		50	25					≥0
TOSTRAW			1.8	2.2				3						≥0

Where:

CG is corn grain

CS is corn silage

BA is barley

OT is oats

ALH is alfalfa hay

ALS is alfalfa silage

SG sorghum silage

LPN is lupins

SB is soybeans

SCG is corn grain sold

SBA is barley sold

SOT oats sold

SSB soybeans sold

such that the amount of feed required by a specific class of cattle meets certain standards. NRC (National Research Council) requirements are modified for SWQ.

It is assumed that the fixed costs are constant for both lupins and soybeans in the plan, and that a return from the sale of milk is constant. The model assumes that there will be no change in milk output when the source of protein supplement is lupins or soybeans. The farm owns all machinery needed to operate crop production. These include tractors, plows (disc, mould board and chisel), harrow, cultivators, a seeder, and seed harvester and forage harvester. The building can house 85 animals. The storage capacity is 9000 hay bales and a bunker capacity of 120 tonnes of silage.

Elements of enterprise crop budgets for the representative farm are compiled from published sources; such as CREAQ, MAPAQ and field trials. Prices are derived using the Farm Input Price Index (Statistics. Canada, 1994a). Various costs; including seed, fertilizer, chemical, fuel and oil, repairs, hired labour and interest cost are calculated on a per hectare basis for the whole farm as well as by crop. Insurance, interest and depreciation are estimated for all machinery but excluded from the crop budgets (Diebel et al., 1995).

The gross margin can be expressed as follows:

$$Y = \Sigma HLS + \Sigma G_iS - \Sigma VC_i \quad \text{...(2)}$$

Where :

Y is gross margin,

Σ HLS is income from the sale of milk produced with quota,

G_iS is income from grain type i sold and

VC_i is variable cost for crops grown on the farm (C = 1...,m).

3.4.3.1 Labour Constraints

The farm is managed by an owner-operator with 6000 hrs of farmer and family labour per year. However, if field operations require more than this available labour, seasonal skilled part-time workers are available on an hourly basis.

$\Omega_i LBC_i + \delta_c LBLS_c \leq \Gamma$ ....(3)

Where:

LBC_i is labour required for crop *i*,

$LBLS_c$ is labor required for livestock class c,

Γ is total supply of labor and

Ω_i and δ_c are fixed coefficients

3.4.3.2 Land use Constraints

The representative dairy farm owns 122 hectares and grows feed required for the herd. The land is classified as class II, sandy loam, with an organic matter of 3 percent. It is the assumed that all forage crops will be grown on the farm.

$LAN \leq 122$, ...(4)

Where LAN is land size in hectares under cultivation

3.4.3.3 Production and Disposition of Crops

3.4.3.3.1 Production

$PC_i - \Sigma C_i FD_c - \Sigma C_i SD_c \geq 0$, for t=1...10 .... (5)

Where:

PC_i, yield of crop *i*

$\Sigma C_i FD_c$, amount of crop i fed to class of livestock c

ΣC_iSD_c, quantity of crop in excess of the nutrition requirements of the herd and sold

Equation (5) states that yield of crop *i* less amount of crop *i* fed to different class of livestock and excess feed sold must be greater than or equal to zero. It means all requirements of crop i should be produced on the farm.

3.4.3.3.2 Prices

The representative dairy farm in SWQ receives government support (income stabilization) for soybean production. However, the farmer does not receive any government support for lupin production. The support price for soybeans and the average lupin price is used. The underlying crop budget prices were converted to 1994 dollars using Farm Input Price Index (Statistics. Canada, 1994a).

3.4.3.3.3 Production and requirement of straw

$TSTP - \Sigma STP_c = 0$ ....(6)

Where:

TSTP, total straw produced in tonnes

STP_c, amount of straw produced from crop c,

$GC_i - \Sigma GFLS_c = 0$ ....(7)

$HC_i - HFLS_c = 0$ ....(8)

$SC_i - SFLS_c = 0$, for i=1...8, c=1..k ....(9)

Where:

Gc_i is grain produce of crop *i*,

$GFLS_c$ is grain fed to livestock,

Hc_i hay produced,

$HFLS_c$ hay fed to livestock,

Sc_i silage produced from crop i and

$SFLS_C$ silage fed to livestock

Equations (7) though (9) imply that grain produced from crop ***i*** must be equal to grain fed to livestock class c, hay produced from crop ***i*** must be equal to hay fed to livestock class c, silage produced from crop ***i*** must be equal to silage fed to livestock class c.

$$TOTSTRAWC_i + \eta BSTRAW - \varphi SSTRAWC_i - \Lambda\ CW \geq 0 \qquad \text{..........................(10)}$$

$$fSTRAWCi - CiSTRAW = 0 \qquad \text{..........................(11)}$$

Where:

TOTSTRAW is total straw produced from crop i,

BSTRAW is straw bought from the market to meet cow bedding,

SSTRAW is quantity of straw sold in excess of animal requirement,

CW is mature cow and

η, φ and Λ are fixed coefficients

Equation (10) indicates that total straw produced plus purchase of off-farm straw for animal bedding minus sold straw and utilized for bedding in the farm must be greater than or equal to 0. Equation (11) states that the total straw produced from crop Ci is equal to the quantity of straw from the acreage of crop Ci, where f is quantity of straw produced from a hectare of crop Ci.

3.4.3.4 Livestock Inventory and composition

3.4.3.4.1 Inventory

As mention earlier, the farm owns 42 Holstein cows, 30 heifers and 12 calves. Lactation length is taken as 305 days. The first 100 days are considered the most productive period for the cow. During the second period, remaining 205 days, cows produce less milk and consume less concentrate.

Birth rate of bull calves is also proportional to heifers. The mortality rate for bull calves and heifers is assumed to be 1 percent but death rate of cows is 2 percent. The farm buys and sells each category of livestock to maintain a constant herd size. Cows are culled because of low productivity, aging or when they fail to conceive.

3.4.3.4.2 Animal Equivalents

$CW_i - \alpha CW = 0$ ....(12)

$DR - \beta CW = 0$ ....(13)

$CALF - \chi CW = 0$ ....(14)

$OP - \delta CW = 0$ ....(15)

$BR - \epsilon CW = 0$ ....(16)

Where:

CW_i is number of cows in class *i* (milking cows in first or second stage),

DR is a dry cow in the last two months of gestation period,

CALF is calf under six months,

OP is open heifer 7 to 15 months old and

BR is a bred heifer 16 to 24 months old ready to replace old and less productive milking cows

α, β, χ, δ and ε are fixed coefficients.

Equations (12) to (16) indicate that the animal unit equivalent of cows, calves, open heifers and bred heifers must be equal to K (where k is the proportion of their respective class for $0 < K < 1$

$$CW_i - Q_mCW = 0, \text{ for } i=1,2 \quad \text{...(17)}$$

$$DR_t - Q_mCW = 0, \quad \text{...(18)}$$

Equation (17) indicates that the number of lactating cows in first 100 days (CW1) and in the first 205 days (CW2) must be a certain proportion (Q) of total number of cows on the farm. The second equation (18), indicates that the number of dry cows is proportional to the total number of cows.

$$\Sigma LS_c \leq BARC \quad \text{...(19)}$$

The above equation (19) states that total number of livestock from class c (for c=1...j) must be less than or equal to the capacity of the barn. The farm has sufficient building space to accommodate all the machinery and storage for all the grain, hay and silage crops required to feed the herd.

3.4.3.4.3 Milk Quota Constraints

m_iCOW-uCALF-MLKP=0 ....(20)

Where:

m is milk produced per cow per year,

u is milk consumed per calf and

MLKP is milk produced.

Total milk produced is equal to the milk produced per cow per year times number of cows less amount consumed by calves.

3.4.3.5 Nutritional requirement of the dairy herd

Demand estimates of nutritional requirements of the dairy herd are based on specific maintenance, reproduction and production requirements. Least-cost ration formulation for lactating and dry cows, and heifers depend on body weight, number of lactating days, milk fat and protein percentages (Erba and Knoblauch, 1995; Gonda et al., 1995; Van Soest, 1994). Furthermore, information regarding milking days, environmental temperatures and proximity to freshening may primarily be used to predict feed intake and estimate nutrient requirements (Eastridge and Weiss, 1994).

The LP model enables the user to vary feed ingredients and their composition to determine a balanced least cost feed ration formulation. The physical constraints of the model restrict the daily volume of feed consumption to meet the animal digestive capacity. The nutritional constraints assume that the daily maintenance requirements for each animal are met.

The basic unit in the model is the dairy cow. Milk production per cow is assumed to be fixed. Cultivated land can be used for producing forages, cereal grains (corn, barley, oats), legume grains (lupins and soybeans), silage (corn, alfalfa, sorghum) and alfalfa hay. Estimates of average daily feed intake and nutrients for dairy cattle are based on National Research Council (1989) recommendations and Pond et al. (1995).

Livestock feed requirements are divided into three categories: maintenance, maintenance and reproduction, and milk production. The maintenance requirement depends on body weight. The average weight considered for a Holstein dairy cow was assumed to be 650 kg. The average weight of a calf, open and bred heifer was 150 kg, 300kg and 500 kg respectively.

Milking cows are fed according to their body weight, production of milk and the fat content of the milk. The average milk production was 6757 kg per year with 3.5 percent milkfat. The lactation period is ten months and the cow is assumed to be dry in the remaining two months.

For nutritional purposes, a Holstein cow, as described above is categorized as CW1, CW2 and DR. Where CW1 is a cow in its first 100 days, CW2 is a cow in the last 205 milking days and DR is the dry period. The other animals are calves, designated as CALF under six months old, open heifers, OP (7-15 months) and bred heifers, BR (16-24 months). Feed requirements of each group of animal is calculated in terms of animal equivalents.

During lactation, CW1 produces more milk and requires a higher quantity of dry matter (DM), net energy for lactation (NEL), crude protein (CP), acid detergent fiber (ADF), calcium (Ca) and phosphorus (P) than CW2 and DR. Similarly, CW2 demands more feed than DR (Berentsen et al., 1991). For calves and replacement heifers, the nutritional requirements are based on their daily body weight gains. The daily weight gain of calves from birth to six months is about 700 g. For open and bred heifer, weight gain is assumed to be 800 g.

The nutrient requirements for DM, NEL, ADF, CP, Ca, P are given in Table 3.3. The minimum and maximum energy for maintenance and energy for gain (NER) for calf, open heifer and bred heifer are calculated by multiplying NEM (net energy for maintenance) and NEG (net energy for grain) values of NRC tables of each crop.

Feed is grown on-farm. On-farm grown feeds are charged by the farm at selling price. Prices for all crops are in 1994 Canadian dollar. Price data is compiled from studies by CREAQ (Comite de References Economique de Quebec) and MAPAQ (Ministere de l'Agriculture, des Pecheries et de l'Alimentation de Quebec). The average price of crops considered in the present study is presented in Appendices 1-9.

Table 3.3 Minimum and maximum nutritional requirement of dairy herd

	CW1	CW2	DR	CALF	OP	BR	CW	HL	RHS
OBJ								55.17	MAX
LABOUR				18		41		1.77	<=6000
DM1	-7665								>=0
DM1MAX	-9490								<=0
NEL1	-11096								>=0
NEL1MA	-16425								<=0
CP1	-1068								>=0
CP1MAX	-1803								<=0
ADF1	-1610								>=0
ADF1MA	-1993								<=0
CA1	-41								>=0
CA1MAX	-183								<=0
P1	-28								>=0
P1MAX	-73								<=0
DM2		-6022.5							>=0
DM2MAX		-8030							<=0
NEL2		-8074							>=0
NEL2MAX		-13505							<=0
CP2		-700							>=0
CP2MAX		-1445							<=0
ADF2		-1264							>=0
ADF2MAX		-1686							<=0
CA2		-28							>=0
CA2MAX		-110							<=0
P2		-18							>=0
P2MAX		-37							<=0
DM3			-5475						>=0
DM3MAX			-6570						<=0
NEL3			-4603						>=0
NEL3MAX			-9417						<=0
CP3			-392						>=0
CP3MAX			-1051						<=0
ADF3			-1478						>=0
ADF3MAX			-1774						<=0
CA3			-14						>=0
CA3MAX			-55						<=0
P3			-9						>=0
P3MAX			-26						<=0
DM4				-1369					>=0
DM4MAX				-1825					<=0
NER4				-1971					>=0
NER4MAX				-2336					<=0
CP4				-219					>=0
CP4MAX				-365					<=0
ADF4				-219					>=0
ADF4MAX				-365					<=0
CA4				-7					>=0
CA4MAX				-10					<=0
P4				-4					>=0
P4MAX				-7					<=0
DM5					2577				>=0
DM5MAX					-3285				<=0
NEL5					-3274				>=0
NEL5MAX					-4125				<=0
CP5					-310				>=0
CP5MAX					-511				<=0
ADF5					-490				>=0
ADF5MAX					-788				<=0
CA5					-9				>=0
CA5MAX					-37				<=0
P5					-7				>=0
P5MAX					-27				<=0
DM6						-4500			>=0
DM6MAX						-6570			<=0
NEL6						-4681			>=0
NEL6MAX						-5950			<=0
CP6						-540			>=0
CP6MAX						-1132			<=0
ADF6						-855			>=0
ADF6MAX						-1643			<=0
CA6						-11			>=0
CA6MAX						-55			<=0
P6						-8			>=0
P6MAX						-27			<=0
NCW1							0.279		>=0
NCW2							0.558		<=0
NDR							0.163		>=0
NCALF							0.376		<=0
NOP							0.368		>=0
NBR							0.335		<=0
MILK				-0.184			67.57	-1	<=0
MILKSALE								1	= 0

The model assumes that all individual animals in each category (lactating, dry, heifer and calf) are homogeneous with respect to their nutritional requirements. Furthermore, it is assumed that crops produced on the farm are valued (priced) at the expected market price. In addition, the nutritional contents of the feed stuffs are assumed to remain constant and are shown in Appendix 10.

The model assumes that the nutritional requirements of the dairy cows remain constant. The lactation length is taken as 305 days of production.

Dry matter (DM): $G_1LS_c - (a_1DMC_i + a_2DMC_i \ldots a_mDMC_i) \leq 0$ .... (21)

Energy (NEL): $G_2LS_c - (b_1NEL_1C_i + b_2NEL_1C_i \ldots b_mNEL_1C_i) \leq 0$ ....(22)

Energy (NER): $G_2LS_c - (b_1NER_1C_i + b_2NER_1C_i \ldots b_mNER_1C_i) \leq 0$ .... (23)

Protein (PR): $G_4LS_c - (d_1PRC_i + d_2PR_1C_i \ldots d_sPRC_i) \leq 0$ .... (24)

ADF: $G_5LS_c - (e_1ADC_i + e_2ADC_i \ldots e_uADC_i) \leq 0$ ....(25)

Mineral (CA): $G_6LS_c - (f_1CAC_i + f_2CAC_i \ldots f_vCAC_i) \leq 0$ .... (26)

Mineral (P) : $G_7LS_c - (g_1PC_i + g_2PC_i \ldots g_wPC_i) \leq 0$, ... (27)

Where:

c= cows, calves, open heifers, bred heifers, lactating cows in first 100 days, lactating cows in the second 205 days, and dry cows;

G_iLS_c, ... are yearly intake of DM, NEL, NER, CP, ADF Ca and P per livestock class c less DM, NEL, NER, ADF, CP, ADF Ca and P produced from crop i must be less than or equal to zero (refer 21 - 27).

The dairy farmer must chose a crop plan that includes, silage, hay, energy crops (cereal grains) and protein supplement legume grains. Once the daily feed requirement of each animal in each group is determined, the feed demand for each class of animal can be determined.

The maximum nutritional requirement for the herd can be higher than the NRC values (Block, 1996). For example, there is no specific need for maximum ADF in the daily requirement. ADF is a factor used to determine the energy level in a specific feed and it is inversely related to NEL and DM intake. Similarly, the model assumes that no limitation of NEL will be placed on CW1. However, DM and ADF are factors that must be taken into account in determining the maximum nutrients requirements.

3.4.3.6 Environmental constraint

3.4.3.6.1 Soil Erosion

It is assumed that plant nutrients are evenly distributed in the topsoil. The maximum soil erosion tolerable level is defined as the permissible soil loss that will maintain long-term productivity. Farm-specific data on soil erosion was not available for the present study. The revised universal soil loss equation for application in Canada (RUSLEFAC) was used to estimate the soil erosion on the farm (Pringle et al., 1995).

RUSLEFAC was used instead of the universal soil loss equation (USLE) because it is the most up to date means of estimating soil loss. More importantly, it was designed to take into account all aspects of Canadian weather and other related conditions, such as snowmelt. Most of the coefficients needed to estimate the RUSLEFAC were obtained from Pringle et al. (1995) with some additional information from personal communications and the published literature.

Mathematically, the soil erosion constraint was defined as:

$\Sigma ER_i C_m \leq$ TOTER, i=1,...6, j=1...6, m= 1...8 and ....(28)

Where $\Sigma ER, C_m$ refer to soil erosion in tonnes ha^{-1} and crop respectively. The equation states that the total erosion from the farm is less than or equal to a fixed amount of total erosion (TOTER).

3.4.3.6.2 Nitrogen Fixation

Nitrogen fixation is one of the major contributions of legumes. The quantities of N left over after lupin, soybean and alfalfa are taken from published sources, research reports and articles. It is reported that lupins and soybeans leave 180 and 56 kg N ha^{-1} following their harvest respectively (Armstrong et al, 1995; Vanotti and Bundy, 1995, Bundy et al., 1993). However, some extension experts in the region suggested that most values obtained from the literature are high and suggested these data be modified to reflect the climatic condition and farming practices of the study area. Therefore, it was recommended that the N transfer be 50 and 25 kg for lupins and soybeans respectively (Leduc, 1997).

For alfalfa the amount of N left in the field is based on the duration of the crop in the field. Each crop plan is planned so that the forage crops, such as alfalfa, are grown for at least for 5 years. Therefore, the yearly average N transfer for alfalfa is taken as 20 kg (Leduc, 1997).

$$TOTN \geq \Sigma NSCm \quad \text{.....(29)}$$

Where :

TOTN is total N transfer (N leftover in the soil after legume harvest)

ΣNSCm is net N contribution from each legume crop

3.5 Summary

The single period LP model has been designed to maximize the gross margin for a typical dairy production in SWQ. The model takes into account the buying and selling activities of the producer. The model is constrained by the nutritional requirements of the herd, land availability, labour, milk quota and environmental concerns (soil erosion and N fixation).

3.6 Data collection

Estimates of input and output price indices were derived from a variety of sources including CREAQ (Comite de References Economique de Quebec) and others were collected from MAPAQ (Ministere de l'Agriculture, des Pecheries et de l'Alimentation), Direction des Etudes Economiques, Service de l'Economie de la Production, St. Martin MAPAQ branch, UPA (Union Producteur) and GREPA (Groupe de Recherche en Economie et Politique Agricoles) and consultations with farmers, extension and research personnel of the region. Milk price for the year 1994 was obtained from the Milk Producers of Quebec, FPLQ (Federation des Producteur de Lait du Quebec). Outputs included in the model are corn grains, corn silage, barley, oats, alfalfa hay, alfalfa silage, sorghum silage, lupins and soybeans. Only variable costs that vary with the volume of output were considered. These include seed, fertilizer, pesticides, other materials, operating machinery costs, hired labour, marketing charges and interest on operating capital. Prices, gross margins and variable costs were assumed to remain constant in real terms during the study period. Farm-gate prices for crops were calculated as the average over a 6-year period (1989-1994). Whenever possible, actual field data from the Southwest Quebec region were used in the analysis. However, some of the field data were modified due to independent evidence that some of the yield data might not have been accurate.

Soil erosion and N fixation figures were take from a typical Quebec farm production plan and different publications. In some cases published coefficients were revised after discussion with agronomists, soil scientists and dairy experts of the region. Moreover, some prices were normalized using price indexes of variable inputs.

