Economics of Introducing Forage and Livestock into Alternative Crop Rotation Systems During the Transition to Organic Agriculture.

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February 2006

A thesis submitted to McGill University
in partial fulfilment of the requirements of the degree of
Master of Science in Agricultural Economics

Your file Votre référence
ISBN: 978-0-494-24780-8
Our file Notre référence
ISBN: 978-0-494-24780-8

ABSTRACT

The purpose of this study was to investigate the economic feasibility of alternative crop rotations and to determine the economic implications of including forages and livestock during the transition to organic agriculture in Nova Scotia. The rotation systems were distinguished by: i) frequency of forage in the rotation, ii) source of nutrient supply, and iii) type of farming operation. The economic analysis was divided in two parts. The first part analysed data from a four-year crop rotation experiment, using enterprise budgeting and statistical methods to compare differences among rotations under different treatments. The second part involved the development of a multi-period linear programming (LP) model to simulate a commercial operation.

The results from the statistical analysis suggest that crop enterprise net returns tended to be higher in forage-based rotations and in the livestock systems compared to cash crop rotations and the stockless system. Results from the LP model suggest that including forages and beef cattle during the transition to organic agriculture can provide considerable economic benefits, especially when crops were grown under ruminant compost.

RÉSUMÉ

Cette étude a pour but de déterminer la faisabilité économique des rotations alternatives de cultures et de déterminer les implications économiques de l'intégration de cultures fourragères et de bétail à la transition à l'agriculture biologique en Nouvelle-Écosse. Les systèmes de rotation des cultures se distinguent par: i) la fréquence de la rotation des cultures fourragères, ii) la source d'apport nutritif, et iii) le type d'opération agricole. L'analyse économique s'est fait en deux parties. La première partie utilise une méthode d'établissement de budget d'entreprise et des méthodes statistiques pour analyser les données d'une étude de quatre ans sur la rotation de cultures, de manière à comparer les divergences parmi les rotations selon des traitements différents. La deuxième partie développe un modèle de programmation linéaire pluri-période (LP) de simulation d'une opération commerciale.

Les résultats de l'analyse statistique suggèrent une tendance de retours nets plus élevés pour les rotations basées sur les cultures fourragères et pour celles qui utilisent un système de bétail, comparés aux systèmes de rotations de cultures marchandes et sans bétail. Les résultats du modèle LP suggèrent que l'ajout de cultures fourragères et de bovins pendant la transition à l'agriculture biologique peut fournir des avantages économiques considérables, particulièrement quand les récoltes ont germées sous le compost des ruminants.

ACKNOWLEDGEMENTS

The completion of this thesis could not have been possible without the guidance of my co-supervisors, Dr. John Henning at McGill, and Dr. Emmanuel Yiridoe at the Nova Scotia Agricultural College, to whom I extend my respect and admiration for their patience and wisdom throughout my graduate studies. Many thanks. You have taught me how to learn.

I am grateful to the Organic Agriculture Centre of Canada for providing funding for this research, especially Dr. Ralph Martin for his consideration. I am also thankful to the Department of Agricultural Economics at McGill University for awarding me the International Fee Waiver for three consecutive terms, and for the Teaching Assistantships provided.

My gratitude also goes to those who helped me with information, ideas and friendship during my studies, especially Dr. Andrew Hammermeister and Mr. Kui Liu from the Organic Agriculture Centre of Canada, Dr. Tess Astatkie from the Nova Scotia Agricultural College, my fellow colleagues and the staff from the Department of Agricultural Economics, and my Chinese friends from Concordia University for making my life easier.

Finally, I would like to thank my wife Alex for being my best friend, for supporting us these years, and for having to again put up with the cold Canadian winter. Thank you also for your patience during my long hours of work. Thanks to my parents, who have cultivated in me a passion for the countryside, and who have raised my brothers and me in close contact with the magnificence of the Ecuadorian Andes. I will certainly follow your steps. Thanks to my father-in-law Max Bade for loving life in the countryside and for sharing with me his extraordinary experiences and fantasies at the farm in Plantagenet.

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CHAPTER 1. INTRODUCTION

1.1 Introduction to the Problem

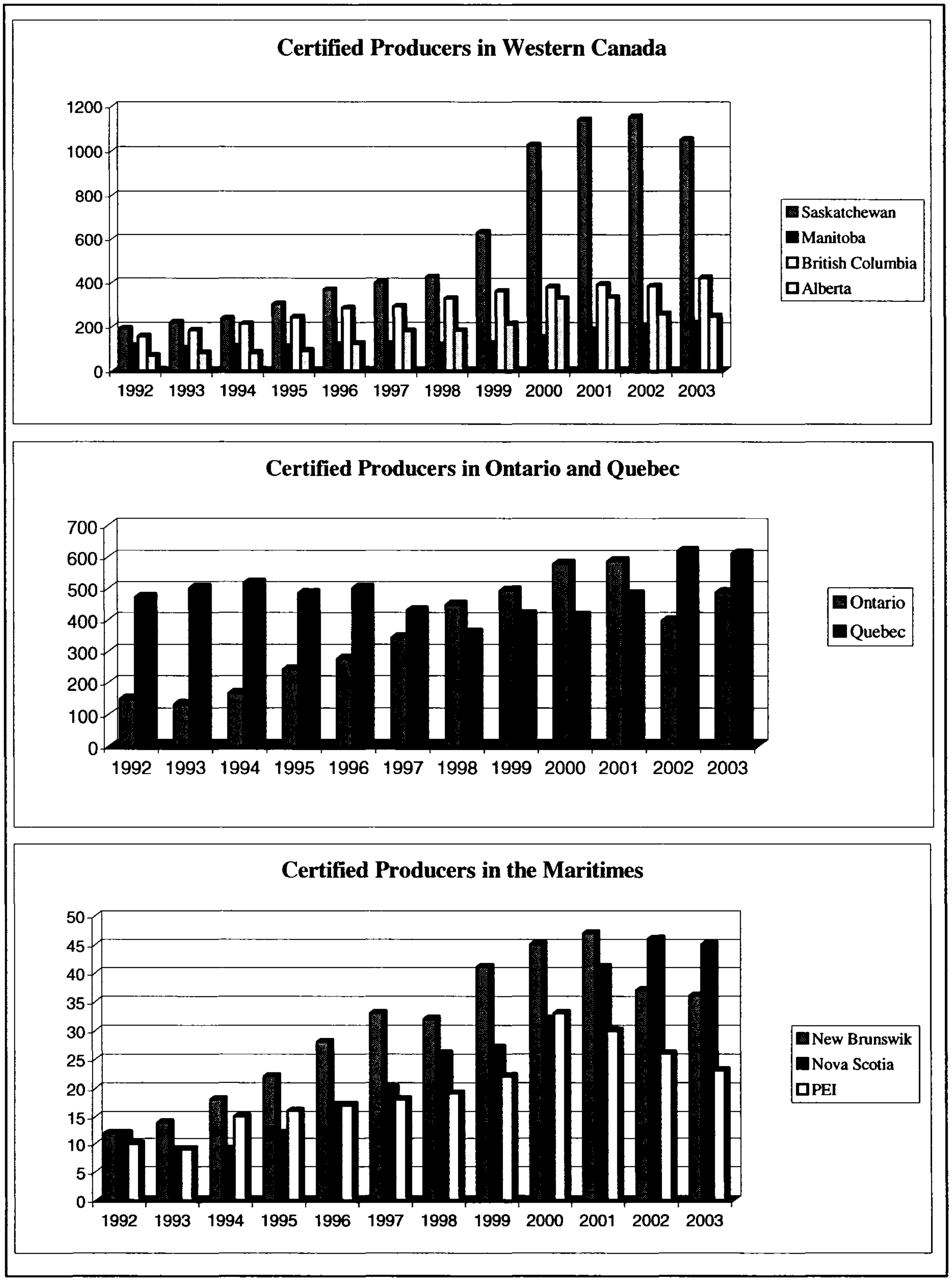
Land under organic agricultural production and the market for organic products is growing throughout the world (Willer and Yussefi, 2004). In February 2004, the total worldwide area under organic agriculture was estimated at more than 24 million hectares (Yussefi, 2004), while the global market for organic food was approximately US$ 23 billion in 2002 (Sahota, 2004). The Canadian retail sector is gradually attracting the interest of several food industry stakeholders. Loblaws, for example, already deals with more than 300 organic items (Macey, 2004a).

Data from various organic certifying bodies in Canada suggests that, in 2003, there were 3,134 certified organic producers, with an estimated area of 510,687 ha that includes 119,564 ha of crown land used for range, maple trees and land for wild-crafting. There were at least 5,424 ha of land under transition to organic agriculture that corresponds to a minimum of 250 farmers (Macey, 2004b). Organic farms in Canada currently represent 1.3% of both the total agricultural area (Yussefi, 2004) and the total number of farms (Macey, 2004b).

The number of organic farms in Canada between 1992 and 2003 is summarized in Figure 1.1. Macey (2004b) reported that Saskatchewan had 1,149 certified farms in 2003, followed by Quebec (610), Ontario (487) and British Columbia (420). Statistics Canada (2002) identified the same provinces as the main organic exporters.

According to the 2001 Census of Agriculture, 64.7% of farms reporting certified organic products are dedicated to field crop production; 27.5% to fruits, vegetables or greenhouse products; 17.1% to livestock and animal products; and 15.2% to maple syrup, herbs and others (Table 1.1). The Census of Agriculture data suggest an emphasis on field crop production for Saskatchewan, Manitoba, Ontario, and Alberta. In contrast, organic fruits and vegetables are the principal products in Newfoundland and Labrador, Nova Scotia, British Columbia, Prince Edward Island, and New Brunswick. In Quebec, the majority of farms are involved in the production of miscellaneous certified products such as maple syrup and herbs, followed by fruits and vegetables, field crops, and animals or animal products (Statistics Canada, 2002).

Figure 1.1 Certified Organic Farms in Canada, 1992 to 2003



Source: Adapted from Macey (2004b).

Table 1.1 Organic Farms in Canada by Type of Product

Region	Number of farms		As a proportion of farms reporting certified organic products (%)			
	All farms	Certified Organic	Fruits, vegetables or greenhouse products.	Field crops.	Animals or animal products.	Other (maple syrup, herbs, etc.)
Canada	246,923	2,230	27.5	64.7	17.1	15.2
Alberta	53,652	197	10.7	72.1	30.5	15.2
British Columbia	20,290	319	83.7	21.9	16.6	14.1
Manitoba	21,071	90	7.8	82.2	18.9	8.9
Newfoundland and L.	643	3	100.0	0	0	33.3
New Brunswick	3,034	25	64.0	24.0	24.0	28.0
Nova Scotia	3,923	23	87.0	26.1	43.5	21.7
Ontario	59,728	405	29.6	76.0	29.6	9.4
Prince Edward Island	1,845	23	73.9	47.8	13.0	26.0
Saskatchewan	50,598	773	2.3	93.1	7.6	6.0
Quebec	32,139	372	33.6	28.2	14.2	41.4

Note: Respondents could choose more than one category.
Source: Statistics Canada (2002)

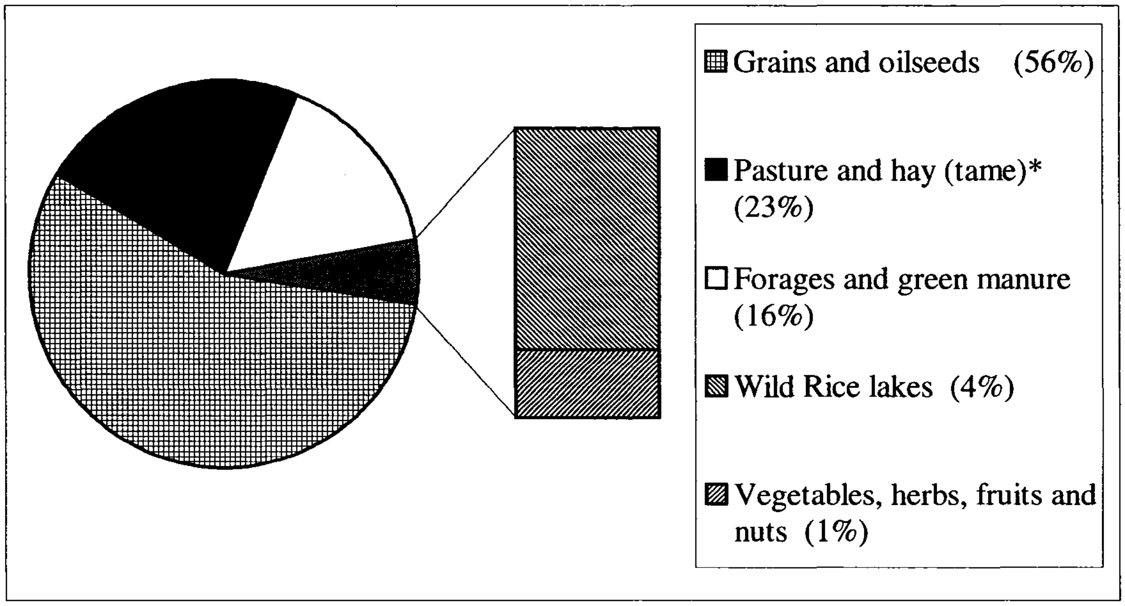
In terms of the area under organic production for Canada as a whole, grains and oilseeds were the main products in 2003 (Figure 1.2). The area seeded to these crops was estimated at 222,210 ha. Current emphasis is on organic wheat, flax, and oats grown mainly in Saskatchewan.

According to Macey (2004b) the second largest area under certified organic is allocated to forage and pastures, with 154,139 ha. It was estimated that there were 163 beef cattle farms and 102 dairy farms, distributed in a similar way as in the conventional agricultural industry: the majority of beef cattle are concentrated in Alberta and Saskatchewan, and most of the dairy farms are in Ontario and Quebec.

Certified vegetables and herbs together rank third, with 3,146 ha (of which 2,552 ha are allocated to vegetables and 594 ha to herbs), followed by fruits and nuts (1,469 ha). British Columbia is the leading producer of organic vegetables, herbs, fruits, and nuts. Organic poultry and egg production is small compared to conventional production; there were about 89 organic egg producers and 74 farms producing meat birds and turkeys in 2003 (Macey, 2004b).

Figure 1.2 Area Under Organic Production in Canada, 2003

Type of Product					
Crop	Grains and oilseeds	Pasture and hay (tame)*	Forages and green manure	Wild Rice lakes	Vegetables, herbs, fruits, and nuts
Area (ha)	222,210	89,870	64,269	15,955	4,615



Note: *Range, crown land and native pasture not included
Source: Adapted from Macey (2004b).

It is important to note that during 2003, most of the organic producers in Atlantic Canada were based in Nova Scotia (45), followed by New Brunswick (36), Prince Edward Island (23), and then Newfoundland and Labrador (3). In Nova Scotia, the majority of farms reporting organic products were devoted to fruits and vegetables, followed by livestock farms, and then grains and oilseeds. The largest area under organic production was devoted to forages and green manures (approximately 300 ha), which represent more than 72% of the total certified area in Atlantic Canada (Macey 2004b).

Since the late 1990's, the organic consumer market in Canada has generated a yearly average growth of 15-20% (Vladicka and Cunningham, 2002), and represents 1-2% of the total retail food market (Macey, 2004b). Although the current organic market share is relatively small, Agriculture and Agri-Food Canada (2003) predicts that the industry will continue to grow at 20% per annum, with the market share increasing to 10% of the Canadian retail market by 2010.

The growing interest in the organic food sector calls for the need to evaluate the economic sustainability of organic farming. Uncertainty about converting from conventional farming is a concern among prospective producers (Mahoney et al., 2004). Several studies in the US, for example, have compared conventional and alternative production systems (Cacek and Lagner, 1986; Berardi, 1979; Brusko et al., 1985; Eberle and Holland, 1979; Helmers et al., 1984; James, 1983; Kraten, 1979; Lockeretz et al., 1978; Roberts et al., 1979; USDA, 1980). Most of these studies concluded that organic production can be competitive with conventional production (e.g., Cacek and Langner, 1986), while others reported higher net returns for organic production when price premiums were considered (e.g., Mahoney et al., 2004).

Studies in Canada that have evaluated the productivity and economic feasibility of organic production include: Entz et al., 1998; MacRae et al., 1990; and Parsons, 2002. Other studies have compared the performance of organic agriculture with conventional production (Ogini et al., 1999; Sholubi et al., 1997; Stonehouse, 1996; and Stonehouse et al., 1996). Studies that focused on profitability during transition include: Forest, 1992; and Sellen et al., 1995. Although the conclusions vary among studies, overall, organic agriculture can be as profitable as conventional agriculture. However, the process of conversion should be carefully planned as lower yields combined with no price premiums could generate considerable losses.

Some analysts suggest that the growth in organic production may come from current organic farmers, as they improve their managerial skills (i.e., better control of pests, weeds and diseases that lower yields) (Parsons, 2002; Sholubi et al., 1997; and Stonehouse, 1996) and the "learning effect" improves (Dabbert and Madden, 1986). However, it is very likely that most of the growth in organic production will come from conventional producers converting to organic, partly due to increasing promotion of organic production (Rigby and Cáceres, 2001), and from farmers' motivation to convert due to potential economic benefits and environmental and health concerns (Cacek and Lagner, 1986; Henning, 1994; Mahoney et al., 2004; Rigby and Cáceres, 2001).

1.2 Problem Statement

Increasing producer interest in organic agriculture as an alternative production system partly stems from the impacts that conventional agricultural practices can have on the environment (Papendick et al., 1986; Senahuer, 1993), human health (Cox, 1994), animal welfare (Harper and Makatouni, 2002) and farm profitability (Cacek and Langner, 1986; Ogini et al., 1996; and Rigby and Cáceres, 2001). Food safety scares reported around the world have raised awareness, especially during the last few years. Foot and Mouth Disease, Bovine Spongiform Encephalopathy (BSE - mad cow disease) and Avian Flu are recent examples of food scares that have raised concerns about conventional agriculture. The increasing number of cases have also reduced confidence in food safety regulations among consumers (Gregory, 2000).

Studies from Europe and the US suggest that consumption of organically produced food is correlated with health and environmentally concerned attitudes (Grunert and Juhl, 1995; Tregear et al., 1994; Schifferstein and Oude-Ophuis, 1998; Wandel and Bugge, 1997; and Wilkins and Hillers, 1994). Grossman (1972) argued that human health is perceived as a good that depreciates with age. Thus consumers tend to invest in "good health", by purchasing "insurance" that would help them mitigate the "losses" of health capital. Yiridoe et al. (2005) assert that in the context of a demand function for "good health", organic food may be thought of as an input, and the investment cost would be the premium paid for organic food.

Wilkins and Hillers (1994) reported that pesticide residue concerns are an important reason for organic food consumption in the US. Mott (1988) found that serious cases of illness have been linked to pesticide exposure and chemical residues in food. Furthermore, the Ontario College of Family Physicians recently conducted an exhaustive review of studies on pesticide exposure and residues, and reported a positive correlation between several types of tumour cancer and leukaemia, along with negative effects in the nervous system, and possible adverse reproductive problems such as birth defects, foetal death and intrauterine growth retardation. Children, pregnant women and seniors were identified as high-risk groups affected by pesticide exposure and chemical residues in food (Sanborn et al., 2004). In addition, pesticide exposure affects farmworkers' health (Cox, 1994; Reeves et al. 2002).

Some consumers are also concerned with ethical issues such as animal welfare. For example, animal welfare and slaughter methods prompt some consumers to avoid meat consumption (Hughes, 1995 and Gregory 2000). Harper and Makatouni (2002) reported that consumers in the UK link safety and healthiness with animal-friendly production methods such as free-range, and tend to regard such products as equivalent to organic. Although free-range production per se does not necessarily comply with organic regulations and certification, this perception suggests that, to a certain extent, consumers link animal welfare with organic methods.

During the 1950's, conservation practices such as crop rotation and the cultivation of legumes and pastures became less important (Papendick et al., 1986), partly because of the availability of pesticides and low cost nitrogen fertilizers. However, these conservation practices are regaining importance among producers because of growing concerns associated with conventional production methods (Papendick et al., 1986), and the potential benefits of alternative practices (Entz et al., 2002; Gebremedhin and Schwab, 1998; Peel, 1998 and Power, 1987)

The concerns with conventional production prompts the need for alternative production methods such as organic agriculture, not only because it can improve soil nutrient levels without polluting ground and surface water systems, but also because organic agriculture could generate long-term benefits that may have positive economic consequences, such as reduced soil erosion, wildlife conservation, and more efficient use of resources. Conservation practices such as the use of soil amendments, crop rotations and alternative methods of pest and weed control need to be continually evaluated from both technical and economic perspectives.

1.2.1 Economic Problem

Economic considerations play an important role during the transition to organic farming (Dabbert and Madden, 1986; Sellen et al., 1995). Indeed Cacek and Langner (1986) noted that some farmers switch to low input organic farming systems as a strategy for risk management and farm financial survival. Currently there are significant price premiums for most organic products (Parsons, 2002). However, premiums will likely decline over time, thereby affecting profit margins, as the industry expands and supply increases.

The transition to organic production involves not only a high level of innovation, but also significant costs. Farmers may incur significant production costs when they replace higher yielding crops with more complex rotations, or for new machinery associated with switching systems or diversifying production (Yiridoe and Weersink, 1994).

Some studies report that organic production involves higher labour costs associated with weed and pest management (Stonehouse et al., 1996; Sellen et al., 1995; Blobaum, 1983). The transition may involve additional costs when substituting synthetic fertilizers with alternative sources of nutrients, along with costs related to the learning process (Dabbert and Madden, 1986).

Cacek and Langner (1986) noted that organic producers are less able to take advantage of income tax credits because they tend to be less capital intensive, tend to invest less in infrastructure, and rely less on input purchases. Similarly Ogini et al. (1999) noted that organic farmers receive less money in the form of government subsidies than conventional farmers. To a certain extent, the inability to receive tax credits and subsidies may be considered disadvantages faced by organic producers since they will not benefit as much from government aid. On the other hand, organic systems that are more energy efficient tend to be less dependent on government financial assistance (Cacek and Langner, 1986; Gebremedhin and Schwab, 1998; Sholubi et al. 1997).

It is important to note that results from partial and single period analysis of organic production systems should be interpreted with caution, since organic farms are inherently whole-farm systems (Henning, 1994; Stonehouse, 1996; Stonehouse et al., 1996; Yiridoe et al., 2005). Yiridoe et al. (2005) noted that, by the nature of organic agriculture, whole-farm analysis is more appropriate, where all crops in rotation are evaluated, as opposed to single enterprise analysis for a given year.

Furthermore, Henning (1994) noted that comparisons between conventional and organic agriculture may be influenced by the context of the comparisons (i.e. the characteristics of the sites and local market conditions). Better management skills may not be the only reason for better overall performance of organic agriculture, In other words, profitability depends on output, output price and production costs, which may differ from one region to another (Stonehouse, 1996). In deed, Rigby and Cáceres (2001) noted that sustainability will depend on the circumstances in which a certain technology is used, and this will be a function of time and space.

The need for economic analysis of farming systems (under transition to organic agriculture) arises from the difficulty and importance of the initial years of conversion. Producers typically do not receive price premiums while incurring additional costs and going through a gradual recovery of yield levels and soil fertility.

1.2.2 Research Problem

Organic production systems can be profitable after the farming system has been established. However, the transition period remains a key barrier to adoption of organic agriculture. The goal of the transition period includes using management strategies that increase soil fertility, reduce the incidence of weeds, and improve general soil health and overall production, in preparation for organic certification, and ultimately, generating a sustainable farming system.

Incorporating a nitrogen-fixing forage or leguminous crop in a rotation is highly recommended (Gebremedhin and Schwab, 1998; Power, 1987). However, there is no one particular rotation that can be recommended for all farmers across different agro-ecosystems. Entz et al. (1998) noted the importance of crop rotations and alternative soil amendments for attaining sustainability and economic viability. Rotations have the potential to improve soil fertility, as well as helping to control weeds, pests and diseases by interrupting their cycles (Babcock and Secchi, 1999; Gebremedhin and Schwab, 1998; Peel, 1998; Younie et al., 2002).

The agronomic benefits of rotating forages with grain crops include higher grain crop yields, improved soil quality, better weed control, and reduced energy requirements when perennial legumes are used (Entz et a., 2002). Power (1987) noted that legumes play a key role in organic production, due to their ability to fix nitrogen from the atmosphere and improve the physical characteristics of the soil.

Green manuring is another alternative practice to be considered in organic agriculture. The incorporation of plant residues into the soil can improve soil structure, slow the release of nutrients (that in turn benefit the crop rather than weeds), and improve soil aeration (Canadian Organic Growers, 2001; Warman, 1980).

According to Voutsinos and Brenton (1995), some farmers in Nova Scotia are now using conservation practices such as conservation tillage, water management, cross-slope and contour farming, cover cropping and green manuring, windbreaks (for the control of wind erosion), mulching, and crop rotations, practices that are suitable in the context of organic agriculture. This is mainly because soil degradation in Nova Scotia has been identified in areas under intensive row crop production, and in about 30-40% of the land under forage production. Soil erosion was identified in corn (for silage purposes), vegetables, apples, and small fruit (Voutsinos and Brenton, 1995).

Voutsinos and Brenton (1995) identified some causes of soil degradation in Nova Scotia including: bare land (during or after cultivation), decline in biological activity, deterioration of soil structure, improper cultivation in hilly land, intensive tillage, soil compaction problems, and water management deficiencies.

Many agricultural soils in the province have shallow and dense subsoil that slows down drainage, and increases water runoff and erosion (Voutsinos and Brenton, 1995). In contrast, drought conditions have also affected the farming sector in Nova Scotia, particularly during the late 1990's and the beginning of the twenty-first century. Field crops including potatoes, vegetables and small fruits, suffered the most from dry periods. Livestock enterprises were also affected by poor pasture conditions (Nova Scotia Agriculture and Fisheries, 2001).

Furthermore, Voutsinos and Brenton (1995) suggested that soil organic matter management is important, especially where manure is not incorporated in the soil, and where forages are not included in crop rotations. The content of soil organic matter may be gradually reduced as a result of crop cultivation, harvesting, erosion and natural decomposition, hence the importance of attending to and managing soil organic matter.

1.3 Purpose and Objectives

The purpose of this study was to investigate the economic feasibility of alternative crop rotations and to determine the economic implications of including forages and livestock during the transition to organic agriculture in Nova Scotia. The farming systems studied are distinguished primarily by: i) the number of years of legume-based forages incorporated in the rotation (i.e., no forage in the rotation, one year, and two years of forage); ii) the type of soil amendment applied (i.e., alfalfa pellets, monogastric compost, and ruminant compost); and iii) the type of farming operation (i.e., cash crop versus mixed cash crop-livestock operation).

Specific objectives of the study include:

1) To carry out an economic analysis of 3 crop rotations with 3 nutrient sources during the transition to organic agriculture by generating enterprise budgets and using statistical methods to evaluate experimental field data.
2) To develop a multi-period linear programming model to compare the economic impacts of including forages and ruminant livestock into cash crop rotations during the transition to organic agriculture for in a hypothetical farm in Nova Scotia.
3) To propose an economically optimal whole-farm plan for a hypothetical farming operation under transition to organic agriculture in Nova Scotia.

1.4 Outline of the Study

This thesis is divided into five chapters. Chapter 2 provides a review of selected literature on the feasibility of organic agriculture, agronomic concerns related to organic production, and economic methods for analyzing organic agriculture during transition. Chapter 3 focuses on the profitability of three alternative farming systems suitable for Atlantic Canada, including enterprise budgeting and statistical analysis of experimental field data. Chapter 4 presents a linear programming model developed with information from Chapter 3. Chapter 5 provides a summary of the study, conclusions, limitations, and recommendations for further research.

CHAPTER 2. LITERATURE REVIEW

2.1 Outline

Literature on selected studies is reviewed to provide background for this thesis. The first section reviews agronomic aspects of organic food production, including the conversion from conventional to organic agriculture, the importance of soil fertility in environmental stewardship, and the use of crop rotation and organic soil amendments as alternatives to conventional methods to control weeds and pests and improve soil fertility. The second section provides information about the economics of organic agriculture, including the economic dimensions of the transition to organic agriculture, the economic implications of crop rotation and soil fertility improvement during the transition period, and selected studies on the economic feasibility of organic production in Canada. In addition, methods for analyzing the economic performance of crop rotation systems during the transition to organic agriculture are assessed.