CHAPTER IV

Results and Analysis

4. Results of the analysis of linear programming

4.1 Introduction

This chapter includes the results of the base case scenario and sensitivity analysis of key parameters that may affect the gross margin and crop mix of the representative dairy farm. In the first section, the base case scenario is defined as having no restrictions on soil erosion and N fixation. Then, changes in the cost of production, yield increase, lupin seed, government subsidy, erosion and nitrogen constraint, price of straw, land and labour are investigated. Finally, a discussion of the results is presented at end of the chapter.

4.1 Base case scenario

The base case scenario refers to the current situation with no adjustments for the lupin cost of production, soil erosion or N fixation. The following crops are included in the base case scenario crop plan: corn grain, barley, oats, soybeans, alfalfa hay and silage, corn silage, sorghum silage. A total of 35 dairy cows, 13 calves and 14 open and 13 bred heifers are raised on the farm.

Dairy farmers receive government support (subsidies) for all grain crops including soybeans. Under this scenario, the dairy farmer produces feeds with conventional farming practices and the soil erosion constraint is not imposed.

The farmer cultivates the 122 ha and operates with a total of 6,000 hours of labour supplied by the family.

The model results confirmed that the current cropping plan, that includes soybeans, is optimal. This result implies that producers are acting in an economically rational manner in their decision to grow soybeans instead of lupins as the major source of protein supplement. These findings are based on a cropping plan that does not take soil erosion into account, nitrogen fixation and the potential subsidy for lupin production.

The optimal crop combination, least-cost ration for the dairy herd of the representative dairy farm, included: corn grain, corn silage, alfalfa hay and soybeans. The gross margin for the optimal crop plan, for the base case scenario was $147,918. This crop plan resulted in an estimated total soil loss (TOTER) of 3,504 tonnes per year. The total crop area and family labour used were 122 hectares and 6,000 hours respectively. Similarly, the optimal dairy herd of the farm was 75 animals of which 35 are milking cows (CW), 13 calves (CALF) and 27 heifers, open (OP) and bred (BR). The optimal mix of crops and dairy herd is presented in Table 4.1

Feed for the milking cows in the first 100 days (CW1) consisted of corn grain (CG), corn silage (CS), alfalfa hay (ALH) and soybeans (SB). However, feed for the second 205 milking days included CG, CS and ALH for cow2 (CW2). Ration requirements for the dry cow (DR) and bred heifer (BR) were met with ALH and CS. The ration for the calves (CALF) and open heifers (OP) was the same as that for the dry cow (DR) but SB was needed for both as a protein supplement.

The gross margin of the dairy farm is influenced by the revenue generated from milk, the cost of feed production, cost of the crops bought and the price received for the crops sold. More of the farm income is derived from

Table 4.1 Optimal crop plan for a dairy farmer in Southwest Quebec: Base case scenario[1].

			Quantities	
	Quantity	Values	Soil loss (tonnes)	Nitrogen fixed (kg)
Gross margin		$147,918		
Crops (# of ha)				
Corn grain (CG)	83.36	($42,686.2)	2482	
Corn silage (CS)	19.74	($14,379.2)	810	
Barley (BA)				
Oats (OT)				
Alfalfa hay (ALH)	13.74	($5,070)	22	412
Alfalfa silage (ALS)				
Sorghum silage (SG)				
Lupins (LPN)				
Soybeans (SB)	5.15	($2,597.6)	191	129
Milking cows (# of CW)	35.3			
Milk production (# of HL) @$55.17 HL^{-1}	2382.2	$131,425.9		
Sold: Corn grain (tonnes) @$192.36 t^{-1}	442.3	$85,080.8		
Bought: Straw (tonnes) @$65 t^{-1}	59.3	($3,854.5)		
Total soil eroded (TOTER)			3504	
Total N fixed (TOTN)				541

[1]Base scenario: Lupin seed is bought every year and the farmer does not receive a subsidy for lupin growing. There are no constraints on soil loss or nitrogen fixation. Figures in parentheses are costs.

the sale of milk, although the sale of crops, in excess of the feed requirement for the dairy herd, is another source of income. Under the base case scenario farm plan, the farm sold more than 442 t of corn contributing to approximately $85,000 to total revenue. Corn is the most profitable crop to sell. One of the main reasons for this is the high average annual subsidy paid to corn farmers. According to MAPAQ, the average annual corn subsidy for the year 1989-1994 was $328 ha^{-1} (MAPAQ, 1989-1994)

The higher the gross margin attributed to a crop, the more likely that it would be a major part of the annual crop plan. If corn is subsidized and continues to be a major source of gross margin, the potential of the soil to produce sufficient feeds will be reduced substantially. This phenomenon would force dairy farmers to purchase supplemental feed. An important strategy to ensure long-term productivity of the soil is the stewardship of land through the reduction of soil erosion. In the current situation, the least cost solution for the dairy producer is to choose a crop combination that relies heavily on corn grain production (43.7%) which produces a high level of soil erosion.

Unless environmental considerations are taken as part of the farm decision making process, the resource base of agriculture will deteriorate and farmers will experience long term crop yield reduction and ultimately reduced profitability (Mawapangna and Debertin, 1996). Thus, farmers should not only be concerned about their gross margin in the short term but must also include environmental considerations in their decision making (Pannell, 1996). This implies that production decisions must take into account additional and sometimes conflicting objectives such as environmental benefits and the costs and tradeoffs between short term higher profits and sustainable dairy farming. Farmers will be required to make these types of decisions.

4.2 Sensitivity Analyses

4.2.1. Introduction

The optimal crop mix obtained in the solution is the set of crops that provides the largest gross margin with the available resources. That is, the optimal plan will satisfy land, labour, animal inventory, barn capacity and other constraints. This section discusses how the optimal combination of crops in the base case cropping plan responds to changes in the restrictive resources.

Changes in the value of one parameter may have a large impact on the maximum gross margin. Sensitivity analysis is performed to examine the extent to which an optional farm plan changes due to changes in selected parameters. Average values of all variables such as crop yields, cost of production, market prices, soil loss, land and family labour were used initially. The magnitude of these variables can change for a number of reasons. Crop yield can be affected by the management practices carried out by individual farmers or by weather conditions. These changes can result in a different optimal solution. There may be a strong possibility that the initial cost of lupins is high and yield low. Farmers may obtain higher lupin yields than initially assumed in this study hence, lowering the cost of production.

A sensitivity analysis was undertaken on the cost of production for lupins, yield of lupins and the effect of a subsidy for lupin production, inclusion of environmental factors into the optimal farm plan, farm size and supply of family labour. These parameters were chosen based on the literature review, trends in the dairy industry, market and competitiveness of the sector. It also helps to evaluate uncertainty of farm revenue or cost as a result of shocks from factors external to the decision-maker. Increasing and decreasing the value of these parameters in other studies had an impact on the objective function, i.e. maximum gross margin, the cropping plan, the animal numbers and output of crops (Upton, 1996).

4.2.2 Cost of Lupin Production

Lupins did not enter the optimal crop plan solution at the current cost of production. The goal of this sensitivity analysis was to examine changes in the cost of lupin that would ensure its inclusion in the optimal farm plan. The cost of production for lupins was reviewed to identify areas where costs were high and could possibly be reduced. Two changes in the base case scenario were investigated. The first was a decrease in the cost of lupin seed while the second was an overall decrease in the total cost of production.

One of the assumptions in the lupin cost of production was the cost of seed. The number of registered lupin seed cultivars are few and farmers were assumed to buy certified seed every year. In the base case scenario, the cost of lupin seed was estimated to be \$127 ha^{-1}. The following seed cost were considered: \$75, \$57 and \$49 ha^{-1}. These values were estimated by taking the price of certified seed for one year and using this seed for 1, 2, and 3 years respectively. Farmers could do this by harvesting enough seed in any one year to be used the following year. Given no change in yield and no subsidy for lupin production, it was found that lupins did not come into solution with this variation in seed costs.

The total cost of lupin production was decreased until it came into the cropping plan. The cost of production of lupins would have to decrease from \$517.74 to \$366.74 ha^{-1}, approximately \$150 ha^{-1}, before it would come into solution. Lupins entered as a marginal crop (0.01 ha) and didn't remove all of the soybeans out of production. This implies that reducing the cost of lupins by \$151 ha^{-1} alone was not enough to incorporate it into the cropping plan. Farmers must be able to use their clean homegrown lupin seed for another two more years or government must step in to assist farmers in the form of a subsidy.

The expected reduction in the cost of lupins, \$151 ha^{-1}, is approximately equivalent to the level of income stabilization given to soybean producers. Therefore, reducing the cost of production of lupins by 29 percent would provide lupins with as similar gross margin as soybeans. However, this reduction in the cost of lupins was not enough to offset soybean production and the area under lupins was only marginal (Table 4.2).

Gross margin, crop combination and quantity produced, number of animals, milk and crop sale, total soil loss and quantity of nitrogen fixation under this scenario was the same as the base case except for the production of a small quantity of lupins. The lupins were used to supplement soybeans in the CALF ration. Most of the soybeans was fed to CW1 and CW2, 727 and 117 kg y^{-1} respectively.

Table 4.2 Optimal crop plan of a dairy farm in Southwest Quebec when the cost of lupin production is \$366.74 ha^{-1}

			Quantities	
	Quantity	Values	Soil loss (tonnes)	Nitrogen fixed (kg)
Gross margin		\$147,918		
Crops (# ha)				
Corn grain (CG)	83.36	(\$42,686.2)	2482	
Corn silage (CS)	19.74	(\$14,379.2)	810	
Barley (BA)				
Oats (OT)				
Alfalfa hay (ALH)	13.74	(\$5,070)	22	412
Alfalfa silage (ALS)				
Sorghum silage (SG)				
Lupins (LPN)	0.01	(5.2)[1]		0.3
Soybeans (SB)	5.15	(\$2,597.6)	191	129
Milking cows (CW)	35.3			
Milk production (# of HL) @\$55.17 HL^{-1}	2382.2	\$131,427.1		
Sold: Corn grain (tonnes) @\$192.36 t^{-1}	442.3	\$85,080		
Bought: Straw (tonnes) @\$65 t^{-1}	59.3	(\$3,852.5)		
Total soil eroded (TOTER)			3504	
Total N fixed (TOTN)				541

[1] Lupin Seed is bought every year and the farmer does not receive a subsidy for lupin growing. There are no constraints on soil loss or nitrogen fixed.
Figures in parentheses are costs.

4.2.3 Subsidy for Lupin Production

Obstacles to the widespread adoption of an alternative crop into existing farming systems may be caused by the current economic conditions, which makes the alternative unprofitable. Government incentive programs, such as a subsidy, may influence a farmer's decision making process to adopt alternative crops. Such programs may have the added benefit of enhancing soil quality and reducing soil erosion.

A subsidy of $328.48 ha^{-1} (109.49 t^{-1}) is required to completely substitute lupins for soybeans. The cropping plan in this scenario included: CG, CS, ALH and LPN. This scenario resulted in a gross margin of about $148,072 ($154 more than the base case). Revenue from CG was $79,502. This was a decrease in CG revenue of $5,549 from the base case. CG was fed to the milking cows (CW1 and CW2, similar to the base case scenario) and calves. The total number of animals was the same as the base case scenario.

In this scenario, the provision of a subsidy for lupins has increased the area allocated for lupin production (see Table 4.3a). The increased production of lupins was fed to milking cows in the first 100 days, calves, and open and breed heifers. The amount of CG and milk sold was 29 t and 9 HL less than that sold in the base case scenario.

This cropping solution resulted in a loss of 3,142 t of soil. This was 362 t less than the base case scenario. The quantity of nitrogen fixed was 984 kg, 82 percent more than the base case scenario. Straw purchase was 35 t less than the base case.

Table 4.3a Optimal crop plan of a dairy farmer in Southwest Quebec with a lupin subsidy.

			Quantities	
	Area (ha)	Values	Soil loss (tonnes)	N2 fixed (kg)
Gross margin		$148,072		
Crops (# of ha)				
Corn grain (CG)	78.25	($40,069.5)	2329	
Corn silage (CS)	18.81	($13,701.8)	772	
Barley (BA)				
Oats (OT)				
Alfalfa hay (ALH)	13.11	($4,837.6)	21	393
Alfalfa silage (ALS)				
Sorghum silage (SG)				
Lupins (LPN)	11.83	($2,238.5)[a]	19	591
Soybeans (SB)				
Milking cows (# of CW)	35.17			
Milk production (# of HL) @$55.17 HL^{-1}	2374	$130,973		
Sold: Corn grain (tonnes) @$192.36 t^{-1}	413.3	$79,502		
Bought: Straw (tonnes) @$65 t^{-1}	23.6	($1,534)		
Total erosion (TOTER), tonnes			3142	
Total N fix (TOTN), kg				984

Lupin seed is purchased in the first year but the lupin producer receives a subsidy of $328.48 ha^{-1}. There are no constraints on soil loss or nitrogen fixation. Figures in parentheses are costs.

[a] Net cost (total cost minus income from lupin subsidy)

The impact of eliminating of the income stabilization program for soybean producers on gross margin of a typical dairy farm was evaluated. Current income stabilization level for SB production is $141 ha^{-1}. However, in order to be a beneficiary of the program, the farmer pays a premium of $32.5 ha^{-1} of soybeans. Then the cost of soybeans with no income stabilization program would increase from $322.89 to $404.39. Total soybean production was reduced by more than 61 percent from the base case scenario. Gross margin was estimated to be $147,587, a decrease of $331 from the base case. This change in SB cost of production brought BA into the solution. A total of 9.6 ha of BA were produced. The entire BA crop was fed to CW1 replacing most of CG. The quantity of CG and milk sold was about 19 t and 8 HL less than the base case scenario (Table 4. 3b).

Table 4.3b Optimal crop plan of a dairy farmer in Southwest Quebec with no income stabilization for soybeans[1].

			Quantities	
	Area (ha)	Values	Soil loss (tonnes)	N2 fixed (kg)
Gross margin		$147,587		
Crops (# of ha)				
Corn grain (CG)	76.86	($39,357.7)	2263	
Corn silage (CS)	19.40	($14,131.5)	766	
Barley (BA)	9.59	($2,330.7)	333	
Oats (OT)				
Alfalfa hay (ALH)	14.13	($5,213.9)	26	468
Alfalfa silage (ALS)				
Sorghum silage (SG)				
Lupins (LPN)				
Soybeans (SB)	2.02	($1,183.5)		
Milking cows (# of CW)	35.22			
Milk production (# of HL) @$55.17 HL^{-1}	2377.2	$131,151.8		
Sold: Corn grain (tonnes) @$192.36 t^{-1}	423.1	$81,373.9		
Buy: Straw (tonnes) @$65 t^{-1}	41.9	($2,723.5)		
Total erosion (TOTER), tonnes			3,498	
Total N fix (TOTN), kg				475

[1] Lupin seed is purchased every year and no subsidy for lupins. There are no constraints on soil loss or nitrogen fixation.

4.2.4 Change of yield

Lupins are a relatively unknown crop in Quebec and as a result do not have a reliable average yield estimate. Yield estimates range from 2.5 to 4 t ha^{-1} The yield used in the base case scenario was 3 t ha^{-1}. With this yield, the cost per tonne of lupin was higher than that of soybeans.

A sensitivity analysis was undertaken on the yield estimate for lupins. Under this scenario, lupin was increased to 3.15 t ha^{-1}, an increase of five percent. This increase is chosen because farmers are likely to achieve this minimum yield increase following sound cultural practices, including timely accomplishment of field operations. The change in gross margin was insignificant ($550 less) compared to the base case scenario but had an effect on the crop mix. The following crops came into solution: CG, CS, BA, OT, ALH and LPN (Table 4.4). Only a marginal amount of land was planted to lupins, 0.42 ha, with this increase in yield. These findings indicate that CS and ALH were fed to all categories of animals. Energy requirements for CW1 were met by 0.389 and 3.007 t of CG and BA respectively, replacing 2.4 t of CG. Similarly, OT replaced most of the energy required by open heifers (OP), consequently, the proportion of ALH in the balanced ration was reduced. Lupins were used to meet the protein supplement for the CALF variable and this reduced the quantity of ALH requirement for this class of livestock.

A 10 percent increase in the yield of lupins, from the base case scenario, resulted in a decrease in gross margin by $521. Crop area allocated to lupins was 1.35 ha. Lupins were fed to both CALF and OP. This increase in lupin

Table 4.4. Optimal crop plan of a dairy farmer in Southwest Quebec with a 5 percent increase in lupin yield[1]

			Quantity	
	Quantity	Values ($)	Soil loss (tonnes)	N2 fixed (kg)
Gross margin		$147,369		
Crops (# of ha)				
Corn grain (CG)	76.04	($38,938.4)	2264	
Corn silage (CS)	18.68	($13,605.7)	766	
Barley (BA)	10.10	($2,453.3)	333	
Oats (OT)	1.18	($163.3)	39	
Alfalfa hay (ALH)	15.58	($5,751.5)	25	468
Alfalfa silage (ALS)				
Sorghum silage (SG)				
Lupins (LPN)	0.42	($217.3)	0.7	21
Soybeans (SB)				
Milking cows (# of CW)	35.31			
Milk production (# of HL) @$55.17 HL^{-1}	2383	$131,493.5		
Sold: Corn grain (tonnes) @$192.36 t^{-1}	412.9	$79,429.4		
Bought: Straw (tonnes) @$65 t^{-1}	37	($2,424.3)		
Total soil eroded (TOTER), tonnes			3427	
Total N fixed (TOTN), kg				489

[1] Lupin seed is bought every year and there is no subsidy for its production. There are no constraints on soil loss or nitrogen fixation. Figures in parentheses are costs

production decreased BA and ALH production by 0.5 and 1.08 ha respectively from the previous scenario (Table 4.5).

The total soil loss with a 5 and 10 percent yield increase of lupins was 3,427 and 3,435 t respectively. This is a reduction of 77 and 69 t from the base

Table 4.5 Optimal crop plan for a dairy farmer in Southwest Quebec with a 10 percent increase in lupin yield[1].

			Quantity	
	Quantity	Values ($)	Soil loss (tonnes)	N2 fixed (kg)
Gross margin		$147,397		
Crops (# of ha)				
Corn grain (CG)	76.05	($38,941.8)	2264	
Corn silage (CS)	19.02	($13,855.3)	780	
Barley (BA)	9.60	($2,331.4)	316	
Oats (OT)	1.48	($206.2)	49	
Alfalfa hay (ALH)	14.50	($ 5,350.8)	23	435
Alfalfa silage (ALS)				
Sorghum silage (SG)				
Lupins (LPN)	1.35	($698.5)	2	68
Soybeans (SB)				
No. Cows (CW)	35.23			
Milk production (HL) @$55.17 HL^{-1}	2378	$131,219		
Sold: Corn grain (tonnes) @$192.36 t^{-1}	414.9	$79,811		
Buy: Straw (tonnes) @$65 t^{-1}	35	($2,249.6)		
Total soil eroded (TOTER)			3435	
Total N fixed (TOTN				503

[1]Lupin seed is purchased every year and there is no subsidy for lupin. production There are no constraints on soil loss or nitrogen fixation. Figures in parenthesis are costs.

case scenario. However, an estimate of N fixed was 489 and 503 kg respectively, 55 and 38 kg less than the base case scenario. It should be noted that a low estimate of N fixed by lupins was taken.

Reducing the yield of lupins by 5% to 2.7 t ha^{-1} excluded them from the optimal crop mix. When lupins and soybeans are excluded from the solution a large area of land is allocated to CG production.

Increasing the yield of lupins by 5 percent and 10 percent increased the hectares of BA and OT entering the solution. As a result, the quantity of straw purchased for bedding was reduced to 37 and 35 t for lupin yield increase of 5 and 10 percent respectively. With increases in the area allocated to lupin production, the farmer used the crop to feed not only CALF but also CW1, OP and BR.

4.2.5 Feeding Crop Production on Farm

Including the crop selling activity increased the farmer's gross margin by allocating relatively more area for the production of cereal crops with higher gross margins. This is the case for CG (corn grain). The major source of income for the representative dairy farm is from milk sales and cash crops in the base case scenario. Crop sales accounted for 39 percent of the total revenue in the base case scenario.

With no buying or selling activities for feed, i.e., assuming all feeds are produced and consumed on the farm, the gross margin for the optimal solution was $120,320. This was a decrease in gross margin of $27,600. The nutritional requirement of the dairy animals was satisfied with only 97 ha in production. Crop mix and acreage were CG, CS, OT and ALH at 1, 1.77, 52 and 38 ha respectively. SB production was insignificant, just about a quarter of a hectare. Under this scenario, milk production was higher 2,617 HL (38.68CW). Total erosion was decreased from the base case scenario, from 3,504 to 2,008 t, while N fixation increased from 541 to 1,156 kg. Self sufficiency in feed production resulted in less soil erosion and more N fixation. This scenario leaves 25 hectare of arable land idle.

4.2.6 Impact of environmental restriction on dairy farming

4.2.6.1 Effect of soil erosion on profitability

Environmental degradation is a major threat to sustainable growth in agricultural production. Existing farm programs may act as an obstacle to environmentally sustainable farming. Highly intensive agricultural systems are blamed for the loss and degradation of the soil resource (Thomas, 1995). Similarly, highly specialized farming operations are considered as the major causes of odor and water pollution in some areas. Farmers must search for farming systems that are economically viable, and ecologically sound and sustainable (Ikerd, 1991). Existing farm programs can sometimes provide the wrong incentives for the adoption of sustainable farming systems.

The environmental impact of an optimal crop plan can be measured by the quantity of soil lost and the total nitrogen contributed by the legume crops. When erosion occurs at a greater rate than soil regeneration, then soil productivity may be reduced and this may result in a negative impact on a farmer's future income. Water quality can be affected by soil erosion and agricultural runoff and is considered to be one of the major contributors of non-point source water pollution.

The estimated annual average soil loss in Quebec is approximately 20 t ha^{-1} y^{-1} (Painter et al., 1995). However, the erosion tolerance level (T) in the study region is estimated to be 14 t ha^{-1} y^{-1} (Painter et al., 1995). Imposing a soil erosion constraint of 14 t ha^{-1} resulted in a decrease in gross margins from $147,918 to $131,198; a decrease of 11.3 percent from the base case scenario. The crop mix associated with this solution was CG, CS, ALH and LPN (see Table 4.6). Crop sales were 244.5 t of CG or $47,032. Total N fixation (TOTN) for this solution was 2,454 kg with LPN producing 38 percent of the total. Straw requirement for bedding was met with a purchase of 8 t. This was a substantial decrease from the 59.3 t in the base case scenario.

This environmental constraint had a major impact on land allocation. Compared to the base case scenario, the acreage allocated to CG went from 83.37 ha to 51.3 ha, while ALH acreage went from 13.75 ha to 50.7 ha. There was no SB acreage in this solution and LPN was allocated to 18.3 ha. Gross margin decreases as the level of soil erosion is further reduced. As soil erosion is decreased, crops with higher gross margins are replaced with less erosive crops in the optimal crop mix plan.

There is some debate on the appropriate tolerance value for the soil type in the region. A sensitivity analysis was conducted on the assumed value of 14 t ha^{-1}. The allowable soil loss levels were increased and decreased by 10, 15, 20 and 25 percent. Increasing the tolerance value by 10,15, 20 and 25 percent increased the annual soil loss to 1,879, 1,964, 2,050 and 2,135 t respectively.

Table 4.6 Impact of soil loss level on gross margin, crop mix and N fixation of Southwest Quebec dairy farmer.

		Crop mix in hectares						Quantity	
Average ha^{-1}	Gross margin ($)	CG	CS	ALH	LPN	SB	Crop sale[1] (tonnes)	Total soil loss (tonnes)	N fix (kg)
7	116,384	22.4	1.8	50.4	25.7		84	854	2,797
8	118,533	26.3	1.8	50.2	25.6		109.1	976	2,786
9	120,682	30.4	1.8	49.9	25.5		134.3	1,098	2,772
10	122,831	34.5	1.7	49.7	25.3		159.4	1,220	2,756
11	124,979	38.7	1.7	49.4	25.2		184.5	1,342	2,742
12	127,128	42.8	1.7	49.1	25.2		209.6	1,464	2,723
13	129,264	47	1.7	49.1	25		233.2	1,586	2,688
14	131,198	51.3	1.7	50.7	18.3		244.5	1,708	2,454
15	133,011	55.6	1.7	52	12.4		255.8	1,803	2,180
16	134,676	59.9	1.7	53	7.6		267	1,952	1,970
17	136,067	64.2	1.7	51.5	4.6	0.1	277.8	2,074	1,797
18	137,379	65.6	2.5	52	5	1.5	289	2,196	1,623
19	138,422	67.7	4.1	48.2	0.5	1.5	303.7	2,318	1,502
20	139,492	69.8	5.7	44.5	0.5	1.5	318.5	2,440	1,398
21	140,551	72	7.4	40.7	0.5	1.5	334	2,562	1,261
22	141,551	73.9	8.9	37.2	0.5	1.5	348	2,684	1,179
23	142,594	76	10.6	33.5	0.5	1.5	363	2,806	1,068
24	143,635	78	12	29.8	0.5	1.5	377	2,928	957
25	144,672	80.5	13.6	26	0.5	1.5	391.8	3,050	840
28.9[a]	147,918	83.37	19.74	13.75		5.15	442.3	3,504	541

[1] Crop sale is corn grain
[a] Base case scenario (no erosion constraint)

Reducing the level of soil erosion by 10 percent from 14 t ha^{-1} decreased the gross margin by $19,504 from the base case scenario. Further reduction in the allocable amount of soil loss 15, 20 and 25 percent decreased gross margin by $21,000, $22,516 and $24,013 or by 14, 15 and 16 percent less than the base case scenario respectively. Imposing a decrease in the allowable soil loss takes out soil erosive crops that generate a large gross margin and replaces them with less erosive crops i.e., a trade-off between gross margin and soil loss. Corn silage generates the largest amount of soil erosion on a per hectare basis . When soil erosion is constrained between 14 - 17 t ha^{-1}, the optimal area allocated to corn silage was less than 1.7 ha. This result implies that less soil erosive crops are substituted for corn silage. When the soil loss constraint is larger than 17 t ha^{-1}, production of corn silage increased.

The hectares planted to lupins (LPN) increased as the level of soil loss is reduced. In the solution, LPN is used to feed animals in all categories except DR. The need to buy straw is eliminated in this solution, since bedding for the animals is met with the stubble from LPN. This solution estimates that the dairy farmer can sell 12 t of hay to the market. The amount of CG sold in the market also declined while production of ALH was increased.

4.2.6.2 Nitrogen fixation, marginal profit and crop mix

Nitrogen fixation is an important component of crop planning. Legumes fix substantial quantities of nitrogen that can be used as an alternative to inorganic N fertilizers. One of the ideas of alternative (low input) agriculture is to incorporate legume crops into cropping plans so as to improve soil productivity through N fixation and increase the organic matter level of the soil that maintains its physical and chemical properties.

N fixation was used as one of the constraints of the study. The N fixation data for the legumes were obtained from local agricultural experts and extension agents of the region. In the base case scenario where N fixation was not restricted, the total amount of N obtained from the crop mix was 541 kg. The impact on gross margin, crop mix and amount of lupins were investigated by imposing a total of N fixation constraint of between 541 - 2,700 kg. The results show that the gross margin decreased from $147,918 to $132,956 as the N fixation constraint was increased from 541 to 2,700 kg. Soil loss was also increased from 3,504 to 4,039 t in that order (Table 4.7).

Crop mix was similar to the base case scenario (seeTable 1) for N fixation constraint levels of 541 to 2,160 kg, but more soybeans produced at the expense of corn grain. As the N fixation constraint level increased to 2,700 kg for the farm, lupins came into the solution as 2.89 ha. One of the unique observations in the N fixation constraint was that more soybeans was sold with increased N fixation constraint levels, displacing corn grain sale.

4.2.7 Land

Choice of crop mix by dairy farmers can be constrained by the availability of land. Dairy farmers with a larger land area may have an advantage over farmers with a smaller area. Note that with more land, farmers have a larger mortgage and therefore, increase their fixed cost. One of their advantages is that they can supplement their income with the sale of cash crops. The base

Table 4.7 Impact of Nitrogen fixation on marginal profit and crop mix of dairy farm in Southwest Quebec.

N Fix (kg)	Gross margin ($)	Crop mix in hectares					Quantity	
		CG	CS	ALH	LPN	SB	Crop sale (tonnes)	Total soil loss (tonnes)
541	147,918	83.30	19.74	13.75		5.15	442.3[a]	3,504
1,080	144, 644	61.67	19.70	12.89		27.74	371.3[a] 26.2b	3,692
1,620	140,790	40.09	19.68	12.87		49.36	241.4[a] 78.6b	3,849
2,160	136,935	18.51	19.66	12.85		70.98	111.47[a] 130.97[b]	4,005
2,700	132,956	-	19.45	12.77	2.89	86.89	- 173.1[b]	4,039

[a] Corn grain
[b] Soybeans

case representative dairy farm contained 122 hectares. A sensitivity analysis was undertaken to estimate the impact of decreasing the land constraints by: 10, 15, 20 and 25 percent of the base case.

Reducing the land area to 110 ha (10 percent less), and imposing a soil erosion constraint of 14 t ha^{-1}, resulted in a gross margin of $127,567. This solution produced 2,035 kg nitrogen. The crop mix was the same as the base case scenario except lupins came into the solution, replacing soybeans. Similarly, decreasing the farm area by 15 and 20 percent did not change the crop mix but the gross margin decreased while herd size increased (Table 4.8).

The area under lupins was 8.3, 5.8 and 2 ha for a decrease in farm size by 10, 15 and 20 percent respectively. However, with a decrease of 25 percent, the area under lupins was marginal (0.5 ha). This would indicate that lupins are profitable as an alternate to soybeans for a large size dairy farm who wants to keep soil erosion at the tolerated level of 14 t ha^{-1}.

Milk production became the major contributor to the total farm revenue as the farm size was reduced from the base case. The contribution of milk sales to total gross revenue was 72, 77, 81 and 85 percent when farm size was reduce by 10, 15, 20 and 25 percent respectively with a 14 t ha^{-1} tolerance scenario. The total quantity of CG for sale was reduced to 185, 154, 123 and 91 t.

Table 4.8 Effect of land size on optimal crop plan and gross margin for a dairy farmer in Southwest Quebec

Relationship between land size, variable profit and lupins				
	Land size in hectares (ha)			
	110	104	98	91
Gross margin ($)	$127,567	$125,399	$123,223	$120,450
Crops (# of ha)				
Corn grain (CG)	45.9	43.3	39.4	33.3
Corn silage (CS)	1.76	1.8	1.8	3.4
Alfalfa hay (ALH)	54	53.2	53.8	52.2
Lupins (LPN)	8.3	5.8	2	0.5
Soybeans (SB)			1	1.5
Milk cows (# of CW)	38.6	39.1	39.3	39.5
Milk production (HL) @$55.17 HL^{-1}	2,604 $143,662.7	2,627 $144,931.6	2,654 $146,421.2	2,666 $147,083.2
Sold: Corn grain (tonnes)	184.5	154.1	122.7	90.6
@$192.36 t^{-1}	$35,490.4	$29,642.7	$23,602.6	$$17,427.8
Buy: Straw (tonnes)	40	48	60	65
Total soil eroded (TOTER), tonnes	1,540	1,456	1,372	1,274
Total N fixed (TOTN), kg	2,035	1,884	1,741	1,631

4.2.8 Labour

The total amount of family labour available on the typical dairy farm is estimated to be 6,000 hrs y^{-1} (Forest, 1992). This is equivalent to more than 16.44 hrs day^{-1}, or approximately 2 man-years of labour. It is interesting to see the change in the farm's activity by adding or reducing the amount of available family labour in the base case scenario. With an increase in the supply of family labour by 10 percent, and imposing a soil erosion tolerance level of 14 t ha^{-1}, the size of the herd increased from 35.3 to 41 dairy cows while gross margins increased from $131,198 to $137,800.

Decreasing the amount of family labour by 10 percent from the base case, resulted in a substantial decline in the gross margin, from $147,918 to $116,222. This was a decline of $31,696 or 21 percent. Reducing family labour supply by 15, 20 and 25 percent resulted in a further drop in gross margin and lupin production. Lupin area went from 20.8, 19.5 and 18.1 ha respectively. The effect of available family labour on herd size, optimal crop mix and gross margin is given in Table 4.9. Land was sometimes left idle when the annual supply of family labour became the limiting resource.

4.2.10 Straw price

The price of straw for animal bedding is considered very low. This can encourage the farmer to allocate more land for growing corn grain for livestock feed and sell the rest. Straw needed for the farm can be purchased at a lower price from the market. Data on the price of straw obtained from Comite de

Table 4.9 Impact of the supply of family labour on crop mix acreage and gross margin

	Supply of family labour (hrs.)			
	5400	5100	4800	4500
Gross margin ($)	$116,222	$116,224	$111,157	$106,089
Crops (hectare)				
Corn grain (CG)	47.4	52.1	52.4	52.8
Corn silage (CS)	0.5	1.4	1.3	1.2
Alfalfa hay (ALH)	48.6	40.8	38.2	35.6
Lupins (LPN)		20.8	19.5	18.1
Soybeans (SB)	1.73			
No. Cows (CW)	35	31.3	29.3	27.3
Milk production (HL)	2363	2113	1978	1842
Sold: Corn grain (tonnes)	172.4	273.6	278.2	282.8
Buy: Straw (tonnes)	59	10[a]	9[a]	9[a]
Total erosion (TOTER), tonnes	1575	1708	1708	1708
Total N fixed (TOTN), kg	1501	2263	2118	1973

[a] Sale of straw (stubble) of lupins for bedding of animals for other dairy farmers

References Economique en Agriculture du Quebec (CREAQ) estimates a cost of $52.50 t^{-1}. The farmer can sell his straw at the market price, $52.50 t^{-1} but can purchase it for $65 t^{-1} (assuming the difference between the purchase and selling price is transportation, $12.50 t^{-1}).

Regional extension agents and local farmers suggested that the current straw price is about $95 t^{-1} (Leduc, 1997). If the market price for straw is $95 t^{-1} a 50 percent increase from the current price, the crop mix changed and more barley (21.4 ha) is produced. This resulted in substituting more barley for corn grains in the nutrition of the herd.

4.3 Discussion

Dairy farmers have to decide on the allocation of scarce resources among competing enterprises in such a way that returns will be maximized. In order to do this, producers must allocate their resources to their highest and best use. Choice of crop mix should be based on returns to land, labour and capital resources used in production. Successful farming requires economic management skills along with crop and animal production knowledge.

Dairy farmers in the study region seem to be acting rationally today in continue using soybeans as a choice over lupins as an alternative protein supplement for dairy animals. The gross margin of the representative farm is higher when soybeans is used. Soybeans constitute about 4 percent of the total farm land in the cropping plan, small but still significant.

The government income stabilization program for soybeans has distorted the relative cost of producing lupins. Income stabilization accounts for a large proportion of soybean income, about \$141 ha^{-1}. Providing lupins with a similar level of government support as soybeans did bring some lupins into the crop mix. This is an important policy implication because the soybean income stabilization program has distorted the farmers' crop mix decision. If the government wants to stimulate adoption of alternative feed crops that would utilize resources more efficiently, a policy that provided an incentive for dairy farmers to grow lupins would be an efficient way to do this.

A government subsidy of \$328.48 ha^{-1} was needed before lupins would replace soybean in the crop mix. A bigger distortion is needed to bring lupins into the solution. This is 2.3 times the income stabilization payment for soybeans. This solution provided an increase in gross margin and decreased the amount of soil erosion. The reduction in soil erosion was 362 t or one percent of the base case scenario.

Market forces alone may do little to conserve non-renewable resources in agriculture, such as soil (McNeely, 1988). Government incentive programs may strongly influence farmer's decision-making processes. Such programs can be designed to enhance soil quality and reduce soil erosion. A policy that encourages incorporating (adoption) lupins as an alternative protein supplement for dairy cows would provide these benefits. Adopting a sound crop mix may increase or maintain farm income of dairy farmers in the long run.

Conflicting interests may arise among dairy farmers, consumers and taxpayers regarding farm programs. Dairy farmers want higher gross margins regardless of soil conservation practices. Consumers desire stable food and lower prices and taxpayers want to reduce or eliminate the deficit. Government can influence farmers to adopt sound crop mixes with the use of taxpayers money.

Soil erosion is one of the components of the study. Soil depletion can increase production cost (soil maintenance), hence higher consumer prices. Producers considered lupins not only as a low input crop but also the stubble left in the field after harvest can protect soil better than soybeans.

Lupins replaced soybeans in the crop mix when a soil tolerance level of 14 t^{-1} was imposed. This solution decreased the amount of soil erosion by more than half the base case erosion and produced 5 times the amount of fixed N. The cost of soil erosion may depend on the expectations of losses in soil productivity, future crop prices as well as on the time preference of the dairy farmer. For a dairy farmer who valued current gross margins relatively higher than future gross margins, the loss in future benefits from the loss of soil productivity may exert less influence on decisions which encourage depletion. However, if farmers valued the loss in future benefits, due to declining soil productivity, then their current decisions may take soil degradation (soil loss) into account when determining their cropping plan. The use of lupins in a cropping plan not only enhances soil productivity but also protects the environment by minimizing nitrate and other chemicals in ground and surface water hence, balancing agriculture and the environmental concerns.

The analysis indicated that when the soil erosion constraint was not imposed, the farmer buys almost all of the straw required for animal bedding. This is because of the low market price for straw. Barley is produced in more quantities, taking land out of corn grain and alfalfa hay production. Consequently, the amount of corn grain in the ration of milking cows and OP was reduced. Purchases of straw were reduced from 59 t (base case) to 17 t.

Lupins can be made more competitive with soybeans if its cost of production can be reduced. This could be achieved through good field management. Lupins can be planted right after the field is worked and as a result weed infestation can be minimal. This would reduce the need for herbicides and other related agrochemicals. Assuming sound cultural practices are followed and suitable weather condition, it may be possible to cut the lupins cost of production by 15 percent.

Legumes are integrated into a cropping system for different reasons among which is to reduce inorganic nitrogen fertilizer requirements. Depending as the management practices, it is estimated that lupins can fix as high as 320 kg, with a N credit (nitrogen left over the field for next growing crop) of 65 - 180 kg ha^{-1}. As the level of the N fixation constraint level increased, gross margin decreased, soybean production increased but soil loss increased. This indicates that there is a tradeoff between gross margin and the amount of N fixation.

Use of homegrown clean seed for more than 2 years following the purchase of certified seed can reduce costs. This cost saving, with a subsidy of equal value to soybeans, resulted in the introduction of lupins and barley into the cropping plan. The respective areas planted were 2.5 and 1.2 ha. Barley produced in this cropping plan was used to substitute for corn grain in the feed ration of milking cows and calves.

Chapter V

Conclusions

5.1 Introduction

Allocation of limited resources between alternative enterprises requires management decisions that depend on factors external to a particular enterprise. Farming is a complex activity and decisions on the best crop combination, management practices and strategies may be influenced by the farmers knowledge of scientific issues, machinery, economic factors, historical trends, climate/weather, environmental considerations, personal circumstances and a number of practical considerations.

Dairy farmers in Quebec and elsewhere in Canada have witnessed several changes in the past three decades. The most significant and relevant to the present study is the introduction of supply management to the dairy sector. External forces, such as the new international trade agreements, have put pressure on the dairy sector to become more competitive and to decrease the amount of government intervention in this sector. To meet these challenges, dairy farmers must find ways of cutting costs. Production costs may be reduced through the adoption of new technologies such as replacing of conventional feed crops with low cost alternative crops.