2.2 Agronomic Considerations

2.2.1 Agronomy of the Transition to Organic Agriculture

Organic agriculture is more than just farming without chemicals; it involves changes to the whole farming system and requires the implementation of biological methods of pest, weed, and nutrient management (Martin, 2003). Crop rotation, cover crops, organic mulches, composting, integrated pest management, modification of machinery and tillage methods, seeding rate alterations, and hand weeding are examples of techniques used in organic farming.

Farmers planning to convert to organic production must undergo a process of transition. The process of transition involves two simultaneous components. First, there are necessary changes to the farming operation to enhance biological activity in the soil. And second, there need to be specific changes to the farming operation to obtain organic certification (i.e., certifying bodies require a verification of initial implementation of approved organic practices before granting organic certification). In the US and Europe, food products that are labelled organic, must be produced within the framework of a mandatory system that includes a standard and certification. In the US, the National Organic Program is based on a federal law and regulates the production and commercialization of organic food products. In the EU, fulfilment of organic standards is regulated by each member state under common legislation (McEvoy, 2003). US regulations require a 3 year transition period (United States Department of Agriculture, 2002), whereas European standards demand 2 years of transition for annual crops and 3 years for perennial crops (The Council of European Communities, 2004). In most of Canada, organic standards are voluntary. However, inappropriate use of the word "organic" may have legal implications. The national standard on organic agriculture requires a minimum of 3 years of production without the use of "prohibited substances" (i.e., synthetic farm inputs or any other restricted material) and requires the full application of the standard for at least 2 years before products can be labelled or marketed as "organic" (Canadian General Standards Board, 1999). Although the Canadian General Standard Board specifies a minimum time frame for the transition process, the transition period may be extended or reduced depending on the previous land use of a farming unit. However, it cannot be less than 12 months (Canadian General Standards Board, 1999).

From an agronomic point of view, the transition process can take several years for the whole system to adjust to organic practices and recover from previous management practices. Once the process of transition begins, synthetic farm inputs cannot be used. Therefore, nutrient availability may be low and weed, pest, and disease incidence may increase. Initially, yields tend to decline and then (depending on management practices) recover to levels that may be close to conventional yields (Martin, 2003; Sustainable Agriculture Research and Education, 2003).

The change in yield may be the key challenge to converting to organic agriculture. Yield variation can result from factors such as soil characteristics, weed, pest and disease incidence, climate conditions, cropping history, and management skills (Dabbert and Madden, 1986). A transition strategy should therefore aim at using appropriate management techniques to reduce any decline in yield. It is important to have a systematic and comprehensive transition plan, including: soil improvement, manure or slurry handling methods, development of crop rotation systems, tillage techniques alterations, adjustment of livestock stocking-rate, implementation of organic weed and pest control techniques, assessment of marketing opportunities, labour estimates, yield estimates, and a financial forecast (Martin, 2003; Lampkin, 1985; Plakholm, 1985).

2.2.2 Importance of Soil Fertility in Environmental Stewardship

Fertility is a key determinant of soil quality. Soil fertility may be defined as the capacity of soil to supply plants with nutrients (Watson et al., 2002). However, soil fertility by itself does not imply that a system is productive. Swift and Palm (2000), noted that it is convenient to identify soil fertility as an ecosystem concept, because it involves nutrient supply, as well as other functions of the soil required for agricultural production. For example, fertile soils in dry areas may not be productive without a good water retention capacity, even if irrigation is provided.

Soil fertility as an ecosystem concept has relevance in organic farming (Watson et al., 2002), where conservation practices can protect the environment, replenish and maintain soil fertility, recycle materials and resources, and help preserve biodiversity (Canadian General Standards Board, 1999). Peet (2004) argued that sustainable organic agriculture depends on good soil conditions and adequate fertility, and identified an ideal soil as one with good water-holding capacity, well drained, balanced nutrient supply, deep rooting zone, good porosity, and resistant to erosion.

Regardless of the method of production, it is important to maintain and recover soil fertility. However, the use of highly soluble synthetic inputs has the associated risk of environmental contamination and adverse effects on the long-term sustainability of soil (Gebremedhin and Schwab 1998). The importance of nutrient management and soil fertility in organic systems arises from reliance on chemical and biological processes to slowly mineralise nutrients, thereby making them readily available to crops (Stockdale et al., 2002). Results from a 21-year study in Europe (the "DOK" experiment) suggest that external nutrient input requirements for organic systems were 34 to 51% lower than in conventional systems, while average yields were only 20% lower (Maeder et al., 2002). In addition, there were significant benefits to soil biological activity, soil aggregate stability, abundance of earthworms and diversity of flora and fauna on organic systems (Maeder et al., 2002). Scullion et al. (2002) noted that earthworms can improve water infiltration, increase soil aggregation, promote the cycling of carbon, and enhance nutrient availability and productivity. Scullion et al. (2002), compared earthworm populations in conventional and organic rotations in various counties in Southern and Eastern England. Seven farm pairs, ranging from arable to mixed farming, were compared. Although the study did not aim to identify individual practices that affect earthworm populations, Scullion at al. (2002) found that earthworm populations tend to be higher in phases of rotations where pastures were involved, regardless of the farming system. However, earthworm biomass tended to be higher on organic farms compared to conventional farms, because organic practices depend to a larger extent on pasture rotations than conventional practices. This underscores the importance of including pastures in rotation systems.

Soil organic matter (SOM) is composed of residues from organic tissue, including decomposed products and materials synthesised by soil fauna (Quideau, 2002). Soil organic matter is the connection between biological, chemical and physical characteristics of the soil (Cooperband, 2002). SOM can directly influence soil quality (Table 2.1) and is closely related to nutrient supply, reduction of nutrient leaching, changes in pH, improvement of soil structure and tilth, and supply of carbon to microbes (Cooperband, 2002).

Shepherd et al., (2002) reported that soil organic matter on organic farms is usually higher than on conventional farms and soil structure is typically better. The benefits of good soil structure include improved soil strength and aggregate stability (offering resistance to erosion), optimal bulk density, and improved water retention and infiltration rates (Carter, 2002; Shepherd et al., 2002).

In addition, Shepherd et al. (2002) suggested that the use of manure and pastures in a rotation are valuable for improving soil structure and increasing the content of SOM. However, it should be noted that, under the Canadian organic regulation, the use of fresh manure on crops for human consumption has to be made four months before harvest, and four months before planting crops that are nitrate accumulators (e.g., radishes, leafy greens, and beets) (Canadian General Standards Board, 1999). Non-organic sources of manure must be composted (Canadian General Standards Board, 1999).

Carter (2002) noted that soil erosion and non-sustainable agricultural practices may contribute to losses of SOM and other soil quality parameters. However, the cultivation of grassland, crop rotation, and the addition of organic materials tend to improve soil quality

Table 2.1 Influence of Soil Organic Matter on Soil Quality

1. Store and supply plant nutrients, as well as increase cation exchange capacity.
2. Improves soil structure by stabilising and holding soil particles as aggregates.
3. Improves porosity, promotes water infiltration and drought resistance, reduces runoff and soil compaction.
4. Provides soil's microbes with a source of carbon and energy.
5. Reduces negative environmental effects of pesticides, heavy metals and other pollutants by binding contaminants.

Source: Adapted from Cooperband (2002).

(Carter, 2002) and help reduce soil erosion (Papendick et al, 1986). The Eastern Canada Soil and Water Conservation Centre (1997) identified several technologies that can be used to reduce erosion, compaction, soil acidification, organic matter loss, drainage problems, and soil contamination (Table 2.2). These conservation technologies involve the modification of common farming practices such as rationalising the use of pesticides, moderating and managing the use of irrigation, reducing traffic and load on fields, and modifying tillage techniques. Other conservation technologies may require the implementation of more innovative farming systems such as innovative crop rotations, cover crops, mulching, strip cropping, and cross-slope farming. The establishment of terraces, windbreaks, grassed waterways, drains, and methods to manage sludge and organic matter are also examples of conservation technologies (Canada Soil and Water Conservation Centre, 1997).

2.2.3 Soil Fertility Improvement Alternatives

Proper management practices can help maintain or even increase the amount of soil organic matter. Cooperband (2002) outlined various strategies for building SOM, depending on the farmer's needs and goals (i.e., short versus long term effects on soil structure and nutrient availability). In general, there are two alternatives for building SOM: by using specific cultural practices such as crop rotations, cover crops and green manures, and by the addition of organic soil amendments. Crop rotation and organic soil amendments play a crucial role in attaining sustainability and economic viability on organic farming (Entz, et al., 1998). Rotations have the potential to recycle nutrients on

Table 2.2 Soil degradation issues and their conservation technologies

Soil conservation technologies	Type of soil degradation									
	Organic matter loss	Structural degradation	Compaction	Water erosion	Wind erosion	Tillage erosion	Soil acidification	Drainage problems	Subsidence of organic soils	Soil contamination
Drainage			x					x		
Rational use of pesticides										x
Sludge characterization and management										x
Surface irrigation									x	
Water table control			x					x	x	
Wind breaks					x					
Terraces	+	+		x						
Grassed waterways	+	+		x						
Strip cropping	+	+		x	x					
Cross-slope farming	+	+		x		x				
Cover crop	x	x		x	x					
Liming		x					x			x
Reduced speed of tillage and/or tillage depth	x	x				x				
Limiting load and traffic		x	x							
Ridge till	x	x	x	x	x	x				
Zero or minimum tillage	x	x	x	x	x	x				
Mulching	x			x	x					
Crop rotation	x	x	x	x	x					
Organic matter management	x	x	x	x	x					x

NB: x indicates a direct effect, + indicates an indirect effect

Source: Adapted from Eastern Canada Soil and Water Conservation Centre (1997).

the farm, and control weeds, pests and diseases by interrupting their cycles (Babcock and Secchi, 1999; Peel, 1998; Younie et al., 2002).

2.2.3.1 Crop Rotation

Crop rotation is the planned cultivation of specific crops on the same field in consecutive periods, where subsequent crops are of a different genus, species, subspecies, or variety than the previous crop, and where the sequence of rotation is repeated (Peel, 1998). Crop rotations are generally intended to improve or maintain soil fertility, reduce erosion, lower the incidence of pests, and reduce reliance on agricultural chemicals (Peel, 1998).

Altieri (1995) identified two phases in crop rotation systems. The first is the soil fertility-building phase. The second is the cropping phase, during which the level of nitrogen is depleted. Watson et al. (2002) suggested that in a system where soluble nitrogen fertilizer is not used, a plan for nitrogen supply is required and crop rotations are the basis for future planning. Furthermore, Watson et al. (2002) noted that in the UK, the fertility-building phase can last from one to five years or longer under forage cultivation (involving combinations of legumes and grasses). In organic farming, the potential of legumes to fix atmospheric nitrogen represents a great advantage to cash crops that follow in the rotation. Forages in a rotation may be incorporated into the soil as green manures prior to cultivating such cash crops. However, there is a risk of nitrate loss by leaching when forages are incorporated in the soil (Watson et al., 2002).

Other benefits of integrating forages in crop rotations include higher yields in grain crops, lower weed populations and improved soil quality. Forages in a rotation can also sequester carbon from the atmosphere, reduce nitrate leaching, and provide a benign habitat for wildlife (Entz et al., 2002).

Crop rotations can influence soil quality in terms of increasing water infiltration and reducing soil crusting and erosion. For example, Peel (1998) found that the inclusion of barley, hay, or pastures into a rotation reduced the degree of soil erosion by more than 50%, compared to continuous corn.

In spite of its advantages, crop rotation requires careful planning because phytotoxicities, allelopathies and auto-toxicity may have a positive or negative influence on subsequent crops. Peel (1998) noted, for example, that growing alfalfa for repeated years in a rotation can reduce yield from auto-toxicity effects. On the other hand, organic farmers can take advantage of allelopathies and phytotoxicites to control weeds. Younie et al. (2002) reported a reduction in seed-bank abundance in organic fields where crop rotation is practiced, and relatively minor changes in weed species diversity.

Crop rotation can be an effective alternative pest control strategy. For example, pest populations may be greater in areas where only one or two crops are grown, as opposed to areas where there are rotations (Peel, 1998). Entz et al. (2002) noted that pathogen incidence may decline in long period forage stands, decreasing the damage in a subsequent crop (Entz et al., 2002).

Forage crop rotation can bring additional benefits to farming operations (Entz et al., 2002). According to Power (1987), the amount of nitrogen fixed by legumes varies not only with the legume species, but also with soil characteristics, nutrient availability, water regimes, and crop management. Forage legumes such as alfalfa, can fix up to 223 kg of nitrogen/ha/year, 112 kg of N/ha/year for birdsfoot trefoil, and 128 kg of N/ha/year for white clover. On the other hand, grain legumes like soybean can fix from 22 kg of N/ha/year to 310 kg of N/ha/year, faba beans up to 251 kg of N/ha/year, and lentils up to 189 kg of N/ha/year (Power, 1987). Power (1987) reported that legumes can also be used as winter cover crops in a continuous cropping system, or in short-term and long-term rotations. Power (1987) noted that farm management can influence the amount of nitrogen that legumes can add to the soil. For example, not removing the last cut of alfalfa hay can increase nitrogen in the soil. Legume rotations have additional long-term benefits including soil structure improvement, better control of nitrogen availability, improvement of ground water quality (e.g., reduced nitrate leaching), and less energy needed for cultivation (Power, 1987).

2.2.3.2 Organic Soil Amendments

Organic farmers depend on organic soil amendments to balance soil nutrient requirements, to improve nutrient supply, and to enhance soil physical characteristics. Canadian Organic Growers (2001) define soil amendments as materials that can be incorporated into soil to enhance its biological activity and improve soil fertility.

In general, soil amendments may be classified into the following groups: plant by-products (i.e., alfalfa and soybean meal), animal by-products (i.e., blood and bone meal), manure and compost-based materials, rock and mineral powders (including calcium carbonate from egg and oyster shells), seaweed products, and microbial inoculants (Sullivan, 2001). However, it is important to emphasize that organic standards may restrict the type of materials that can be used as soil amendment. In general, Canadian organic standards restrict the use of animal by-products, compost (from off and on-enterprise organic and non-organic sources), fresh manure, and some sources of minerals (Canadian General Standards Board, 1999).

2.2.4 Magnitude of Soil Fertility and Environmental Concerns in Atlantic Canada

As in the rest of the country, soil degradation and decline in soil fertility is of great interest in the agricultural sector in Atlantic Canada. According to the Eastern Canada Soil and Water Conservation Centre (1997), soil erosion caused by water is the most important problem in the region. Intensive row crop production (for example potatoes in New Brunswick and Prince Edwards Island, vegetables in Nova Scotia and Newfoundland, and blueberries in the Annapolis Valley) is one of the main causes of soil erosion. Intensive row crop production accelerates the decomposition of soil organic matter, increases soil compaction, and reduces soil fertility (Voutsinos and Brenton, 1995). Water Erosion contributes to sedimentation of streams in Atlantic Canada. Sedimentation of streams has a negative impact on drainage, the flow of watercourses, and the productivity of surrounding land. Moreover, it can be a serious hazard for aquatic life (Eastern Canada Soil and Water Conservation Centre, 1997).

Although soil erosion caused by wind is another important problem in Atlantic Canada, particularly for land left uncovered (Voutsinos and Brenton, 1995), there have been improvements over the years (Environment Canada, 2003). Indeed, between 1981 and 1996, the number of "bare-soil days" (number of days that soil has not been covered by a crop, crop residue, or snow) declined by 20% in the region. On the other hand, over the same period, there was a 50% increase in the share of farmland with more than 5 kg/ha of residual nitrogen in the soil. Consequently, the risk of ground and surface water contamination by residual nitrogen has increased. Several sources of surface and ground water contamination have been identified in Atlantic Canada (Table 2.3).

According to the Eastern Canada Soil and Water Conservation Centre (1997), bacterial contamination of groundwater has been observed. Although the risk of bacteria

Table 2.3 Sources of Surface and Groundwater Contamination in Atlantic Canada

Soil sediments eroded from farm fields and stream banks
Nutrients carried with eroded soil sediments
Nutrients leached from fertilizer and manure applied to crops
Nutrients leached from forages ploughed early in the season
Runoff and leaches from manure storage
Pesticides (herbicides, insecticides, etc.)
Bacteria from livestock manure and septic systems
Land application of wastes
Road salt, soil eroded from roads, acid and metals from mining activities (not related to agriculture activities)

Source: Adapted from Eastern Canada Soil and Water Conservation Centre (1997).

contamination from agricultural practices may be difficult to eliminate, good management and storage methods can reduce the risk. Incidents of pesticide contamination have also occurred in the region, but in most cases the level of contaminants is below the drinking water standard. On the other hand, the Eastern Canada Soil and Water Conservation Centre (1997) noted that drinking water guidelines have not been established for all pesticides and pesticide metabolites. Furthermore, the Centre identified potato and corn production as a latent risk for pesticide contamination of water systems in Atlantic Canada, because of the leacheability of pesticides used in these crops.

2.3 Economic Considerations

2.3.1 Economic Feasibility of Organic Agriculture

Canadian farmers have traditionally relied on public and private loans to finance their operations (Sabih, 1998). According to Agriculture and Agri-food Canada (2004), total farm debt has been increasing since the early 1990s. In 2003, Statistics Canada (2004a) reported a 7.2% increase in Canadian farm debt (11.4% in Atlantic Canada, 8.7% in Western Canada, and 5,1% in Ontario and Quebec) (Table 2.4). Statistics Canada (2004b) reported that, net cash income (cash receipts minus operating expenses) declined 39.1% in 2003, the lowest level in 25 years. In 2003, net cash income dropped 25.9% in Atlantic Canada, 55.9% in Western Canada, and 2.5% in Ontario and Quebec. The reduction in net cash income was attributed to a carryover effect of severe droughts in 2001 and 2002,

Table 2.4 Trend in Canadian Farm Debt

Year	Newfoundland	Prince Edward Island	Nova Scotia	New Brunswick	Atlantic Canada	Annual Increase
	in $ million					
1990	33.4	178.6	264.7	218.0	694.7	N/A
1991	37.4	188.3	276.3	226.2	728.2	4.8%
1992	36.6	207.5	270.5	230.8	745.4	2.4%
1993	35.0	234.9	263.6	231.3	764.8	2.6%
1994	39.0	284.9	306.8	231.3	862.0	12.7%
1995	39.7	310.6	308.5	272.1	930.9	8.0%
1996	42.6	333.1	326.7	301.2	1,003.6	7.8%
1997	41.1	376.6	364.5	331.1	1,113.3	10.9%
1998	44.3	420.2	400.6	357.7	1,222.8	9.8%
1999	48.7	443.3	422.1	382.3	1,296.4	6.0%
2000	46.6	472.3	464.5	426.6	1,410.0	8.8%
2001	53.6	507.8	491.1	472.1	1,524.6	8.1%
2002	67.2	551.0	548.9	519.6	1,686.7	10.6%
2003	65.8	610.3	596.8	606.2	1,879.1	11.4%

Year	Manitoba	Saskatchewan	Alberta	British Columbia	Western Canada	Annual Increase
	in $ million					
1990	2,101.8	5,163.6	6,179.0	1,146.9	14,591.3	N/A
1991	1,989.3	4,921.2	6,401.4	1,155.3	14,467.2	-0.9%
1992	2,058.2	4,740.0	6,226.9	1,101.3	14,126.4	-2.4%
1993	2,019.7	4,481.8	6,359.6	1,177.4	14,038.5	-0.6%
1994	2,216.6	4,410.8	6,398.9	1,298.2	14,324.5	2.0%
1995	2,427.4	4,517.7	6,632.7	1,373.4	14,951.2	4.4%
1996	2,588.4	4,810.8	6,894.2	1,482.9	15,776.3	5.5%
1997	2,820.5	5,171.2	7,611.4	1,652.3	17,255.4	9.4%
1998	3,150.7	5,584.0	8,218.9	1,859.3	18,812.9	9.0%
1999	3,509.6	5,809.9	8,685.0	2,072.8	20,077.3	6.7%
2000	3,714.7	5,961.6	9,128.2	2,155.7	20,960.2	4.4%
2001	3,947.6	6,060.5	9,485.2	2,217.1	21,710.4	3.6%
2002	4,249.4	6,069.7	9,775.4	2,327.0	22,421.5	3.3%
2003	4,768.7	6,661.0	10,493.1	2,445.6	24,368.4	8.7%

Note: N/A= non applicable.
Source: Adapted from Statistics Canada. 2004a.

Table 2.4 Trend in Canadian Farm Debt

Year	Quebec	Ontario	Total Ontario and Quebec	Annual Increase	Total Canada	Annual Increase
	in $ million				in $ million	
1990	3,366.9	4,978.9	8,345.8	N/A	23,631.8	N/A
1991	3,525.1	4,812.8	8,337.9	-0.1%	23,533.3	-0.4%
1992	3,713.9	4,798.5	8,512.4	2.1%	23,384.2	-0.6%
1993	3,630.7	4,975.4	8,606.1	1.1%	23,409.4	0.1%
1994	4,113.6	5,159.7	9,273.3	7.8%	24,459.8	4.5%
1995	4,403.0	5,457.3	9,860.3	6.3%	25,742.4	5.2%
1996	4,868.1	5,966.9	10,835.0	9.9%	27,614.9	7.3%
1997	5,435.4	6,866.5	12,301.9	13.5%	30,670.6	11.1%
1998	6,097.3	7,635.5	13,732.8	11.6%	33,768.5	10.1%
1999	6,844.8	8,205.8	15,050.6	9.6%	36,424.3	7.9%
2000	7,610.7	9,097.0	16,707.7	11.0%	39,077.9	7.3%
2001	8,133.4	9,691.6	17,825.0	6.7%	41,060.0	5.1%
2002	9,285.1	11,103.8	20,388.9	14.4%	44,497.1	8.4%
2003	9,740.6	11,693.1	21,433.7	5.1%	47,681.2	7.2%

Note: N/A= non applicable.
Source: Adapted from Statistics Canada. 2004a.

and to the 2003 Bovine Spongiform Ecephalophaty (BSE) crisis. The National Farmers Union (2003) reported that, Canadian farmers have been selling their products at the same prices for the past 25 years, while production costs have continued to rise In deed, Statistics Canada (2004b) reported a 3.1% increase in farm operating expenses in 2003. As a result, Agriculture and Agri-food Canada (2004) reported 222 farm bankruptcies across the country in 2003 and an increase of 2.5% in government expenditures to support the agri-food sector (mainly in the form of program payments, research, and inspection). Gilson (1992) noted that Canadian family farms are facing a financial distress that may be more "chronic or structural" than "periodic or cyclical."

A number of studies suggest that organic agriculture has potential as an alternative production method that could help farmers ease their financial difficulties (Cacek and Langner, 1986; Ogini et al., 1999; Rigby and Cáceres, 2001). Indeed, Cacek and Langner (1986) noted that some farmers switch to low input organic farming systems as a strategy for risk management and farm financial survival. An increasing number of farmers have been converting to organic production across Canada. For example, the number of certified organic farms in Saskatchewan has grown from 190 in 1992 to 1,149 in 2003.

Studies in the US have suggested that, in general, financial returns in organic production are comparable to conventional production (Cacek and Langner, 1986; Mahoney et al., 2004; Roberts and Swinton, 1996). Mahoney et al. (2004), for example, reported that the organic and conventional systems they studied had statistically similar net returns per acre even when price premiums were not considered. Mahoney et al. (2004) noted that the organic systems studied had lower yields than the conventional counterparts, but production costs were also lower. Furthermore, when price premiums were taken into account, organic systems outperformed their conventional production alternatives. However, Dabbert and Madden (1986) suggested that during the transition to organic farming, farmers can experience severe financial difficulties, if there is a large yield reduction.

Comparisons between organic and conventional agriculture have also been conducted in Canada. One group of studies compared the performance of conventional and organic production systems (e.g., Ogini et al., 1999; Sholubi et al., 1997; Stonehouse, 1996; and Stonehouse et al., 1996), and a second group evaluated the productivity and economic feasibility of organic agriculture by itself (e.g., Entz et al., 1998; MacRae et al., 1990; and Parsons, 2002). Although some of these studies investigate both technical and economic aspects (e.g., Entz et al., 1998; Ogini et al., 1999; Sholubi et al., 1997; Stonehouse, 1996; and Stonehouse et al., 1996), in general, there are more studies on technical aspects than on economic analysis, especially for Atlantic Canada.

Most of the studies have been conducted for Western Canada, Ontario, and Quebec, with very little information available for organic agriculture in Atlantic Canada. Given the regional differences in farming systems, studies on actual farms are important for understanding the technical and economic implications for Atlantic Canada. Some of the knowledge gaps in organic agriculture relate to the technical and economic implications of substituting synthetic sources of inputs with more benign alternatives and the impacts of altering traditional crop rotations, the incorporation of organic soil amendments, and weed and pest control.

Various organic agricultural systems have been studied in Central and Western Canada. Organic dairy farming, for example, was found to be economically feasible and profitable in Ontario, primarily due to cost-efficiency in production (Ogini et al., 1999; Sholubi et al. 1997). Ogini et al. (1999) reported that organic dairy farms generated milk yields (5,882 liters/cow/yr) that were similar to their conventional alternatives (5,865 liters/cow/yr), while organic production costs on a whole-farm basis represented 77% of conventional production. Similarly, Sholubi et al. (1997) reported that organic dairy farms in Ontario were no more labour intensive than conventional systems. Furthermore, neither farm size (land area) nor the size of the herd were constraints on organic milk production.

In contrast to organic dairy farming, other organic production systems have not performed well in terms of yield. In a survey conducted for Statistics Canada, Parsons (2002) reported that, in general, organic fruits and vegetable farms across the country generated lower yields compared to conventional. Similarly, Entz et al. (1998) found that crop yields on organic farms in the Eastern Prairies fluctuated between 50-70% of conventional yield, for farms of similar size. However, in some cases, yield-risk reducing practices, such as preservation of soil fertility and prudent management of weeds and pests, can help to achieve yields that are comparable or even higher than conventional yields (Entz et al., 1998; Parsons, 2002).

Stonehouse (1996) reported that gross income per hectare and net farm income were higher on some organic farms with lower yields. Direct crop production costs were found to be lower than conventional farms, even when organic methods for weed control were more expensive on a per hectare basis (Stonehouse et al., 1996). Higher net returns generated by the organic farms studied were due not only to lower production costs, and output price premiums, but also because of greater enterprise diversification, and less reliance on purchased inputs (Stonehouse et al., 1996). Entz et al. (1998) found that some organic cropping enterprises may not be able to generate positive net returns without a price premium. Exceptions were for durum wheat, white soft wheat, and alfalfa hay. Entz et al. (1998) reported that alfalfa hay in the prairies can be quite profitable. However, in most cases, the economic performance of organic cropping is directly related to the availability of price premiums. In addition, Entz et al. (1998) noted that soil fertility and weed management also influenced the viability of organic production.

Stonehouse (1996) suggested that net farm income varies among production systems (i.e., organic, low-input and conventional) and attributed these variations to differences in the scale of operation, enterprise combinations of the farming systems themselves, and human capital endowments. Sholubi et al. (1997) noted that organic production systems are more management intensive, with considerable time spent thinking, observing and planning appropriate crop rotations and scheduling field operations.

2.3.2 Economics of the Transition to Organic Agriculture

Economic considerations play an important role during the transition to organic farming and are a key barrier to adoption (Dabbert and Madden, 1986; MacRae et al, 1990; Sellen et al., 1995). Conversion to organic agriculture may involve significant cost and innovation. For instance, Sellen et al. (1995) found that organic vegetable production was not profitable during the early stages of transition. Farmers may incur higher labour costs for weed and pest management (Stonehouse et al., 1996; Sellen et al., 1995; Blobaum, 1983), as well as significant production costs when replacing higher yielding crops with more complex rotations, or machinery costs associated with switching systems or diversifying production (Yiridoe and Weersink, 1994).

According to Dabbert and Madden (1986), changes in profits due to switching from conventional to organic farming may stem from five different effects: rotation adjustment, biological transition, price effect, learning effect, and a perennial effect. The rotation adjustment effect relates to a reduction in farm income caused by implementing crop rotations needed to establish an organic operation, because farmers may need to substitute profitable crops with crops that are less profitable but needed as part of the organic system. However, this effect may be limited or non-existent if the previous farming operation included rotations with legume crops. The biological transition effect is the reduction in income due to lower yield. However, the biological effect is a function of cropping history, climate and soil characteristics, as well as the transition strategy selected. Dabbert and Madden (1986) described the three cases where income is affected by prices received. First, income may increase if transitional organic products receive a price premium (i.e., if there was a market for products in transition). Second, a non-existent price effect exists when commodities in the transition phase are sold at conventional prices. Third, there can be a negative price effect as a result of quality changes.