Several management alternatives are available to the dairy farmer. The farmer has many choices to make concerning what crops to grow and to feed the herd, how to manage those crops and the dairy herd. Some trade-offs may be made when considering many of the alternatives. This would include such things as the trade-off between lower lupin yield, reduced soil erosion and higher organic matter. In general, the trade-offs are based on short-term gains and long-term losses i.e., the dairy farmer has to choose between short-term profitability and long-term sustainable farming.

Milk quotas (supply management) have effectively placed a ceiling on the supply of milk in the short run. This has a direct impact on the revenue the farmer receives for milk. Increasing the margin between production costs and selling price can provide an increase in profit for the producer. Minimization of feed cost should be an on going concern to dairy farmers because it is the single most important component of the cost of production of dairy farming.

Lupins may be a potential alternative crop as protein supplement for dairy cattle in SWQ. The feed value of lupins is similar to soybeans, a traditional feed crop for dairy livestock. The seed can be directly consumed by milking cows without the need for roasting (processing).

The environmental benefit of lupins is that more nitrogen can be fixed than by soybeans and this can reduce the cost of inorganic fertilizers. Unlike soybeans that require the soil temperature to be a certain level prior to planting, lupins can be seeded after the soil is worked. Intercropping with cereal crops for silage, lupins can increase the crude protein level of the feed for dairy cattle. The quantity of stubble after lupin harvest is estimated at 3 - 4 t and can be used for feeding animals in the field, thus extending the grazing season, or used for animal bedding. This can reduce the amount of straw required on the farm. Lupins provide a better field cover and protects the soil better than soybeans. This study investigated the economic feasibility of lupins for a dairy farm in SWQ. Three hypotheses were tested and the results as follows.

The first two hypotheses addressed whether or not it was profitable for farmers to adopt lupins. At current price levels, lupins were uneconomical to substitute for soybeans in a cropping plan for a dairy farm in SWQ. Farmers are rational in growing soybeans. The base case supports the economic theory. i.e., farmers are rational and are choosing the least cost solution. Lupins is a new crop and producers require information on agronomic and other cultural practices to incorporate it into a cropping plan. Currently, there are few registered lupin varieties, hence the seed price is expensive. Lupins can be a substitute for soybeans if the cost of production is reduced to about \$367 ha^{-1}. This would require a substantial decrease in its cost of production or subsidy of \$328 ha^{-1}. A yield increase by 5 percent can also reduce the cost of lupins and make it more competitive with soybeans.

The third hypothesis suggested that there was a trade-off between gross margins and soil erosion. The amount of soil erosion generated in the base case was 3,504 t (28.7 t ha^{-1}), more than double the soil tolerance level of 14 t ha^{-1}. Increasing or decreasing the level of soil loss has an impact on the gross margin of the farm. Gross margins increased as soil loss increased, thus there is a tradeoff between gross margin and soil loss. Similarly, more lupins were substituted for soybeans when soil loss was constrained to lower levels.

The final hypothesis suggested there was a trade-off between gross margin and N fixation. The analysis indicated that an increase in the N fixation constraint, resulted in a decrease of gross margin while soil loss increased. More soybeans were produced and sold while corn grain sales reduced and eventually replaced by soybeans. The tradeoff between N fixation and gross margins was observed. Lupins came into solution as 2.89 ha when N fixation was constrained to 2,700 kg for the farm.

5.2 Summary and Conclusions

There are many factors affecting the incorporation of lupins in the optimal crop plan of a typical dairy farmer. These include higher seed prices, limited availability of lupin cultivars and lack of high quality seeds, farmers preference to grow traditional crops and the lack of government assistance.

Analysis of the optimal cropping plan (base case scenario) indicates a cropping plan that substituting soybeans by lupins would not be profitable. Throughout this thesis, it has been noted that soybean is part of an income stabilization program. It implies that its cost to dairy farmers will be lower compared to other crops that aren't part of the program (e.g. lupins). On the other hand, there is an increasing trend towards the removal of government intervention along with the need to integrate environmental concerns into the optimal crop plan. To examine changes in selected parameters of the typical dairy farm crop plan, several sensitivity analyses were conducted.

The findings of the present study indicated that lupins would be incorporated into the optimal farm plan if any of the following requirements are satisfied:

i) yield increased at least by 5 percent using better agronomic or management techniques;

ii) cost of production of lupin is reduced by at least 10 percent (by reducing field operation and use of farm grown clean seed) and

iii) government provides subsidies to lupin equivalent to soybean income stabilization payments.

These would make the dairy farmers indifferent between growing lupins and soybeans.

In summary, if producers receive a subsidy for lupins, they would also be reducing soil erosion, and therefore enhancing the long-term productivity of soil. Lupins are able to reduce the energy, required to produce N fertilizer and for machinery because of its ability to fix N and minimize weed and insect infestation.

5.3 Limitation of the study

The aim of the present study was to assess the economic feasibility of lupins as a source of protein supplement, in a cropping plan for a dairy farmers in SWQ. Other potential alternative legume crops were not investigated. As a result, the gross margins associated with these other alternative crops are not known.

Some costs and prices were based upon the average production costs of dairy and cash crop growers in central Quebec. Some of these costs were machinery repair and maintenance, ensilage and farm transport. Also, the price of straw is an average for the region. These indexed values may not reflect the costs and prices of a specific producer in SWQ.

This study investigated the short term decisions of the dairy producer. It did not take into account the long term impact of increased soil quality from using lupins.

5.4 Recommendation for further research

1. Lupin is a new crop to Southwest Quebec and Quebec in general. More agronomic information on yields and other related practices are required. Seed price for lupins is higher than the traditional dairy protein crop, soybeans. Tillage method, impact of no-till on yield and soil loss is worthy of investigation.
2. More information is required on lupins as a dairy feed. If lupins can completely substitute for soybeans nutritionally, this could impact on the selection of crops in the plan. This may expand to other animals, expand the potential for lupins as an animal feed.
3. The study focused only on a short term impact of lupins on the gross margins of a dairy farm. However, it may be necessary to look at the long term effect of lupins in crop rotations. This study would have to take into account the impact of improved soil quality, nitrogen fixation, and the dynamic or time dimensions of improved soil quality.
4. Farmers may continue to mine the soil for short term profits. This can cause soil depletion (soil loss). Sustainable dairy farming may be achieved by minimizing soil loss levels or integrating crops that leave more organic matter

in the soil. One way to incorporate lupins into the cropping plan may be through a government tax or levy on soil erosion and/or N fixation.

5. Free trade has brought several changes in the agricultural sector. The dairy industry is faced with several challenges including the elimination of subsidies, tariffs and milk quota. Structural change in herd size, farm size, and structure of the dairy industry is imminent with an increase in production costs of dairy feeds.

References

Agrawal, R. C. and E. O. Heady. 1972. *Operation research methods for agricultural decisions*. Ames, Iowa State Univ. Press.

Aguilera, J. M. and A. Trier. 1978. "The Revival of the lupin". *Food Technology* 32(8):70-76

Allison, J. R. and S. L. Otto. 1987. *Economics of using legumes as a nitrogen source in conservation tillage systems*. In *The Role of legumes in conservation tillage systems*. J. F. Power (ed.). Soil Conserv. Soc. Amer. Ankeny, IA. pp 145-150

American Society of Agronomy. 1989. "Decision reached on sustainable agriculture". *Agron. News*, January, p. 15

Aniszewski, T. 1993a. "Nutritive quality of the alkaloid-poor Washington lupin (*Lupinus poluphyllus* Lindl.) var SF/TA as a potential protein crop". *J. Sci. Food Agr.* 61:409-421

Aniszewski, T. 1993b. "The Alkaloid-rich and alkaloid-poor Washington lupines (*Lupinus polyphyllus* Lindl.) as a potential industrial crop". *Industrial Crops and Products*. 1:147-155

Aniszewski, T. 1993c. *Lupins: A Potential crop in Finland. Studies on the ecology, productivity and quality of Lupinus spp.* PhD. Thesis Summary. University of Joensuu, Publ. No.29. Joensuu, Finland.

Antle, J. M. 1983. "Incorporating risk in production analysis". *Amer. J. Agr. Econ.* 65:1099-1106

Antle, J. M. and S. M. Capalbo. 1991. "Physical and economic model integration for measurement of the environmental impacts of agricultural chemical use". *Northeastern J. Agr. and Resource Econ.*20:68-82

Apland, J., L. Jonasson and B. Ohlemer. 1994. "Sector modeling for prediction and evaluation". *Swedish J. Agric. Res.* 24:119-130

Armstrong, E. L., D. P. Heenan, J. S. Pate and M. J. Unkovich. 1997. " Nitrogen benefits of lupins, field pea, and chickpea to wheat production in South-eastern Australia". *Aust. J. Agric. Res.* 48)1):39-47

Baffoe, J. K. 1982. *A Comparison benefit and cost analysis of monocultural and rotational systems for g rain corn production (A Multiperiod linear programming approach)*. Unpublished M.Sc. Thesis. University of Guelph, Ontario, Canada.

Baffoe, J. K., D. P. Stonehouse and B. D. Kay. 1986. "A Methodology for farm-level economic analysis of soil erosion effects under alternative crop rotational system in Ontario". *Can. J. Agric. Econ.* 35:55-73

Batte, M. T., D. L. Forster and J. Hitzhusen. 1993. "Organic agriculture in Ohio: An Economic perspective". *J. Prod. Agr.* 6(3):536-542

Beaurefard, G. And A. Brunelle. 1995. Budget Foin Mil-Luzerne 1995 L'hectare. Des Bois-Fencs, Quebec, Canada.

Beaurefard, G. And A. Brunelle. 1996. Government du Quebec Ministre de l'Alimentation, Bureau Regional Ste-Martin, Direction General de la Monteregie, Sector Ouest.

Bell, P. 1991. "High protein lupin for Maine? Enthusiasm of the early 80s may be revived in the 90s". *Maine Organic Farmer & Gardner.* July/August pp 9-10

Berentsen, P.G. M., G. W. Guensen and R. F. Speelman. 1991. "Economic and environmental effects of a new protein evaluation." *J. Dairy Sci.* 76:2332-2343

Berglund, S. H. and E. L. Michalson. 1981. "Soil erosion control in Idaho's Cow Creek watershed: An Economic analysis". *J. Soil and Water Conserv.* 36:158-162

Bertrand, F. and A. Bourbeau. 1995. "Pour une hausse prix du lait de consummation: L'audience a la RMAAQ". *Le Producteur de lait Quebecois.* 16(1)10-14

Bhagat, R. M., P. K. Sharma and T. S. Verma. 1994. "Tillage and residue management effects on soil physical properties and rice yield in Northern Himalayan soils". *Soil Tillage Research.* 29:323-334

Blair, R. and E. E. Lister. 1994. "The Future of animal agriculture in Canada". *Outlook on Agriculture* 23(2):137-142

Block, E. 1996. Personal communication. Department of Animal Science. McGill University. Montreal, Canada.

Bowen, G. D and S. K. A. Danson. 1987. "Nitrogen Research for Perennial crops". *IAEA Bulletin.* 29:5-8

Bradley, S. P., A. C. Hax ann T. L. Magnanti. 1977. *Applied mathematical programming.* Addison-Wesley, New York. N.Y.

Broqua, B., L. Drilleau, J. P. Granier, L. Huguet and M. Simiane. 1984. "Use of sweet lupin seeds for dairy goats". *Dairy Sci. Abstr.*46:384

Brown, S. J. 1995a. "Dairy target and support prices remain unchanged". *Quebec Farmers Advocate, QFA.* 15(2):1

—. 1995b. "Millions expected to slashed from MAPAQ". *Quebec Farmers Advocate, QFA.* 15(2):2

Brubaker, S. and E. N. Castle. 1982. *Alternative policies and strategies to achieve soil conservation. In Soil conservation policies institutions and incentives.* H. G. Halcrow, E. O. Heady and M. L. Cotner (eds.) Soil Conservation Society of America. North Central Research Committee 111: Natural Resource use and environmental policy, Ankey, Iowa. Chpt 14

Brusko, M. 1985. "Beans that save Soil". *The New Farm.* March/April 1985. p. 25-27.

Bundy, L. G., T. W. Andraski and R. P. Wolkwoski. 1993. "Nitrogen credits in soybean-corn sequences on three soils". *Agron. J.* 85:1061-1067

Campos, M. S., C. J. Wilcox and T. H. Spreen. 1995. "Effects of interrelationships of production and reproduction on net returns in Florida". *J. Dairy Sci.* 78(3):704-709

Cao, Y. Z, D. R. Coote, M. C. Nolin and C. Wang. 1993. "Using ^{137}Cs to investigate net soil erosion at two benchmark sites in Quebec". *Can. J. Soil Sci.* 73:515-526

Carlson, G. S. 1995. "Wisconsin's Cropp says dairy industry must export more". *Feedstuffs.* 67(17):5

Cheam, A. H. and G. Gill. 1992. "Managing bromgrass in the Wheat:lupin rotation". *W. Aust. J. Agr.* 33(3):95-99

Chantel, D. L and I. C. Rowland. 1982. "Nitrogen Fixation and Inoculation by Lupins". *J. Agr. Western Aust.* 23:92-95

Chisholm, A. H. 1992. "Australian agriculture: A Sustainable story". *Aust. J. Agr. Econ.*36(1):1-30

Christensen, L. A. and P. E. Norris. 1988. "Management effects on runoff soil and nutrient losses from highly erodible soils in the Souther Plains". *J. Soil Water Conserv.* 43:407-410

Church, D. C. 1984. *Livestock feeds and feeding.* 2nd ed. O & B Books Inc. Corvallis, Oregon, USA.

Cooper, E. L. 1990. *Fundamentals and applications. AgriScience.* New York:. Delmar Publ. Inc. p. 103

Coote, R. D., J. Dumanski and J. F. Ramsey. 1981. *An Assessment of the degradation of agrucultual lands in Canada*. L.R.R.I. contribution No. 118. Research Branch, Agr. Can., Ottawa, Ontario. pp.86

Coote, R. D. and H. N. Hayhoe. 1995. *The Rainfall and runoff factor (R).* In *RUSLEFAC: Revised Universal Soil Loss Equation for Application in Canada.* Chapter 2. A Handbook for estimating soil loss from water erosion in Canada. E. A., Pringle, G. J. Wall and I. J. Shelton (eds.). Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

Coote, R. D.. 1995. *The Slope factor (S). In RUSLEFAC: Revised Universal Soil Loss Equation for Application in Canada.* Chapter 4. A Handbook for estimating soil loss from water erosion in Canada. E. A., Pringle, G. J. Wall and I. J. Shelton (eds.). Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

Cransberg, L. and D. J. McFarlane. 1994. "Can perennial pastures provide the basis for a sustainable farming system in Southern Australia?". *New Zealand J. Agr. Res.* 37:287-294

CREAQ. Avril 1988. *Sorgho fourrager.* Agdex126/821

CREAQ. Octobre 1990. *Foin de luzerne et fleole.* Agdex 121/821

CREAQ. Juin1993. *Mais fourrager* 111/821

CREAQ. Novembre 1993. *Avoine (Pour alimentation animale).* Agdex 113/821

CREAQ. Novembre 1993. *Orge (Pour alimentation animale).* Agdex 114/821

CREAQ. Novembre 1993. *Mais-grain* 111/821

CREAQ. Novembre 1993. *Soya.* Agdex 141/821

CREAQ. 1994. *Intrants en agriculture.* Indice des prix. Agdex 855

Croker, K. P.; J. G. Allen; D. S. Petterson; H. G. Masters and R. F. Frayne. 1979. "Utilization of Lupin Stubble by Merino Sheep: Studies of Animal Performance, Rates and Time of Stocking, Lupinosis, Liver Copper and Zinc, and Circulating Plasma Enzymes". *Aust. J. Agr. Res.* 30:551-564

Croker, K., C. Macdonald and J. Allen. 1994. "Lupins stubbles: Getting the best with weaner sheep". *W. Aust. J. Agr.* 35:148-150

Crowder, B. M., H. B. Poinke, D. J. Epp and C. E. Young.1985. "Using CREAMS and economic modeling to evaluate conservation practices: An Application". *J. Environ. Quality*. 4:428-434

Culver, D., O. R. Morris and Y. Beaulieu. 1985. *Nitrogen fertilizer use and productivity opportunities for Eastern Canadian farmers*. Ottawa, Ont. Development Policy Directorate, Agriculture Canada

Dabbert, S. and P. Madden. 1986. The Transition to organic agriculture: A Multi-year simulation model of a Pennsylvania agriculture. *Amer. J. Alt. Agr.* 1:99-107

Davis, N., B. Stanton and R. D. Smith. 1989. *Farm productivity/profitability*. In *Staying competitive into the 21st century: Issues and challenges facing the New York State dairy industry, Report of Governor's conference held in Albany, New York, June 21-22,1988*. O. D. Forker and A Novakovic (eds.) Dept. Agr. Economics, New York State College of Agr. and Life Sci., Cornell Univ., Ithaca, New York. pp 8-13

Diebel, P. L., J. R. Williams and R. V. Llewelyn. 1995. "An Economic comparison of conventional and alternative cropping systems for a representative Northeast Kansas farm". *Review Agr. Econ. 17(3):323-335*

Dillon, J. L. 1976. "The Economics of systems research". *Agricultural Systems*. 1:5-22

Domanico, J. L, P. Madden and E. J. Partenheimer. 1986. "Income effects of limiting soil erosion under organic, conventional, and no-till systems in Easter Pennsylvania". *Amer. J. Alt. Agr.* 1:75-82

Domanico, J. L, C. Gempesaw, R. Bacon and U. Toensmeyer. 1989. "Qualitative choice models for determining factors influencing consumer's preference for package sizes of selected produce items". *J. Food Dist. Res.* 20:54-55

Dobbs, T. L., L. A. Weiss and M. G. Leddy. 1987. *Costs of production and net returns for alternative farming systems in northeastern South Dakota*. 1986 and normalized situations. Research Report 87-5. Economics Dept. South Dakota State Univ. Brooklings.

Doster, D. H. , D. R. Griffith, J. V. Mannering and S. D. Parsons. 1983. "Economic returns from alternative corn and soybean tillage systems in Indiana". *J. Soil and Water Conserv.* 38:504-508

Duffy, P. A. and C. R. Taylor. 1993. "Long-term Nitrogen placing on a corn-soybean farm: A Dynamic programming analysis". *Agr. Systems*. 42(1):57-72

Easter, K. W. and M. L. Cotner. 1982. *Evaluation of current soil conservation stragegies. In Soil conservation policies institutions and incentives.* H. G. Halcrow, E. O. Heady and M. L. Cotner (eds.) Soil Conservation Society of America. North Central Research Committee: Natural Resource use and environmental policy, Ankey, Iowa. pp.283-391

Eastridge, M. L. and W. P. Weiss. 1994. *New release of Ohio dairy ration program: Research highlights*, August 1994. OARDC, Ohio.

Elmore, R. W. 1996. "Our relationship with the ecosystem and its impact on sustainable agriculture". *J. Prod. Agr.* 9(1):42-45

El-Nazer, T and B. A. McCarl. 1986. "The Choice of crop rotation: A Modeling approach and case study". *Amer. J. Agr. Econ.* 68:125-136

Ensminger, M. E., J. O. Oldfield and W. W. Heimemann. 1990. *Feeds and nutrition.* 2nd ed. The Ensminger Publishing Co. Clovis, California, USA.

Epplin, F. and E. O. Heady. 1984. *Beef gain response to alternative protein levels.* In *Livestock response functions.* E. O. Heady and S. Bhide (eds.). The Iowa State University Press, Ames, Iowa. Chpt 10 (pp.251-256)

Erba, E. M., and W. A. Knoblauch. 1995. "Two potential uses of excess capacity in the milking parlor". *J. Dairy Sci.* 78(3):710-718

Erwing, M. A.; D. J. Pannell and P.K. James. 1987. The Profitability of Lupin:Cereal Rotations. In MIDAS - A *Bioeconomic Model of a Dryland Farm system.* Kingwell, R. S. & D.L. Pannell. (Eds), Pudoc, Wageningen

Ess, D. R., D. H. Vaughan, J. M. Luna and P. G. Sullivan. 1994. "Energy and economic savings from the use of legume cover crops in Virginia corn production". *Amer. J. Alt. Agr.* 9(4):17

Evans, J., G. E. O'Conner, G. L. Turner, D. R. Conventry, N. Fettell, J. Mahoney, E. L. Armstrong and D. N. Walsgott. 1989. "N_2 fixation and its value to soil N increase in lupin, field pea and other legumes in South-Eastern Australia". *Aust. J. Agri. Res.* 40:791-805

Evans, J; N. A. Feuell; D. R. Coventry; G. E. O'Connor; D. N. Walsgott; J. Mahoney; and E. L. Armstrong. 1991. "Wheat Response After Temperate Crop Legumes in South-Eastern Australia". *Aust. J. Agr. Res.* 42(1):31-43

Fahad, A. A, L. N. Mielke, A. D. Flowerday, and D. Swartzendruber. 1982. "Soil physical properties as affected by soybeans and other cropping sequences". *Soil Sci. Soc. Amer. J.* 46:377-381.

Fisher, L. K. 1982. *Trade-offs among soil conservation, energy use, exports and environmental quality: A Discussion.* In *Soil conservation policies institutions and incentives*. H. G. Halcrow, E. O. Heady and M. L. Cotner (eds.) Soil Conservation Society of America. North Central Research Committee 111: Natural Resource use and environmental policy, Ankey, Iowa. pp.274-279

Foltz, J. C., J. G. Lee, M. A. Martin and P. W. Preckel. 1995. "Multiattribute assessement of alternative cropping systems". *Amer. J. Agr. Econ.* 77(2):408-420

Forest, J. F. 1992. *The Economics of conversion to organic agriculture: A Rotation plan. Unpublished M.Sc.* Thesis, McGill University, Montreal, Canada.

Fox, G., A. Weersink, G. Sarwar, S. Duff and B. Deen. 1991. "Comparative economics of alternative agricultural production systems". *Northeastern J. Agr. and Resource Econ.* 20:124-142

Francis, C. A. and J. W. King. 1988. "Cropping Systems based on farm derived, renewable resources". *Agricultural Systems.* 27:67-75

Frey, F. 1989. "Range of adaptation of lupines as a crop for organic agriculture". *International Federation of Organic Agricultural Movements, (IFOAM)* Bulletin No. 8:10-13

Frye, W. W., O. L. Bennett and G. J. Buntely. 1985. *Restoration of crop productivity on eroded or degraded soils. In Soil erosion and crop productivity.* R. F. Follette and B. A. Stewart (eds.). America Society of Agronomy, Inc., Crop Science Society of America, Inc. Soil Science Society of America, Inc., Publishers, Madison, Wisconsin. pp. 335-335

Fuglie, K. O. and D. J. Bosch. 1995. "Economic and environmental implications of soil nitrogen testing: A Switching-regression analysis". *Amer. J. Agr. Econ.* 77(4):891-900

Gardiner, M. R. 1975. "Lupinosis". *J. Agr. Western Aust.*16(2):26-33

Gaudencio, C. De. A.; J. T. Yorinori; D. L. P. Gazziero; Y. R. Mehta; J. F. M. Bairrao; M. C. N. De. Oliveira and E. Torres. 1988. "Rotations and Succession of Crops with Soybeans in a Direct-drilling System in Londrina". *Field Crop Abstr.* 1990 43(8):740

Gempesaw, C. W. II., J. R. Bacon and J. C. Elterich. 1992. "An Economic analysis of dairy concentrate feeding systems under uncertain feed costs and milk prices". *J. Prod. Agr.* 5(3):399-404

Gillespie, J. R. 1987. *Animal nutrition and feeding*. Delmar Publishing Inc., Albany, NY. pp.133-148

Gladestone, J. S. 1970. "Lupins as crop plants". *Field Crops Abstr.* 24:123

Gladestone, J. S. 1990. "Development of lupins as a new crop legume". *Food Aust.* 42:270-272

Godfrey, N. W. 1982. "Lupins: Using Lupins in Pig Feeds". *J. Agr. Western Aust.* 23(4):98-99

Gonda, H. L. Lindberg and J. Bertilsson. 1995. "Effects of level and degradability of rapeseed meal in rations for dairy cows". *Acta. Agric. Scand. Sect. A. Animal Sci.* 45(1):36-44

Govindasamy, R. and M. Huffman. 1993. "Efficiency of U.S. conservation compliance program". *Agr. Econ.* 8:173-185

Groupe de recherche en economie et politique agricoles. 1995. *Les Faits saillants laitiers quebecois*. Department D'Economie Rurale. University of Laval. 9th Edition.

GROUPE GEARGI inc. 1994. *Intrants en agriculture.* Indice des prix. Agdex 855

Gum, R. L., L. M. Arthur, E. B. Oswald and W. E. Martin. 1982. *Quantified evaluation for decisions: Measuring achievement of environmental goals and analysing tradeoff.* Oregon State University, Corvallis, Oregon.

Guillaume, J., J. C. Chenieux and M. Rideau. 1979. "Feeding value of *Lupinus albus* L. in chicken diets". *Nutr. Rep. Int.* 20:57-65

Guillaume, B., D. E. Otterby, J. G. Linn and M D. Stern. 1987. "Comparison of sweet white lupin seeds with soybean meal as a protein supplement for lactating dairy cows". *J. Dairy Sci.* 70:2339-2348

Hale, O. M. and J. D. Miller. 1985. "Effect of either sweet or semi-sweet blue lupine on performance of swine". *J. Anim. Sci.* 60:989

Haq, N. 1993. *Lupins (Lupinus species). In Underutilized crops: Pulses and vegetables.* J. T. Williams (ed.). Chapman & Hall, London. pp. 103-130

Hawthorne, H. A. and G. M. Fromm. 1978. "An evaluation of whole lupin grain, hammer-milled barely, and mixtures of the two as concentrates in rations for yearling steers fed in pens". *Aust. J. Exp. Agr. Anim. Husb.* 18:613

Hazell, P. B. and R. D. Norton. 1986. *Mathematical programming for economic analysis*. MacMillan Publ. Co. New York. N.Y.

Heady, E. O. 1982. *Trade-offs among soil conservation, energy use, exports and environmental quality. In Soil conservation policies institutions and incentives.* H. G. Halcrow, E. O. Heady and M. L. Cotner (eds.) *Soil Conservation Society of America. North Central Research Committee 111: Natural Resource use and environmental policy*, Ankey, Iowa. pp.254-273

Heady, E. O. and W. V. Candler. 1958. *Linear Programming Methods*. Ames, Iowa: Iowa State University Press. Chapter 6.

Heady, E. O. and J. L. Dillon. 1961. *Agricultural production functions*. Ames, Iowa State Univ. Press. Iowa.

Heady, E. O., K. J. Nicol and J. C. Wade. 1976. "Economic trade-offs to limit nonpoint sources of agricultural pollution". *Water Air Soil Poll.* 5:415-430

Heady, E. O. and G. Vocke. 1979. "Programmed impact of environmental restraints applied to U.S. agriculture". *J. Environ. Qual.*. 8:143-148

Heady, E. O. and G. Vocke. 1992. *Economic models of agricultural land conservation and environmental improvements.* 1st ed. Iowa Univ. Press.

Heenan, D. P. and A. C. Taylor. 1995. "Soil pH decline in relation to rotation, tillage stubble retention and nitrogen fertilizer in S.E. Australia". *Soil use and management.* 11(1):4-9

Heichel G. H, and D. K. Barnes. 1984. Opportunities for meeting crop nitrogen needs from symbiotic nitrogen fixation. In Organic Farming: Current technology and its role in sustainable agriculture. *Amer. Soc. Agron.* Spec. Publ. 46:49-60

Henery, G. M., M. A. DeLorenzo, D. R. Beede, H. H. Van Horn, C. B. Moss and W. G. Boggess. 1995. "Determining optimal nutrient management strategies for dairy farms". *J. Dairy Sci. 78(3):693-703*

Herbek, J. H., W. W. Frye and R. L. Blevins. 1987. *Nitrogen from legume cover crops for no-till corn and grain sorghum. In The Role of legumes in conservation tillage systems.* The Proceedings of national conference University of Georgia, Athens. April 27-29,1987. J. F. Power (ed.) Soil Society of America. Soil conservation of America. pp 51-52

Herman, J. W. 1995. "Outmoded policies hamper development of U.S. dairy industry". *Feedstuffs.* 67(17):12

Herridge, D. F. 1982. *Crop rotations involving legumes. In Nitrogen fixation in legumes*. J. M. Vincent (ed.), Academic Press, Tokyo. pp.254-261

Herridge, D. F. and K. A. Dano. 1995. Enhancing crop legume N_2 fixation through selection and breeding. *Plant and Sci.* 174(1-2):51-82

Hesterman, O. B. 1988. *Exploiting forage legumes for nitrogen contribution in cropping systems*. In *Cropping strategies for efficient use of water and nitrogen*. W. L. Hargrove (ed.) ASA Special Publ. 51. ASA, CSSA and SSSA, Madison, WI. pp 155-166

Hesterman, O. B. and T. L. Thorburn. 1994. A Comparative approach to sustainable agriculture: W. K. Kelloggg's integrated farming systems initiative. *J. Prod. Agr.* 7:132-134.

Higgs, R. L.; A. E. Patterson and W. H. Paulson. 1990. Crop rotations: Sustainable and profitable. *J. Soil and Water Conservation.* 45(1):68-70

Hill, G. D. 1977a. The Composition and nutrition value of lupin seed. *Nutr. Abstr. Rev. B.* 47:511

Hill, L. D. 1977b. Super lupin. *The Henery Doubleday Res. Assoc. Newsletter.* 69:23-25

Hoag, D. L. and K. E. Jack. 1990. Low-input farming systems under conservation compliance. *J. Soil and Water Conserv.* 45:71-74

Hooge, D. M. 1996. Strategies necessary to cope with rising feed costs. *Feedstuffs.* 68(8):1,16-17

Hough, C. 1979. *What's New in Water Conservation*. Crop Prod. Symp. Proc., Amarillo, Texas. p. 1-3

House, C. 1996. Per-cow milk output drops; economist cites costly feed. *Feedstuffs.* 68(9):3

Huang, W-Y and N. D. Uri. 1992. An Analysis of the marginal value of cropland and nitrogen under alternative farm programs. *Agr Systems.* 35:433-453

Hudson, N. 1995. *Soil conservation.* 3nd ed. B. T. Butsford Limited, London. pp 36-52

Hulme, D. J., R. C. Kellaway, P. J. Booth and L. Bennett. 1986. The CAMDAIRY model for formulating and analysing dairy cow rations. *Agricultural Systems.* 22:81-108

Hunt, P. G; T. A. Matheny, and A. G. Wollum II. 1985. *Rhizobium japonicum* nodular occupancy, nitrogen accumulation, and yield for determinate soybean under conservation and conventional tillage. *Agron. J.* 77:579-584

Hunter, D. and L. H. Keller. 1983. *Economic Evaluation of Alternative Crop and Soil Management Systems for Reducing Soil Erosion Losses on West Tennessee Farms.* The University of Tennessee Agr. Exp. Station, Knoxiville, Tennessee, Bulletin 627.

Hwang, S. W., J. Alwang and G. W. Norton. 1994. Soil conservation practices and farm income in the Dominican Republic. *Agricultural Systems.* 46:59-77

Ikerd, J. E. 1991. A Decision support system for sustainable farming. *Northeastern J. Agr. and Resource Econ.* 20:109-113

Innes, R. and S. Ardila. 1994. Agricultural insurance and soil depletion in a simple dynamic model. *Amer. J. Agr. Econ.* 76:371-384

Irwin, G. D. 1968. A Comparative review of some firm growth models. *Agr. Econ. Res.* 20:82-100

Isabelle, R., R. Daine and C. Line. 1995. *Les Faits Sallants laitiers, quebecois.* Group de Recherche en Economie et Politique Agricoles Department d'Economie Rurale. 1995. 9th edition.

Jannasch, R. 1994. Alternative silage: Lupins intercropped with cereals. *Sustainable Farming.* Spring 1994

Johnson, L. M. 1979. Crop rotation economics in Western Canada using farm budgeting criteria. *Can. Farm Econ.* 14:20-28

Johnson, R. G. and B. Ali. 1982. Economics of wheat fallow cropping systems in Western North Dakota. *Western J. Agr. Econ. 7:67-78*

Johnson, J. L., A. M. Heagler and H. O. Zapata. 1993. Economic impact of alternative rotation in sugarcane production. *Louisiana Agr.* 36(2):14-17

Johnson, J. R. Jr., J. D. Miller and D. M. Bedell. 1986. Tiftwhite-78 lupine seed as a fed stuff for cattle. *J. Dairy Sci.* 64:142

Johnson, D. E., G. M. Ward and J. Torrent. 1992. The environmental impact of Bovin Somatropin use in dairy cattle. *J. Environ. Quality.* 21:157-162

Kalter, R. J. and A. L. Skidmore. 1991. *DAIRYPERT™: An Expert systems approach for improving dairy farm management practices and assisting technology transfer*. Dept. Agr. Econ. N.Y. State college of Agr. and Life Sci., Cornell Univ., Ithaca, New York pp. 1-8

Kaplan, K. 1988. White lupin: Future grain for the North? *Agr. Res.* Jan. P.5

Katz, M. 1985. *A System analysis of the contribution of legume crops to energy and conservation and to profitability in the corn cropping program*. M.Sc. Thesis, McGill University Montreal. p. 4-6

Kay, R. D. 1986. *Farm management: Planning, control,and implementation*. 2nd ed. McGraw-Hill Book Company, Toronto. Chpt.5 (pp.83-306)

Keenely, D. R. 1989. Towards a sustainable agriculture: Need for clarification on concepts and terminology. *Amer. J. Alt. Agr.* 4(3/4):101-105

King, P. M. 1984. Crop and pasture rotations a Coonalpyn, South Australia: Effects on soil born diseases, soil nitrogen and cereal production. *Aust. J. Exp. Agric. Anim. Husb.* 24:555-564

Kingwell, R. 1996. Programming models of farm supply response: The impact of specification errors. *Agr. Systems* 50(3):307-324

Kirby, P. C. and G. R. Mehuys. 1987. The Seasonal variation of soil erosion by water in SouthWestern Quebec. *Can. J. Soil. Sci.* 67:55-63

Kung, L. Jr., K. Maciorowski, K. M. Powell, S. Weidner and C. L. Eley. 1991. Lupin as a protein supplement for growing lambs. *J. Anim. Sci.* 69:3339-3405

Kurtz, L.T., L. V. Boone, T. R. Peck and R. G. Hoeft. 1984. *Crop rotations for efficient nitrogen use. In Nitrogen in crop production.* R. D. Hauck (ed.) American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. Madison, Wisconsin, U.S.A. pp. 295-306

LaFrance, J. 1992. Do increased commodity prices lead to more or less soil degradation? *Aust. J. Agr. Econ.* 36:57-82

Lal, R. 1987. Effect of soil erosion on crop productivity. Crit. Rev. Plant Sci.. Boca Raton, Fla. *CRC. Press.* 5:303-367

Lal, R. 1992. Conservation tillage for sustainable agriculture: Tropical versus temperate environments. *Adv. Agron.* 42:85-197

Lal, R. 1995. *Minimum tillage systems. In Subsoil management techniques*. N. S. Jayawardane and B. A. Stewart (eds.) Lewis Publishers, Tokyo. pp. 1-33

Larney, F. J., R. C. Izaurralde, H. H. Janzen, B. M. Olson, E. D. Solberg, C. W. Lindwall and M. Nyborg. 1995. Soil erosion - crop productivity relationships for six Alberta soils. *J. Soil and Water Cons.* 50(1)87-91

Lazarus, S. S. and G. B. White. 1983. *The economic potential of crop rotations in long island potato production*. Depart. Agr. Econ., Cornell Univ. Exp. Stn. A.R.Res 83-20

Leddy, M. G. 1987. *An Economic analysis of alternative farming systems in Northeastern South Dakota*. Unpublished M.Sc. Thesis, South Dakota State University.

Le Producteur de lait Quebecois. 1995. Rapport Annuel 1994

Leduc, R. 1997. Personal communication. Ministere de l'Agriculture des Pecheries et de l'Alimentation, Conseiller en productions animals, Direction regionale 07, Quebec.

Lees, P. 1978. High protein lupins. *Practical Self Sufficiency* 15:8-9

Lefebvre, D. 1996. Personal communication. Programme d'Analysis des Troupeaux Latiers du Quebec (PATLQ).

Legault, B. 1996. UPA. Union producteur D'Agricoles. Personal communication.

Leger, K. 1996. Dairy industry glad uncertainty is over. *Financial post*. March 8,1996 pp8

Liebman, M. and R. R. Janke. 1990. *Sustainable weed management practices*. In *Sustainable agriculture in temperate zones*. C. B. Francis; C. B. Flora, and L.D. King. (eds.). John Wiley and Sons, Inc. New York. N.Y. pp.111-143

Lindstorm, M. J. 1986. Effects of residue harvesting on water runoff, soil erosion and nutrient loss. *Agriculture, Ecosystems and Environment* 16:103-112

Lockie, S., A. Mead, F. Vanclay and B. Butler. 1995. Factors encouraging the adoption of more sustainable crop rotations in South-East Australia: Profit,, sustainability, risk and stability. *J. Sust. Agr.* 6(1):61-79.

Lopez-Bellido, L. and M. Fuentez. 1986. Lupins as Alternative Protein source. *Adv. Agron.* 40:239-295

Lopez-Bellido, L. and M. Fuentes. 1990. Growth and yield components of lupin cultivars. *Agron. J.* 82:1050-1056

Lory, J. A., M. R. Russell and T. A. Peterson. 1995. A Comparison of two nitrogen credit method: Traditional vs. Difference. *Agron. J.* 87(4):648-651

Lyman, B. E., R. A. Levins, M. A. Schmitt and W. F. Lazarus. 1990. Commodity programs and sustainable cash grain farming. *J. Soil and Water Conserv.* 45:86-87

Madden, J. P. 1989. What is alternative agriculture? *Amer. J. Alt. Agric.* 4:32-34

Malinda, D. K. 1995. Factors in conservation farming that reduce erosion. *Aust. J. Exp. Agr.* 35(7):969-978

MAPAQ. 1989-1994. Ministere de l'Agriculture, des Pecheries et de l'Alimantation du Quebec. Direction des etudes economiques. Service de l'economie de la production.

MAPAQ. 1995. *Mais-Grain. Cout de production indexe.* Janvier 1994 Decembre 1994

MAPAQ. 1995. *Orge fourragere. Cout de production indexe.* Janvier 1994 Decembre 1994

MAPAQ. 1995. *Avoine. Cout de production indexe.* Janvier 1994 Decembre 1994

MAPAQ. 1995. *Soya. Cout de production indexe.* Janvier 1994 Decembre 1994

Martin, J. H. and W. H. Leonard. 1967. *Principles of field crop production.* 2nd ed. The Macmillan Company, New York, N.Y.