The learning effect is perhaps the most complicated to determine, and is the change in income due to a farmer's lack of experience or knowledge regarding organic practices (Dabbert and Madden, 1986). However, it is becoming less difficult for farmers to become informed about organic agriculture, because there is much more farmer oriented literature available, and more organic farmers to learn from than there were in the past. Prospective farmers can also put organic methods into practice before formally starting the process. For example, farmers may convert their farming operation in stages and reduce the dependence on synthetic farm inputs gradually.

Dabbert and Madden (1986) also noted that there is a perennial effect on income, which is the long-term effect caused by the whole farming system when it is fully implemented. This relates to a change in profits caused by changing the combination of crops grown and livestock enterprises. Dabbert and Madden (1986) noted that this effect may be positive or negative, depending on the profitability of the farm on a year-to-year basis.

In summary, there is a strong possibility of short-term financial losses throughout the transition period due to declines in average yields, inability to access price premiums prior to obtaining organic certification, and higher production costs during the transition period. The initial cost of controlling weeds, pests, and diseases can be high, as well as the costs related to biological control, additional cultivations, and hand weeding. Organic nutrient supply could also be expensive in the initial years of transition, especially if the application of manure, compost, and other sources of nutrients require extra time or modifications to machinery. In the short-run, organic sources of nutrients may be more expensive than synthetic fertilizers. Organic seeds may be more expensive relative to conventional seeds. Certification fees can also increase the initial costs of implementing the system.

The above issues suggest that economic performance during the transition to organic agriculture is indeed different than when the system is in complete operation; i.e., when yield levels are recovered, price premiums are accessible, and when production cost stabilize. Therefore, it may be premature to judge the long-term performance of an organic system based on results during the process of transition. In this case, the potential economic losses during the years of transition may be considered as an investment, and the profits obtained from organic production as the returns from investing in a good strategy for the transition period.

2.3.3 Economic Implications of Crop Rotation and Soil Fertility Improvement

The economic performance of crop rotations and soil fertility improvement alternatives are not only site specific, but also depend, to a large extent, on management skills of the farm operator. Guertal et al. (1997) noted that in evaluating of the economic consequences of crop rotations, consideration should be given to the rotation sequence, rotation length, and the stage of the rotation. Gebremedhin and Schwab (1998) argued that because different crop rotations vary in terms of production costs and output levels, it is important to carry out comparative analysis on returns to farm resources and consider income variability.

There is a long history of the application of economic theory to selecting a profit maximizing crop rotation. Some of the early discussions of crop rotations include: Galloway, 1933; Heady, 1948; and Johnson, 1933. Johnson (1933) recognised that the combination of enterprises on an individual farm level is a "highly dynamic problem," that can be analyzed using a comparative advantage approach. The profitability of a particular enterprise may depend on its association with other enterprises managed on the same farm. In addition, physical, biological, social, historical, political, and economic factors can influence the analysis. Furthermore, Johnson (1933) noted that an analysis of physical and price relationships between enterprises is important to determine the "highest profit combination," and that the principle of substitution as discussed by Marshall (1920) is an important tool for comparing net returns of different enterprise combinations.

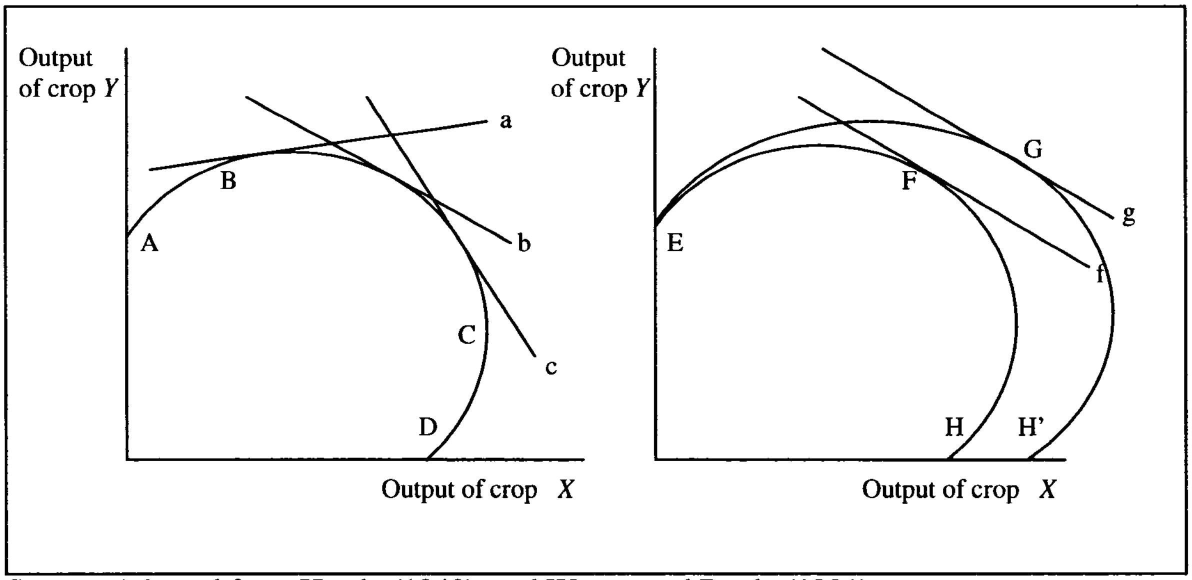
Heady (1948) discussed the economics of crop rotations in a two dimensional context, and defined the problem as the choice of output of two different products that can be produced with the same given resource (i.e., at the same cost) represented by a production possibility frontier or iso-cost (iso-factor) curve. Heady (1948) identified four different relationships between enterprises. The first is a competitive case, where an increase in output of one crop decreases output of the other and vice versa, and a substitution of one crop with the other occurs at a constant marginal rate. The second is also a competitive case, but the substitution occurs at a diminishing marginal rate. The third case is where the two crops are strict complements, in the sense that an increase in output of one crop also increases output of the other at a diminishing marginal rate. Finally, a fourth case can occur, although not in agriculture, where the two crops are produced in fixed amounts, and there is no substitution (i.e., the marginal rate of substitution is zero).

Heady (1948) used the above discussion to introduce the concept of iso-land curves. Iso-land curves are a type of iso-cost curves, but instead of total costs, the iso-land curve represents a fixed area of land and its associated fixed cost on which two crops can be grown in rotation. The slope of an iso-land curve is given by the rate of product transformation, or the rate at which one of the crops can be substituted with the other without changing the level of the factor used. Heady (1948) noted that iso-land curves are appropriate to illustrate rotation experiments, where each experiment (or crop combination) is a point on the iso-land curve. Iso-land curves also present the competitive and complementary relationship of iso-cost curves. In Figure 2.1, there is a complementary relationship between crops along the iso-land curve from points A to B, and C to D, whereas along the curve from point B to C the relationship is competitive. For example, the yield of potato under a potato-based rotation that includes legume forages can be higher as the number of years of forages increases in the rotation (points A-B and C-D). However, forages can also compete with the target crop. As forage output increases, potato output decreases (points B-C).

The total revenue generated by a rotation can be illustrated with iso-revenue curves. The slope of the iso-revenue curve is the price ratio of the two crops, and since prices are fixed, iso-revenue curves are straight lines. The further away the iso-revenue curve is from the origin, the greater the revenue. Assuming that total revenues are higher than total cost, and given the price ratio and the technology, the point of tangency between an iso-land curve and an iso-revenue curve is the maximum level of net revenue (Heady, 1948). This is illustrated by point F in Figure 2.1.

As the amount of the factor (land) is increased, the iso-land curve is shifted outwards and to the right. Assuming that more output is produced and sold, iso-revenue curves also shift outwards. Westra and Boyle (1991) noted that technological improvement also shifts

Figure 2.1 Iso-land and iso-revenue curves



Source: Adapted from Heady (1948), and Westra and Boyle (1991)

the iso-land curve outwards and to the right, but not necessarily in a concentric manner. For example, a potato harvester that causes less damage to the product can increase the marketable output of potato and the net return maximizing level is shifted as in Figure 2.1 from point F to G.

The Economic implications of crop rotation can vary among production systems (i.e., mixed, livestock, stockless, or purely horticulture systems). For example, Watson et al. (2002) reported that a mixed farming operation could have positive economic returns generated from the livestock enterprise, which would benefit from forages produced as part of a rotation planned for soil fertility building purposes. However, the costs of implementing a crop-livestock system in a conventional stockless farm planning to convert to organic farming can be quite high, partly because the potential economic benefits from a livestock enterprise may not be able to offset the costs of diversifying. On the other hand, stockless operations that will not profit from livestock enterprises could still have economic benefits if there is a market for forage/legumes produced as part of a rotation scheme.

Crop rotation plans have associated opportunity costs. The opportunity cost of producing a particular crop in a rotation is the value that a farmer could have obtained by growing the next best alternative crop (Gebremedhin and Schwab, 1998). There may be significant production costs when profitable crops are replaced with crops that are more convenient in a rotation plan (Yiridoe and Weersink, 1994). However, this may not be the case for forage-based crop rotations. For example, a long-term experiment in Manitoba (the Glenlea study) suggested that an organic forage-based crop rotation can have lower production costs compared to the corresponding conventional alternative (University of Manitoba, 2005).

The cost efficiency of some organic systems may be the result of both fewer inputs used and lower cost of organic inputs. A study for Atlantic Canada by the Eastern Canada Soil and Water Conservation Centre (1997) suggested that a rotation consisting of potato – cereal – forage was optimum from both environmental and economic perspectives. These findings are of interest in the present study because the optimum number of years of forage crops included in a crop rotation plan will be analyzed.

Jacks (1954) argued that farmers will only maintain a fertile soil when it pays to do so. Gebremedhin and Schwab (1998) suggested that farm profitability is a critical factor for individual farmers, in the sense that they will select a farming alternative that, apart from being feasible from an agronomic stand point, is also financially sustainable. Carter (2002) supports this argument by suggesting that soil organic matter and the sustainability of intensive farming systems can be affected by the short-term economic viability of maintaining soil quality. Since building soil organic matter can be an investment, farmers may differ in terms of soil fertility preservation, depending on ownership status. Martin (2003) suggested that land tenancy status could be a decisive factor in the transition to organic agriculture. Land-owners are more likely to be interested in building and maintaining soil fertility (i.e., preserve their natural resource), whereas short-term tenants may not be interested unless there are contractual stipulations that require them to do so or a long term lease. Therefore, landowners may be more attracted by organic systems than land tenants would be.

Watson et al. (2002) suggested that, the complexity of organic systems themselves can challenge the development of organic agriculture. Most management decisions in organic farming have economic and environmental effects on its performance. Given that crop rotations can help improve soil fertility, control the incidence of pests and weeds, and reduce erosion, there may be economic externalities that are not often considered. An economic assessment of a crop rotation becomes more complex when particular environmental, economic, and social factors influence the long-term sustainability of a production system. In addition, a particular crop rotation system may be convenient (i.e., feasible) to be carried out even if it is not profitable in the short-term.

2.3.4 Economic Methods for Analyzing Crop Rotation Systems

A number of analytical economic methods have been used to analyze crop rotations, as well as to compare organic and conventional agricultural production systems. Enterprise budgeting, break-even analysis, whole farm budgeting, partial budgeting, linear programming, multi-period programming, and stochastic dominance analysis are commonly used techniques (Gebremedhin and Schwab, 1998). Examples of studies that used these methods are summarized in Table 2.5.

Enterprise budgeting is a technique used to estimate the profitability of a single crop or livestock commodity that produces a marketable good. An enterprise budget includes the estimates of income and expenses generated by an enterprise for a specific period of time under specific practices (Colorado State University, 2000). Roberts and Swinton (1996) identified enterprise budget analysis as the most common method used for comparing profitability of different cropping systems. Enterprise budget analysis is appropriate when the differences between systems affect only part of the farm operation (Gebremedhin and Schwab, 1998). Gebremedhin and Schwab (1998) reported that enterprise budgeting has been used to determine the technical viability of a particular crop for a crop rotation, and the profitability of a crop under a particular rotation. Enterprise budgeting has also been used to compare organic and conventional production systems (e.g., Entz, 1998; Mahoney et al., 2004; Ogini et al., 1999; Sellen, 1995). According to Gebremedhin and Schwab (1998), enterprise budgeting can be used to obtain various measures of returns (e.g., gross margin, accounting profits, economic profits), and requires including the monetary value of all relevant inputs and outputs. A number of studies have used enterprise budgets in developing linear programming models to simulate the economic impacts of crop rotations (see e.g., Dabbert and Madden, 1986; Forest, 1992; Lazarus and White, 1984; Musser et al., 1985). Enterprise budgeting is relevant for the present study, since the profitability of three production systems under transition to organic agriculture will be evaluated.

Partial Budgeting is a decision making tool used to analyze a change on a given

Table 2.5 Economic Methods for Analyzing Crop Rotation Systems

Method of Analysis	Examples of Studies that Used this Method	
Enterprise Budgeting	Christenson et al., 1995.	Compared economic returns of various crop rotations consisting of sugar beets, navy beans, corn, oats and alfalfa.
	Entz, 1998.	Evaluated the performance of organic production under different crop rotations in the eastern Prairie region.
	Juergens et al. 2004.	Assessed agronomic and economic performance of alternative no-till rotations consisting of three combinations of soft white wheat, barley, yellow mustard, and safflower in Washington State.
	Mahoney et al., 2004.	Compared low and high input production systems versus organic production. The study used data from two different cropping sequences, corn-soybean and corn-soybean-oats/alfalfa-alfalfa in South Western Minnesota.
	Ogini et al., 1999.	This study compared economic performance and scale of operation of a sample of eight organic dairy farms with 120 conventional dairy farms in Ontario.
	Sellen, 1995.	Investigated the financial viability of a vegetable rotation during the initial years of transition to organic farming in Ontario. The study included a comparison with conventional vegetable production under similar rotations.
	Zentner et al., 1988.	Compared economic performance of conventional and no-till practices for continuous wheat, wheat-fallow, and wheat-barley-fallow in Southern Alberta.
Linear Programming	Domanico et al., 1986.	Analyzed income variability of soil erosion reduction. The study compared organic, conventional, and no-till cropping systems in Eastern Pennsylvania.
	Foltz et al., 1993.	Evaluated the economic and environmental impacts of including alfalfa into a corn crop rotation in the Eastern corn belt. Simulation techniques were also used.
	Hesterman et al., 1986.	Analyzed the economic feasibility of continuous corn in Minnesota with two rotations, corn-alfalfa and corn-soybean.
	Lazarus and White, 1984.	Studied potato production in rotation with grains and vegetables. The information obtained from enterprise budgets was used to generate a linear programming model of a representative 150 ha potato farm in Long Island, New York. The crop rotations studied included rye, corn, wheat, soybeans, oats, sunflower, dry beans, cauliflower, and cabbage.

NB: Underlined references identify studies where analytical methods were applied to organic production systems. Adapted from Gebremedhin and Schwab, 1998; and Roberts, and Swinton, 1996.

Table 2.5 Economic Methods for Analyzing Crop Rotation Systems (*continued*)

Method of Analysis	Examples of Studies that Used this Method	
Linear Programming	Musser et al., 1985.	Developed a mathematic programming model for vegetable rotations in Southeastern United States. The model was developed using information from enterprise budgets.
	Stonehouse et al., 1996.	Surveyed twenty-five farmers in Ontario and conducted comparative analysis of weed management strategies for field cash crops under conventional, low-input, and organic practices. A model of net farm income was developed for the three systems.
	Taylor et. al., 1992.	This study links environmental standards and economic performance of cropping systems in the Willamette Valley, Oregon. The analysis included the selection of a profit-maximizing rotation under pollution control policies and biophysical simulation.
Multi-period Linear Programming	Baffoe et al., 1987.	Analyzed the economic performance of continuous corn and corn under alternative crop rotations in Ontario. The study also evaluated the effects that these cropping systems generated on soil erosion reduction.
	Dabbert and Madden, 1986.	Analyzed the trends in income for a dairy farm during the transition to organic agriculture in Pennsylvania. Enterprise budgeting was used to develop an optimization model.
	Forest, 1992.	The economics of the conversion to organic dairy. This study developed a programming model of a representative farm in Quebec using data from enterprise budgets.
Sensitivity Analysis	Janosky et al, 2002.	Compared economic performance of conventional and minimum tillage for a wheat-fallow rotation. The study was primarily motivated by wind erosion and blowing dust generated by conventional tillage methods in Eastern Washington. Enterprise budgets were used to do sensitivity analysis.
	Jones, 1996.	Compared economic performance of continuous corn versus a corn-based rotation of soybean and wheat after two consecutive corn cultivations in Michigan. The study included an analysis of price ratios and net returns. Enterprise budgeting constituted part of the analysis.
	Westra and Boyle, 1991.	Enterprise budgets were used to perform sensitivity analysis and compare continuous potato with potato-based rotations that included barley, oats, and processing peas. Barley and oats underseeded with clover also constituted part of the various crop sequences. This study was conducted in Aroostook county, Maine.

NB: Underlined references identify studies where analytical methods were applied to organic production systems. Adapted from Gebremedhin and Schwab, 1998; and Roberts, and Swinton, 1996.

Table 2.5 Economic Methods for Analyzing Crop Rotation Systems (*continued*)

Method of Analysis	Examples of Studies that Used this Method	
Stochastic Dominance Analysis	Brown, 1987.	Analyzed different wheat-based crop rotations involving output and price risk in Saskatchewan.
	DeVuyst and Halvorson, 2004.	Analyzed the economic effects of tillage practices from two cropping systems that included a rotation of spring wheat-winter wheat-sunflower versus spring wheat-fallow in the Northern Great Plains.
	Gebremedhin et al., 1998.	Studied risk efficiency of sugar beets and navy beans rotated with corn, oats and alfalfa in Michigan.
	Maynard et al., 1997.	Determined the risk preference for various cropping systems, including continuous corn and corn under rotations that involved different combinations of soybeans, alfalfa, oats, and wheat in Central Pennsylvania. The study included enterprise budgeting analysis.
	Poe et al., 1991.	Evaluated the impact of commodity programs and soil degradation on the selection of crop rotations.
Whole Farm Budgeting	<u>Batte et al. 1993.</u>	Investigated the economic performance of organic production systems in Ohio.
	Bole and Freeze, 1986.	Studied the performance of continuous barley, barley-fallow and flexible crop rotations in the Canadian Prairies.
	<u>Hanson et al. 1990.</u>	Compared conventional and low input grain production systems using data from the Rodale Institute. Whole farm budgets were generated from enterprise budgets.
	Johnson, 1984.	Enterprise budgeting was used to analyze and compare whole farm data of wheat-fallow versus a rotation of wheat-barley-fallow in Western Canada.
	Schoney and Thorson, 1986.	Compared farm income impact of two cropping systems, wheat-fallow versus wheat-wheat-fallow in Saskatchewan.
	<u>Sholubi et al., 1997.</u>	Compared size, labour requirements, yield, net farm income, cropping practices, and overall management of organic and conventional dairy farms in Ontario. Eight organic dairy farms were compared with published data of conventional dairy farms from the Ontario Dairy Farm Accounting Project.
Break-even Analysis	<u>Diebel et al., 1995.</u>	Comparative analysis of conventional and alternative cropping systems in Northeast Kansas. This study included whole farm analysis.

NB: Underlined references identify studies where analytical methods were applied to organic production systems. Adapted from Gebremedhin and Schwab, 1998; and Roberts, and Swinton, 1996.

enterprise. Partial budgeting evaluates changes in variable resources (Colorado State University, 2000). Gebremedhin and Schwab (1998) noted that partial budgeting is suitable when the choice of crops selected for a rotation plan is changed, and is especially useful when the switching of crops does not affect the rest of the farm operation, because a partial budget evaluates the economic effects of minor changes in a part of a business operation (Colorado State University, 2000). Roberts and Swinton (1996) noted that enterprise budgeting constitutes the foundation for whole farm analysis (see e.g., Hanson et al. 1990; Johnson, 1984) since whole farm analysis deals with changes that affect the operation as a whole. Whole farm analysis is a detailed evaluation of the resources of an entire business (Colorado State University, 2000). Whole farm analysis is appropriate for analyzing cropping systems that involve major changes in a farm operation (Gebremedhin and Schwab, 1998). Yiridoe et al. (2005) suggested that whole farm analysis is particularly useful in the context of organic agriculture, because all crops in the rotation are evaluated to determine the profitability of a farm system. Sholubi et al. (1997), for example, have compared organic and conventional dairy farms from a whole-farm basis. On the other hand, Gebremedhin and Schwab (1998) suggested that break-even analysis can be used to establish yield or price levels at which two crop rotations are equally suitable. Break-even analysis is a tool to determine the point at which total revenue equals total costs. Thus, it is possible to estimate the price required to reach the break-even point given various yields, and the yields required to achieve the break-even point at given prices.

Stochastic dominance is a decision tool used to rank cumulative distributions as a function of attitudes towards risk (Labarta, et al. 2002). It has been used in agriculture to analyze income risk efficiency associated with crop rotations, that is, an evaluation of a farmer's choice of a particular crop rotation based on the farmer's degree of risk aversion. Studies that have used stochastic dominance analysis include: Brown, 1987; DeVuyst and Halvorson, 2004; Gebremedhin et al., 1998; Maynard et al., 1997; Poe et al., 1991.

Sensitivity analysis can be useful to evaluate enterprise budgets at different prices and yields (Roberts and Swinton, 1996). Different crop rotations can be evaluated using sensitivity analysis. For example, Westra and Boyle (1991) carried out sensitivity analysis to determine the responsiveness of net present value of different potato-based rotations to changes in prices and yields. Jones (1996) also used sensitivity analysis to compare the economics of continuous corn versus corn-based rotations. The sensitivity results are more robust if a change in a parameter does not affect the net present value of a rotation or its rank relative to other rotations. Conversely, a result is sensitive if the opposite happens (Westra and Boyle, 1991).

Linear programming is a technique used to optimize an objective function subject to a set of constraints, where all relationships within the model are linear equations (Moore and Weatherford, 2001). Roberts and Swinton (1996) reported that linear programming is commonly used in farm management analysis to maximize farm profits and to measure how crop rotations or environmental standards affect profits (see e.g., Domanico et al., 1986; Foltz et al., 1993; Lazarus and White, 1984; Stonehouse et al., 1996; Taylor et. al., 1992). Multi-period linear programming is in essence the same technique, but carried out for more than one period. Roberts and Swinton (1996) indicated that, multi-period linear programming is more appropriate for measuring the carryover effect from one period to another, for example, how the profitability of organic farming evolves during transition. Studies on the transition to organic agriculture that have used multi-period linear programming include Dabbert and Madden (1986), and Forest (1992). Dabbert and Madden (1986) investigated trends in income for a dairy farm during the transition to organic agriculture in the US. A similar analysis was conducted by Forest (1992) for a Canadian dairy farm. According to Dabbert and Madden (1986), multi-period linear programming is particularly useful in studies that evaluate the economic implications of the transition to organic agriculture, because it has the capacity to rule out the effect that different management skills may have on the transition process. This is important because the transition can be affected by the experience or knowledge of a farm operator. Therefore the variation in income due to the "learning effect" can be excluded from the analysis by not taking into account the costs related to the learning process.

2.4 Summary

Maintaining soil fertility is one of the crucial aspects of organic agriculture. The incorporation of leguminous forages in crop rotation systems, as well as the use of organic soil amendments, can help build soil organic matter. In addition, crop rotations can reduce the incidence of pests and weeds.

Although soil fertility is not a major concern in Atlantic Canada, soil erosion and water contamination are issues affecting the region. Corn and potato production have been identified as crops that increase the risk of water contamination from pesticide run-off.

The economic feasibility of organic agriculture has been studied in many parts of the US and in several Canadian regions. However, little information is available for Atlantic Canada. With a few exceptions, most of the studies conclude that organic agriculture can be profitable, especially when the system is fully established. On the other hand, during the transition to organic agriculture, farmers may encounter financial losses where yields decline, price premiums are not accessible, and farmers incur significant production costs. However, forage-based crop rotations can help reduce losses.

A number of analytical methods have been used to evaluate the economic performance of organic production systems. Various studies suggest that enterprise budgeting and multi-period linear programming are appropriate methods for evaluating the economic performance of alternative production systems under transition to organic agriculture. These analytical methods will be adapted and used in this study to evaluate the economic performance of three alternative organic production systems for Atlantic Canada.

CHAPTER 3. ENTERPRISE BUDGETS AND STATISTICAL ANALYSIS

3.1 Outline

This chapter is divided into four sections. The first section provides details of the experimental design, characteristics of the experimental site and a description of the treatments studied, along with inputs used and farming activities undertaken. Production costs of the farm enterprises involved, including details of input expenditures, field operation costs, and fixed costs, are described in section two. Results of the statistical analysis of yields, production costs and net returns are discussed in section three. A summary of the main findings is presented in section four.

3.2 Experimental Design and Study Methods

Data for this study were collected from a four-year crop rotation experiment under transition to organic agriculture. The experimental trials were carried out on an experimental farm at the Nova Scotia Agricultural College (NSAC), Truro, Nova Scotia, and in Manitoba from 2002 to 2005. However, this study focuses on the trials conducted in Nova Scotia.

The Truro site was previously in perennial pasture. Beef cattle, dairy heifers, and sheep grazed this land for about 20 years prior to establishing the trials. The soil is a loam to sandy-loam soil, with 38.8% sand, 22% clay, 39.2% silt, and 4.5% organic matter. Soil test results (Table 3.1) indicated that the experimental site had low to medium fertility in terms of phosphorus (i.e., 73–144 kg/ha), and medium to high fertility in terms of potassium (i.e., 176–272 kg/ha). Nitrogen availability was not provided in the soil tests results. However, it is likely that the site was highly fertile in terms of nitrogen (Hammermeister, 2005).

The experiment was a two-factor nested design, where 3 types of soil amendment (i.e., stockless, monogastric, and ruminant) were combined with 3 levels of forage-based crop rotations (i.e., 0, 1, and 2 years of forage) (Table 3.2). The soil amendment factor was nested in the forage level factor (i.e., the quantity applied of each type of soil amendment varied with the frequency of forages grown in the rotation). However, it is important to clarify that the quantity of soil amendment applied not only depends on forage level, but also on other factors outside the scope of the present study. Such factors

Table 3.1 Soil Test Results

		Block 1	Block 2	Block 3
Phosphorus (P_2O_5)	Nutrient in soil (kg/ha)	144	93	73
	Fertility rating	M -	L -	L -
Potassium (K_2O)	Nutrient in soil (kg/ha)	272	230	176
	Fertility rating	H -	M+	M
Organic Matter (%)		4.5	4.5	4.6
pH		5.7	6	5.9

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: L=low, M=medium, H=high; +/- means high or low level within each rating. Nitrogen information was not provided in soil test results.

Table 3.2 Organic Treatments at the Truro Experimental Site

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">Source of Soil Amendment</td></tr>
<tr><td>Stockless (alfalfa pellets)</td><td>Monogastric compost</td><td>Ruminant compost</td></tr>
<tr><td colspan="2">Forage Management</td><td colspan="3">Sequence of crops in four- year rotation</td></tr>
<tr><td colspan="5">a) Core Plots</td></tr>
<tr><td rowspan="3">Frequency of Forage in Rotation System</td><td>0</td><td>WSBP</td><td>WSBP</td><td>WSBP</td></tr>
<tr><td>1</td><td>WBFP</td><td>WBFP</td><td>WBFP</td></tr>
<tr><td>2</td><td>WFFP</td><td>WFFP</td><td>WFFP</td></tr>
<tr><td colspan="5">b) Extra Experimental Plots</td></tr>
<tr><td rowspan="7">Frequency of Forage in Rotation System</td><td>0</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="3">1</td><td>BFPW</td><td>N/A</td><td>N/A</td></tr>
<tr><td>FPWB</td><td>N/A</td><td>N/A</td></tr>
<tr><td>PWBF</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="3">2</td><td>FFPW</td><td>N/A</td><td>N/A</td></tr>
<tr><td>FPWF</td><td>N/A</td><td>N/A</td></tr>
<tr><td>PWFF</td><td>N/A</td><td>N/A</td></tr>
</table>

Note: W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage, N/A= non applicable

include soil fertility, soil test recommendations, compost nutrient composition, and mulching practices in potato plots. The experiment at the Truro site was conducted in 3 blocks, where each block was a repetition of the treatments. Each block was divided into a set of core plots and extra experimental plots. The purpose of the core plots was to grow the crop(s) in the respective rotation in a factorial combination of the two factors, while the extra experimental plots were primarily intended to fully-phase the rotations (i.e., grow all crops in the rotation every year). The crops in the rotations were wheat (W), soybean (S), barley (B) and potato (P), where forage (F) replaced soybean and/or barley depending on the level of forage in the rotation. Each experimental plot was 3m x 10m, with a 1m buffer zone between individual plots, and a 4m alley between blocks.