Martin, G. W. and J. T. Touchton. 1983. Legumes as a cover crop and source of nitrogen. *J. Soil and water Conser.* 38:214-416

Mason, S. 1995. Increase intake to boost feed efficiency and profit. *Dairy Guide.* 114(5):5

May, M. G., D. G. Johnson, D. E. Otterby and J. G. Linn. 1990. Effects of substituting lupine seed protein for soybean meal in dairy cattle diets. *J. Dairy Sci.* (Suppl. 1) Abstract. 73:167

Mayer, D. G., J. A. Belward and K. Burrage. 1996. Use of Advanced techniques to optimize a multi-dimensional dairy model. *Agr. Systems.* 50:239-253

Mawapangna, M. N. and D. Debertin. 1996. Choosing between alternative farming systems: An Application of the analytical hierarchy process. *Review Agr. Econ.* 18:385-401

McCarl, B. A. and Nuthall. 1982. Linear programming for repeated use in the analysis of agricultural systems. *Agricultural Systems.* 8:17-39

McConnel, K. E. 1983. An Economic model of soil conservation. *Amer. J. Agr. Econ.* 65:83-89

McCullough, M. E. 1973. *Optimum feeding of dairy animals for meat and milk.* University of Georgia Press, Athens. pp 143

McLaughlin, A. and P. Mineau. 1995. The Impact of agricultural practices on the biodiversity. *Agriculture, Ecosystems and Environment.* 55:201-212

McNeely, J. A. 1988. *Economics and biological diversity: Developing and using economic incentives to conserve biological resources.International Union for conservation of Nature and Natural Resources.* Gland, Swizerland. pp 123-194QH75 M366 1988

Miranowski, J. A. and B. D. Hammes. 1984. Implicit prices of soil characteristics for farm land in Iowa. *Amer. J. Agr. Econ.* 66:745-749

Molina, J. A. E., Shaffer, M, J., R. H. Dowdy and J. F. Power. 1985. *Simulation of tillage residue and nitrogen management. In Soil erosion and crop productivity.* (eds) R. F. Follett and B. A. Stewart.

Mooso, G. D. 1990. Nitrogen fertilizer replacement value of clovers. *Louisiana Agr.* 34(2):19

Motha, J. G; R. W. Buckland and W. B. Traill. 1972. *The Role of cereals and other crops as livestock feed.* Bureau of Agricultural Economics, Canberra, A.C.T., Australia. pp 17.

Muirhead, S. 1996. Heat-processed soybeans considered good supplement for dairy cows. *Feedstuffs.* 67(7):2

Munson, R. D. and J. P. Doll. 1959. The Economics of fertilizer use in crop production. *Adv. Agron.* 11:133-168

Narayanan, A. V. S., H. T. M. Colwell, Y. Beaulieu and R. D. Zentner. 1983. Economics of selected on farm adjustments for prairie grain farmers in response to rising future energy price. *Agr. Can., Can. Farm Econ.* 18(2)3-11

National Research Council. 1989. *Nutrition requirements of dairy cattle*. National Academy Press, Washington D.C. pp 1

Nelson, A. and R. W. Weaver. 1980. Seasonal nitrogen accumulation and fixation by soybeans grown at different densities. Agron. J. 72:613-616

Nevo, A. R. and T. H. Podmore. 1994. An Integrated expert system for optimal crop planning. *Agr. Systems* 45(1):73-92

Norton, G. W. 1981. The productivity and allocation of research: U.S. Agricultural Experiment Stations, Revisited. *Review Agr. Econ.* 3:1-12

Odegaar, G. 1995. *The world dairy Situation 1995*. Bulletin of the International Dairy Federation. Brussels, Belgium. No. 303/1995

Olney, G. and W. Standing. 1989. Increasing profit on dairy farms. *J. Agr. W. Aust.* 29-30:144-149

Olson, K. and D. Putnam. 1991. *An Economic analysis of lupin as a cash crop compared to soybean.* In *Prospects for lupins in North America: A Symposium sponsored by the centre for alternative plant and animal products*, Univ. of Minnesota, St. Paul, Mn. March 21-22,1991. pp. 165-169

Orazem, P. F. J. A. Miranowski. 1994. A Dynamic model of acreage allocation with general and crop-specific soil capital. *Amer. J. Agr. Econ.* 76:385-395

Osburn, D. D. and K. C. Schneeberger. 1983. *Modern agricultural management: A Systems approach to farming*. 2nd ed. Reston Publishing Company, Inc. Reston, Virginia. Chpt. 9 (pp.164-183).

Ostergaard, S., J. T. Sorensen, J. Hindhede and A. R. Kristensen. 1996. Technical and economical effects of feeding one vs. multiple total mixed rations estimated by stochastic simulation under different dairy herd and management characteristics. *Livestock Prod.* 45(1):23-33

Painter, K. M., D. L. Young, D. M. Granatsein and D. J. Mulla. 1995. Combining alternative and conventional systems for environmental gains. *Amer. J. Alt. Agr.* 10(2):88-96

Pannell, D. J. 1995. Economic aspects of legume management and legume research in dryland farming systems of Southern Australia. *Agricultural Systems* 49:217-236

Pannell, D. 1996. Lessons from a decade of whole-farm modeling in Western Australia. *Review Agr. Econ.* 18:373-383.

Pannell, D. J. and D. A. Falconer. 1988. The Relative Contributions to Profit of Fixed and Applied Nitrogen in a Crop-Livestock Farm System. *Agr. Systems.* 26:1-17

Papendick, R. I., D. L. Young, D. K. McCool and H. A. Krauss. 1985. *Regional effects of soil erosion on crop productivity: The Palouse area of the Pacific Northwest.* In R. F. Follett and B. A. Stewart (ed.) Soil and crop productivity. American Society of Agronomy, Madison, WI. pp. 305-320

Parr, J. F., R. I. Papendick, S. B. Honick and R. E. Meyer. 1992. Soil quality: Alternatives and relationship to alternative and sustainable agriculture. *Amer. J. Alt. Agr.* 7)1):5-11

Peoples, M. B., D. F. Herridge and J. K. Lidha. 1995. Biological nitrogen fixation: An Efficient source of nitrogen for sustainable agricultural production? *Plant and Sci.* 174(1-2):3-28

Perreault Y. and L. Robert. 1992. *Resume du producteurs de lupin.* Region 07. Quebec.

Peterson, W. 1995. Farm programs and the environment: The Case for a limited land payment. *J. Sust. Agr.* 6(2/3):123-156

Peterson, W. R., D. T. Walters, R. J. Supalla and R. A. Olson. 1990. Irrigated crop rotation for energy conservation: A Nebraska case study. *J. Soil and Water cons.* 45:584-588

Pimentel, D. H. C., P. Resosudarmo, K. Sinclair, D. Kurz, M. McNair, S. Crist, L. Shpritz, L. Fitton, R. Saffouri and R. Blair. 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science.* February 24, 1995. 267:1117

Pond, W. G., D. C. Church and K. R. Pond. 1995. *Basic animal nutrition and feeding.* John Wiley & Sons. Toronto. pp 365-414

Pope, C. A. III., S. Bhide and E. O. Heady. 1983. Economics of conservation tillage in Iowa. *J. Soil and Water Conserv.* 38:371-373.

Postgate, J. 1987. *Nitrogen fixation.* 2nd ed. Edward Arnold, A Division of Hodder & Stoughton. London.

Preston, T. R. and A. Zapata. 1995. *Feed resources for milk production in the tropics.* In *Dairy development in the Caribbean region.* D. Walmsley (ed.) Ocho Rios, Jamaica. pp. 139-152

Pringle, E. A., G. J. Wall and J. Shelton. 1995. *RUSLEFAC: Revised Universal Soil Loss Equations for Applications in Canada.* A Handbook for estimating soil loss from water erosion in Canada. Agriculture and Agr-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa

Putnam, J. and K. Alt. 1987. Erosion control: How does it change farm income? *J. Soil and Water Cons.* 42:265-267

Reberge, I., D. Gilbert and L. Cote. *Les Faits Sallants laitiers, quebecois.* 1994. Group de Recherche en Economie et Politique Agricoles Department d'Economie Rurale. 8th edition.

Reeves, T. G., A. Ellington and H. D. Brooke. 1984. Effect of lupins-wheat rotations on soil of subsequent wheat crops grown at several fertility, crop disease and crop yield. *Aust. J. Exp. Agric. Animal Husb* 24:595-600

Reganold, J. P; L. F. Elliot, and Y. L. Unger. 1987. Long-term effects of organic and conventional farming on soil erosion. *Nature.* 330:370-372

Renard, K. G., H. C. Heineman and J. R. Williams. 1978. Comments on measuring of sediment control impact of agriculture. *Water Resource Res.* 15:1278-1280

Richardson, J. W. and D. E. Ray. 1979. *An Application of optimal control techniques to agricultural policy analysis.* Agricultural Experiment Station, Oklahoma State University, Technical Bulletin T-154. 41 pp

Robert, I; D. Gilbert and L.Cote. 1995. *Les faits saillants laitiers, Quebecois.* GREPA.

Rowland, I. C; M. G. Mason and J. Hamblin. 1988. Effect of lupins and wheat on the yield of subsequent wheat crops grown at several rates of applied nitrogen. *Aust. J. Exp. Agr.* 28:91-97

Rowland, I. C; M. G. Mason and J. Hamblin. 1989. The Nitrogen Responses of Wheat Crops Following Lupins. *Western Aust. J. Agr.* 30:22-25

Roy, J. H. B., C. C. Balch, E. L. Miller, E. R. Orskov and R. H. Smith. 1977. *Calculation of the N-requirement for ruminants from nitrogen metabolism studies. In Protein metabolism and nutrition.* Proceedings of the second international symposium in protein metabolism. S. Tamminga (ed.), Wageningen, The Netherlands, May 2-6,1977. pp. 126-129

Rust, J. W., C. C. Sheafter, V. R. Eidman, R. D. Moon and R. D. Mathison. 1995. Intensive rotational grazing for dairy cattle feeding. *Amer. J. Alt. Agr.* 10(4):145-151

Sanderson, J. B. and J. A. Macleod. 1994. Soil nitrate profile and response of potatoes to fertilizer N in relation to time of incorporation of lupin (*Lupinus albus*). *Can J. Soil Sci.* 74:241-246

Santos, H. P. Dos; L. R. Pereira and E. M. Reis. 1990. Crop Rotation. VIII. Effect of Cropping Systems on Wheat yields. *Field Crop Abstr.* 1990 43(7):589

Sarawakoon, S. M. M. and P. Abeygunawaradena. 1995. An Economic assessement of on-site effects of soil erosion in potatio lands in Nuwara Eliya District of Sri Lanaka. *J. Sust. Agr.* 6(2/3):81-92

Sathe S. K; S. S. Deshpande, and D. K. Salunkhe. 1982. Functional Properties of lupin seed *(Lupinus mutabilis)* proteins and protein concentrates. *J. Food Sci.* 47:491

Schmersal, J. 1996. Making the most of your time. *Soybean digest.* 56(1):F-G

Schmitz, A. and T. G. Schmitz. 1994. Supply management: The Past and future. *Can. J. Agr. Econ.* 42(2):125-148

Science Council of Canada. 1986. A Growing concern: Soil degradation in Canada. September 1986.

Science Council of Canada. 1994. *It's Everybody's business: Submissions to the Science Council's Committee on sustainable agriculture*, A Discussion paper. Ottawa. Cat. SS21-5/1991-3E.

Senate of Canada. 1984. *Soil at risk: Canada's eroding future. Standing Senate Committee on Agriculture, Fisheries and Forestry.* Committees and Private Legislation Branch, Ottawa, Ontario. pp.105-121

Shelton, I. J. 1995. *The Crop/vegetation and management factor (C).* In RUSLEFAC: Revised Universal Soil Loss Equation for Application in Canada. Chapter 5. A Handbook for estimating soil loss from water erosion in Canada. E. A., Pringle, G. J. Wall and I. J. Shelton (eds.). Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

Short, C. and E. O. Heady. 1983. *CAR.* Rep-Iowa-State University Center Agr-Rural-Development. Ames, Iowa.

Siddique, K., S. Loss and I. Pritchard. 1995. Pulses: Profitable new crops for the wheatbelt. *W. Aust. J. Agr.* 36(4):112-115

Sinner, J. 1990. Soil conservation: We can get more for our tax dollars. *Choices.* 6:10-13

Smith, D. 1996. Personal communication. Department of Plant Science. McGill University. Montreal, Canada.

Smith, S. R., R. L. Nelson and B. L. Vasilas. 1988. Variation among soybean breeding lines in relation to yield and seedfill duration. *Agron. J.* 80:825-829

Snapp, S. S. and G. D. Jolliff. 1988. New crop development: Opportunity and challenges. J. Prod. Agr. 1:83-89

Solbrig, O.T. and D. J. Solbrig. 1994. *So shall you reap: Farming and crops in human affairs.* Island Press, Washington, D.C. Chpt 11:206-252

Statistics of Canada. 1993. *Farming Facts.* Stat. Can. Catelogue No. 21-522E

Statistics of Canada. 1994a. *Indice des prix des intrants en agriculture.* Agdex 855.

Statistics of Canada. 1994b (various Issues). *Agriculture Economic Statistics.* Stat. Can. Catelogue No. 21-603E.

Statistics of Canada. 1994c. *Dairy review*, Monthly. Cat. No. 23-001

Statistics of Canada. 1997. *Statistics Canada, CANSIM matrices 2623-2631, 4997, 4998 and 6950.CANSIM.* http:\\www.StatCan.Ca

Stocking, M. 1984. *Erosion and soil productivity.* A Review consultants working paper 1. FAO, Rome.

Stonehouse, D. P. 1995. Profitability of soil and water conservation in Canada: A Review. *J. Soil and Water Cons.* 50(2):215-219

Stonehouse, D. P., J. K Baffoe and B. D. Kay. 1987. The impacts of changes in key economic variables on crop rotational choices on Ontario cash-cropping farms. *Can J. Agr. Econ.* 35:403-420

Stonehouse, D. P., B. D. Kay, J. K Baffoe and D. L. Johnston-Drury. 1988. Economic choices of cropping sequences on cash-cropping farms with alternative crop yield trends. *J. Soil Water Conserv.* 43:266-270

Straw, R. A., C. A Mullins, D. L. Coffey and G. M. Milessman. 1991. Nitrogen fertilization of sweet corn varieties. *Tennessee Farm and Home Sci.* 158:20-24

Swanson, E. R. 1956. Application of programming analysis to corn belt farms. *J. Farm Economics.* 38:408-419

Taverner, M. R., D. M. Curic and C. J. Rayner. 1984. A Comparison of the extent and site of energy and protein digestion of wheat, lupin and meat and bone meal by pigs. *J. Sci. Food Agric.* 34:122-128

Thomas, E. 1995. Fertilizer prices expected to rise. *Quebec Farmers' Advocate.* 15(3):14

Troeh, F. R., J. A. Hobbs and R. L. Donahue. 1991. *Soil and water conservation.* 2nd ed. Prenctice-Hall, Engewood Cliffs, N.J.

Unger, P. W. and T. M. McCalla. 1980. Conservation tillage systems. *Adv Agron.* 33:1-58

Unkovich, M. J., J. S. Pate and J. Hamblin. 1994. The nitrogen economy Broadcare lupin in Southwest Australia. *Aust. J. Agric. Res.* 45:149-164

Unkovich, M. J., J. S. Pate, E. L. Armstrong and P. Sanford. 1995. Nitrogen economy of annual crop and pasture legumes in Southwest Australia. *Soil Biol. Biolchem.* 27(4/5):585-588.

UPA. 1994. Union des Producteurs Agricoles: *New Highlights*: Dec. 5,1994. 12(3/4)

Upton, M. 1996. *The Economics of tropical farming system.* Cambridge University Press, New York, NY. pp.328-363

Utter, H. D. and F. E. Justus. 1961. *Determining maximum net returns for cropping systems on Marshall soil using linear programming.* University of Missouri. Agr. Exp. Stat. No. 780

Van Doren, Jr., D. M., W. C. Moldenhauer and G. B. Triplet, Jr. 1984. Influence of long-term tillage and crop rotation on water erosion. *Soil Sci. Soc. Amer. J.* 48:636-640

Van Soest, P. J. 1994. *Nutritional ecology of the ruminant.* 2nd ed. Comstock Publishing Associates: A Division of Cornell University Press. Ithaca. N.Y. pp 337-353

Van Vliet, L. P. 1995. *The Support practice factor (P). In RUSLEFAC: Revised Universal Soil Loss Equation for Application in Canada.* Chapter 6. A Handbook for estimating soil loss from water erosion in Canada. E. A., Pringle, G. J. Wall and I. J. Shelton (eds.). Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

Vanotti, M. B. and L. G. Bundy. 1995. Soybean effects on soil nitrogen availability in crop rotation. *Agron. J.* 87(4):676-680

Vigueault, J. 1995. Federarion des producteurs de lait du Quebec. Longueuil, Quebec. Canada.

Vocke, G. F. and E. O. Heady. 1992. *Analysis of some environmental policies for American agriculture*. In *Economic models of agricultural land conservation and environmental improvement*. E. Heady and G. Vocke (eds.). Iowa State University Press, Ames. Chapt.4 (pp. 109-125)

Walker, D. J. and D. L. Young. 1986. The Effect of technical progress on economic damages and economic incentives for soil conservation. *Land Economics*. 62:83-93

Wall, G. J. 1995a. *The Soil erodibility factor (K). In RUSLEFAC: Revised Universal Soil Loss Equation for Application in Canada*. Chapter 3. A Handbook for estimating soil loss from water erosion in Canada. E. A., Pringle, G. J. Wall and i. J. Shelton (eds.). Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

Wall, G. J. 1995b. Personal Communication. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa

Watkins, B. A. and L. W. Mirosh. 1987. White lupin as a protein source for layers. *Poultry Sci.* 66:1798-1806

Wilson, J. M. and J. Hamblin. 1990. The effect of fumigation, rotation with lupins, and nitrogen application on plant growth and common root rot of wheat at Geraldton, Western Australia. *Aust. J. Agric. Res.* 41:619-631

Wossink, G. A. A., T. J. de Koeijer and J. A. Renkema. 1992. Environmental-economic policy assessment: A Farm economic approach. *Agricultural Systems* 39:421-438

Xu, F., T. Prato and J. C. Ma. 1995. A Farm-level case study of sustainable agricultural production. *J. Soil and Soil Cons.* 50(1):39-44

Young, D. L. and W. A. Goldstein. 1988. *How government farm programs discourage sustainable cropping systems*. In *Proceedings of farm systems research symposium Fayetteville*, Arkansas. pp.443-459

Zahradnik, F. 1984. New soil-healing legumes make poor sites profitable. *The New Farm* 6(5):29

Zobisch, M. A., C. Richter, B. Heiligtag and R. Schlott. 1995. Nutrient losses from cropland in the central highlands of Kenya due to surface runoff and soil erosion. *Soil & Tillage Research*. 33(2):109-116

APPENDICES

Appendix 1. Crop budget of corn grain (CG) grown in 1994 by a representative dairy farmer in Southwest Quebec[u]

Item	Description	1994[*] $/ha	1994[*] $/t
Seed	Grains: 70,000/ha@$93.54/80,000grains	81.85	11.69
Fertilizer	12-27-22: 200kg/ha @$275.95/t	55.19	7.88
	46-00-00: 320kg/ha@$339.65/t	108.69	15.53
Lime	CaCO3 : 5t/ha/5years 1t/ha@$27/t	27.00	3.86
Pesticides	Dual 960-E: 2.25L/ha@$22.10/L*40%	19.89	2.84
	Marksman : 4.50L/ha@$8.65/L*40%	15.56	2.22
Sub-total		**308.18**	44.03
Ploughing	N/A		
Disking	N/A		
Fertilizer spreading	N/A		
Chem spray	N/A		
Seeding	N/A		
Harvesting	N/A		
Total field operation		66.91	9.56
Farm transport		8.00	1.14
Fuel and lubrication		29.73	4.25
Machinery repair and maintenance[γ]		28.95	4.14
Sub-total		**133.59**	19.08
Other costs			
Drying	Propane: 39L/t@$0.22/L@7t	60.62	8.66
Electricity	16kwh/t@$0.76/kwh@7t	7.91	1.13
Storage and aeration	7KWh/t@$0.12/KWh@7t	3.46	0.49
Hired labour[c]	5.3 hrs/ha@$10.20/hr	54.06	7.72
Harvest insurance[c]	$25.11/ha	25.11	3.59
Stabilization insurance[c]	$18.11/ha	18.11	2.59
Gross revenue insurance[c]	$82.9/ha	82.90	11.84
Marketing board	$0.75/t@7t	5.25	0.75
Short-term interest	$699.19/ha@11% for 6 months	38.46	5.49
Sub-total		**295.88**	42.27
Total variable cost		**737.65**	105.38
Compensation, Stablization[c]		177.15	25.31
Compensation, Gross revenue[c]		48.43	6.92
Total compensation		225.58	32.23
Cost after compensation		**512.07**	73.15
Selling price[c]		1176.18	168.03
Less transportation (off-farm)		18.20	2.60
Net selling price		1157.98	165.43
Yield (tonnes/ha)[µ]	7		
selling price[v]	6.08t/ha	**1157.98**	**192.36**
Family labour (hr./ha)[u]	7.2	7.2	1.03

[*] Price derived from CREAQ. Novembre 1993. Mais-grain. Agdex 111/821, with Farm Input Price Index (CREAQ, 1994)

[µ] Yield taken as harvested

[v] Yield assumed as 100% DM basis

Appendix 2. Crop budget of corn silage (CS) grown in 1994 by a representative dairy farm in Southwest Quebec

Item	Description	1994* $/ha	$/t
Seed	Grains: 76,000/ha@$86/80,000grains	81.85	2.04
Fertilizer	18-46-00: 200/ha @$310/t	65.81	1.65
	30-00-20: 450/ha@$320/t	152.84	3.82
Lime	1/ha@$27/t	27	0.68
Pesticides	Dual 960-E: 2.25L/ha@$22.10/L	49.73	1.14
	Marksman : 4.50L/ha@$8.50/L	38.91	0.97
Sub-total		**416.14**	**10.3**
Field operation			
Ploughing		16.73	0.42
Disking		10.47	0.26
Fertilizer spread		5.39	0.13
Chem spray		2.57	0.06
Seeding		8.19	0.20
Harvest and ensilage		64.06	1.60
Blowing silage to silo[J]		13.07	0.33
Farm transportation		19.14	0.48
Fuel and lubrication[Ψ]			
Machinery repair and maintenance[7]		24.46	0.61
Sub-total		**164.08**	**2.69**
Other costs			
Storage[J]		100.40	2.51
Harvest insurance[J]		10.27	0.26
Interest (short)	$682.26/ha@11% for 6 months	37.54	0.94
Sub-total		**148.21**	**3.71**
Total variable costs		**728.43**	**18.21**
Yield (tonnes/ha)	40		
Family labour (hr.)[P]	20.84	20.84	0.52

* Price derived from CREAQ. Juin 1993. Mais fourrager. Agdex 111/821, with Farm Input Price Index (CREAQ, 1994)

[7] Taken as 10% of the difference between contract service cost paid to hired operator and cost of variable incurred when worked by the owner

[Ψ] cost included in the field operation

Appendix 3. Crop budget of barley (BA) grown in 1994 by a representative dairy farm in Southwest Quebec[d]

Item	Description	1994* $/ha	$/t
Seed	150 kg/ha@$12.20/40 kg	45.75	13.07
Fertilizer	25-15-15: 300kg/ha @$343.90/t	103.17	29.48
Lime	CaCO2 : 5t/ha/8years 0.625t/ha@$27/t	16.88	4.82
Pesticides	Round-up: 5L/ha@10%@$11.18/L	5.59	1.60
	Herbicide for straw: $13.22/ha	13.22	3.78
String bale[δ]	1.8t/ha@$2.86/t	5.15	1.47
Sub-total		**189.76**	**54.22**
Field operation			
Ploughing	N/A	16.73	4.78
Disking	2x vibro	8.46	2.42
Fertilizer spread	N/A	2.69	0.77
Chem spray	N/A	1.98	0.57
Seeding	N/A	5.95	1.70
Harvesting	N/A	20.19	5.77
Farm transport	N/A	3.19	0.91
Fuel and lubrication[Ψ]			
Machinery repair and maintenance[Ψ]	N/A	22.00	6.29
Baling straw	N/A	15.61	4.46
Sub-total		**96.80**	**27.66**
Other costs			
Drying	3.5t/ha@$2.10/t	7.55	2.16
Electricity	N/A		
Storage and aeration	3.5t/ha@$2.20/t	7.70	2.20
Hired labour	5 hrs@$10.20/hr	51.00	14.57
Harvest insurance[δ]	3.5t/ha@$100/t@4.01%@80%	10.22	2.92
stabilization insurance[δ]	$45.29/ha	45.29	12.94
Gross revenue insurance[δ]	$55.20/ha	55.20	15.77
Marketing board	3.5t/ha@$0.85	2.98	0.85
Short-term interest	$466.50/ha@11% 6 months	25.66	7.33
Sub-total		**205.60**	**58.74**
Total variable cost		**492.16**	**140.62**
Compensation,stabilization[δ]	$18.91/ha	18.91	5.40
Compensation, gross revenue[δ]	$230.32/ha	230.32	65.81
Total compensation		**249.23**	**71.21**
Straw	1.8t/ha@$52.50/t	**94.50**	27.00
Revenue from stabilisation, gross revenue compensation and sales of straw		343.73	98.21
Total cost after compens.		148.43	42.41
Selling price[δ]		697.33	199.24
Less transportation (off-farm)		26.60	7.60
Net selling price (grain and straw)		670.73	191.64
Cost of production (grain and straw) after compensation		**242.93**	**69.41**
Yield (tonnes/ha)[μ]	3.5	576.23	164.64
Selling price for grains[v]	3.08t/ha	**576.23**	**187.09**
Family labour (hr.)[d]	9	9	2.57

* Price derived from CREAQ. Novembre 1993. Orge pour alimentation animale. Agdex 114/821, with Farm Input Price Index (CREAQ, 1994).

Ψ cost included in the field operation

δ For straw

μ Yield taken as harvested

v Yield assumed as 100% DM basis

Appendix 4. Crop budget of oats (OT) grown in 1994 by a representative dairy farm in Southwest Quebec[€]

Item	Description	1994[*] $/ha	$/t
Seed	120 kg/ha@$12.71/40 kg	38.13	13.62
Fertilizer	219-19-19: 230/ha @$351.30/t	80.80	28.86
Lime	CaCO2 : 5t/ha/8years 0.625t/ha@$27/t	16.88	6.03
Pesticides	Round-up: 5L/ha@10%@$11.20/L	5.60	2.00
	Herbicide for straw: $13.22/ha	13.23	4.73
tring bale[δ]	2.2t/ha@$2.86/t	6.29	2.25
Sub-total		**160.93**	57.48
Field operation			
Ploughing	N/A	16.73	5.98
Disking	(2X vibro)	8.47	3.03
Fertiler spread	1X	2.72	0.97
Chem spray	1X	1.92	0.69
Seeding	N/A	5.95	2.13
Harvesting	N/A	20.18	7.21
Farm transport	N/A	3.19	1.14
Machinery repair and maintenance[γ]	N/A	19.72	7.04
Baling straw	N/A	15.60	5.57
Fuel and lubrication[Ψ]			
Sub-total		**94.48**	**33.74**
Other costs			
Drying	2.8t/ha@$2.10/t	5.88	2.10
Electricity	N/A		
Storage and aeration	2.8t/ha@$2.20/t	6.16	2.20
Hired labour[ι]	5 hrs@$10.20/hr	51.00	18.21
Harvest insurance[h]	$8.97/ha	8.97	3.20
Stabilization insurance[h]	$42.27/ha	42.27	15.10
Gross revenue insurance[h]	$69.50/ha	69.50	24.82
Marketing board	2.8t/ha@0.85/t	2.38	0.85
Short-term interest	$441.57/ha@11% 6 months	24.29	8.68
Sub-total		**210.45**	**75.16**
Total variable cost		**465.86**	**166.38**
Compensation for Stabilization[h]	$87.58/ha	87.58	31.28
Compensation for harvest[h]	$239.88/ha	239.88	85.67
Total compensation		**327.46**	**116.95**
Straw	2.2t/ha@$52.50/t	**115.50**	41.25
Revenue from stablization, gross revenue compensation and sales of straw		442.96	158.20
Cost after compensation		**22.90**	8.18
Selling price[h]		642.66	229.52
Less transportation (off-farm		26.59	9.50
Net selling price (grain and straw)		616.07	220.03
Cost of prod. (grain and straw) after compen.		**138.40**	**49.43**
Yield (tonnes/ha)[μ]	2.8		
Selling price for grain[ν]	2.464 t/ha	**500.57**	**203.15**
Family labour (hrs)[c]	8	8	2.86

[*] Price derived from CREAQ. Novembre 1993. Avoine pour alimentation animale. Agdex 113/821, with Farm Input Pric Index (CREAQ, 1994).

[Ψ] cost included in the field operation

[δ] For straw

[μ] Yield taken as harvested

[ν] Yield assumed as 100% DM basis

Appendix 5. Crop budget of soybeans (SB) grown in 1994 by a representative dairy farm in Southwest Quebec[n]

Item	Description	1994* $/ha	$/t
Seed	90 kg/ha@$19.32/25kg	69.55	25.29
Fertilizer	12-27-22: 75 kg/ha@$276/t	20.70	7.53
Lime	1t/ha@$27	27.00	9.82
Pesticides	Pursuit: 0.31L/ha@$185.65/L@40%	23.02	8.37
	Sencor: 1.28L/ha@$57.78/L@40%	29.58	10.76
Inoculant	400g/125kg seed@$17.32/400g	12.47	4.53
Sub-total		**182.32**	**66.30**
Field operation			
Ploughing	N/A		
Disking	N/A		
Fertiler spread	1 X		
Chem spray	1 X		
Seeding			
Harvesting			
Total field operation		49.74	18.09
Fuel and lubrication		22.79	8.29
Farm transport	N/A	24.63	8.96
Machinery repair and maintenance[7]	N/A	17.03	6.19
Sub-total		**114.19**	**41.52**
Drying		2.09	0.76
Electricity	N/A		
Storage and aeration		2.39	0.87
Hired labour	4.52hrs@$10.20/hr	46.10	16.76
Harvest insurance[n]	$26.30/ha	26.30	9.56
Stabilization insurance[n]	$1.01/ha	1.01	0.37
Gross revenue insurance[n]	$7.10/ha	7.10	2.58
Marketing board	$0.85/ha	2.34	0.85
Interest (short)	$376.26/ha@11% 6 months	20.69	7.52
Sub-total		**108.02**	**39.28**
Total variable cost		**404.53**	**147.10**
Compensation, Stabilization[n]		81.64	29.69
Compensation, Gross revenue			0.00
Total compensation		**81.64**	29.69
Total cost after compensation		**322.89**	**117.41**
Micronization[v]	$46/t@2.75t/ha	126.50	46.00
Transportation	$20/t@2.75t/ha	55.00	20.00
Total cost of micrinization and transport		**181.50**	66.00
Total cost of feeding of soybeans	2.75t/ha@$190.11/t	504.39	183.41
Selling price[n]		811.72	295.17
Less transportation (off-farm)		17.05	6.20
Net selling price		794.67	288.97
Net selling price[µ]	2.75		
Yield (tonnes/ha)[v]	2.42 t/ha	**794.67**	**328.38**
Family labour (hr/ha.)[v]	7.5	7.5	2.73

* Price derived from CREAQ. Novembre1993.Soya. Agdex 141/821, with the Farm Input Price Index (CREAQ, 199

[µ] Yield taken as harvested

[v] Yield assumed as 100% DM basis

Appendix 6. Crop budget of alfalfa hay (ALH) grown in 1994 by a representative dairy farm in Southwest Quebec[J]

		1994*		
Item	Description	$/ha/5y	$/ha/y	$/t
Seed	Certified alfalfa: 9 kg/ha@$168/25kg	66.61	13.32	2.26
	Certified Timothy: 7kg/ha@$60/25	18.20	3.64	0.62
Fertilizer	Establishment year	103.08	20.62	3.49
	First year	103.08	20.62	3.49
	Second year	128.14	25.63	4.34
	Third year	128.14	25.63	4.34
	Fourth year	121.51	24.30	4.12
Lime	2.5t/ha@$27/t	67.50	13.50	2.29
Pesticides	2,4-DB (625): 3.5L/ha@$11.09/L	38.80	7.76	1.32
String bale	29.5t@8t/bundle@$21.34/bundle	78.69	15.74	2.67
Sub-total		**853.75**	**170.75**	**28.94**
Field operation				
Ploughing (once in 5 years)	(1/5)	16.73	3.35	0.57
Disking (once in 5 years	(1/5)	10.05	2.01	0.34
Fertilizer spread (2 times)	2 X	26.90	5.38	0.91
Chem spray	1 X	1.75	0.35	0.06
Seeding	(1/5)	5.95	1.19	0.20
Cutting and conditioning	2 X	65.40	13.08	2.22
Baling hay	2 X	116.80	19.80	3.36
Farm transportation	2 X	43.90	8.78	1.49
Fuel and lubrication[Ψ]				
Machinery repair and maintenance[γ]		78.49	15.70	2.66
Sub-total		**365.97**	**73.19**	**12.41**
Other costs				
Storage	29.5t/ha@$3.25/t		19.20	3.25
Drying	29.5t/ha@$3.71/t		21.88	3.71
Hired labour[1]	5hrs/ha@$10.20/hr		51.00	8.64
Harvest insurance	29.5t/ha@90/85 * $110 * 2%		13.74	2.33
Interest (short)	$349.77/ha@11%@6 months		19.24	3.26
Sub-total			**125.06**	21.20
Total cost			**369.00**	**62.54**
Yield (tonnes/ha/y)[1]	5.9			
Family labour (hr.)[1]	18	18	3.6	0.61

* Beauregard and Brunelle, 1994

[1] CREAQ. October 1990. Foin de luzerene et fleole. Agdex 121/821

[γ] Taken as 10% of the difference between contract service cost paid to hired operator and cost of variable incurred when worked by the owner

[Ψ] cost included in the field operation

Appendix 7. Crop budget of alfalfa silage (ALS) grown in 1994 by a representative dairy farm in Southwest Quebec[a]

Item	Description	1994* $/ha/5y	$/ha/y	$/t
Seed	Certified alfalfa: 9 kg/ha@$168/25k	66.61	13.32	1.00
	Certified Timothy: 7kg/ha@$60/25	18.20	3.64	0.27
Fertilizer	Establishment year	103.08	20.62	1.55
	First year	103.08	20.62	1.55
	Second year	128.14	25.63	1.93
	Third year	128.14	25.63	1.93
	Fourth year	121.51	24.30	1.83
Lime	2.5t/ha@$27/t	67.50	13.50	1.02
Pesticides	2,4-DB (625): 3.5L/ha@$11.09/L	38.80	7.76	0.58
Sub-total		**775.06**	**155.01**	**11.66**
Field operation				
Ploughing (once in 5 years)	(1/5)	16.73	3.35	0.25
Disking (once in 5 years	(1/5)	10.05	2.01	0.15
Fertilizer spread (2 times)	2 X	26.90	5.38	0.40
Chem spray	1 X	1.65	0.33	0.02
Seeding	1 X	5.95	1.19	0.09
Cutting and conditioning	3 X	98.10	19.62	1.48
Ensilage	3 X	240.15	48.03	3.61
Blowing silage to silo	3 X	68.40	13.68	1.03
Farm transportation	3 X	130.35	26.07	1.96
Fuel and lubrication[Ψ]				
Machinery repair and maintenance[γ]		150.40	30.08	2.26
Sub-total		**748.68**	149.74	**9.00**
Other costs				
Storage	N/A		61.45	4.62
Hired labour[J]	5hrs/ha@$10.20/hr		51.00	3.83
Harvest insurance	N/A		13.22	0.99
Interest (short)	$430.42/ha@11%@6 months		23.67	1.78
Sub-total			**149.34**	**6.61**
Total cost			**454.09**	**27.26**
Yield (tonnes/ha/y)	13.3			
Family labour (hr.)	18		3.6	0.61

* Beauregard and Brunelle, 1994

[γ] Taken as 10% of the difference between contract service cost paid to hired operator and cost of variable incurred when worked by the owner

[Ψ] cost included in the field operation

Appendix 8. Crop budget of sorghum silage (SG) grown in 1994 by a representative dairy farm in Southwest Quebec[r]

Item	Description	1994* $/ha	$/t
Seed	30 kg/ha@$28.53/25 kg	34.24	1.40
Fertilizer[k]	0-0-60: 50 kg/ha@$309/t	14.68	0.60
	19-19-19: 320 kg/ha@$403/t	122.51	5.00
	34-0-0 : 235 kg/ha@$422/t	94.17	3.84
Lime	CaCO3 : 1 t/ha@$27/t	27	1.10
Pesticides	Atrazine 90W, 1.35 kg/ha@$5.94/kg	8.78	0.36
Sub-total		**301.38**	12.30
Field operation			
Ploughing		16.73	0.68
Harrowing	2 X	8.74	0.36
Fertiler spread	2 X	6.09	0.25
Chem spray		2.6	0.11
Seeding		6.42	0.26
Cutting and conditioning	2 X	11.51	0.47
Ensilage	2 X	48.8	1.99
Blowing silage[♦]		7.94	0.32
Fuel and lubrication[Ψ]			
Farm transport[♦]		11.74	0.48
Machinery repair and maintenance[γ]		25.57	1.04
Sub-total		**146.14**	5.96
Other costs			
Storage[♦]		61.60	2.51
Harvest insurance[♦]		2.64	0.11
Interest (short)	$509.87/ha@11%/6 months	28.04	1.14
Sub-total		**92.28**	**3.77**
Total cost		539.80	22.03
Yield (tonnes/ha)	24.5		
Family labour (hr.)[p]	16.32	16.32	0.67

* Price derived from CREAQ. Avril 1988. Sorgho. Agdex 126/821, with Farm Input Price Index (CREAQ, 1994)

♦ Assumed the same as corn silage

γ Taken as 10% of the difference between contract service cost paid to hired operator and cost of variable incurred when worked by the owner

Ψ cost included in the field operation

Appendix 9. Crop budget for lupins (LP) grown in 1994 by a representative dairy farmer in Southwest Quebec[1]

		1994*	
Item	Description	$/ha	$/t
Seed	170 kg/ha @18.64/25kg	126.75	42.25
Fertilizer	9-23-30: 200kg/ha @$298.50/t	59.70	19.90
Lime	CaCO2 : 1t/ha/@$27/t	27.00	9.00
Inoculant	3 bags@$5.63/bag	16.50	5.50
Pesticides	Dual 960-E: 2.2L/ha@$22.1/L	48.62	16.21
	Lorox : 2L/ha@$23.94/L	47.89	15.96
Sub-total		**326.46**	**108.82**
Field operation			
Ploughing		16.73	5.58
Harrowing		9.87	3.29
Fertiler spread		2.71	0.90
Chem spray		1.77	0.59
Seeding		5.98	1.99
Harvesting		27.48	9.16
Farm transport		23.51	7.84
Fuel and lubrication[Ψ]			
Machinery repair and maintenance[γ]		15.70	5.23
Sub-total		**103.75**	**34.58**
Other costs			
Drying[α]		2.39	0.80
Storage[α]		2.09	0.70
Transport (off-farm)	N/A		
Hired labour	4.2hrs@$10.20/hr	42.84	14.28
Harvest insurance[β]	N/A	13.22	4.41
Stabilization insurance[n]	N/A		
Gross revenue insurance[n]	N/A		
Marketing board	N/A		
Interest (short)	$490.75/ha@11% 6 months	26.99	9.00
Sub-total		**87.53**	**29.18**
Total cost		**517.74**	**172.58**
Stubble bales for bedding	3 t/ha@$35/t	105.00	35.00
Total cost less value of bales		**412.74**	**137.58**
Yield (tonnes/ha)[m]	3		
Family labour (hr.)[p]	9.68		3.23