In the core plots, crops were grown in a 3x3 factorial combination of treatments: 3 types of soil amendment and 3 levels of forage in the rotation. The sequence of crop rotation in the core plots varied with the level of forage in the rotation. Therefore, there were 3 crop rotations: WSBP, WBFP, WFFP (Table 3.3). In the extra experimental plots, crops were grown with one type of soil amendment (i.e., stockless) at two levels of forage (i.e. 1 and 2 years of forage). There were 6 rotations in the extra experimental plots, with the crop sequence differentiated not only by the number of years of forage in the rotation, but also by the order in which crops were grown. This allowed for the determination of whether biophysical and economic performance were influenced by the place that a crop occupied in the rotation. The crop rotations in the extra experimental plots were: BFPW, FPWB, PWBF, FFPW, FPWF, PWFF (Table 3.3). Unfortunately, the trials in the extra experimental plots were discontinued after the 2004 harvest due to funding limitations.

As required by national organic standards, the treatments relied on organic soil amendments and crop rotation to build soil structure, maintain soil fertility, and control weeds, pests, and diseases. Potato plots were sprayed with permitted pesticides when required. The first three years of the experiment constituted a transition phase to organic agriculture, and it was assumed that organic certification would be granted in the fourth year.

It was assumed that the stockless system was a cash crop operation that used alfalfa pellets as the main source of soil nitrogen, while livestock-based systems were assumed to be mixed cash crop-livestock operations that used composted beef cattle or poultry manure. In the case of the ruminant system, it was assumed that forages were used to feed beef cattle on the farm, while in the monogastric system, forages were assumed to be sold. On the other hand, in forage-based rotations, in the stockless system, part of the forage was used as mulch for potato production and the rest was assumed to be sold. Furthermore, in the stockless system, straw from cereal crops was maintained on the soil surface, whereas in livestock systems, straw was used for bedding. It is important to note that the livestock enterprises (i.e., beef cattle and poultry) were not included in the analysis presented in this chapter. However, the analysis in the next chapter includes the

Table 3.3 Crop Rotations in Core and Extra Experimental Plots

Experimental Plots		Year			
		2002	2003	2004	2005 *
Core Plots	1	Wheat	Soybean	Barley	Potato
	2	Wheat	Barley	Forage	Potato
	3	Wheat	Forage	Forage	Potato
Extra Experimental Plots	1	Barley	Forage	Potato	Wheat
	2	Forage	Potato	Wheat	Barley
	3	Potato	Wheat	Barley	Forage
	4	Forage	Forage	Potato	Wheat
	5	Forage	Potato	Wheat	Forage
	6	Potato	Wheat	Forage	Forage

Note: * the trials in the extra experimental plots were discontinued after the 2004 harvest.

beef cattle enterprise and a discussion regarding the poultry enterprise.

In general, growing conditions were similar for all treatments. Crop varieties and seeding rates were the same for all crops, except for wheat and barley where the seeding rate was reduced when wheat and barley were underseeded with forages in a year preceding a forage crop (Table 3.4). Field operations varied according to particular crop requirements. All field operations at the Truro site were carried out either manually or with experimental scale machinery.

Farming practices were similar for all crops, except for the potato plots, which received mulch applications (forage-based rotations in the stockless system), Colorado potato beetle (CPB) control, and fungus control. In general, CPB infestations were controlled using a biological pesticide. However, in 2003 beetle larvae were collected manually from all potato plots. Therefore, for consistency in the potato budgets, it was assumed that CPB was controlled using the biological pesticide only (i.e., Entrust™). Fungal infestations in potato were controlled using copper hydroxide. The number of pesticide applications reflected the level of infestation in each plot. In addition, limestone was applied once to all rotations at the beginning of the experiment at 4 tonne/ha, and fall rye was seeded as a cover crop after potato harvest (i.e., the end of the rotation in the core plots). However, limestone costs ($1,760/ha) and fall rye costs ($84/ha) were not included in the individual crop budgets because these expenses were attributed to the whole rotation. Table 3.5 summarizes input prices and input rates in potato plots.

Table 3.4 Seeding Rates and Crop Varieties

Crop	Variety	Seeding rate (kg/ha)	Price ($/kg)	Cost ($/ha)
Wheat	AC Helena	170	0.525	89.25
Wheat (underseeded with forages)		128	0.525	67.20
Soybean	AC Vision	90	1.540	138.60
Barley	AC Queens	175	0.425	74.38
Barley (underseeded with forages)		131	0.425	55.68
Potato	Superior	1,100	0.570	627.00
Red Clover	AC Endor	7	4.610	32.27
Timothy	Richmond	6	5.570	33.42

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.

Table 3.5 Potato Input Prices and Application Rates

Item	Application rate (kg/ha)	Rotation Sequence	Price per unit ($)	Total Cost ($/ha)
Entrust™	0.105*	All rotations	1,100	115.5
Copper hydroxide	3.3 l/ha*	All rotations	14	46.2
Forage mulch on a dry weight basis (kg/ha)		Stockless system in core plots		
	4,612	WBFP	0.03**	138.4
	7,840	WFFP		235.2
		Extra experimental plots		
	5,160	BFPW	0.03**	154.8
	4,840	FPWB		145.2
	6,838	PWBF		205.1
	11,620	FFPW		348.6
	12,100	FPWF		363.0
	11,836	PWFF		355.1

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage. Entrust™ uses spinosad as the active ingredient. Spinosad is produced by the bacteria *Saccharopolyspora spinosa* (Thompson et al., 1999).
* The number of applications depended on the level of infestation.
** Forage mulch costs per kg were estimated based on field operation costs involved in forage production (including raking and bailing costs) and average forage yield in core and extra experimental plots.

Nutrient application rates were aimed at meeting soil test recommendations and differed among blocks for the core and extra experimental plots. Apart from the organic soil amendments evaluated (i.e., alfalfa pellets, monogastric and ruminant compost), two certified-organic mineral nutrient sources were used to meet soil test recommendations: rock phosphate (a source of phosphorus) and langbeinite (a source of potassium). Nutrient application rates were calculated according to nutrient composition and soil test recommendations. The nutrient composition of soil amendments was based on the actual amount of nutrients in soil amendments and their availability to the plant (i.e., nutrients supplied from alfalfa pellets and composted manure were not immediately available for the plant, while phosphorus and potassium from rock phosphate and langbeinite were assumed to be readily available). Therefore, it was assumed that, nitrogen was available at 30% from alfalfa pellets, 50% from monogastric compost, and 25% from ruminant compost, while phosphorus was available at 20%, and potassium at 90%. On the other hand, phosphorus was available at 3% from rock phosphate, while potassium was available at 22% from langbeinite (Hammermeister, 2005).

Although the sources of alfalfa pellets and compost were the same throughout the experiment, the actual amount of nutrients contained in alfalfa pellets and compost were different between 2002 and 2005 (Table 3.6). Soil test recommendations are presented in Tables 3.7-3.8, and actual application rates, on a dry weight basis (DWB), are summarized in Appendix 1. In 2003, neither compost nor alfalfa pellets were applied to core plots, assuming that there was enough nitrogen available from the previous year.

It is important to clarify that, by the nature of the experiment, nutrient application was aimed at meeting soil test recommendations. However, due to time constraints, phosphorus recommendations were not met accurately (i.e., phosphorus availability exceeded the soil test recommendations in some cases, while it was insufficient in others) because phosphorus availability was estimated before the actual results of the phosphorus content in compost were obtained from the laboratory. All information regarding input and soil amendment application rates, soil amendment composition, and nutrient supply recommendations, were obtained from the standard operating procedures for the experiment at the Truro site. Therefore, the assumptions regarding soil fertility management are outside the scope of this study.

3.3 Production Systems Costs

3.3.1 Description of the Farm

Actual production costs associated with the experimental farming systems did not accurately represent those of a commercial operation. Therefore, in order to perform an economic analysis of the results, it was necessary to make some general assumptions.

Table 3.6 Nutrient Contributions of Organic Soil Amendments*

Crops in rotation						Estimated nutrient contribution (%)								
						2002			2004			2005		
2002	2003	2004	2005	Block	Treatment	N	P	K	N	P	K	N	P	K
W	S	B	Po	1	St.	0.64	0.09	1.93	0.90	0.12	2.54	0.69	0.10	2.33
W	S	B	Po	1	M	0.82	0.67	1.48	0.34	0.24	0.35	0.36	0.24	0.31
W	S	B	Po	1	R	0.66	0.44	3.49	0.52	0.32	1.78	0.63	0.38	1.70
W	S	B	Po	2	St.	0.64	0.09	1.93	0.90	0.12	2.54	0.69	0.10	2.33
W	S	B	Po	2	M	0.82	0.67	1.48	0.34	0.24	0.35	0.36	0.24	0.31
W	S	B	Po	2	R	0.66	0.44	3.49	0.52	0.32	1.78	0.63	0.38	1.70
W	S	B	Po	3	St.	0.64	0.09	1.93	0.90	0.12	2.54	0.69	0.10	2.33
W	S	B	Po	3	M	0.82	0.67	1.48	0.34	0.24	0.35	0.36	0.24	0.31
W	S	B	Po	3	R	0.66	0.44	3.49	0.52	0.32	1.78	0.63	0.38	1.70
W	B	F	Po	1	St.	0.64	0.09	1.93	N/A	N/A	N/A	0.69	0.10	2.33
W	B	F	Po	1	M	0.82	0.67	1.48	N/A	N/A	0.35	0.36	0.24	0.31
W	B	F	Po	1	R	0.66	0.44	3.49	0.34	0.24	1.29	0.63	0.38	1.70
W	B	F	Po	2	St.	0.64	0.09	1.93	0.41	0.28	N/A	0.69	0.10	2.33
W	B	F	Po	2	M	0.82	0.67	1.48	N/A	N/A	0.35	0.36	0.24	0.31
W	B	F	Po	2	R	0.66	0.44	3.49	0.34	0.24	1.29	0.63	0.38	1.70
W	B	F	Po	3	St.	0.64	0.09	1.93	0.41	0.28	N/A	0.69	0.10	2.33
W	B	F	Po	3	M	0.82	0.67	1.48	N/A	N/A	0.35	0.36	0.24	0.31
W	B	F	Po	3	R	0.66	0.44	3.49	0.34	0.24	1.29	0.63	0.38	1.70
W	F	F	Po	1	St.	0.64	0.09	1.93	0.41	0.28	N/A	0.69	0.10	2.33
W	F	F	Po	1	M	0.82	0.67	1.48	0.34	0.24	0.35	0.36	0.24	0.31
W	F	F	Po	1	R	0.66	0.44	3.49	N/A	N/A	N/A	0.63	0.38	1.70
W	F	F	Po	2	St.	0.64	0.09	1.93	N/A	N/A	N/A	0.69	0.10	2.33
W	F	F	Po	2	M	0.82	0.67	1.48	0.34	0.24	0.35	0.36	0.24	0.31
W	F	F	Po	2	R	0.66	0.44	3.49	0.41	0.28	1.29	0.63	0.38	1.70
W	F	F	Po	3	St.	0.64	0.09	1.93	N/A	N/A	N/A	0.69	0.10	2.33
W	F	F	Po	3	M	0.82	0.67	1.48	0.34	0.24	0.35	0.36	0.24	0.31
W	F	F	Po	3	R	0.66	0.44	3.49	0.41	0.28	1.29	0.63	0.38	1.70

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.

Note: W= Wheat, S= Soybean, B= Barley, Po=Potato, F= Forage, N=Nitrogen, P=Phosphorus, K=Potassium, St.= Stockless, M= Monogastric, R= Ruminant, N/A= non applicable.

* Applies also to extra experimental plots. Potassium in 2004 was estimated at 2.54% in all plots.

Table 3.7 Nutrient Recommendations for Core Plots

Crops in rotation						Nutrient Recommendation (kg/ha)											
						2002			2003			2004			2005		
2002	2003	2004	2005	Block	Treatment	N	P	K	N	P	K	N	P	K	N	P	K
W	S	B	Po	1	St.	170	108	65	25	55	0	50	70	0	77	160	34
W	S	B	Po	1	M	170	108	65	25	0	0	50	40	0	86	135	22
W	S	B	Po	1	R	170	108	65	25	40	0	50	55	0	62	145	30
W	S	B	Po	2	St.	170	108	65	25	55	0	50	100	0	77	160	34
W	S	B	Po	2	M	170	108	65	25	0	0	50	40	0	86	135	22
W	S	B	Po	2	R	170	108	65	25	40	0	50	100	0	62	145	30
W	S	B	Po	3	St.	170	108	65	25	55	0	50	100	0	77	160	34
W	S	B	Po	3	M	170	108	65	25	0	0	50	85	0	86	135	22
W	S	B	Po	3	R	170	108	65	25	40	0	50	100	0	62	145	30
W	B	F	Po	1	St.	170	108	65	70	40	0	0	120	0	63	160	18
W	B	F	Po	1	M	170	108	65	70	0	40	0	75	0	80	135	24
W	B	F	Po	1	R	170	108	65	70	40	0	0	75	0	62	145	19
W	B	F	Po	2	St.	170	108	65	70	40	0	0	85	0	63	160	18
W	B	F	Po	2	M	170	108	65	70	0	40	0	120	0	80	135	24
W	B	F	Po	2	R	170	108	65	70	40	0	0	85	0	62	145	19
W	B	F	Po	3	St.	170	108	65	70	40	0	0	120	0	63	160	18
W	B	F	Po	3	M	170	108	65	70	0	40	0	120	0	80	135	24
W	B	F	Po	3	R	170	108	65	70	40	0	0	120	0	62	145	19
W	F	F	Po	1	St.	85	108	65	100	65	40	0	120	0	81	160	49
W	F	F	Po	1	M	85	108	65	100	40	40	0	85	0	65	135	37
W	F	F	Po	1	R	85	108	65	100	55	0	0	0	0	58	145	29
W	F	F	Po	2	St.	85	108	65	100	65	40	0	120	0	81	160	49
W	F	F	Po	2	M	85	108	65	100	40	40	0	95	0	65	135	37
W	F	F	Po	2	R	85	108	65	100	55	0	0	120	0	58	145	29
W	F	F	Po	3	St.	85	108	65	100	65	40	0	120	0	81	160	49
W	F	F	Po	3	M	85	108	65	100	40	40	0	110	0	65	135	37
W	F	F	Po	3	R	85	108	65	100	55	0	0	120	0	58	145	29

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, S= Soybean, B= Barley, Po=Potato, F= Forage, N=Nitrogen, P=Phosphorus, K=Potassium, St.= Stockless, M= Monogastric, R= Ruminant, N/A= non applicable.

Table 3.8 Nutrient Recommendations for Extra Experimental Plots

Crops in rotation					Nutrient Recommendation (kg/ha)								
					2002			2003			2004		
2002	2003	2004	2005	Block	N	P	K	N	P	K	N	P	K
B	F	Po	W	1	35	70	65	0	50	55	80	160	0
F	Po	W	B	1	0	100	105	125	80	60	120	110	0
Po	W	B	F	1	130	160	130	135	55	35	0	85	0
F	F	Po	W	1	0	100	105	0	50	55	80	160	0
F	Po	W	F	1	0	100	105	125	80	60	35	110	0
Po	W	F	F	1	130	160	130	50	55	35	0	110	0
B	F	Po	W	2	35	70	55	0	50	55	80	160	0
F	Po	W	B	2	0	100	105	125	80	60	120	110	0
Po	W	B	F	2	130	160	100	135	55	35	0	85	0
F	F	Po	W	2	0	100	105	0	50	55	80	160	0
F	Po	W	F	2	0	100	105	125	80	60	35	110	0
Po	W	F	F	2	130	160	100	50	55	35	0	110	0
B	F	Po	W	3	35	70	70	0	50	55	80	160	0
F	Po	W	B	3	0	100	105	125	80	60	120	110	0
Po	W	B	F	3	130	160	130	135	55	35	0	85	0
F	F	Po	W	3	0	100	105	0	50	55	80	160	0
F	Po	W	F	3	0	100	105	125	80	60	35	100	0
Po	W	F	F	3	130	160	130	50	55	35	0	100	0

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, B= Barley, Po=Potato, F= Forage, N=Nitrogen, P=Phosphorus, K=Potassium. All crops in extra experimental plots were grown under the stockless system only. Wheat and barley were underseeded with forages in a year preceding a forage crop.

First, there is currently no statistical information regarding farms under transition to organic agriculture for Nova Scotia. Therefore, the size of a commercial farm under transition to organic agriculture was assumed to be 93 ha, based on the average farm size in Nova Scotia, which includes conventional and organic farms. The 2001 census of agriculture reported 23 organic farms and 3,900 conventional farms in Nova Scotia (Statistics Canada, 2002). Due to the small number of organic farms relative to conventional farms, it is likely that the average farm in the province reflects more the size of a conventional farm, than the size of an organic farm. Therefore, it was reasonable to use this average since this study focused on the transition from conventional to organic farming. Furthermore, it was assumed that a farmer would not invest in converting rented land to organic agriculture unless the land was on a long-term lease (Forest, 1992).

Second, it was necessary to determine a base-line area allocation for crop production. It was assumed that the farm would grow all crops in rotation every year, and each crop in a particular crop rotation would be planted to 23.25 ha, except forages, which would be allocated 23.25 ha or (2 x 23.25 = 46.50) 46.50 ha depending on the crop rotation selected (i.e., wheat/barley/forage/potato, or wheat/forage/forage/potato).

Third, it was assumed that most machinery necessary to complete field operations, and to prepare compost and silage was owned, as opposed to leased or rented (Table 3.9). The machinery complement differed among rotations. For example, forage equipment would only be included in rotations that involved forage. Similarly, rotations in the stockless system did not include a manure spreader. A grain combine, grain and potato grading and cleaning equipment, and a sprayer were not included in the machinery complement, because it was assumed that small-scale farmers are likely to hire custom operators to complete field operations that require i) high machinery investment (since the price of a grain combine nearly equals the investment of the whole machinery complement), ii) specialised machinery (such as grain and potato grading and cleaning equipment), and iii) few hours of use per year (such as a sprayer). It was also assumed that the farmer owns a 53.88 kW (72.22 hp) tractor, with the size of the tractor based on engine power requirements of the farm equipment selected. The selection of farm equipment was based on farm size and crop requirements. This assumption is consistent with a report from Statistics Canada (2002) that noted that the majority of tractors in

Table 3.9 Machinery Inventory (in order of field operation)

Machinery Type	Field Operation	Engine Power Required (kW)	Width (m)	Speed (km/hr)	Suggested Field Efficiency (%)	Time to complete one pass (hr/ha)	Fuel use (l/ha)	Estimated Annual usage (93 ha farm) (hr)
Moldboard Plough*	Primary tillage at 20 cm depth	51.8	1.8	6.5	80	1.05	20.5	97.8
Disk Harrow*	Secondary tillage at 10 cm depth	30.5	3.7	6.5	80	0.52	6.7	47.9
Spin Spreader*	Application of soil amendments (1 tonne/pass/ha)	24.7	14.0	7.0	70	0.15	1.7	13.5
Manure Spreader†	Compost preparation and application (9 tonnes/pass/ha)	31.3	2.5	11.0	80	0.45	5.9	42.3
S-Tine*	Bed preparation at 7.5 cm depth	13.2	3.7	7.0	85	0.46	4.0	42.7
Grain Drill* (Seeder)	Grain/forage seeding	22.3	4.0	8.0	70	0.45	5.1	31.4
Potato Hiller and Planter*	Potato planting and row hilling	45.3	1.8	7.0	70	1.12	18.7	51.9
Fingerweed/ Lely weeder‡	Weeding	2.5	4.3	6.0	80	0.49	1.2	11.4
Forage Mulch Blower#	Mulch application in potato rows (40kg/minute)	13.4	1.0	8.5	70	1.68	14.9	39.1
Forage Harvester§	Forage Harvesting	30.2	2.1	5.5	70	1.22**	15.6	56.6
Forage Blower§	Silage preparation	31.3	N/A	N/A	N/A	0.32	4.2	14.9
Forage Box§	Forage transportation – Silage	15.7	2.1	5.5	70	1.22**	11.7	56.6
Rake†	Straw removal	14.5	3.2	10.0	80	0.39	3.6	18.2
Baler† (small square bales)	Straw removal	13.4	2.2	6.5	75	0.93	8.2	43.4
Potato Harvester*	Potato Harvesting	52.3	1.8	4.0	60	2.34	46.2	54.5
Tractor 53.88 kW (72.22 hp)*	Used for all operations	N/A	N/A	N/A	N/A	N/A	662.7	N/A

Source: Adapted from ASAE, 2003.

Note: *Used in all rotations. †Used in rotations in livestock systems. ‡Used in non-forage rotations (i.e., WSBP) and extra experimental plots. §Used in forage based rotations. #Used in all rotations in extra experimental plots and WBFP and WFFP in stockless systems in core plots. **Shared time.

Nova Scotia do not exceed 74.6 kW (100 hp). Furthermore, it was assumed that all machinery were five years old.

Finally, it was assumed that the farm owner also manages the farm and would carry out most of the field operations using family labour. However, compost preparation would be carried out by hired farmworkers, while grain harvesting, spraying of certified-organic pesticides, and grain and potato grading and cleaning would be carried out by custom operators. Information regarding custom operator rates is limited in Nova Scotia. Therefore, custom operator rates were based on data from similar farming systems in neighbouring provinces. Fees for sorting and cleaning services were based on quotations from companies operating in Nova Scotia. Costs related to farm-family labour were calculated at opportunity cost.

Production costs are divided into fixed and variable costs. Machinery fixed costs were assumed based on the machinery complement, while variable costs were based on information from the experimental trials. Further assumptions and calculations regarding fixed and variable costs are described in the following sections.

3.3.2 Fixed Costs

Fixed costs are incurred independent of the level of output, and include machinery depreciation, interest on investment, insurance and storage expenses, soil tests, and certification fees. Fixed costs of particular crops varied since the machinery complement varied among rotations. Details of fixed costs in core and extra experimental plots are provided in section 3.4.2. Machinery contributions to fixed costs are presented in Table 3.10.

Machinery depreciation costs in 2005 were calculated using the declining balance method. Since it was assumed that all machinery were 5 years old, it was necessary to determine the purchase price in 2000. The initial purchase price of farm machinery was calculated based on actual list price of new machinery in 2005. It was assumed that the price of farm machinery in Nova Scotia increased 10% in the past 5 years, based on average farm input price index (see Statistics Canada, 2004c). All prices were obtained from actual farm equipment dealers in Nova Scotia and from dealer websites (www.agdealer.ca). Machinery depreciation was calculated using a constant rate of 15% for powered equipment (tractor and forage mulch blower), and 10% for non-powered

Table 3.10 Machinery Contributions to Fixed Cost

Farm Machine	Purchase Price in 2000 ($)	Non-depreciated Balance in 2005 ($)	Depreciation Cost in 2005 ($)	Interest on Investment ($)	Insurance and Storage ($)	Total Machinery Contribution to Fixed Cost ($)
Powered equipment depreciated at 15% rate						
Tractor 53.88 kW (72.22 hp)	33,636	17,558	2,634	1,541	336	4,511
Forage Mulch Blower	7,427	3,877	582	340	74	996
Non-powered equipment depreciated at 10% rate						
Tillage						
Chisel Plough	11,818	7,754	775	541	118	1,434
Disk Harrow	12,845	8,427	843	588	128	1,559
S-Tine	6,636	4,354	435	304	66	805
Sowing equipment						
Grain Drill	22,727	14,911	1,491	1,041	227	2,759
Forage and straw management						
Forage Harvester	36,364	23,858	2,386	1,666	364	4,416
Forage Blower	7,727	5,070	507	354	77	938
Forage Box	17,727	11,631	1,163	812	177	2,152
Rake	5,909	3,877	388	271	59	718
Baler (square bales)	21,818	14,315	1,431	999	218	2,648
Soil fertility management						
Manure Spreader	22,727	14,911	1,491	1,041	227	2,759
Spin Spreader	4,545	2,982	298	208	45	551
Potato equipment						
Potato Hiller/Planter	18,182	11,929	1,193	833	181	2,207
Potato Harvester	36,000	23,620	2,362	1,649	360	4,371
Lely weeder	3,098	2,033	203	142	31	376

machines (Ontario Ministry of Agriculture Food and Rural Affairs, 1989). Depreciation can be calculated using the following (Kay and Edwards, 1994; Forest, 1992):

(1) $D_i = B_i \times dr$

(2) $B_{i+1} = B_i - D_i$

Where:
D_i = depreciation cost in year i
B_{i+1} =non-depreciated balance in year i+1
dr =depreciation rate
B_i = non-depreciated balance in year i

It was assumed that 30% of the capital invested in farm machinery was debt and 70% was equity (Yiridoe et al., 1994). The debt component was assumed to be financed at 8.27% interest rate, which was the 2000 average prime interest rate charged by chartered banks plus one (Bank of Canada, 2005a), The opportunity cost on the money invested in farm machinery (i.e., interest on the equity portion) was based on the assumption that the farmer could have invested the money in a guaranteed investment certificate (GIC) that generated interest at 3%. Therefore, total interest on capital investment was calculated at 4.581% (0.3x8.27 + 0.7x3). In addition, insurance and machinery storage expenses were assumed to be 0.25% and 0.75% of machinery purchase price respectively (ASAE, 2003).

Soil tests were assumed to be carried out every four years, for $120 ($1.30/ha). Soil test costs were determined by assuming that the farmer would send four samples to a soil test laboratory that charges $30 each (as mentioned before, the farm would be divided in four blocks, one planted to each crop in the rotation). Certification fees were based on information provided by an accredited certifying body in Atlantic Canada. Certification fees were assumed to be paid every year from the fourth year onwards (i.e., after 3 years of transition) and include affiliation ($57.5) and inspection charges ($287.5). Certification fees per hectare were estimated at $3.71 ((57.5 + 287.5)/93 = 3.71).

It is important to note that soil test costs and certification fees were not included in individual crop budgets, because these are attributed to the whole rotation and not to a particular crop. Therefore, soil test costs and certification fees were included in the whole-farm analysis in the next chapter. In addition, this study does not include expenses related to maintenance and investment in land and buildings (including a silo), nor does it include expenses related to utilities, administrative costs, and income and property taxes.

3.3.3 Variable Costs

Variable costs are a function of output and can be divided into input costs, custom operator rates (depending on the crop), field operations (machinery and labour expenses), and interest on operating expenses. Most inputs were assumed to be bought, except for compost that was assumed to be produced on the farm. Compost costs were estimated based on information from the experimental trials. Compost was produced at the NSAC experimental farm, and included manure, labour, and machinery costs (Tables 3.11-3.12). Raw poultry manure was bought and mixed with organic matter (silage residue and bark peeling available at the experimental farm), while raw ruminant manure was bought premixed with straw. A front-end loader of a tractor and a manure spreader, were used for compost blending, while compost turning was carried out with the tractor loader. Labour for both operations was assumed to be hired. Time spent on compost preparation was based on the average time devoted to this operation at the research farm. Machinery costs were calculated based on fuel consumption of a tractor and include: 4 l/hr (when the loader was used), and 13.07 l/hr (when the manure spreader was used). The cost of compost from monogastric manure was estimated at $110/tonne on a dry weight basis (DWB), while compost from ruminant manure was estimated at $151/tonne (DWB). In addition, alfalfa pellets were bought at $520/tonne (DWB), rock phosphate at $530/tonne, and langbeinite at $560/tonne.

Custom rates and field operation costs are summarized in Table 3.13.Custom operator rates were obtained from Fletcher (2004). Grain grading and cleaning was estimated based on a $50/tonne fee charged in Nova Scotia, and total average yields obtained in both core plots and extra experimental plots (i.e., barley 2,707kg/ha, soybean 309kg/ha, and wheat 3,098kg/ha). Potato grading and cleaning costs were based on information from potato equipment dealers in Nova Scotia.

The estimation of particular field operation costs can be very complex if detailed machinery specifications are not available. However, field operation costs were based on calculations using data from the American Society of Agricultural Engineers (2003). Field operation costs reflected those of a commercial operation and included: 1) fuel

Table 3.11 Monogastric Compost Preparation Costs

Input	Unit	Quantity	Unit Price ($)	Cost in wet weight basis ($)
Poultry manure	kg	13,600	0.04*	600.00
Silage residue	kg	2,350	0	0
Bark peeling	kg	8,750	0	0
Hired labour	hr	21.5	7.76	166.84
Fuel cost for compost blending (tractor loader and manure spreader)	$/hr	16	7.97	127.56
Fuel cost for compost turning (tractor loader)	$/hr	5.5	2.44	13.42
			Total cost	$907.82
		Estimated dry compost produced		8,275 kg**
		Estimated unit cost (dry weight basis)		$0.11/kg

Note: *Delivered price. ** It was assumed that 46.4% of mass was lost during composting and that compost had 37.5% of moisture ((13,600 kg +2,350 kg +8,750 kg) x 53.6% x 62.5% = 8,274.5 kg in a dry weight basis).

Table 3.12 Ruminant Compost Preparation Costs

Input	Unit	Quantity	Unit Price ($)	Cost in wet weight basis ($)
Ruminant manure and bedding	kg	35,374	0.07*	2,500.00
Hired Labour	hr	13	7.76	100.88
Fuel cost for compost blending (tractor loader and manure spreader)	$/hr	8	7.97	63.78
Fuel cost for compost turning (tractor loader)	$/hr	5	2.44	12.20
			Total cost	$2,685.12
		Estimated dry compost produced		17,687 kg**
		Estimated unit cost (dry weight basis)		$0.15/kg

Note: * Delivered price. ** It was assumed that 20% of mass was lost during composting and that compost had 37.5% of moisture (35,374 kg x 80% x 62.5% = 17,687 kg in a dry weight basis).

Table 3.13 Summary of Field Operation Costs

Field Operation	Labour ($)	Machinery costs ($)	Total Cost per pass ($)	Wheat		Soybean		Barley		Potato		Forage	
				Pass.	Cost ($/ha)	Pass.	Cost ($/ha)	Pass.	Cost ($/ha)	Pass.	Cost ($/ha)	Pass.	Cost ($/ha)
Primary Tillage	14.6	16.6	31.2	1	31.2	1	31.2	1	31.2	1	31.2	1	31.2
Secondary Tillage - harrow	7.2	5.2	12.4	3	37.2	2	24.8	2	24.8	2	24.8	1	12.4
Secondary Tillage (S-tine)	6.4	3.3	9.7	3	29.1	2	19.4	2	19.4	2	19.4	1	9.7
Weeding	6.7	1.2	7.9	N/A	N/A	N/A	N/A	N/A	N/A	1	7.9	N/A	N/A
Potato Hilling/ planting	15.5	13.9	29.4	N/A	N/A	N/A	N/A	N/A	N/A	2	58.8	N/A	N/A
C. P. Beetle Control*	N/A	N/A	22	N/A	N/A	N/A	N/A	N/A	N/A	3	66	N/A	N/A
Fungus control*	N/A	N/A	22	N/A	N/A	N/A	N/A	N/A	N/A	1	22	N/A	N/A
Seeding	6.3	4.0	10.3	1	10.3	1	10.3	1	10.3	N/A	N/A	1	10.3
Harvesting	N/A	N/A	N/A	1	76.6	1	81.5*	1	76.6	1	111.8	2	63.4
Raking and bailing	18.5	9.8	28.3	1	28.3	N/A	N/A	1	28.3	N/A	N/A	N/A	N/A
Grading/ cleaning**	N/A	N/A	N/A	N/A	154.9	N/A	15.45	N/A	135	N/A	243	N/A	N/A
Ensiling (forage transport and silo filling)	4.4	3.0	7.44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	14.88
			TOTAL ($/ha)	367.60		182.65		326.00		584.9		141.88	

Note: This table is presented as a reference since the time required to apply soil amendments and the number of passes to complete field operations varied among treatments. Compost application costs were estimated at $1.22/tonne, mulch application at $12/tonne, and alfalfa meal, rock phosphate and langbeinite at 3.4/tonne. *Custom operator rate. ** Custom operator rate based on average yields of the experimental trials. ‡ Potato harvesting includes 1 tractor operator and 2 workers.

and lubricant consumption, 2) time required for completing field operations, 3) machinery repairs and maintenance, and 4) labour costs.

To calculate fuel and lubricant consumption, the first step was to calculate total power required for each operation. According to ASAE (2003, see clause 4.2 ASAE EP496.2), total tractor power requirements depend on factors such as drawbar power (i.e., the force required to propel the implement, which in turn is a function of implement width, tillage depth, soil texture, motion resistance, and field speed), mechanical efficiency of the transmission, traction efficiency, power requirements from the power-takeoff (PTO) (that in turn depends on working capacity, implement width, and rotary power parameters), and power requirements from hydraulic and electric systems. Hydraulic and electric power requirements were not directly calculated. However, an additional 25% was added to total power requirements to account for these factors. It is important to note that total power requirement has to be expressed in "equivalent PTO power", which is 90% of the engine power requirement.

The second step was to obtain diesel consumption for the tractor by dividing total tractor power requirement (equivalent PTO power) for a particular operation by the maximum available PTO power from the tractor. This yields the percent load of the engine for that operation. Fuel consumption at that percent load was then calculated using the following formula (ASAE, 2003):

(3) $$Q_S = 2.64X + 3.91 - [0.203\,(738X+173)^{1/2}]$$

Where:
Q_S = specific diesel consumption for the given tractor, l/kW hr
X = ratio of equivalent PTO power for a field operation and maximum available PTO power from the tractor.

Third, fuel consumption of a particular operation was estimated by the following formula:

(4) $$Q_i = Q_S P_T$$

Where:
Q_i = estimated diesel consumption for a particular field operation, l/hr
Q_S = specific diesel consumption for the given tractor, l/kW hr
P_T = total tractor power (or equivalent PTO) for the field operation, kW

In order to calculate fuel costs, it was necessary to estimate the time that a particular machine was assumed to be used to complete a field operation. Effective Field Capacity (EFC) can be calculated using typical field machinery efficiencies from ASAE (2003):

(5) $$EFC = \frac{swE_f}{10}$$

Where:

EFC =effective field capacity or capacity area, ha/hr
s = field speed, km/hr w = machinery width, m
E_f =field efficiency (decimal)

Fuel costs per hectare were calculated by dividing estimated fuel consumption (Q_i) by effective field capacity (EFC) and multiplying by the price of diesel, $0.61/l. The price of diesel was based on the average retail price of farming diesel (i.e., dyed diesel) in Nova Scotia in 2005 (Newcomb, 2005). In addition, ASAE (2003) estimates that total engine lubrication costs as 15% of total fuel cost.

Repairs and maintenance costs can be estimated as a function of the list price of the equipment (i.e., current price), accumulated hours of use, and repair and maintenance factors RF1 and RF2, which are factors estimated from average costs of repairs and maintenance of equipment used under typical field and speed conditions. Repair and maintenance costs were calculated using the following formula (ASAE, 2003):

(6) $$C_{rm} = (RF1)\, P\, [h/1000]^{RF2}$$

Where:

C_{rm} =accumulated repair and maintenance costs, dollars
P = implement list price, dollars
h = accumulated use of machine, hr
RF1 and RF2 = repair and maintenance factors

The last component needed to estimate field operation costs was labour expenses. According to Human Resources and Skills Development Canada (2004), the average salary paid to a general farm worker in Nova Scotia was $7.76 per hour, while the highest salary was $13.86 per hour. It was assumed that farm-workers hired for compost preparation would be paid the average wage of $7.76. Furthermore, it was reasonable to include an opportunity cost for family labour. The opportunity cost for the farm-operator was assumed to be equivalent to the salary of a highly skilled farm worker (i.e., the higher rate of $13.86/hr), while the opportunity costs for other farm-family members was assumed to be equivalent to the lower average wage of \$7.76/hr. Additional time to prepare machinery and implements for field operations, as well as to go from one location to another was not included in this study.

Interest on operating expenses were calculated on all cash expenses, based on the assumption that farmers could invest the money needed to cultivate their land in a guaranteed investment certificate (GIC) at 3% interest rate.

3.4 Results and Discussion

3.4.1 Statistical Analysis and Procedures

Yield, production costs, and net returns were compared among the various treatments, to test if there were significant differences in yield and net returns. Statistical analysis for production costs was not carried out because a distribution of costs could not be generated. However, production costs were examined to identify the main contributions to differences among treatments and rotations.

The nested condition of the experiment (i.e., soil amendment factor nested within forage level factor) was not taken into consideration because the quantity of soil amendment applied depended not only on the type of soil amendment and the forage level factor, but also on other factors as explained in section 3.2. Therefore, within the scope of this study, the factorial structure of the experimental design was more appropriate to be analyzed.

Statistical analysis can be performed using two methods: parametric and non-parametric. Parametric tests are based on particular assumptions regarding the shape of the distribution. The t-test and analysis of variance (ANOVA), for example, are parametric tests that assume that the distribution of differences is normal, while nonparametric tests estimate percentiles of a continuous distribution without a particular shape defined by parameters (Snedecor and Cochran, 1980). The data from the Truro experiment raised questions regarding the shape of the distribution, primarily due to the limited number of observations per factor combination (i.e., 3). Therefore, three alternatives were considered for the statistical analysis: i) non-parametric methods (Mann-Whitney and Kruskal-Wallis tests), ii) parametric methods (one and two-way

ANOVA), and iii) ANOVA of the rank-transformed data (a method regarded as non-parametric).

Wheat data from core plots were used to run tests using the three alternatives. First, non-parametric methods were used to compare wheat yield and net returns by individual factors separately (forage and type of soil amendment), and for a factor-combination (as if it was a single factor). Second, wheat yield and net returns were rank-transformed and analyzed using an ANOVA. Finally, the ANOVA procedure was used to compare the raw data by individual factors, and in a two-way factorial ANOVA. In general, the results of non-parametric tests yielded higher p-values than those obtained from one-way ANOVA of the raw data. However, the rejection of the null hypothesis coincided in both methods. Furthermore, results from the ANOVA procedure of rank-transformed yield were similar to those from ANOVA of actual yield. On the other hand, the results from ANOVA of rank-transformed net returns did not reject the null hypothesis, while those from ANOVA of net returns rejected the null hypothesis.

It was concluded that parametric methods were more reliable for this study because, non-parametric methods ignore the factorial structure of the experiment (Shah and Madden, 2004), and no interaction effects would have been assumed (Miller, 1986). In addition, analysis of variance of rank-transformed data is not commonly recommended for data analysis of factorial experiments (Hettmansperger and McKean, 1998; Shah and Madden, 2004). Furthermore, according to Miller (1986), non-normality has little effect on the results of analysis of variance (F-test) of one and two factor designs. Although, Miller (1986) noted that, this is particularly true when sample sizes are "not too small," Shah and Madden (2004) suggested that ANOVA is an appropriate procedure for experiments with as little as 3 replications (as is the case in the Truro experiment). In general, the assumptions of normality and equal variance of the residuals in core plots were reasonably met. On the other hand, in the extra experimental plots, non-normality of the residuals was an issue for forage (yield and net returns) and potato (net returns), while unequal variance was only an issue in forage yield residuals.

Data from core plots in the Truro experiment were analyzed using the two-way ANOVA procedure. Tukey's procedure was used to carry out multiple comparisons where interaction effects were determined. However, within the scope of this study, it was not possible to identify particular reasons for interactions between soil amendments and forage level factors. Therefore, further comparisons were made to identify differences in yield and net returns when crops were preceded by forage, and when the seeding rate was determined exclusively by forage level. In the case of wheat, for example, comparisons were made at two seeding rates: 170kg/ha (wheat seeded on its own) and 128kg/ha (i.e., wheat underseeded with forage). In addition, where interaction effects were not significant, but main effects were, the least significant difference (LSD) procedure was used to carry out paired comparisons among factors. For potato in 2005, the Sidak procedure was used in comparisons of adjusted means with plant population per ha as a covariate.

Data from the extra experimental plots were analyzed using one-way ANOVA at the forage level factor, since crops were grown only at one level of soil amendment (i.e., stockless system). However, further comparisons were made to assess differences depending on both the sequence of a crop in the rotation, and the number of years that forages preceded a particular crop. A post-hoc analysis in extra experimental plots was carried out using the LSD procedure.

The objective of all comparisons in the core and extra experimental plots was to test the null hypothesis that the means among the different treatments were identical. Statistical analysis was carried out in SPSS.

3.4.2 Yield Comparison

3.4.2.1 Core Plots

The core plots were sown with wheat in 2002; soybean, barley, and forage in 2003; barley and forage in 2004; and potatoes in 2005. Results of the four-year experiment showed significant differences among treatments for wheat, forage, and potato. In 2002, wheat yields under the ruminant system were higher than the stockless system ($p=0.035$). For both 2003 and 2004, forage yields were higher when forages were preceded by one year of forage ($p=0.003$), and in 2005, potato yields under the ruminant system were higher than under the monogastric ($p=0.092$) and stockless ($p=0.105$) systems. The main test statistics and mean yields are summarized in Tables 3.14 and 3.15. However, due to lack of space, the p-values of paired comparisons appear in the text but not in tables.

In 2002, wheat yield comparisons had neither main nor interaction effects (i.e., forage

Table 3.14 Test Statistics of Yield Comparisons in Core Plots

Crop	Grouping criterion	Rotations	Description	Sum of Squares	Df	*F*	P-value
Barley	Soil amendment	WSBP	Between Groups	34730.35	2	0.848	0.474
			Within Groups	122884.55	6	N/A	N/A
			Total	157614.90	8	N/A	N/A
Forage	Factor Interaction	WBFP and WFFP	Corrected Model	1997389.92	5	0.270	0.925
			Intercept	1721951568.86	1	1161.76	<0.0001
			Forage	986849.15	1	0.666	0.424
			Amendment	1006408.11	2	0.340	0.716
			Forage x amendment	75986.52	2	0.026	0.975
			Error	31126014.83	21	N/A	N/A
			Total	1939525292.31	27	N/A	N/A
			Corrected Total	33123404.75	26	N/A	N/A
	Forage preceded by forage	WBFP and WFFP	Between Groups	9779522.00	1	10.47	**0.003**
			Within Groups	23343882.75	25	N/A	N/A
			Total	33123404.75	26	N/A	N/A
Potato*	Factor Interaction	WSBP, WBFP and WFFP	Corrected Model	868726563.07	9	2.012	0.103
			Intercept	181549.27	1	0.004	0.952
			Plants per ha**	101420647.94	1	2.114	0.164
			Forage	92309216.63	2	0.962	0.402
			Amendment	340280632.08	2	3.547	**0.052**
			Forage x amendment	24248072.60	4	0.126	0.971
			Error	815525600.67	17	N/A	N/A
			Total	21542540697.11	27	N/A	N/A
			Corrected Total	1684252163.73	26	N/A	N/A
Wheat	Factor Interaction	WSBP, WBFP and WFFP	Corrected Model	2048546.18	8	1.040	0.444
			Intercept	410637006.66	1	1667.05	<0.0001
			Forage	60476.85	2	0.123	0.885
			Amendment	1277707.82	2	2.594	**0.102**
			Forage x amendment	710361.51	4	0.721	0.589
			Error	4433854.00	18	N/A	N/A
			Total	417119406.85	27	N/A	N/A
			Corrected Total	6482400.19	26	N/A	N/A
	Wheat underseeded with forage	WSBP, WBFP and WFFP	Between Groups	57387.08	1	0.223	0.641
			Within Groups	6425013.10	25	N/A	N/A
			Total	6482400.19	26	N/A	N/A

Note: Variables and figures in bold denote results where significant differences were found. Df.= degrees of freedom, N/A= non applicable. * Potato plots where amendments were applied. ** The number of plants per ha was included as a covariate in the model.

Table 3.15 Average Yields in Core Plots

Crop	Grouping criterion	Rotation	Forage factor	Amendment factor	Mean	Std. Deviation	N
Barley	Soil amendment	WSBP	Zero years of forage in rotation	Stockless	2667.08	161.57	3
				Monogastric	2813.95	154.83	3
				Ruminant	2706.07	106.62	3
Forage	Factor Interaction	WBFP	One year of forage in rotation	Stockless	8431.89	293.62	3
				Monogastric	8551.98	595.12	3
				Ruminant	9035.72	798.24	3
		WFFP	Two years of forage in rotation	Stockless	8134.95	1884.49	6
				Monogastric	8192.86	1036.21	6
				Ruminant	8475.12	1081.28	6
	Forage preceded by forage	WBFP and WFFP (not preceded)	One and two years of forage in rotation	Stockless, monogastric, and ruminant	**7977.26**	1016.35	18
		WFFP (preceded)	Two years of forage in rotation	Stockless, monogastric, and ruminant	**9253.95**	850.24	9
Potato*	Factor Interaction	WSBP	No forage in rotation	Stockless	26500.51	5363.78	3
				Monogastric	31268.42	1453.51	3
				Ruminant	36126.65	5533.65	3
		WBFP	One year of forage in rotation	Stockless	25618.72	1000.25	3
				Monogastric	18895.68	5929.41	3
				Ruminant	28089.71	13932.04	3
		WFFP	Two years of forage in rotation	Stockless	21120.78	9754.70	3
				Monogastric	23342.39	6182.55	3
				Ruminant	33116.77	5773.28	3
Wheat	Factor Interaction	WSBP	No forage in rotation	Stockless	3340.58	831.96	3
				Monogastric	3966.65	325.72	3
				Ruminant	4255.20	273.04	3
		WBFP	One year of forage in rotation	Stockless	3871.28	393.02	3
				Monogastric	3650.91	535.30	3
				Ruminant	4118.85	200.83	3
		WFFP	Two years of forage in rotation	Stockless	3688.24	261.88	3
				Monogastric	4082.27	192.29	3
				Ruminant	4124.62	870.19	3
	Wheat underseeded with forage	WSBP and WBFP (not underseeded)	Zero and one year of forage in rotation	Stockless, monogastric, and ruminant	3867.24	505.96	18
		WFFP (underseeded)	Two years of forage in rotation	Stockless, monogastric, and ruminant	3965.04	509.05	9

Note: Grouping criteria and yields are in bold where significant differences were found.
* Potato plots where amendments were applied

factor p=0.885, amendment factor p=0.102, interaction forage-amendment p=0.589). However, in general, average wheat yields tended to be higher under ruminant compost than the remaining soil amendments (p=0.102, $\alpha = 0.05$). The LSD procedure was carried out to test for differences based on the amendment factor. The results revealed differences between ruminant and stockless systems (p=0.035). Average wheat yield grown with ruminant compost was 4,166kg/ha, while with alfalfa pellets, average yields were 3,633kg/ha. Wheat yields under monogastric compost (3,900kg/ha) were not different from yields under alfalfa pellets (p=0.269) and ruminant compost (p=0.270). In addition, wheat underseeded with forage had no effect on yields (p=0.641). The total average wheat yield (3,900kg/ha) in the Truro experiment was 5% higher than the 2000-2004 conventional wheat yield in Nova Scotia (3,700kg/ha) (Statistics Canada, 2005b).

In 2003, soybean and barley were not harvested because both crops were in bad condition. In the case of soybean, poor seed emergence caused by low temperatures, combined with shattered pods, and deer damage at maturity, resulted in yields that could not be harvested. The main reason for not harvesting barley was that the crop was heavily infested with weeds. Nevertheless, soybean yields were estimated based on sampled kernel weight, and averaged 309 kg/ha. Barley yields were estimated based on biomass weight and averaged 959 kg/ha. The estimated soybean and barley yields were respectively 85% and 68.5% lower than the 2000-2004 average conventional crop yields of soybean (2,040kg/ha) and barley (3,040kg/ha) in the Maritimes (Statistics Canada, 2005b). Consequently, soybean and barley yields in 2003 were not considered in the statistical analysis.

Barley yield data from the 2004 harvest was compared by the soil amendment factor and no significant differences were found (p=0.474). Overall, the total average barley yield in 2004 (2,729kg/ha) was 10% lower than the 2000-2004 average conventional barley yield in Nova Scotia (3,040kg/ha) (Statistics Canada, 2005b).

Forage yields from 2003 and 2004 had neither main nor interaction effects (i.e., forage factor p=0.424, amendment factor p=0.716, forage-amendment interaction p= 0.975). However, it was found that forage yields averaged higher when grown after one year of forage (p=0.003), i.e., two consecutive years of forage in the rotation had a positive effect on forage yields. Forages grown in 2004 under WF<u>F</u>P, had an average yield of 9,254kg/ha (dry weight), while forage grown in 2003 and 2004 as the first forage crop in the rotation (i.e., WFFP and WBFP and) had an average yield of 7,977kg/ha (dry weight). Higher yields in the second year of forages could have been the result of a better-established forage crop rather than a particular effect that forages had on soil quality. Overall, the total average forage yield in the Truro experiment (8,403kg/ha in dry weight basis) was 52% higher than the 2000-2004 average tame hay yield in Nova Scotia (5,518kg/ha) (Statistics Canada, 2005b).

In 2005, the last year of the crop rotation trials in the core plots, individual potato plots were split in halves. One half received soil amendments according to soil test recommendations, while the other half was left without soil amendments. The intention was to determine the effect of soil amendments applied to potatoes in 2005, as well as to determine if the rotation systems had any effects on potato yields from the unamended plots (i.e., residual effects of the previous years of soil fertility management). Potato yields were compared using the factorial ANOVA procedure for the amendment-approach factor (i.e., with and without soil amendments), the forage factor (0, 1 and 2 years of forage in the rotation) and the soil amendment factor (stockless, monogastric and ruminant), including the number of plants per hectare as a covariate. At this stage, there were no interaction effects (i.e., p=0.990 for amendment-approach x forage, p=0.433 for amendment-approach x type of soil amendment, p=0.367for forage x type of soil amendment, and p=0.777 for amendment-approach x forage x type of soil amendment), but main effects were significant (i.e., p=0.045 for the amendment-approach factor, p=0.055 for the forage factor, and p=0.005 for the type of soil amendment factor). Potato yields for plots with soil amendment were statistically higher (adjusted mean of 26,561 kg/ha) than yields on plots without amendment (adjusted mean of 22,680 kg/ha). Therefore, the next step was to analyze the levels of the amendment-approach factor separately, i.e. compare the means within the amended plots and the means within the unamended plots by the factorial combination of forage and type of soil amendment.

The Sidak procedure was used to carry out paired comparisons of the adjusted means of the 2005 potato yield after ANOVA in both amended and unamended plots (means were adjusted for the number of plants per hectare). The potato plots that received soil amendments had no interaction effects (p=0.971) (see Table 3.14), and main effects were significant only for the type of soil amendment (p=0.052) (p=0.402 for the forage factor). Paired comparisons revealed that yields under the ruminant system (adjusted mean of 32,165 kg/ha) were higher than yields under the monogastric (adjusted mean of 24,502kg/ha) and the stockless (adjusted mean of 24,693kg/ha) systems, with p-values of 0.092 and 0.105 respectively. Yields under the monogastric system were not different from the stockless system (p>0.99). Overall, the unadjusted average yield in the amended potato plots (27,120kg/ha) was 14% higher than the 2000-2004 average conventional potato yield in Nova Scotia (23,764kg/ha) (Statistics Canada, 2005c).

Similarly, potato yields from plots without soil amendments were analyzed in a factorial combination of the forage factor and the type of soil amendment. Even though potatoes on these plots did not receive soil amendments, both factors were included in the analysis because the soil fertility of these plots was managed according to the experimental treatment combination (i.e., forage level x type of soil amendment). The results show no interaction effects (p=0.226), and significant differences only for the type of soil amendment factor (p=0.052) (p=0.196 for the forage factor). Paired comparisons of adjusted means of the soil amendment factor revealed that potato yields on plots that had received ruminant compost the previous 3 years (adjusted mean of 25,760kg/ha) were higher than yields from plots that were previously under monogastric compost (17,789kg/ha) (p=0.054). The adjusted mean yields of plots that were previously under stockless systems were not different from the monogastric (p=0.285) and ruminant systems (p=0.723). Overall, the unadjusted average yield in the potato plots without soil amendments (22,121kg/ha) was 7% lower than the 2000-2004 average conventional potato yield in Nova Scotia (23,764kg/ha) (Statistics Canada, 2005c).

3.4.2.2 Extra Experimental Plots

Results of yield comparisons are summarized in Tables 3.16 and 3.17. Yield comparisons were carried out only for three years of the crop rotation (i.e., 2002-2004), since the trials in the extra experimental plots were discontinued after the 2004 harvest. In general, significant differences were found for selected crops. Forage, potato, and wheat yields were different when the crops were grown after forages, and when the crops were compared on a yearly basis (i.e., different sequence in the rotation). On the other hand, barley yields were not significantly different when grouped by sequence in the rotation

Table 3.16 Test Statistics of Yield Comparisons in Extra Experimental Plots

Crop	Grouping criterion	Rotations	Description	Sum of Squares	Df	*F*	P-value
Barley	Place in the rotation	BFPW and PWBF	Between Groups	1823.74	1	0.004	0.951
			Within Groups	1677527.16	4	N/A	N/A
			Total	1679350.90	5	N/A	N/A
Forage	Forage level	BFPW, FPWB, FFPW, FPWF, and PWFF	Between Groups	10986478.14	1	1.439	0.248
			Within Groups	122165694.50	16	N/A	N/A
			Total	133152172.64	17	N/A	N/A
	Forage preceded by forage	BFPW, FPWB, FFPW, FPWF, PWFF, and FFPW	Between Groups	25173375.33	1	3.730	**0.071**
			Within Groups	107978797.32	16	N/A	N/A
			Total	133152172.64	17	N/A	N/A
	Place in the rotation	FPWB, FFPW, FPWF BFPW, FFPW, and PWFF	Between Groups	109748387.80	2	35.17	**<0.0001**
			Within Groups	23403784.84	15	N/A	N/A
			Total	133152172.64	17	N/A	N/A
Potato	Forage level	BFPW, FPWB, PWBF FFPW, FPWF, and PWFF	Between Groups	620913.59	1	0.019	0.892
			Within Groups	518273482.70	16	N/A	N/A
			Total	518894396.29	17	N/A	N/A
	Potato preceded by forage	PWBF, PWFF, BFPW, FPWB, FPWF, and FFPW	Between Groups	245623761.05	2	6.741	**0.008**
			Within Groups	273270635.24	15	N/A	N/A
			Total	518894396.29	17	N/A	N/A
	Place in the rotation	PWBF, PWFF, FPWB, FPWF, BFPW, and FFPW	Between Groups	427397904.41	2	35.034	**<0.0001**
			Within Groups	91496491.88	15	N/A	N/A
			Total	518894396.29	17	N/A	N/A
Wheat	Forage level	FPWB, PWBF, FPWF, and PWFF	Between Groups	167960.92	1	0.752	0.406
			Within Groups	2233902.25	10	N/A	N/A
			Total	2401863.17	11	N/A	N/A
	Wheat preceded by forage or grouped by place	PWBF, PWFF, FPWB, and FPWF	Between Groups	515271.01	1	2.731	**0.129**
			Within Groups	1886592.16	10	N/A	N/A
			Total	2401863.17	11	N/A	N/A

Note: Variables and figures in bold denote results where significant differences were found. Df.= degrees of freedom, N/A= non applicable

Table 3.17 Average Yields in Extra Experimental Plots

Crop	Grouping criterion	Description	Rotations	Mean	Std. Deviation	N
Barley	Place in the rotation	First	BFPW	2691.67	621.98	3
		Third	PWBF	2656.80	672.24	3
Forage	Forage level	One year of forage in rotation	BFPW and FPWB	2766.28	1748.45	6
		Two years of forage in rotation	FFPW, FPWF, and PWFF	4423.57	3117.11	12
	Forage preceded by forage	No forage preceding the crop	BFPW, FPWB, FFPW, FPWF, and PWFF	**3342.27**	2750.02	15
		One year of forage preceding the crop	FFPW	**6515.50**	1025.29	3
	Place in the rotation	First	FPWB, FFPW, and FPWF	**1606.89**	283.04	9
		Second	BFPW, FFPW	**5150.36**	2108.91	6
		Third	PWFF	**8105.46**	512.54	3
Potato	Forage level	One year of forage in rotation	BFPW, FPWB, and PWBF	12336.10	4940.89	9
		Two years of forage in rotation	FFPW, FPWF, and PWFF	11964.65	6353.88	9
	Potato preceded by forage	No forage preceding the crop	PWBF and PWFF	8303.54	1636.70	6
		One year of forage preceding the crop	BFPW, FPWB, and FPWF	**12306.49**	5038.57	9
		Two years of forage preceding the crop	FFPW	**19375.69**	5328.18	3
	Place	First	PWBF and PWFF	**8303.54**	1636.70	6
		Second	FPWB and FPWF	**9122.23**	1579.81	6
		Third	BFPW and FFPW	**19025.35**	3622.80	6
Wheat	Forage level	One year of forage in rotation	FPWB, and PWBF	1174.64	563.89	6
		Two years of forage in rotation	PWF and PWFF	1411.26	358.90	6
	Wheat preceded by forage and/or grouped by place	No forage preceding the crop	PWBF and PWFF	**1085.73**	507.80	6
		One year of forage preceding the crop	FPWB and FPWF	**1500.17**	345.62	6

Note: Grouping criteria and yields are in bold where significant differences were found.