* Price derived from Perreault and Robert 1992, with Farm Input Price Index (CREAQ, 1994)

[a] Assumed the same cost as for soybeans

[b] Same as cost for alfalfa

[γ] Taken as 10% of the difference between contract service cost paid to hired operator and cost of variable incurred when worked by the owner

[Ψ] cost included in the field operation

Appendix 10. Yield and dry matter of feed crops grown by dairy farm in Southwest Quebec

Crop	Yield kg ha-1 (at harvest)	DM (%) (at harvest)	DM yield ha^{-1} (kg)	Source
Corn grain	7,000	86	6,020	Beaurgard and Brunelle[1]
Corn silage	40,000	30	12,000	Beaurgard and Brunelle[1]
Barley	3,500	88	3,080	CREAQ Agdex 113/821 [2]
Oats	2,800	88	2,464	CREAQ Agdex 113/821 [2]
Alfalfa hay	5,900	89	5,251	CREAQ Agdex 113/821 [2]
Alfalfa silage	13,300	40	5,320	Beaurgard and Brunelle[1]
Sorghum silage	24,540	32.6 [3]	8,000	CREAQ Agdex 113/821 [2]
Lupins	3,000	87	2,610	Perreault, Yevs[4]
Soybeans	2,750	88	2,420	Beaurgard and Brunelle[1]

Notes

[1] Beaurgard, G. and A. Brunelle. 1996. Government du Quebec Ministre de l'Alimentation, Bureau Regional Ste-Martin, Direction Generale de la Monteregie, Secteur Ouest

[2] CREAQ, Le Comite de References Economique en Agriculture du Quebec

[3] Forest, J. F. 1992. Unpublished M.Sc. McGill University

[4] Perreault, Y. 1992. Budget de production l'hectare de lupin 1992. Direction Regeionale 7, Quebec

Appendix 11. Nutritional values of feed crops of dairy cattle

Crop	DM	NEL	NER[4]	CP	ADF	Ca	P
Corn grain[1]	86	1.84	1.73	10	3	0.03	0.3
Corn silage[1]	3	1.6	1.43	8	23	0.23	0.22
Barley[2]	88	1.94	1.84	13.5	7	0.05	0.38
Oats[2]	88	1.77	1.65	13.3	16	0.07	0.38
Alfalfa hay[2]	89	1.35	1.12	18	31	1.41	0.22
Alfalfa silage[1]	40	1.35	1.12	18	31	1.41	0.22
Sorghum silage[3]	32.6	1.23	0.95	10.8	42	0.46	0.21
Lupins[5]	87	1.7	1.55	44.8	17.2	0.26	0.44
Soybeans[2]	89	2.18	2.11	42.2	11	0.28	0.66

Where,
DM, Dry matter (%)
NEL, Net energy for lactation (Mcal kg^{-1} DM)
NER, Net energy for maintenace and gain (Mcal kg-1 DM)
CP, Crude protein (%)
ADF, Acid detergent fiber (%)
Ca, Calcium (%)
P, Phosphorus (%)

Source:
[1] Lefebvre, D. 1996. Programme d'Analysis des Troupeaux Latiers du Quebec (PATLQ). Pers. Communication
[2] Forest, J. F. 1992. Unpublished M. Sc. Thesis. McGill University
[3] National Research Council (NRC). 1989. Nutrietional requirement of dairy cattle. 6th ed.
[4] Church, D. C. 1984. Livestock feeds and feeding. 2nd ed. O & B Books Inc. Corvallis, Oregon, USA.
[5] Ensminger, M. E., J. O. Oldfield and W.W. Heimemann. 1990. Feeds and nutrition. 2nd. ed. The Ensminger Publishing Co., Clovis, California, USA.

Appendix 12. Nutritional content of feed crops for dairy herd

	FCG	FCS	FBA	FOT	FALH	FALS	FSG	FLPN	FSB	RHS
OBJ										MAX
LABOUR										<=6000
DM1	1	1	1	1	1	1	1	1	1	>=0
DM1MAX	1	1	1	1	1	1	1		1	<=0
NEL1	1.84	1.6	1.94	1.77	1.36	1.35	1.23	1.89	2.16	>=0
NEL1MAX	1.84	1.6	1.94	1.77	1.36	1.35	1.23	1.89	2.16	<=0
CP1	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	>=0
CP1MAX	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	<=0
ADF1	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	>=0
ADF1MA	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	<=0
CA1	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	>=0
CA1MAX	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	<=0
P1	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	>=0
P1MAX	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	<=0
DM2	1	1	1	1	1	1	1	1	1	>=0
DM2MAX	1	1	1	1	1	1	1		1	<=0
NEL2	1.84	1.6	1.94	1.77	1.36	1.35	1.23	1.89	2.16	>=0
NEL2MAX	1.84	1.6	1.94	1.77	1.36	1.35	1.23	1.89	2.16	<=0
CP2	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	>=0
CP2MAX	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	<=0
ADF2	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	>=0
ADF2MA	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	<=0
CA2	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	>=0
CA2MAX	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	<=0
P2	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	>=0
P2MAX	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0066	<=0
DM3	1	1	1	1	1	1	1	1	1	>=0
DM3MAX	1	1	1	1	1	1	1		1	<=0
NEL3	1.84	1.6	1.94	1.77	1.36	1.35	1.23	1.89	2.16	>=0
NEL3MAX	1.84	1.6	1.94	1.77	1.36	1.35	1.23	1.89	2.16	<=0
CP3	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	>=0
CP3MAX	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	<=0
ADF3	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	>=0
ADF3MA	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	<=0
CA3	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	>=0
CA3MAX	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	<=0
P3	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	>=0
P3MAX	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	<=0
DM4	1	1	1	1	1	1	1	1	1	>=0
DM4MAX	1	1	1	1	1	1	1		1	<=0
NEL4	0.173	1.43	1.84	1.65	1.12	1.12	0.95	1.55	2.11	>=0
NEL4MAX	0.173	1.43	1.84	1.65	1.12	1.12	0.95	1.55	2.11	<=0
CP4	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	>=0
CP4MAX	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	<=0
ADF4	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	>=0
ADF4MA	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	<=0
CA4	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	>=0
CA4MAX	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	<=0
P4	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	>=0
P4MAX	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0066	<=0
DM5	1	1	1	1	1	1	1	1	1	>=0
DM5MAX	1	1	1	1	1	1	1		1	<=0
NEL5	0.173	1.43	1.84	1.65	1.12	1.12	0.95	1.55	2.11	>=0
NEL5MAX	0.173	1.43	1.84	1.65	1.12	1.12	0.95	1.55	2.11	<=0
CP5	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	>=0
CP5MAX	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	<=0
ADF5	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	>=0
ADF5MA	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	<=0
CA5	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	>=0
CA5MAX	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	<=0
P5	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	>=0
P5MAX	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0066	<=0
DM6	1	1	1	1	1	1	1	1	1	>=0
DM6MAX	1	1	1	1	1	1	1		1	<=0
NEL6	0.173	1.43	1.84	1.65	1.12	1.12	0.95	1.55	2.11	>=0
NEL6MAX	0.173	1.43	1.84	1.65	1.12	1.12	0.95	1.55	2.11	<=0
CP6	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	>=0
CP6MAX	0.1	0.81	0.135	0.133	0.18	0.18	0.108	0.333	0.422	<=0
ADF6	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	>=0
ADF6MA	0.3	0.28	0.07	0.16	0.31	0.31	0.42	0.172	0.11	<=0
CA6	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	>=0
CA6MAX	0.0003	0.0023	0.0005	0.0007	0.0022	0.0141	0.0141	0.0025	0.0048	<=0
P6	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0068	>=0
P6MAX	0.003	0.0022	0.0038	0.0038	0.0022	0.0022	0.0021	0.0038	0.0066	<=0

Appendix 13. Soil loss rates for Southwestern Quebec representative dairy farm

Crop	R[1]	K[2]	LS[3]	C[4]	P[5]	A
Corn grain	1375	0.038	1.54	0.37	1	29.77
Corn silage	1375	0.038	1.54	0.51	1	41.03
Barley	1375	0.038	1.54	0.41	1	32.99
Oats	1375	0.038	1.54	0.41	1	32.99
Alfalfa hay	1375	0.038	1.54	0.02	1	1.61
Alfalfa silage	1375	0.038	1.54	0.02	1	1.61
Sorghum silage	1375	0.038	1.54	0.41 [6]	1	41.03
Lupins	1375	0.038	1.54	0.02 [6]	1	1.61
Soybeans	1375	0.038	1.54	0.46	1	37.01

Where,
R, rainfall and runoff erosivity index, i.e., average annual sum of all erosive rainfall
K, soil erodibility factor, quanitative measure of a soil's susceptibility/resistance to erosion and the soil's influence on runoff amount and rate
LS, slope length and steepness factor
C, cropping management factor, ratio used to compare soil eroded under specific crop and management system to continuous fallow condition
P, erosion control effectiveness of support practice (contour farming, stripe cropping, terracing)
A, annual soil loss in tonnes per hectare

Note
[1] Coote and Hayhoe (1995).
[2] Wall (1995a)
[3] Coote (1995)
[4] Shelton (1995)
[5] van Vliet (1995)
[6] Wall (1995b) personal communication

1. Coote, D. R. and H. N. Hayhoe. 1995. The Rainfall and runoff factor (R). In RUSLEFAC: Revised Universal Soil Loss Equation for Applications in Canada Chpt.2. A Handbook for estimating soil loss from water erosion in Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

2. Wall, G. J. 1995. The Soil erodibility factor (K). In RUSLEFAC: Revised Universal Soil Loss Equation for Applications in Canada Chpt.3. A Handbook for estimating soil loss from water erosion in Canada. Agriculture and Agri-Food Canada, Branch, Centre for Land and Biological Research. Ottawa.

3. Coote, D. R. 1995. The Slope factor (K). In RUSLEFAC: Revised Universal Soil Loss Equation for Applications in Canada Chpt.4. A Handbook for estimating soil loss from water erosion in Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

4. Shelton I. J. 1995. The Crop/vegetation and management factor (C). In RUSLEFAC: Revised Universal Soil Loss Equation for Applications in Canada Chpt.5. A Handbook for estimating soil loss from water erosion in Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

5. van Vliet, L.P. 1995. The Support practice factor (P). In RUSLEFAC: Revised Universal Soil Loss Equation for Applications in Canada Chpt.6. A Handbook for estimating soil loss from water erosion in Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Research. Ottawa.

Pringle, E. A., G. J. Wall and I. J.Shelton (eds.). 1995. RUSLEFAC: Revised Universal Soil Loss Equations for Applicationss in Canada. A Handbook for estimating soil loss from water erosion in Canada. Agriculture and Agr-Food Canad, Research Branch, Centre for Land and Biological Research. Ottawa.

Assumptions:
R(The farm is assumed located in Southwest Montreal and R is taken from Isoerodant map)
K(Soil is sand clay loam and contains >=2% organic matter)
LS(the field is with a slope of 5% and slope length 150m)
C(the relative effectiveness of soil and crop management system is take from C values for Quebec)
P(absence of support practice to control erosion i.e., no terracing, stripe cropping or contour farming)

Appendix 14. Dry matter yield and nitrogen benefit from a harvest of lupins, soybeans and alfalfa in dairy farm in Southwest Quebec[1]

Crop	Harvest yield[a] kg ha^{-1}	DM yield kg ha^{-1}	Estimated N left over kg ha^{-1} y^{-1}	Residue (Straw) t ha^{-1}
Alfalfa	5,900	5,251[b]	30[c]	1.5
Lupins	3,000	2,610[d]	50	3
Soybeans	2,750	2,420[d]	25	1.1

[1] Leduc, R. (personal communication) 1997. Ministere de l'Agriculture des Pecheries et de l'Alimentation, Conseiller en productions animals, Direction regionale 07, Quebec.
[a] Yield at harvest with moisture level of 11 to 12 percent.
[b] Hay harvest,
[c] An assumption of 100 kg N ha^{-1} is contributed in 5 years of crop stand,
[d] Grain yield (100% DM)

Appendix 15. Gross revenues of crops in Quebe for the year 1989 - 94

	Corn		Barley		Oats		Soybeans	
Production year: 1989								
	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}
Selling price	858.05	138.53	495.03	130.27	253.02	102.26	604.95	241.98
Income stabilization	278.98	45.04	225.47	59.34	348.42	140.82	201.19	80.47
Harvest insurance								
Total revenue	1,137	184	720.5	189.61	601.44	243.08	806.14	322.45
Production year: 1990								
	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}
Selling price	794.95	122.3	414.15	110.6	218.8	88.43	N/A	N/A
Income stabilization	466.56	71.78	370.94	98.92	422.08	170.59	N/A	N/A
Harvest insurance								
Total revenue	1,261	194.08	785.69	209.52	640.88	259.02	N/A	N/A
Production year: 1991								
	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}
Selling price	786.89	121.06	387.26	103.27	238.94	96.57	590.77	227.22
Income stabilization	421.65	64.87	368.58	98.29	402.1	162.51	279.78	107.61
Harvest insurance								
Total revenue	1,209	186	755.84	201.56	641.04	259.08	870.56	334.83
Production year: 1992								
	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}
Selling price	793.73	117.59	335.44	95.84	304.35	94.52	641.27	241.99
Income stabilization	401.94	59.55	354.01	101.15	342.42	106.34	142.28	53.69
Harvest insurance								
Total revenue	1,196	177	689.45	196.99	646.77	200.86	783.55	295.68
Production year: 1993								
	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}
Selling price	960.73	142.33	363.34	103.81	317.62	98.64	779.82	294.27
Income stabilization			133.93	38.27	150.12	46.62		
Harvest insurance	172.63	25.57	168.47	48.13	148.68	46.17		
Total revenue	1,133	170	665.74	190.21	616.42	191.43	779.82	294.27
Production year: 1994								
	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}	$ ha^{-1}	$ t^{-1}
Selling price	950.6	135.80	448.11	128.03	315.21	97.89	730.08	
Income stabilization	177.15	25.31	18.91	5.4	87.58	27.20	81.64	275.5
Harvest insurance	48.43	6.92	230.32	65.81	239.88	74.50		
Total revenue	**1176.18**	**168.03**	**697.33**	**199.24**	**642.66**	**199.59**	**811.72**	**306.31**
Total payments	1967.23	292.13	1870.60	509.91	2141.28	783.61	704.89	271.46
Average	**327.87**	**48.69**	**311.77**	**84.99**	**356.88**	**130.60**	**140.98**	**45.24**

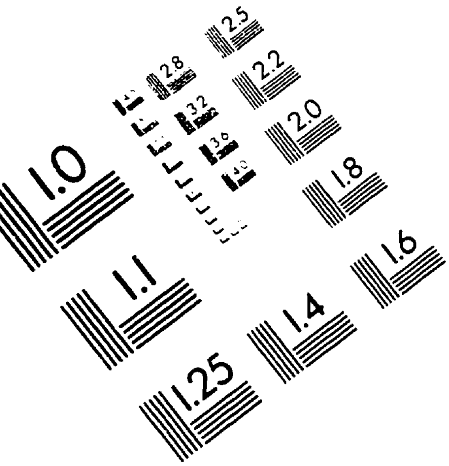
Source: MAPAQ, 1989-1994
N/A, Data unavailable

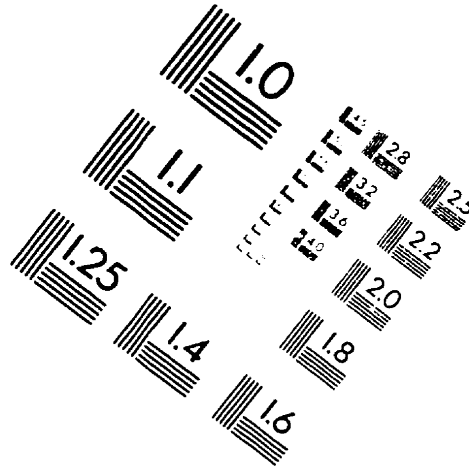
Appendix 16. Income stabilization payment ($\$ha^{-1}$) for certain crops in Quebec 1989-94

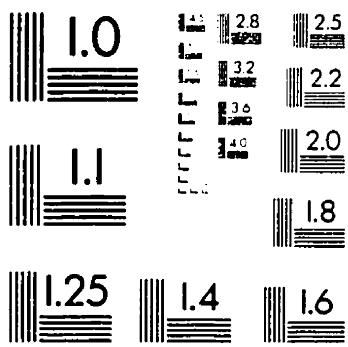
Year	Crops							
	Corn		Barley		Oats		Soybeans	
	$\$ ha^{-1}$	$\$ t^{-1}$	$\$ ha^{-1}$	$\$ t^{-1}$	$\$ ha^{-1}$	$\$ t^{-1}$	$\$ ha^{-1}$	$\$ t^{-1}$
1989	278.89	39.84	225.47	64.42	348.42	124.44	201.19	73.16
1990	466.56	66.65	370.94	98.92	422.08	150.74	N/A	N/A
1991	421.65	60.24	368.58	98.29	402.10	143.61	279.78	101.74
1992	401.94	57.42	354.01	101.15	342.42	122.29	142.28	51.74
1993	172.63	24.66	302.40	86.4	298.80	106.71	0	0.00
1994	**225.58**	32.23	**249.23**	65.81	**327.46**	116.95	**81.64**	29.69
Total	1967.3	281.04	1870.6	514.99	2141.3	764.74	704.89	256.32
Average	**327.88**	46.84	**311.77**	85.83	**356.88**	127.46	**140.98**	51.26

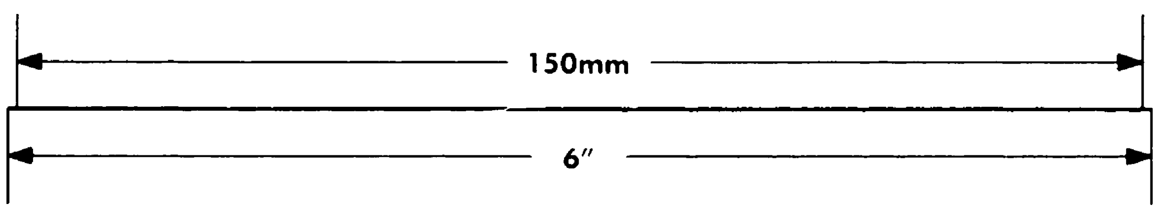
Source: MAPAQ, 1989-1994

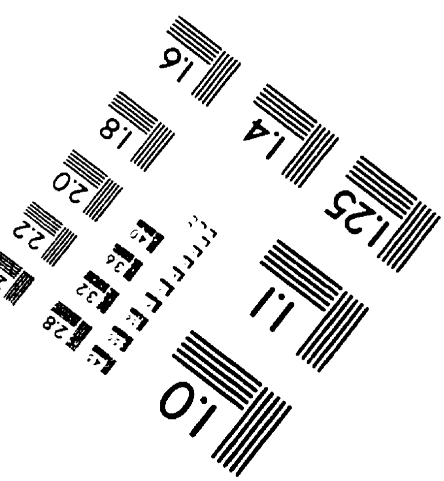
IMAGE EVALUATION TEST TARGET (QA-3)

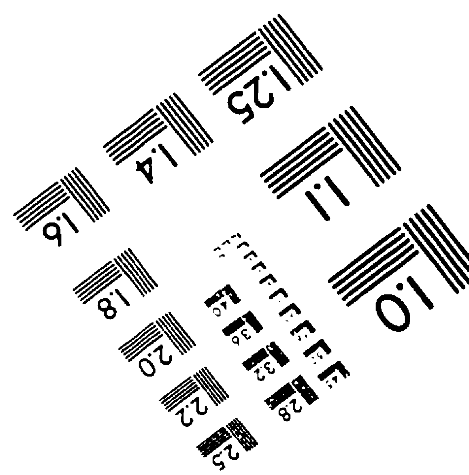












APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989