(2002 vs. 2004) (p=0.951). The average barley yield in the extra experimental plots (2,674kg/ha) was 12% lower than the 2000-2004 average yield of conventional barley in Nova Scotia (3,040kg/ha) (Statistics Canada, 2005b). Recall that the extra experimental plots received alfalfa pellets as the source of nutrients.

There were no significant differences in forage yield among the forage level factor (average yields from 2002-2004) (p=0.248). However, yield for forage grown after one year of forage (2003 average yields in the rotation FFPW) was higher (6,516kg/ha) than forage not preceded by forage (2002-2004 average yields in rotations BFPW, FPWB, FFPW, FPWF, and PWFF) (3,342kg/ha) with a p-value of 0.071. Significant differences were also found when forage yields were compared by the sequence of forage in the rotation (forage starting the rotation in 2002 FPWB, FFPW, and FPWF; forage in the second year, i.e. 2003, BFPW, FFPW; and forage in the third year, i.e. 2004, PWFF in 2004). Thus, the rotation sequence does influence forge yield performance (p<0.0001). Indeed, paired comparisons using the LSD procedure confirmed that yields from forage in third place in the rotation (2004) were the highest (8,105kg/ha) (2002 vs. 2004 p<0.0001, and 2003 vs. 2004 p=0.004), while yields from forage in first place (2002) were the lowest (2004) (1,607kg/ha) (p<0.0001). Yields from forage in second place (2003) averaged 5,150kg/ha. It is important to note that weather from one year to another may have also had an effect. In contrast to core plots, overall average forage yield in extra experimental plots (3,871kg/ha) was 30% lower than the 2000-2004 average yield of tame hay in Nova Scotia (5,518kg/ha) (Statistics Canada, 2005b).

Potato yields from 2002 to 2004, were not significantly different among the forage level factor (p=0.892), yet differed when grown after forage (p=0.008). Indeed, potatoes grown immediately after two years of forage (2004 average yields in FFPW) outperformed those grown after one year of forage (2003-2004 average yields in BFPW, FPWB, and FPWF) (p=0.025) and when no forage preceded potato (2002 average yields in PWBF and PWFF) (p=0.002). Furthermore, yield after one year of forage was higher than when no forage preceded potatoes (p=0.095). Potato averaged 19,375kg/ha after two years of forage, 12,306kg/ha after one year, and 8,303kg/ha with no forage. Differences were also found when potato was grouped by the place in the rotation (p<0.0001). However, there seemed to be no difference when potato occupied the first (2002 in

PWBF and PWFF) and second place (2003 in FPWB and FPWF) in the rotation sequence ($p=0.574$). Nevertheless, growing potato the third year in rotation (2004 in BFPW and FFPW) averaged higher yield than growing potatoes the first and second year in the sequence ($p<0.0001$). Average potato yields in extra experimental plots (12,150kg/ha) were 49% lower than the 2000-2004 average conventional potato yield in Nova Scotia (23,764kg/ha) (Statistics Canada, 2005c).

Wheat yields were not different when compared by forage level (2003-2004) ($p=0.406$). However, when wheat yields were grouped by wheat grown after forage or by place in the rotation (i.e., average wheat yields from 2003 vs. 2004) differences were found at 13% confidence. Higher yields were found when wheat was preceded by one year of forage (2004 in FPWB and FPWF) (1,500kg/ha), compared to yields when wheat was not preceded by forage in the rotation (2003 in PWBF and PWFF) (1,086kg/ha). Overall, average wheat yields in extra experimental plots (1,293kg/ha) were 65% lower than the 2000-2004 conventional wheat yield in Nova Scotia (3,700kg/ha) (Statistics Canada, 2005b).

3.4.3 Cost Comparisons

Crop budgets were generated based on actual operations for the experiments, input prices, and estimated field operation costs in 2005 (examples are provided in Appendix 2). It is important to note that, in the context of organic agriculture, this experiment aimed at meeting soil test recommendations by building soil organic matter through forage-based crop rotations and organic soil amendments. In contrast to synthetic fertilizers, nutrients in organic soil amendments are not immediately available to the plant. Therefore, the amounts of soil amendment used in the experiment were substantial. In addition, despite its high cost, alfalfa pellets were chosen as a source of nitrogen in the stockless systems, and compost costs were estimated at opportunity cost. Therefore, as mentioned in section 3.3.1, production costs from the Truro experiment do not necessarily represent those of a commercial operation, in particular with respect to nutrient supply costs. However, all other estimated costs did represent those of a commercial operation.

Fixed costs were different between rotations and treatments. Differences can be attributed to the machinery complement, since machinery were selected according to the crops and treatments involved in the rotations. For example, forage machinery was not included in the wheat/soybean/barley/potato rotation, and a manure spreader (which was used for compost applications) was not included in the rotations in the stockless system. However, fixed costs per hectare were identical for each of the four crops involved in each rotation.

Variable costs differed between treatments and from one block to another. Differences arose because: i) nutrient supply was block specific, ii) the price of alfalfa pellets was more than four times the cost of monogastric compost and more than three times the cost of ruminant compost, iii) potato and grain grading and cleaning costs were calculated based on yield, and iv) field operations differed among treatments.

3.4.3.1 Core Plots

All crops in forage-based crop rotations had higher fixed costs than crops in rotations with no forage. In addition, fixed costs were higher in treatments involving compost. Differences in fixed costs were associated with the costs of the forage equipment, the manure spreader, the Lely weeder, and straw bailing equipment. Fixed costs ranged from \$205/ha for crops in the WSBP rotation in the stockless system, to \$347/ha for crops in forage-based rotations (WBFP and WFFP) under monogastric and ruminant compost. Indeed, fixed costs of monogastric and ruminant treatments compared to the stockless treatment, were 32% higher in the WSBP rotation, and 19% higher in both forage-based rotations (WBFP and WFFP). Similarly, fixed costs for the stockless system in forage-based rotations (i.e., WBFP and WFFP) were 43% higher than the stockless system in WSBP. In addition, monogastric and ruminant treatments were 28% higher in forage-based rotations than in WSBP. Details of fixed costs are presented in Table 3.18 and Figure 3.1.

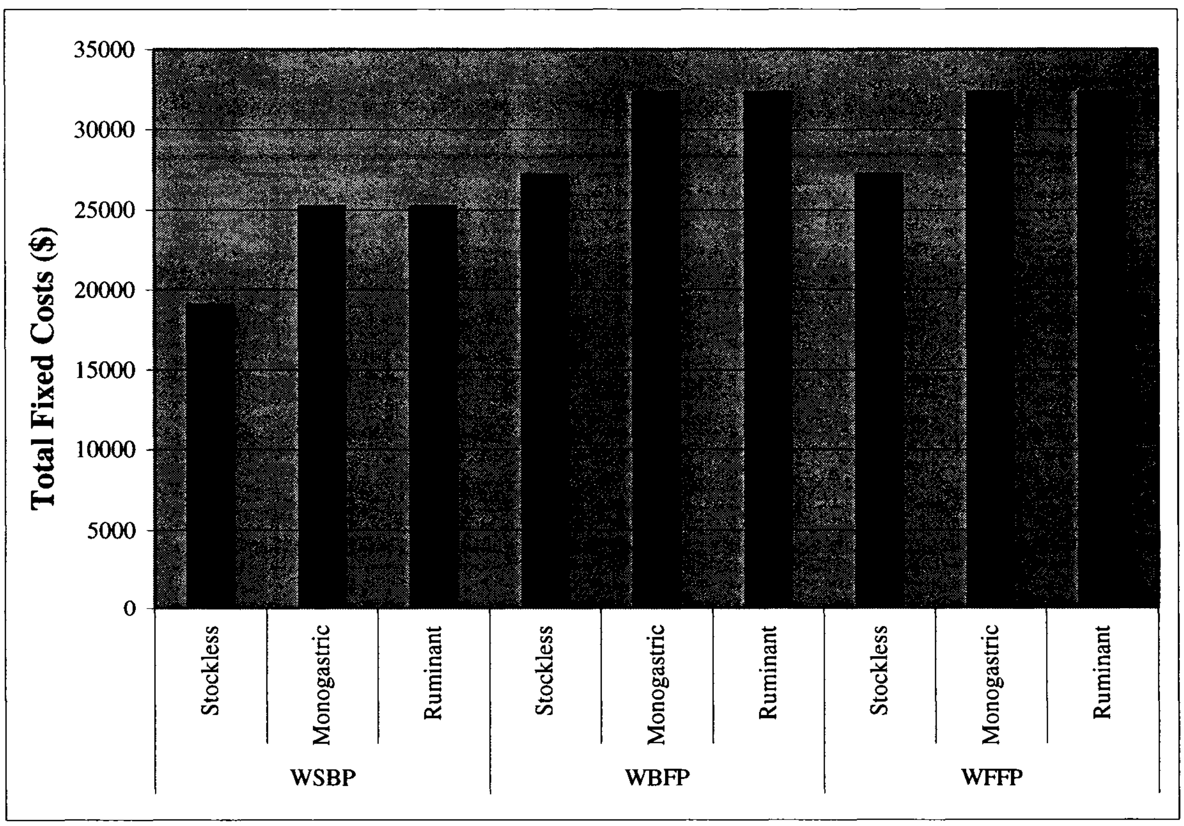
Variable costs for crops in the core experiments are summarized in Table 3.19. In 2002, wheat variable costs were lower under monogastric compost at every level of forage rotation. Wheat under the stockless system was by far the most expensive treatment, mainly because the cost of alfalfa pellets was high, compared to compost costs. Across sources of nutrient supply, wheat variable costs were lower in forage-based rotations with two years of forage. The lowest cost was generated in the WFFP rotation (\$2,761/ha), while the highest was for one year of forage (WBFP) under the stockless system (\$15,974/ha). Differences in wheat variable costs were mostly related to soil

Table 3.18 Fixed Costs of Selected Crop Rotation Systems, Core Plot Experiments

Rotation	Treatment	Investment on machinery complement ($)	Fixed cost ($)					TOTAL FIXED COST ($)	TOTAL FIXED COST ($/ha)
			Depreciation	Interest on investment	Insurance and storage expenses	Soil test cost	Cert. fees		
WSBP	Stockless	149,488	10,234.80	6,848.05	1,494.88	120	345	19,042.73	204.76
	Monogastric	199,943	13,545.12	9,159.38	1,999.43	120	345	25,168.92	270.63
	Ruminant	199,943	13,545.12	9,159.38	1,999.43	120	345	25,168.92	270.63
WBFP	Stockless	215,635	14,668.93	9,878.23	2,156.35	120	345	27,168.51	292.13
	Monogastric	258,663	17,397.74	11,849.34	2,586.63	120	345	32,298.71	347.30
	Ruminant	258,663	17,397.74	11,849.34	2,586.63	120	345	32,298.71	347.30
WFFP	Stockless	215,635	14,668.93	9,878.23	2,156.35	120	345	27,168.51	292.13
	Monogastric	258,663	17,397.74	11,849.34	2,586.63	120	345	32,298.71	347.30
	Ruminant	258,663	17,397.74	11,849.34	2,586.63	120	345	32,298.71	347.30

Note: Although soil tests costs and certification fees were not included in individual crop budgets, these appear in this table because they are attributed to the whole rotation system. W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage.

Figure 3.1 Fixed Costs of Selected Crop Rotation Systems, Core Plot Experiments



Note: W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage.

Table 3.19 Variable Costs of Crops in the Core Plots (average of 3 blocks)

Crop	Year	Rotation	Variable costs grouped by source of soil amendment ($/ha)		
			Stockless (alfalfa pellets)	Monogastric Compost	Ruminant Compost
Wheat	2002	WSBP	15,946.1	**3,040.1**	4,593.6
		WBFP	15,973.6	**3,023.8**	4,614.3
		WFFP	9,270.6	**2,760.5**	3,706.3
Soybean	2003	WSBP	1,312.6	**435.0**	1,038.0
Barley	2004	WSBP	4,915.1	**2,734.2**	3,349.5
	2003	WBFP	1,082.8	**930.3**	1,033.4
Forage	2004	WBFP	**2,033.7**	4,795.2	6,101.6
	2003	WFFP	1,269.2	**811.6**	1,086.3
	2004	WFFP	**2,308.4**	4,962.5	4,534.8
Potato	2005	WSBP	9,440.0	6,421.8	5,899.1
		WBFP	8,827.8	6,056.2	**5,726.6**
		WFFP	9,914.0	5,852.8	5,780.8

Note: Lowest variable costs are in bold. W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage.

amendment application rates and the price of alfalfa pellets.

Barley variable costs ranged from $930/ha in 2003 (WBFP under monogastric system) to $4,915/ha in 2004 (WSBP under stockless system), with the main differences attributed to a low application rate of rock phosphate in 2003, and high cost of nutrient supply in the stockless system in 2004. Overall, barley variable costs in the forage-based crop rotation WBFP were lower than in WSBP.

Forages in the WFFP rotation were less expensive to produce under monogastric compost in 2003 ($812/ha), since the rock phosphate application rate was the lowest in plots under monogastric compost. However, for the following year of forage (i.e., the same rotation in 2004), forage variable costs under monogastric compost were the highest ($4,963/ha), and lowest under the stockless system ($2,308/ha). This difference was primarily because in 2003 neither alfalfa pellets nor compost were applied, while in 2004 only compost was applied. Variable costs of forage grown in WBFP were the lowest under the stockless system ($2,034/ha) and the highest under the ruminant system

($6,102). However, this difference was mainly because nitrogen was not supplied to plots under the stockless system in 2004 in WBFP.

In 2003, soybean grown under monogastric compost had the lowest variable costs ($435/ha), while the highest was for the stockless system ($1,313/ha). This difference was because rock phosphate was applied at a lower rate in plots under the monogastric system.

In general, potato variable costs in 2005 in the stockless system were higher than in the livestock systems (i.e., monogastric and ruminant), and lower in forage-based rotations (WBFP and WFFP) than in non forage-based rotations (WSBP). The highest variable cost was $9,440/ha for WSBP under the stockless system, while the lowest was $5,726/ha in WBFP under the ruminant system. The main differences were attributed to nutrient supply costs. For instance, while the livestock systems required more nitrogen, the stockless system required more phosphorus. However, the cost of supplying nitrogen and phosphorus with alfalfa pellets (i.e., stockless system) was considerably higher than with any of the two types of compost (i.e., livestock systems) (a discussion regarding nutrient supply costs follows in section 3.4.4).

Taking the various rotations as a whole, rotations under monogastric systems had the lowest variable costs (Table 3.20 and Figure 3.2). However, rotations under ruminant systems had, on average, only 13% higher variable costs, while stockless systems were 97% higher. Similarly, on average, forage-based rotations with two years of forage (i.e., WFFP) generated the lowest variable costs. However, variable costs for non-forage based rotations (i.e., WSBP) were only 13% higher, while the rotation WBFP was 15% higher.

An interesting finding was that, monogastric systems were more labour and machinery intensive than the other two systems, primarily because monogastric compost required more labour to turn and blend than ruminant compost (i.e., monogastric manure was more moist), and the stockless system did not require such hired-labour since alfalfa pellets were bought ready to be applied (recall that it was assumed that compost preparation was carried out by hired-labour). On the other hand, monogastric systems demanded less operating capital than the others, and stockless systems demanded the most.

It is also interesting to note that, overall, forage-based rotations require more labour,

Table 3.20 Variable Costs for Rotations in the Core Plots (average of 3 blocks)

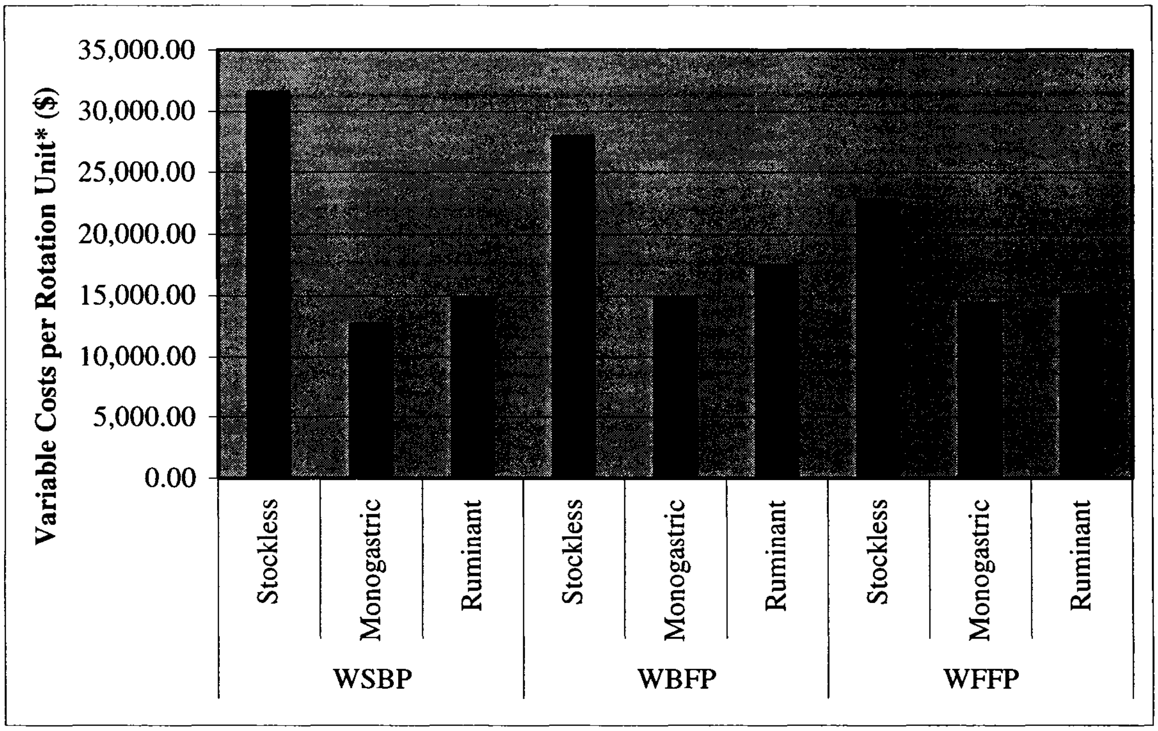
Rotation	Treatment	Operating Expenses Paid in Cash ($)* +	Variable cost ($ per rotation unit*)						Total Variable Costs per Rotation Unit ($*)
			Inputs	Family Labour	Hired Labour	Machinery Expenses	Custom Operator Charges	Interest on Operating Expenses	
WSBP	St	30,281	28,780.7	424.6	0	287.5	1,212.6	908.5	31,613.9
	M	11,854	7,872.0	422.0	1,268	1,367.0	1,347.0	356.0	**12,632.0**
	R	14,055	11,832	404.0	285	485.0	1,453.0	422.0	14,881.0
WBFP	St	26,650	25,285.6	468.9	0	324.8	1,039.1	799.5	27,917.9
	M	13,966	9,642.0	422.0	1,688	1,742.0	894.0	419.0	**14,807.0**
	R	16,562	14,466.0	416.0	422	621.0	1,053.0	497.0	17,475.0
WFFP	St	21,639	20,504.0	474.1	0	319.5	815.4	649.2	22,762.2
	M	13,570	9,754.0	412.0	1,424	1,512.0	880.0	407.0	**14,389.0**
	R	14,281	12,065.0	399.0	288	509.0	1,419.0	428.0	15,108.0

Note: Lowest variable costs are in bold. W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage, St=Stockless, M= Monogastric, R= ruminant.

+ Operating expenses paid in cash = inputs + hired labour + machinery expenses + custom operator charges.

* 1 rotation unit = 4 hectares.

Figure 3.2 Variable Costs for Rotations in the Core Plots



Note: W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage. * 1 rotation unit = 4 hectares.

machinery and operating capital than non forage-based rotations. However, as the number of years of forage in forage-based rotations increases, the demand for labour, machinery and operating capital decreases. Therefore, across soil amendments, WFFP rotations had lower variable costs per unit (i.e., 4 ha) than WBFP rotations.

3.4.3.2 Extra Experimental Plots

Fixed costs for the extra experimental plots were not substantially different among rotation systems, since the machinery complement were similar (Table 3.21). Fixed costs associated with the rotations in the extra experimental plots did not include the costs of a manure spreader since no compost was applied. Total fixed cost was $27,080 or $291/ha.

Barley cost of production under PWBF was lower in 2004 ($1,994/ha) compared to barley in BFPW in 2002 ($4,535/ha). The main difference was that alfalfa pellets were not required in barley plots in 2004.

Forage variable costs differed among rotations primarily because forage plots in 2003 (BFPW and FFPW) received less rock phosphate relative to forage plots in 2002 (FPWB, FFPW, and FPWF) and in 2004 (PWFF). Alfalfa pellets were not applied to forage in the first three years of rotation because nitrogen was not required. The lowest forage variable cost was in 2003 ($995/ha) under both BFPW and FFPW, while the highest forage variable cost was in 2002 ($2,337/ha) under FPWB, FFPW, and FPWF.

In general, potato production costs were lower when potatoes were grown after forages. The lowest cost occurred when potato was grown after barley and forage in 2004 ($9,643 in BFPW). The highest potato variable cost was found in 2002 in the PWFF rotation ($15,159.85/ha). The main differences were that potato plots required more nitrogen when grown during the first two years of a particular rotation (2002 and 2003) compared to potato grown during the third year (2004), and that forage mulch was applied at a higher rate in potato plots in rotations with two years of forage.

Wheat variable costs were lower in rotations where wheat was followed by forage (i.e., in 2003 and 2004 wheat was underseeded with forage in FPWF and PWFF) compared to rotations where wheat was followed by barley (i.e., 2003 in PWBF and 2004 in FPWB). The main reason for differences in variable costs arose because the nitrogen application rate in wheat underseeded with forage was lower than wheat plots followed by barley. In other words, forages provided part of the nitrogen required by wheat.

Table 3.21 Variable Costs of Crops in the Extra Experimental Plots (average of 3 blocks)

Crop	Year	Rotation sequence	Variable cost ($/ha)
Barley	2002	BFPW	4,535.47
	2004	PWBF	**1,994.45**
Forage	2003	BFPW	**994.92**
	2002	FPWB	2,337.15
	2002	FFPW	2,337.15
	2003	FFPW	**994.92**
	2002	FPWF	2,337.15
	2004	PWFF	2,032.57
Potato	2004	BFPW	**9,643.57**
	2003	FPWB	10,554.88
	2002	PWBF	14,985.08
	2004	FFPW	9,935.68
	2003	FPWF	10,869.63
	2002	PWFF	15,159.85
Wheat	2004	FPWB	9,272.19
	2003	PWBF	9,072.66
	2004	FPWF	4,431.40
	2003	PWFF	**4,233.34**

Note: Lowest variable costs are in bold. W= Wheat, B= Barley, P=Potato, F= Forage.

Furthermore, the rock phosphate application rate on wheat plots was lower in 2003 in the rotation PWFF compared to other rotations. Therefore, the lowest wheat variable cost was recorded in 2003 in the rotation PWFF ($4,233/ha), while the highest variable cost was in 2004 for FPWB ($9,272/ha).

3.4.4 Net Returns Comparisons

Net returns for individual crops were calculated by subtracting variable and fixed costs from gross revenues. Gross revenues from 2002 to 2004 (i.e., transitional period) were calculated by multiplying yield by 3-year average conventional prices, since farm products in transition do not receive organic price premiums. Average conventional prices paid to producers in Nova Scotia from 2002 to 2004 (Table 3.22) were obtained from various sources, such as Agriculture and Agri-food Canada (AAFC) (2005a and 2005b), Statistics Canada (2005a), and the Nova Scotia Department of Agriculture and Fisheries (NSDAF) (2005a). On the other hand, gross revenues received in 2005 (i.e., potato in

Table 3.22 Average Annual Prices Paid to Producers in Nova Scotia ($/tonne)

Year	Barley	Forage*	Potato	Soybean	Wheat
2002	231.67	60.56	223.30	307.55	291.16
2003	198.86	80.59	203.43	395.04	242.39
2004	169.72	87.04	...	242.83	237.67
3 year average	200.08	76.06	213.38**	315.14	257.07

Note: *Estimated price of forage in dry weight basis. **Potato three-year average prices from 2001-2003 (2001 price =$213.4/tonne). ... Price not available.

core plots) were calculated assuming that organic certification was granted after 3 years of transition, with an average price premium of 87%. The average premium was based on the difference between conventional and organic potato retail price information from the Organic Agriculture Centre of Canada's website.

According to the Canadian Grain Commission (2005), barley of the variety AC Queens is classified as feed barley and wheat AC Helena is classified as Canadian Eastern Red Spring (CERS) for human consumption. Barley prices were obtained from personal communication with the Market Analysis Division (MAD) of AAFC (2005a). Information for the CERS wheat price in Nova Scotia is limited. Therefore, wheat prices were based on the CWRS-St. Lawrence price (AAFC, 2005b). This price was used based on information provided by a wheat trade expert from the Market Analysis Division of AAFC (Lennox, 2005). Soybean net returns were calculated from yields estimated based on sampled kernel weight, because soybean was not harvested. The soybean No. 2 Canada Eastern price was used as reference (AAFC, 2005b).

Potato prices for the transition period were obtained from Statistics Canada (2005a). However, the average potato price in 2004 was not available. Therefore, the 2001 price was included to obtain a 2001-2003 three-year average.

Forage silage prices were based on hay prices from the weekly price report of the Nova Scotia Department of Agriculture and Fisheries (NSDAF) (2005a). This assumption was made based on two considerations: i) even though forage silage in Nova Scotia is more common than hay (Hammermeister, 2005), the NSDAF collects only hay prices, and ii) forage yield information from the Truro experiment was on a dry weight basis. Therefore, hay prices were an appropriate proxy. The hay price was adjusted for 14% moisture content.

In general, net returns were negative for enterprises in both core and extra experimental plots. Positive net returns were found for forage in 2004 ($226/ha in block 1 for WFFP under ruminant compost) and for most of the potato plots in the core plots in 2005. Negative net returns were not unexpected because of high production costs, and these results can still be used to select crop rotations and soil amendments that maximize the financial returns during the transition to organic agriculture.

The negative net returns were primarily the result of high nutrient supply costs, and the amount of nutrients needed to meet soil test recommendations. In fact, based on the nutrient sources used in the Truro study, it was found that on average, supplying 1kg/ha of nitrogen cost $78.6 with alfalfa pellets, $21.7 with monogastric compost, and $26.4 with ruminant compost. Supplying 1kg/ha of phosphorus cost $400 with alfalfa pellets, $28.7 with monogastric compost, $41.2 with ruminant compost, and $17.7 with rock phosphate, while supplying 1kg/ha of potassium cost $22.9 with alfalfa pellets, $15.4 with monogastric compost, $6.8 with ruminant compost, and $2.6 with langbeinite.

Gross margins were also calculated as the difference between revenues and variable costs (Table 3.23). However, statistical analysis was carried out only for net returns, since significant differences in net returns would include costs associated to both fixed and variable factors of production.

It is worthwhile clarifying that an agronomic optimum is not necessarily the same as an economic optimum. Certainly, meeting soil test recommendations can be a necessary condition to reach a maximum yield. However, meeting soil test recommendations is not a necessary condition to reach the maximum net return. Nonetheless, in order to preserve the quality of soil and the long-term economic sustainability of a farming operation, agronomic and economic aspects should be considered simultaneously, in particular, in the context of a holistic production system such as organic agriculture.

3.4.4.1 Core Plots

Statistical differences in average net returns were found for crops in the core plots (Tables 3.24-3.25). Comparisons of wheat net returns for 2002 revealed that the interaction of the forage level and the type of soil amendment was significant ($p<0.0001$). Therefore, it is very likely that wheat in a rotation with two years of forage (i.e., WFFP) under monogastric compost would provide higher net returns ($-2,053/ha) than any other

Table 3.23 Gross Margins (average of 3 blocks)

Rotation	Treatment	a) Crops in Core Plots					
		Wheat ($/ha)	Soybean ($/ha)	Barley ($/ha)	Forage 2003 ($/ha)	Forage 2004 ($/ha)	Potato ($/ha)
WSBP	Stockless	-15,087.33	-1,215.16+	-4,381.43	N/A	N/A	1,134.07
WBFP	Stockless	-14,978.36	N/A	-891.01+	N/A	-1,392.39	1,394.44
WFFP	Stockless	-8,322.42	N/A	N/A	-767.81	-1,572.30	- 1,486.47
WSBP	Monogastric	-2,020.39	-337.52+	-2,171.16	N/A	N/A	6,054.72
WBFP	Monogastric	-2,085.29	N/A	-738.48+	N/A	-4,144.75	1,483.47
WFFP	Monogastric	-1,711.09	N/A	N/A	-232.89	-4,294.91	3,461.11
WSBP	Ruminant	-3,499.72	-940.49+	-2,808.04	N/A	N/A	8,515.94
WBFP	Ruminant	-3,555.48	N/A	-841.65+	N/A	-5,414.32	5,481.62
WFFP	Ruminant	-2,645.97	N/A	N/A	-504.92	-3,826.93	7,433.27

Rotations under the stockless treatment	b) Crops in Extra Experimental Plots					
	Wheat ($/ha)	Barley ($/ha)	Forage 2002 ($/ha)	Forage 2003 ($/ha)	Forage 2004 ($/ha)	Potato ($/ha)
BFPW	...	-3,996.91	N/A	-707.01	N/A	-5,658.76
FPWB	-8,925.03	...	-2,204.25	N/A	N/A	-8,622.28
PWBF	-8,815.88	-1,462.87	N/A	N/A	N/A	-13,005.78
FFPW	...	N/A	-2,218.47	-499.33	N/A	-5,801.36
FPWF	-4,007.25	N/A	-2,222.07	N/A	N/A	-8,909.29
PWFF	-3,931.90	N/A	N/A	N/A	-1,416.04	-13,595.59

Note: Trials in extra experimental plots were discontinued after the 2004 harvest. N/A= non applicable

... Data not available.

+ Based on yield estimated from sample kernel weight.

Table 3.24 Test Statistics of Net Return Comparisons in Core Plots

Crop	Grouping criterion	Rotations	Description	Sum of Squares	Df.	*F*	P-value
Barley	**Soil amendment**	WSBP	**Between Groups**	7276710.28	2	7.08	**0.026**
			Within Groups	3081582.80	6	N/A	N/A
			Total	10358293.08	8	N/A	N/A
Forage	Factor Interaction	WBFP and WFFP	Corrected Model	50078686.51	5	2.71	0.049
			Intercept	228038388.60	1	61.59	<0.0001
			Forage	28883023.37	2	3.90	**0.036**
			Amendment	19092980.97	1	5.16	**0.034**
			Forage x amendment	9185242.83	2	1.24	0.310
			Error	77756702.10	21	N/A	N/A
			Total	337276946.33	27	N/A	N/A
			Corrected Total	127835388.62	26	N/A	N/A
	Forage preceded by forage	WBFP and WFFP	Between Groups	8006900.84	1	1.67	0.208
			Within Groups	119828487.77	25	N/A	N/A
			Total	127835388.62	26	N/A	N/A
Potato	Factor Interaction	WSBP, WBFP and WFFP	Corrected Model	282006352.35	9	4.561	0.004
			Intercept	6147554.93	1	0.895	0.357
			Plants per ha*	14523182.99	1	2.114	0.164
			Forage	15318657.27	2	1.115	0.351
			Amendment	189083432.72	2	13.76	**<0.0001**
			Forage x amendment	4432916.91	4	.161	0.955
			Error	116781143.92	17	N/A	N/A
			Total	714953707.12	27	N/A	N/A
			Corrected Total	398787496.27	26	N/A	N/A
Wheat	**Factor Interaction**	WSBP, WBFP and WFFP	Corrected Model	716352934.73	8	624.95	<0.0001
			Intercept	1067118127.43	1	7447.71	<0.0001
			Forage	625798649.28	2	2183.81	**<0.0001**
			Amendment	40731940.14	2	142.14	**<0.0001**
			Forage x amendment	49822345.31	4	86.93	**<0.0001**
			Error	2579063.47	18	N/A	N/A
			Total	1786050125.63	27	N/A	N/A
			Corrected Total	718931998.21	26	N/A	N/A
	Wheat underseeded with forage	WSBP, WBFP and WFFP	Between Groups	40700084.50	1	1.50	0.232
			Within Groups	678231903.00	25	N/A	N/A
			Total	718931988.00	26	N/A	N/A

Note: Variables and figures in bold denote results where significant differences were found. Df.= degrees of freedom, N/A= non applicable. * The number of plants per ha was used as a covariate.

Table 3.25 Average Net returns of Crops in Core Plots

Crop	Grouping criterion	Rotation	Forage factor	Amendment factor	Mean	Std. Deviation	N
Barley	**Soil amendment**	WSBP	Zero years of forage in rotation	Stockless	**-4581.19**	300.05	3
				Monogastric	**-2436.79**	786.38	3
				Ruminant	**-3073.67**	912.34	3
Forage	Factor Interaction	WBFP	One year of forage in rotation	Stockless	-1679.53	453.52	3
				Monogastric	-4487.05	1140.93	3
				Ruminant	-5756.62	1165.17	3
		WFFP	Two years of forage in rotation	Stockless	-1457.12	445.17	6
				Monogastric	-2606.20	2258.39	6
				Ruminant	-2508.22	3017.75	6
	Forage preceded by forage	WBFP and WFFP (not preceded)	One and two years of forage in rotation	Stockless, monogastric, and ruminant	-2400.09	2125.87	18
		WFFP (preceded)	Two years of forage in rotation	Stockless, monogastric, and ruminant	-3555.29	2318.40	9
Potato	Factor Interaction	WSBP	No forage in rotation	Stockless	934.31	2029.73	3
				Monogastric	5789.09	550.03	3
				Ruminant	8250.31	2094.01	3
		WBFP	One year of forage in rotation	Stockless	1107.31	378.51	3
				Monogastric	1141.17	2243.77	3
				Ruminant	5139.33	5272.08	3
		WFFP	Two years of forage in rotation	Stockless	-1773.5994	3691.32	3
				Monogastric	3118.8178	2339.57	3
				Ruminant	7090.9733	2184.69	3
Wheat	**Factor Interaction**	WSBP	No forage in rotation	Stockless	**-15287.08**	528.87	3
				Monogastric	**-2286.02**	160.20	3
				Ruminant	**-3765.35**	56.13	3
		WBFP	One year of forage in rotation	Stockless	**-15265.49**	441.80	3
				Monogastric	**-2427.59**	209.50	3
				Ruminant	**-3897.78**	78.50	3
		WFFP	Two years of forage in rotation	Stockless	**-8609.55**	322.43	3
				Monogastric	**-2053.39**	405.68	3
				Ruminant	**-2988.26**	683.54	3
	Wheat underseeded with forage	WSBP and WBFP (not underseeded)	Zero and one year of forage in rotation	Stockless, monogastric, and ruminant	-7154.89	5947.34	18
		WFFP (underseeded)	Two years of forage in rotation	Stockless, monogastric, and ruminant	-4550.4	3100.96	9

Note: Grouping criteria and net returns are in bold where significant differences were found.

treatment combination. Multiple comparisons using the Tukey's procedure at the soil amendment and forage level factors yielded significant differences ($p<0.0001$), except for comparisons between rotations with no forage (WSBP) and one year of forage (WBFP) ($p=0.885$). Furthermore, it was found that wheat underseeded with forage had no effect on wheat net returns ($p=0.232$)

Soybean net returns for 2003 were based on estimated yields. Therefore, statistical analysis was not carried out since net returns were not a random variable. Average net returns of soybean in WSBP were higher under monogastric compost ($-603/ha) than under ruminant compost ($-1,206/ha) and alfalfa pellets (-$1,415/ha).

Similarly, statistical analysis for barley net returns in 2003 was not carried out because yields were only an estimate. However, barley net returns for 2003 in WBFP were higher under monogastric compost ($-1,081/ha) than under the stockless ($-1,178/ha) and ruminant systems ($-1,184/ha). On the other hand, barley net returns for 2004 in WSBP were significantly different among the three types of soil amendments ($p=0.026$). Paired comparisons using the LSD procedure revealed that barley net returns in 2004 (in WSBP) were lower under the stockless system ($-4,581/ha) compared to barley under monogastric ($-2,437/ha) ($p=0.011$) and ruminant compost (-3,074/ha) ($p=0.042$). However, the monogastric and ruminant systems were not different ($p=0.318$).

Forage net returns in 2003 and 2004 had no interaction effects ($p=0.31$). However, there were main effects (i.e., forage $p=0.036$, soil amendment $p=0.034$). Net returns were higher for WFFP ($-2,191/ha) (average for 2003 and 2004) than for WBFP ($-3,974l/ha) (average for 2004). Average forage net returns for 2003 and 2004 under the stockless system were higher ($-1,531/ha) compared to the monogastric system ($-3,233/ha) ($p=0.075$), and the ruminant system ($-3,591/ha) ($p=0.034$). These differences were due mainly because alfalfa pellets were not applied to forage plots in 2004 (i.e., WBFP), while compost was applied. Monogastric and ruminant systems generated no significant differences ($p=0.697$).

Net returns for potatoes in 2005 were calculated only for the systems that received soil amendments. Net returns for potato plots without soil amendments were not calculated because these trials were exclusively conducted to determine changes in yield. Furthermore, it is not realistic that an organic farmer would decide not to apply nutrients to a crop. The Sidak procedure was used to carry out paired comparisons, with the number of plants per hectare as a covariate. Neither interaction effects (p=0.955), nor main effects of the forage level factor were significant (p=0.351). However, the soil amendment factor had significant differences (p<0.0001). Paired comparisons of the adjusted means of potato net returns at the soil amendment factor revealed that the ruminant system had the highest net returns (adjusted mean of $6,721/ha) compared to the stockless (adjusted mean of $195.2/ha) and monogastric systems (adjusted mean of $3,350/ha) with p-values of <0.0001 and 0.043 respectively. Potato net returns in the monogastric system were higher than in the stockless system (p=0.061).

3.4.4.2 Extra Experimental Plots

Net returns of crops from 2002 to 2004 in the extra experimental plots were analyzed by forage level, sequence in the rotation, and the number of years that forage preceded a crop. Differences were found for barley, forage, potato, and wheat (Table 3.26). Average net returns are summarized in Table 3.27.

Barley net returns were higher in 2004 for PWBF ($-1,754/ha) compared to net returns in 2002 ($-4,2288/ha in BFPW) (p<0.0001). These suggested that the rotation sequence affected barley net returns.

Forage net returns for 2003 to 2004 were not statistically different between forage levels (p=0.734). However, significant differences were found in forage net returns compared by the number of years that forage was preceded by forage (p=0.004). Indeed, growing forage for two years increased forage net returns from an average of $-2,044/ha in rotations BFPW, FPWB, FFPW, FPWF, and PWFF (2002-2004) to an average of $-790/ha in the rotation FFPW (2003). Significant differences were also found when grouped by the sequence of the forage in the rotation system (p<0.0001). Paired comparisons revealed that forage net returns in 2003 ($-894/ha in the rotations BFPW and FFPW) were higher than net returns in 2004 ($-1,707/ha in PWFF), and in 2002 ($-2,506/ha in the rotations FPWB, FPWF, and FFPW). Differences in net returns between 2002 and 2004 were also significant. All paired comparisons had a p-value <0.0001.

Potato net returns from 2002-2004 were not significantly different for the forage factor (p=0.831). However, when potato net returns were compared by the number of years that forage preceded potato, significant differences were found (p<0.0001). Net

Table 3.26 Test Statistics of Net Return Comparisons in Extra Experimental Plots

Crop	Grouping criterion	Rotations	Description	Sum of Squares	Df	*F*	P-value
Barley	**Place in the rotation**	BFPW and PWBF	Between Groups	9632050.69	1	1040.32	**<0.0001**
			Within Groups	37035.03	4	N/A	N/A
			Total	9669085.72	5	N/A	N/A
Forage	Forage level	BFPW, FPWB, FFPW, FPWF, and PWFF	Between Groups	71132.01	1	0.120	0.734
			Within Groups	9482443.29	16	N/A	N/A
			Total	9553575.30	17	N/A	N/A
	Forage preceded by forage	BFPW, FPWB, FFPW, FPWF, PWFF, and FFPW	Between Groups	3932744.59	1	11.195	**0.004**
			Within Groups	5620830.71	16	N/A	N/A
			Total	9553575.30	17	N/A	N/A
	Place in the rotation	FPWB, FFPW, FPWF BFPW, FFPW, and PWFF	Between Groups	9411377.75	2	496.39	**<0.0001**
			Within Groups	142197.55	15	N/A	N/A
			Total	9553575.30	17	N/A	N/A
Potato	Forage level	BFPW, FPWB, PWBF FFPW, FPWF, and PWFF	Between Groups	519608.61	1	0.047	0.831
			Within Groups	177507784.26	16	N/A	N/A
			Total	178027392.87	17	N/A	N/A
	Potato preceded by forage	PWBF, PWFF, BFPW, FPWB, FPWF, and FFPW	Between Groups	154913718.58	2	50.27	**<0.0001**
			Within Groups	23113674.29	15	N/A	N/A
			Total	178027392.87	17	N/A	N/A
	Place in the rotation	PWBF, PWFF, FPWB, FPWF, BFPW, and FFPW	Between Groups	174190464.88	2	340.49	**<0.0001**
			Within Groups	3836927.99	15	N/A	N/A
			Total	178027392.87	17	N/A	N/A
Wheat	**Forage level**	FPWB, PWBF, FPWF, and PWFF	Between Groups	72055880.68	1	7314.26	**<0.0001**
			Within Groups	98514.23	10	N/A	N/A
			Total	72154394.91	11	N/A	N/A
	Wheat preceded by forage and/or grouped by place	PWBF, PWFF, FPWB, and FPWF	Between Groups	25529.02	1	0.004	0.954
			Within Groups	72128865.90	10	N/A	N/A
			Total	72154394.91	11	N/A	N/A

Note: Variables and figures in bold denote results where significant differences were found. Df.= degrees of freedom, N/A= non applicable

Table 3.27 Average Net Returns of Crops in Extra Experimental Plots

Crop	Grouping criterion	Description	Rotations	Mean	Std. Deviation	N
Barley	**Place in the rotation**	First	BFPW	**-4288.09**	92.42	3
		Third	PWBF	**-1754.05**	99.88	3
Forage	Forage level	One year of forage in rotation	BFPW and FPWB	-1746.80	826.44	6
		Two years of forage in rotation	FFPW, FPWF, and PWFF	-1880.16	742.69	12
	Forage preceded by forage	No forage preceding the crop	BFPW, FPWB, FFPW, FPWF, and PWFF	**-2044.74**	632.94	15
		One year of forage preceding the crop	FFPW	**-790.51**	77.99	3
	Place in the rotation	First	FPWB, FFPW, and FPWF	**-2506.11**	21.53	9
		Second	BFPW, FFPW	**-894.35**	160.41	6
		Third	PWFF	**-1707.22**	70.12	3
Potato	Forage level	One year of forage in rotation	BFPW, FPWB, and PWBF	-9386.79	3211.54	9
		Two years of forage in rotation	FFPW, FPWF, and PWFF	-9726.59	3445.94	9
	Potato preceded by forage	No forage preceding the crop	PWBF and PWFF	**-13591.86**	402.16	6
		One year of forage preceding the crop	BFPW, FPWB, and FPWF	**-8021.29**	1588.83	9
		Two years of forage preceding the crop	FFPW	**-6092.54**	1027.15	3
	Place	First	PWBF and PWFF	**-13591.86**	402.16	6
		Second	FPWB and FPWF	**-9056.96**	342.45	6
		Third	BFPW and FFPW	**-6021.24**	698.84	6
Wheat	**Forage level**	One year of forage in rotation	FPWB, and PWBF	**-9161.63**	124.28	6
		Two years of forage in rotation	FPWF and PWFF	**-4260.75**	65.26	6
	Wheat preceded by forage and/or grouped by place	No forage preceding the crop	PWBF and PWFF	-6665.07	2677.03	6
		One year of forage preceding the crop	FPWB and FPWF	-6757.32	2694.30	6

Note: Grouping criteria and net returns are in bold where significant differences were found.

returns were higher when potatoes were preceded by two years of forage ($-6,093/ha, average of 2004 in the rotation FFPW) compared to net returns when potatoes were preceded by one year of forage ($-8,021/ha, average for BFPW, FPWB and FPWF in 2002 and 2003) ($p=0.034$), and when potatoes were not preceded by forage ($-13,592/ha, average for PWBF and PWFF in 2002) ($p<0.0001$). Potato not preceded by forage was also different from potato preceded by one year of forage ($p<0.0001$). Significant differences were also found between potatoes grown the first, second and third year in the rotation ($p<0.0001$). All paired comparisons between net returns in 2002, 2003, and 2004 generated significant differences ($p<0.0001$). Net returns in 2004 ($-6,021/ha in BFPW and FFPW) were higher than net returns in 2003 ($-9,056/ha in FPWB and FPWF) and 2002 ($-13,592/ha PWBF and PWFF).

It was found that forage level in the rotation had a significant effect on wheat net returns between 2003 and 2004. Differences were found between wheat grown in rotation with one year of forage versus two years of forage ($p<0.0001$). Net returns from rotationswith two years of forage ($-4,261/ha average for 2003 and 2004 in FPWF and PWFF) were higher than rotations with one year of forage ($-9,162/ha average for 2003 and 2004 in FPWB and PWBF). This result also shows that wheat underseeded with forage, outperformed wheat seeded on its own. However, wheat net returns for 2003 (i.e, $-6,665/ha in PWBF and PWFF) compared to wheat net returns for 2004 (i.e., $-6,757/ha in FPWB and FPWF) were not different ($p=0.954$). This result also reveals that forage preceding wheat had no effect on wheat net returns and that the place that wheat occupied in the rotations had no effect on net returns.

3.5 Summary

Crop rotations under transition to organic agriculture were evaluated using data from a four-year crop rotation experiment in Truro, Nova Scotia. Three types of soil amendment distinguished by the source of nutrient supply (i.e., stockless, monogastric, and ruminant) were combined with three levels of forage (i.e., 0, 1, and 2 years of forage). The baseline four-year rotation was wheat (W), soybean (S), barley (B) and potato (P), with forage (F) replacing soybean and/or barley depending on the level of forage in the rotation. The experiment was divided into core and extra experimental plots. Crops in the core plots were grown under the three types of soil amendment in the following rotations: WSBP, WBFP, and WFFP. On the other hand, crops in the extra experimental plots were grown only under a stockless system in 6 different rotations: BFPW, FPWB, PWBF, FFPW, FPWF, and PWFF.

The average farm size in Nova Scotia (93 ha) was used as a basis for allocating and estimating fixed and variable costs. Enterprise budgets were generated based on estimated variable and fixed costs, yield information from the experiments, and average annual prices paid to producers in Nova Scotia. Enterprise budgets were then used to calculate net returns. Parametric statistical methods (one and two-way ANOVA) were used to test differences in mean yields and net returns. Multiple comparisons were made using the Tukey, the LSD and the Sidak procedures. Variable and fixed costs were also examined to determine the main contributions to total production costs.

Yield comparisons in the core plots revealed significant differences for wheat, forage, and potato. In 2002, wheat yields tended to be higher under ruminant compost (4,166kg/ha). Regardless of the type of soil amendment, the highest forage yield (9,254 kg/ha dry weight) was found in the rotation with two consecutive years of forage in 2004 (i.e., WFFP). In 2005, potato yields were higher under the ruminant system (32,165 kg/ha). In the extra experimental plots, significant differences were found in forage, potato, and wheat yields. Forages performed better in 2004 compared to other years (8,105 kg/ha dry weight in rotation PWFF). Potato yield was influenced by both the number of years that forage preceded potato, and the place that potato occupied in the rotation. The highest potato yield (19,376 kg/ha) was from FFPW in 2004.

Fixed costs varied among rotations, primarily because the machinery complement differed. In general, higher fixed costs were found in forage-based crop rotations, and rotations involving compost applications. Variable costs were high and also varied considerably among rotations. High variable costs were mainly attributed to the amount and cost of soil amendment required to meet soil test recommendations. Soil test recommendations were block and crop-specific. The price of alfalfa pellets was more than four times the cost of monogastric compost preparation and more than three times the cost of ruminant compost. In general, variable costs in the core plots were lower under monogastric systems and two years of forage, and ranged from $435/ha (soybean in 2003 in WSBP under the monogastric system), to $15,973/ha (wheat in 2002 in WBFP under the stockless system). On the other hand, variable costs in the extra experimental plots ranged from $995/ha for forage in 2003 (in BFPW and FFPW) to $15,160/ha for potato in 2002 (in PWFF).

Net returns were greatly influenced by nutrient supply costs. On average, most crops generated negative net returns that ranged from $-575/ha for forage in 2003 (in WFFP under monogastric system) to $-15,287/ha for wheat in 2002 (in WSBP under stockless system). However, in 2005, certified-organic potatoes with a price premium of 87% above the conventional price generated positive net returns that ranged from $934/ha (WBFP under the stockless system) to $8,250/ha (WSBP in the ruminant system). Overall, negative net returns in the first three years of transition and positive net returns once certification was granted were not unexpected results. In general, crop net returns tended to be higher in forage-based crop rotations and in livestock systems, compared to rotations with no forages and in the stockless system. In particular, rotations with two years of forage and monogastric compost yielded higher net returns. In 2002 in the core plots, the highest wheat net returns were found in WFFP rotation under the monogastric system ($-2,053/ha). Surprisingly, on average, the highest forage net returns from 2003 to 2004 were found under the stockless system ($-1,531/ha). The highest barley net returns were found in 2004 in the rotation WSBP under monogastric compost ($-2,437/ha). In 2005, the highest potato net returns were positive and generated from the ruminant system ($6,721/ha).

In the extra experimental plots, the highest barley net return was found in 2004 ($-1,754/ha, where barley occupied third place in the rotation PWBF). The highest forage net return was found in 2003 ($-791/ha) in FFPW rotation. The highest net returns for potato were found in 2004 ($-6,021/ha, when potato occupied the third place in rotations BFPW and FFPW). Finally, the highest wheat net returns between 2003 and 2004 were found in rotations with two years of forage (i.e., FPWF and PWFF) ($-4,260/ha).

On average, ruminant compost provided the highest net returns per rotation unit (i.e., 4 ha) among soil amendments, while two years of forage in the rotation WFFP outperformed rotations with one year of forage (WBFP) and WSBP rotation. Rotations under the stockless system ($-16,887 /rotation unit) had 691% lower net returns than the ruminant system ($-2,136 /rotation unit), while rotations under monogastric compost ($-3,512 /rotation unit) were 65% lower. Similarly, non-forage-based rotations (WSBP) ($-6,560 /rotation unit) had only 7% lower net returns than rotations with two years of forages (WFFP) ($-6,119 /rotation unit), while rotations with one year of forage (WBFP) ($-9,856 /rotation unit) had 61% lower net returns.

The information provided in this chapter will be used in the next chapter to develop a whole farm plan linear programming model to simulate various scenarios of crop rotations under transition to organic agriculture in a representative farm in Nova Scotia.

CHAPTER 4. WHOLE-FARM ANALYSIS: MATHEMATICAL PROGRAMMING MODEL

4.1 Outline

A linear programming model was developed and used to compare the economic impacts of including forages and livestock into cash crop rotation systems during the transition to organic agriculture for a representative farm in Nova Scotia. The profitability of various crop rotations evaluated along with a description of the main changes in gross margins, labour, operating capital, and soil amendment applications when forages and livestock are included in a farming operation. Technical coefficients used in the model were generated based on information from the Truro experiment. The chapter has four sections. The first formulates the model. The second section describes the model, including a discussion of the main assumptions, an explanation of the general structure of the model, and an outline of the different scenarios. The third section provides a discussion of the results, followed by a summary in the last section.

4.2 Formulation of the Model

Results from the previous chapter indicated that individual crop net returns, under particular crop rotations, can vary depending on the number of years of forage in the rotation, and the type of nutrient source used to meet soil test recommendations. It was found that a major factor contributing to negative crop net returns was the cost of substituting organic soil amendments for synthetic fertilizers. However, little was said regarding the economic implications of the rotations as a whole. Therefore, the previous chapter raised four important questions:

i) For a given set of crop rotation systems, which rotation provides the highest economic benefits on a whole-farm basis?

ii) Which nutrient source (monogastric or ruminant compost) would provide higher gross margins for a whole-farm operation?

iii) What is the effect of including livestock production into a forage-based farming system?

iv) Is it economically feasible to meet soil test recommendations using organic nutrient sources?

Although answers to these questions are not as straightforward as a farmer may wish, a linear programming (LP) model can be used to investigate various whole-farm plans to help address the first three questions outlined above. However, the fourth question is more complex to address, mainly because soil quality and fertility management practices are site specific. Nevertheless, the results from the previous chapter suggest that, in the context of the Truro experiment, meeting soil test recommendations may not be economically feasible, i.e., negative net returns were mainly caused by the high amount of organic soil amendments required, and their high costs compared to synthetic fertilizers.

A linear programming model was developed based on a representative Nova Scotia farm, described in the previous chapter. Recall that the assumptions made to describe this farm, such as soil fertility management and farming practices, were based on the context of the Truro experiment. Therefore, the intention of the model was to answer the first three questions based on the following considerations:

First, the previous chapter provided an economic evaluation of individual crops grown in particular rotations. However, the rotations as a whole-farm were not evaluated. Thus, the present chapter provides such an evaluation.

Second, the soil fertility management plans prepared by the agronomists for the experimental trials were not optimum from an economic perspective i.e., the actual mix of soil amendments applied to field experiments met soil test recommendations but did not minimize its costs. For example, in 2004, neither nitrogen nor potassium were required for forage plots. However, around 40 tonnes of compost per hectare were used to meet phosphorus requirements (120 kg/ha), when it would have been less expensive to meet phosphorus recommendations with rock-phosphate. Therefore, new soil fertility management plans were created for each rotation included in the LP model to minimize the cost of soil amendments (section 4.3.1.5).

Third, although the budget analysis provided in the previous chapter involved ruminant and monogastric compost for crop production, the analysis did not consider livestock production jointly with crops. Therefore, the analysis presented in this chapter includes a mixed cash crop-livestock operation. Although the Truro experiment included monogastric and ruminant compost as the main nutrient sources, only ruminant livestock were included in the analysis (i.e., a beef cattle backgrounding operation). This was primarily because this study analyzed the effects of including forage into crop rotations, and beef cattle can be fed 100% with forage. Thus, there is a direct output-input relationship between the forage-based rotations and the beef cattle enterprise. The size of the herd is constrained by the area allocated to forage production and forage yield. On the other hand, monogastric animals (i.e., poultry) can only use up to 20% of their diet from forage, and insects in the field (Henry, 2002). Consequently, the size of a poultry flock is less constrained by the area allocated to forage production and to forage yields.

Finally, the core plots from the Truro experiment dealt with rotations that were not fully-phased (i.e., the crops in the rotations were not grown every year). Therefore, the model provides the opportunity to deal with a diversified whole farm operation. In this chapter, the full phase of the rotation was analyzed on a yearly basis, assuming that the rotations were already established and that synthetic fertilizers were replaced with organic nutrient sources.

4.3 Model and Model Scenarios

The model considered alternative 4-year crop rotations and livestock production. The rotations are presented in Table 4.1, and were based on information from the core plots in the Truro experiment. However, the enterprise budgets created for the Truro experiment were modified to better resemble a commercial operation. These modified budgets were generated for each year and each crop in the rotations and differed from those presented in the previous chapter mainly because: i) the number of field operations carried out in the Truro experiment were not representative of a commercial operation, ii) a different soil fertility management plan was implemented, iii) the amount of soil amendments applied in the core plots did not consider fully-phased rotations, and iv) the budgets presented in the previous chapter did not include organic prices for all crops in the rotations (i.e., only the potato price included an organic price premium because potatoes were the only crop grown after the three transitional years).

Table 4.1 Rotations and Crops Included in the LP Model

CROP ROTATIONS		Source of Nitrogen-based Soil Amendments	
		Monogastric compost	Ruminant compost
Frequency of forage in the rotation system	0	WSBP	WSBP
	1	WBFP	WBFP
	2	WFFP	WFFP

Year	Status	Field 1	Field 2	Field 3	Field 4
Rotation 1, WSBP					
Year	Status	Field 1	Field 2	Field 3	Field 4
0	*Conventional*	*P*	*W*	*S*	*B*
1	Transition	W	S	B	P
2	Transition	S	B	P	W
3	Transition	B	P	W	S
4	Organic	P	W	S	B
Rotation 2, WBFP					
Year	Status	Field 1	Field 2	Field 3	Field 4
0	*Conventional*	*P*	*W*	*B*	*F*
1	Transition	W	B	F	P
2	Transition	B	F	P	W
3	Transition	F	P	W	B
4	Organic	P	W	B	F
Rotation 3, WFFP					
Year	Status	Field 1	Field 2	Field 3	Field 4
0	*Conventional*	*P*	*W*	*F*	*F*
1	Transition	W	F	F	P
2	Transition	F	F	P	W
3	Transition	F	P	W	F
4	Organic	P	W	F	F

Note: The conventional crops (in italics) were not included in the LP model, and are presented for reference of the crops preceding the transitional rotations. W= Wheat, S= Soybean, B= Barley, F= Forage, P=Potato.

4.3.1 Assumptions of the Model

4.3.1.1 Land Labour and Capital Assumptions

As explained in the previous chapter, it was assumed that the farm was 93 ha, divided into four fields of equal size. Labour considerations were also consistent with the assumptions made in the previous chapter. Labour wages were based on information from Human Resources and Skills Development Canada (2004). It was assumed that hired labour would receive the average salary paid to a general farm worker in Nova Scotia (i.e., $7.76/hr). On the other hand, the farmer's labour was calculated at opportunity cost, and it was assumed to be equivalent to the salary that a highly skilled farm worker would receive in Nova Scotia (i.e., $13.86/hr). It was assumed that the farmer had 2,400 hours available per year, where 1,500 hours were available in the spring/summer (60 hours per week x 25 weeks), and 900 hours in the fall/winter (36 hours per week x 25 weeks).

Operating capital requirements were assumed to be financed at 8.27%, the same interest rate used to finance capital investments in the previous chapter. Interest payments were included in the model but not the repayment of principal. It was assumed that no operating capital was provided by the farmer.

4.3.1.2 Yield Assumptions

In general, the results from the previous chapter suggested that yields were not significantly influenced by the number of years of forage in the rotations. On the other hand, the type of nutrient source did influence yields, especially for wheat and potato. It was assumed that yields were the same throughout the four years of rotation, and that there was no particular yield depression due to the transition process. This was primarily because the model focused on comparing the economic impacts of various production alternatives suitable for the transition to organic agriculture, rather than the economic impacts of biophysical changes during the transition process. Furthermore, yield data for every crop in every year of the rotation were not available from the Truro experiment, and it is realistic to assume that in the long run, any yield variation specifically attributed to a rotation effect would tend to stabilize as yields become stable throughout the years.

It is important to recall that the fields used for the experiment were previously in permanent pasture. Therefore, it is likely that the site was fertile in nitrogen, and wheat yields may have been positively influenced since wheat was the first crop grown. For this reason, the experimental wheat yield was modified for the LP model. The average experimental wheat yield (i.e., 3,900 kg/ha for the monogastric treatment and 4,166 kg/ha for the ruminant treatment) was modified as follows: 80% of the experimental yield from WSBP rotation, 90% of the experimental yield from WBFP rotation, and 100% of the experimental yield from WFFP rotation. Yield assumptions were suggested by the agronomist in charge of the field experiments (Hammermeister, 2005). Table 4.2 summarizes the suggested yields used in the LP model.

Results from the statistical analysis suggest that potato yields were not influenced by the frequency of forage in the rotation. Therefore, the potato yield used was the average experimental yield for the monogastric and ruminant treatments. Barley, forage, and soybean yields were based on information from the trials but not the actual experimental yields, i.e., barley, forage, and soybean yields were suggested by the agronomist in charge of the experiment, because barley and soybean yield data were distorted due to various reasons explained earlier in section 3.4.2.1, and forage yields were quite high compared to typical forage yields in Nova Scotia. Barley, forage and soybean yields were assumed to be equal for both types of compost. This assumption is also consistent with the results from the previous chapter. In addition, it was assumed that straw from grain crops was 3 tonnes/ha (Hammermeister, 2005).

4.3.1.3 Price Assumptions

As in the previous chapter, average conventional prices were used for the first three years of rotation, while organic prices were used for the fourth year, assuming organic certification and price premiums were available. Conventional prices were the same as for the previous chapter. Information regarding organic prices in Nova Scotia is scarce. Therefore, prices received by producers in other provinces were used to estimate a percentage price premium as a proxy for organic price premiums for Nova Scotia. Grain and forage price premiums were obtained from information in Western Canada (University of Saskatchewan, 2004), while soybean price premiums were obtained from information in Ontario (Canadian Organic Growers, 2005). On the other hand, potato price premiums were estimated from conventional and organic retail prices in Nova Scotia (Organic Agriculture Centre of Canada, 2005), assuming that the price premium received by producers was equivalent to the retail price premium. Straw price premiums were assumed to be equivalent to forage price premiums. Prices used in the model are presented in Table 4.3.

4.3.1.4 Assumptions on Field Operations

Field operations assumptions are consistent with those of the previous chapter. However, the number of passes in field operations was modified because the field experiments were not necessarily typical of a representative farm in Nova Scotia. The number of passes presented in Table 4.4 were suggested by the agronomist in charge of the Truro experiment (Hammermeister, 2005). Nevertheless, it is important to note that in reality, the number of passes to complete field operations can vary widely depending on

Table 4.2 Yields Used in the LP Model

Crop	Source of Nitrogen-based Soil Amendments	
	Average crop yield under monogastric compost (kg/ha)	Average crop yield under ruminant compost (kg/ha)
Barley	1,750	1,750
Forage	7,000	7,000
Grain Straw	3,000	3,000
Potato	24,502	32,165
Soybean	1,400	1,400
Wheat in WSBP	3,120	3,333
Wheat in WBFP	3,510	3,749
Wheat in WFFP	3,900	4,166

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, S= Soybean, B= Barley, F= Forage, P=Potato.

Table 4.3 Commodity Prices Assumed in the Model

Crop	Conventional Price ($/tonne)	Organic Price Premium (%)	Estimated Organic Price ($/tonne)
Barley	200.08 #	27 *	254.10
Forage	76.06 §	7 *	81.38
Potato	213.38 ‡	87 ‡‡	399.02
Soybean	315.14 †	166 **	838.27
Wheat	257.07 †	85 *	475.58
Straw	80.8 §	7 ***	86.5
Beef Cattle ($/kg of live weight)	1.95 §	N/A	N/A

Source: # Agriculture and Agri-food Canada (2005a), § Nova Scotia Department of Agriculture and Fisheries (2005), ‡ Statistics Canada (2005a), † Agriculture and Agri-food Canada (2005b), * University of Saskatchewan (2004), ** Canadian Organic Growers (2005), ‡‡ Organic Agriculture Centre of Canada (2005), and *** Assumed to be equivalent to forage price premium.

soil and machinery characteristics.

The time needed to complete a field operation is presented in Table 3.9. Compost and silage preparation and the application of soil amendments were calculated per kg of material (Table 3.11 – 3.13). The assumptions regarding field operations carried out by hired labour and custom operators discussed in the previous chapter were maintained for the model.

Table 4.4 Number of Passes of Field Operations Assumed for the Model

Field Operation	Number of passes	Crop
Ploughing	1	All crops except for forage*
Disk harrowing	1	All crops except for forage*
	2	Potato when planted after forage (i.e., WBFP and WFFP)
S-tine	1	All crops except for forage*
Weeding	2	All crops except for forage*
Hilling	1	Potato
Seeding/planting	1	All crops
Crop harvesting	1	All crops
Forage harvesting	2	Forage
Colorado potato beetle control	4	Potato
Fungus control	2	Potato
Straw removal	1	Wheat and barley

Note: * No tillage or weeding operations were carried out for forage.

4.3.1.5 Nutrient Management Plan Assumed for the Model

As explained in section 4.2, it was necessary to prepare a new soil fertility management plan for each rotation included in the main LP model (i.e., 3 crop rotations under 2 different treatments = 6 rotations). This was because the costs of organic nutrients were not taken into account for the experimental plots. The new fertility management plans were generated through six LP "blending" models, based on crop nutrient requirements, soil test recommendations suitable for Nova Scotia, and soil amendment costs.

It is important to clarify that these LP blending models were not part of the main LP model developed in this chapter. However, the optimum results from these models were used as technical coefficients in the main LP model, i.e., the results of each blending model provided an economically optimum mix of soil amendments for each rotation. The objective of the individual models was to minimize soil amendment costs while meeting soil test recommendations for each crop in the rotations. The activities in these models were the amounts of monogastric compost, ruminant compost, rock-phosphate and langbeinite needed to meet nitrogen, phosphorus and potassium recommendations for each of the crops in the rotations on a yearly basis (i.e., soil nutrient constraints).

The soil nutrient constraints (i.e., targets) (Table 4.5) were prepared by the agronomist in charge of the Truro experiment, assuming that the farm was already using the particular crop rotations (i.e., no alterations to crop rotations were made at the beginning of the transition phase) and based on a M- (medium minus) pre-transition soil fertility rating for phosphorus and potassium. Nitrogen targets were suggested based on the agronomist's experience of crop uptake and targeted protein content (Hammermeister, 2005). The technical coefficients for the individual LP models (i.e., the amount of nutrients available in each soil amendment) were obtained from the previous chapter (Table 3.6).

Each of the six LP matrices developed for the soil fertility plans had 48 activities, i.e., 3 nutrient sources (either monogastric or ruminant compost, rock-phosphate, and langbeinite) for 4 crops in rotation (from a set of 5 crops: wheat, soybean, barley, forage, and potato) during 4 years of production (48 = 3 x 4 x 4), and 48 constraints, i.e., 3 nutrient requirements (nitrogen, phosphorus, and potassium) for 4 crops in a 4 year rotation (48 = 3 x 4 x 4). The structure of the blending models is presented in Table. 4.6, while Table 4.7 summarizes the average amounts of soil amendments to be used in the main LP model as a result of the blending models.

4.3.1.6 Manure and Compost Credit Assumptions

Manure needed for compost preparation was assumed to be bought from local poultry and beef producers. However, if the beef enterprise entered the plan in the ruminant treatment, then part of the manure needed for compost preparation was credited in the model after the first year, with the option of selling compost, if there was surplus. On the other hand, if the beef enterprise was included with the monogastric treatment, it was assumed that poultry manure was bought for compost preparation, and the ruminant compost produced on the farm was sold. This assumption was necessary to maintain the crops under only one type of compost. In addition, this assumption is realistic in the sense that it might be optimal to sell manure produced on the farm at a high market value, in order to buy cheaper manure for compost production.

4.3.1.7 Ruminant livestock assumptions

A winter backgrounding operation was assumed for the model because it was better suited for the comparisons among crop rotation systems. A backgrounding operation can

Table 4.5 Nutrient Requirements for Crops in the Model (kg/ha)

Rotation WSBP: Crop Nutrient Requirements by Field

Year	Field 1			Field 2			Field 3			Field 4		
	N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
1	Wheat			Soybean			Barley			Potato		
	100	57	57	0	57	57	60	45	45	125	87	87
2	Soybean			Barley			Potato			Wheat		
	0	72	72	70	60	60	130	102	102	120	72	72
3	Barley			Potato			Wheat			Soybean		
	70	60	60	130	102	102	120	72	72	0	72	72
4	Potato			Wheat			Soybean			Barley		
	130	102	102	120	72	72	0	72	72	70	60	60

Rotation WBFP: Crop Nutrient Requirements by Field

Year	Field 1			Field 2			Field 3			Field 4		
	N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
1	Wheat			Barley			Forage			Potato		
	100	57	57	65	45	45	0	57	104	55	87	87
2	Barley			Forage			Potato			Wheat		
	70	60	60	0	72	119	60	102	102	120	72	72
3	Forage			Potato			Wheat			Barley		
	0	72	119	60	102	102	120	72	72	70	60	60
4	Potato			Wheat			Barley			Forage		
	60	102	102	120	72	72	70	60	60	0	72	119

Rotation WFFP: Crop Nutrient Requirements by Field

Year	Field 1			Field 2			Field 3			Field 4		
	N	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*	*N*	*P*	*K*
1	Wheat			Forage			Forage			Potato		
	100	57	57	0	57	104	0	57	104	55	87	87
2	Forage			Forage			Potato			Wheat		
	0	72	119	0	72	119	60	102	102	120	72	72
3	Forage			Potato			Wheat			Forage		
	0	72	119	60	102	102	120	72	72	0	72	119
4	Potato			Wheat			Forage			Forage		
	60	102	102	120	72	72	0	72	119	0	72	119

Note: N= Nitrogen, P= Phosphorus, K= Potassium, W= Wheat, S= Soybean, B= Barley, F= Forage, P=Potato. All values are in kg/ha.

Table 4.6 Structure of the LP Models for the Soil Fertility Management Plans

Constraints		Activities: Crop 1…4, Year 1…4 — Monogastric or Ruminant Compost	Rock-Phosphate	Langbeinite	RHS
Crop 1…4, Year 1…4	Nitrogen requirements	a_{ij}	a_{ij}	a_{ij}	>= b_i
	Phosphorus requirements	a_{ij}	a_{ij}	a_{ij}	>= b_i
	Potassium requirements	a_{ij}	a_{ij}	a_{ij}	>= b_i
Objective Function		Cost (-)	Cost (-)	Cost (-)	

Note: a_{ij} = technical coefficients, b_i = soil nutrient targets constraints, for i = 1…48 and j = 1…48.

Table 4.7 Average Soil Amendment Applications Used in the Main LP Model

Crop rotations	Year	Monogastric Compost (kg/ha)	Rock-phosphate (kg/ha)	Langbeinite (kg/ha)
WSBP	1	14,062	475	65
	2	15,788	689	82
	3	15,788	689	82
	4	15,788	689	82
WBFP	1	10,855	853	129
	2	12,335	1,131	155
	3	12,335	1,131	155
	4	12,335	1,131	155
WFFP	1	7,646	1,328	247
	2	8,881	1,672	290
	3	8,881	1,672	290
	4	8,881	1,672	290
Crop rotations		Ruminant Compost (kg/ha)	Rock-phosphate (kg/ha)	Langbeinite (kg/ha)
WSBP	1	12,463	586	65
	2	13,993	881	82
	3	13,993	881	82
	4	13,993	881	82
WBFP	1	9,620	934	118
	2	10,932	1,255	135
	3	10,932	1,255	135
	4	10,932	1,255	135
WFFP	1	6,778	1,381	236
	2	7,871	1,729	270
	3	7,871	1,729	270
	4	7,871	1,729	270

Note: W= Wheat, S= Soybean, B= Barley, F= Forage, P=Potato.

provide faster cash flow benefits than a cow-calf operation, since stockers can be bought and sold within a relatively short period of time (i.e., 6 months), while calves from a cow-calf operation, will be normally sold over a longer period (i.e., 16 to 17 months from breeding to selling weaned calves). In addition, during the winter months, ruminant livestock grow well outdoors (Macey, 2000; and Henry 2002), where the herd is allowed to wander the land that is effectively unused, and no alterations to fencing are needed. Furthermore, in the context of organic agriculture (i.e., where livestock are not kept in close confinement), more manure can be collected during the winter compared to the summer because, normally, the herd would spend most of the time close to the shelter and feeders. Also, feeding stockers during the winter can be a more efficient use of machinery and time, since no field operations take place during the winter.

Most of the assumptions regarding the livestock enterprise were based on consultations with a ruminant specialist based in Nova Scotia (Firth, 2005). Details of the beef budgets are presented in Table 4.8. The livestock enterprise was assumed to be managed under organic practices. However, it cannot be certified organic since, under the organic standard, beef animals have to be born on the farm (Canadian General Standards Board, 1999). According to Macey (2000), livestock enterprises are usually the last farm-components to be certified.

It was assumed that stockers would be bought late in the fall at an average weight of 250 kg, and sold 180 days later in the spring at 430 kg. It was assumed that stockers were fed good quality forage silage produced on the farm, and that the average daily gain (ADG) per head was 1 kg (Firth, 2005).

A constant price was used for buying and selling stockers (i.e., $1.95/kg). This price was estimated from historical annual beef prices in Nova Scotia for 250 kg to 318+ kg stockers from 1985 to 2004 (Nova Scotia Department of Agriculture and Fisheries, 2005). A 20-year average price was used in order to offset any price variations due to the BSE crisis of recent years. The beef budget was calculated at opportunity cost. Thus, forage silage and straw costs were included even though these were resources available from the farm. For example, when beef entered the plan there was a cost related to the forage silage consumed by beef, because forage silage could have been sold. The same applies to straw used for bedding. However, the model included the option of buying

Table 4.8 Beef Budget (per head)

Variable costs	*Unit*	*Unit price ($/unit)*	*Quantity (unit)*	*Total ($)*
Forage*	kg (DM)	0.07606	1,735.2	131.98
Silage preparation	kg (DM)	0.00088	1,735.2	1.52
Steer costs	kg (BW)	1.95	250.0	487.50
Bedding (straw)**	kg	0.0808	1,071.4	86.57
Labour	hr	13.86	2.0	27.72
Salt and minerals	per head	10	1.0	10.00
Death loss (2.5% of steer cost)	N/A	N/A	N/A	12.19
Operating expenses (8.27% of cash expenses)***	N/A	N/A	N/A	41.27
Total Variable Cost				798.75
Total revenue	kg (DM)	1.95	430	838.50
Gross margin				39.75

Note: DM = Dry matter, BW= Body weight. *9.64 kg x 180 days = 1,735.2. ** 5.95 kg x 180 days = 1,071
*** Include steer cost, salt and minerals, and death loss ($509.69).

straw, since it was a scarce resource. Labour requirements were assumed to be 2 hours per head per fattening period (Saskatchewan Agriculture, Food and Rural Revitalization, 2003) and this costs was calculated as explained in section 4.3.1.1.

Dry matter intake (DMI) was estimated at 9.64 kg/day (1,735.2 kg in 180 days). This is 2.7% of the average body weight (ABW) between the initial and final weight (250 kg and 430 kg respectively), and includes an additional 5% to account for the intake increase due to low temperatures. Straw requirements for bedding were assumed to be 5.95 kg/day, or 250 kg every 6 weeks. Death loss was 2.5% of the stocker purchase cost, and salt and minerals were assumed to be $10 per head (Firth, 2005). Veterinary expenses, homeopathic treatment costs, and marketing costs were not included in the budget.

Manure production was assumed to be 22 kg per head per day (American Society of Agricultural Engineers, 2005). However, only 85% would be collected for composting, since the animals would not be kept in close confinement. The total amount of manure produced per head would be 3,960 kg but only 3,366 kg were assumed to be collected (3,366 = 3,960 x 85%). The manure collected would be combined with used bedding straw (1,071.4 kg) and used for compost preparation. It was assumed that the manure-straw mix (i.e., 4,437.4 = 3,366 + 1,071.4) would loose 20% of its mass during composting, and would have 37.5% moisture. Therefore, each stocker could generate 2,218.7 kg of compost on a dry weight basis (i.e., 4,437.4 x 80% x 62.5% = 2,218.7).

4.3.2 General Structure of the LP Model

In algebraic notation, the model can be represented as follows:

$$(7) \qquad \text{Maximize} \sum_{j=1}^{n} c_j X_j$$

Subject to:

$$(8) \qquad \sum_{j=1}^{n} a_{ij} X_j \leq b_i \quad \text{for } i = 1 \ldots m$$

$$(9) \qquad \sum_{j=1}^{n} a_{ij} X_j \leq 0 \ \text{ or } \sum_{j=1}^{n} a_{ij} X_j \geq 0 \quad \text{for } i = 1 \ldots m$$

$$(10) \qquad \text{and } X_j \geq 0 \quad \text{for } j = 1 \ldots n$$

The objective function represented in (7) was set to maximize the sum of revenues minus variable costs (i.e., gross margins) of the j^{th} activities (i.e., c_j) multiplied by the number of units allocated to the j^{th} activities or decision variables (i.e., X_j). The j activities were year specific.

Activities within each of the four years were divided into six groups: i) crop production activities (crop production variable costs), ii) soil fertility management activities (including soil amendment requirements and compost credits), iii) beef enterprise activities (including straw and ruminant livestock purchases, and forage silage opportunity cost), iv) selling activities (including revenues from crops, forage, straw, livestock, and compost sales), v) labour activities (including farmer's and hired labour), and vi) capital activities (borrowed capital). These groups were subdivided into activities that represented both the crop rotations and the compost treatments. Furthermore, for the forage-based rotations, the model allowed the option of selling forage or feeding beef cattle. In total, there were 124 activities (columns) (i.e., j = 1...124).

Constraints are represented in equations (8) to (10), and were divided into four groups: i) resource constraints including land and labour; ii) technical constraints including compost and soil amendment requirements, hired labour requirements, and capital requirements; iii) management constraints, including the selection of crop rotation and nutrient source, the type of farming operation (i.e., whether beef entered the plan), the choices between selling and buying straw, and compost credits from ruminant livestock;

and iv) accounting constraints or transfer rows, which were needed to link activities throughout the model, such as crop production and selling activities within each year, whole crop rotations from one year to another, buying and selling beef, and capital and labour transfers.

Equation (8) represents the resource constraints, which were set as the sum of technical coefficients a_{ij} (i.e., the i^{th} resource required per unit of the j^{th} activity) multiplied by the decision variable X_j to be less than or equal to the amount of the i^{th} resource available (i.e., b_i). Equation (9) represents technical, management, and transfer constraints, which were set as the sum of technical coefficients a_{ij} times the decision variable X_j to be smaller than or equal to, and greater than or equal to zero. In addition, equation (10) specifies that the decision variables (or the number of units of the j^{th} activity) are non-negative. In total, there were 110 constraints and transfer rows (i.e., i = 1...110). The general structure of the LP model is presented in Table 4.9.

4.3.3 Model Scenarios

Variations of the model were run using the solver *What's Best 8.0*, an add-in tool for Microsoft Excel developed by Lindo Systems Inc. There were three different scenarios. The first scenario considered a cash crop rotation WSBP, with either monogastric or ruminant compost. The purpose of this scenario was to determine a baseline operation, where neither forage nor livestock entered the plan. The second scenario was run using three rotations (i.e., WSBP, WBFP, and WFFP) under both compost treatments. This scenario was intended to determine the economic impacts of including forages in the rotations. In this case, it was assumed that forages were sold as a cash crop.

The third scenario included all crop rotations (i.e., 6) plus the beef cattle enterprise, to determine if livestock made a difference to gross margin. Therefore, the model decided whether to sell forages or feed them to beef. The non-forage based rotation WSBP, was included in this scenario so that the model could choose between all of the alternatives proposed. Table 4.10 summarizes all the rotations analyzed.

4.4 Results and Discussion

The rotations selected as optimal from each scenario were compared to determine the changes in revenues, total variable costs, gross margins, labour, operating capital, and the

Table 4.9 General Structure of the LP Model

Constraint and row type	Constraints	Crop Rotation Production Activities	Fertility Management and Compost Credit Activities	Beef Activities (straw, silage, and beef)	Selling Activities (crops, forage, straw, beef, and compost)	Labour Activities (hired and farmer's labour)	Capital Activities (loaned capital)	RHS
Transfer	Multi-period linking rows	Year 1= 3 Years 2 to 4= -1	0	0	0	0	0	>= 0
Resource	Land	93	0	0	0	0	0	= 93
Management	Selection of a crop rotation	0.5	0	0	0.5	0	0	=1
Transfer	Crop production and Selling linking rows	1	0	0	-1	0	0	<= 0
Management	Forage (production, selling or beef feeding)	a_{ij}	0	- a_{ij}	-1	0	0	>= 0
Transfer	Beef	0	0	-1	1	0	0	<=0
Management	Silage consumption by beef	0	0	1, - a_{ij}	0	0	0	>= 0
Management	Straw (prod., buying, selling, or beef bedding.)	a_{ij}	0	1, - a_{ij}	-1	0	0	>=0
Management	Number of beef animals	0	0	0	1	0	0	>=0
Technical	Monogastric compost requirement	- a_{ij}	1	0	0	0	0	>=0
Tec. & Mgt	Ruminant compost requirement, selling compost surplus	- a_{ij}	1	a_{ij}	-1	0	0	>= 0
Management	Ruminant compost credit from beef in monogastric treatment	0	0	a_{ij}	-1	0	0	>= 0
Management	Ruminant compost credit from beef in ruminant treatment	0	-1	a_{ij}	0	0	0	<= 0
Technical	Rock phosphate requirement	- a_{ij}	1	0	0	0	0	>= 0
Technical	Langbeinite requirement	- a_{ij}	1	0	0	0	0	>= 0
Technical	Total Labour required	a_{ij}	a_{ij}	a_{ij}	0	-1	0	<= 0
Resource	Farmer's labour available	0	0	0	0	1	0	<= 1,500* <= 2,400+
Transfer	Hired labour required	0	0	0	0	1	0	>= 0
Technical	Total Capital required	a_{ij}	a_{ij}	a_{ij}	0	a_{ij}	-1	<= 0
Transfer	Loaned capital transfer	0	0	0	0	0	1	>= 0
	Objective Function	Cost (-)	Cost (-)	Cost / price (-)	Gross revenue/ price (+)	Wage (-)	Interest rate (-)	

Note: Among the decision variables (i.e., X_j), 92 were continuous, 24 binaries, and 8 general integers * For scenarios 1&2. + For scenario 3.

Table 4.10 Rotations in the Model Scenarios

	Type of operation	Source of Nitrogen-based Soil Amendment	
		Monogastric compost	Ruminant compost
Rotations in Scenario 1	Cash crop	WSBP	WSBP
Rotations in Scenario 2	Cash crop	WSBP	WSBP
		WBFP	WBFP
		WFFP	WFFP
Rotations in Scenario 3	Cash crop and mixed cash crop-livestock	WSBP	WSBP
		WBFP	WBFP
		WFFP	WFFP
		Beef Cattle*	Beef Cattle

Note: W= Wheat, S= Soybean, B= Barley, F= Forage, P=Potato.
* Ruminant compost produced from beef cattle in the monogastric treatment was assumed to be sold, since the crops were grown with monogastric compost produced from poultry manure bought from a local producer.

amount of soil amendments applied. The fundamental purpose of these comparisons was to determine the economic implications of including forages and livestock into cash crop rotations.

4.4.1 Overview of the Optimal Rotations

The results obtained from the LP model suggest that, profitability can improve considerably when a rotation in a mixed cash crop-livestock operation includes two years of forage (Table 4.11). Forages and livestock can provide additional economic benefits, especially when crops are grown using ruminant compost (i.e., the rotation WFFP in scenario 3).

The results from Scenario 1 (Table 4.12) suggest that growing wheat, soybean, barley and potato (WSBP) under monogastric compost was the most profitable alternative among stockless non-forage based rotations. However, the gross margin for this farm operation was negative ($-340,327) over a four year period. Total variable costs were quite high ($1,184,061 over 4 years), mainly due to the high cost of soil amendments ($655,628), which represented 55.4% of total variable costs. Labour requirements were relatively high (17,522 hrs in 4 years), which represents 3 people working an average of 58 hours/week for 25 weeks, over a four year period. Labour requirements were mainly attributed to time required for compost preparation.

The results from Scenario 2, suggest that growing wheat and potato in rotation with two years of forage (i.e., WFFP) was the best alternative for a cash crop operation under

Table 4.11 Summary of the 4-year Optimal Solutions

	OPTIMAL SOLUTIONS		
	Scenario 1	Scenario 2	Scenario 3
Type of operation	Cash crops	Cash crops	Mixed cash crop-livestock
Crop rotation	WSBP	WFFP	WFFP
Type of nutrient supply	Monogastric compost	Ruminant compost	Ruminant compost
Gross margins ($)	-340,326.89	-161,070.07	- 22,397.95
Farmer's labour (hr)	6,000.00	4,572.64	5,694.64
Hired labour (hr)	11,522.16	0	0
Total labour (hr)	17,522.16	4,572.64	5,694.64
Operating capital ($)	1,016,810.78	1,033,786.70	1,139,241.34
Soil amendment costs ($)	655,628.47	788,179.60	613,050.35
Compost (kg)	5,712,699.82	2,826,438.69	2,826,438.69
Compost costs ($)	514,142.98	409,833.61	234,704.37
Rock-phosphate (kg)	236,469.52	610,906.32	610,906.32
Rock-phosphate ($)	125,328.85	323,780.35	323,780.35
Langbeinite (kg)	28,851.14	97,438.64	97,438.64
Langbeinite ($)	16,156.64	54,565.64	54,565.64
Number of animals	0	0	561

Table 4.12 Optimal Solutions from Scenario 1

Rotation WSBP under monogastric compost	*OPTIMAL SOLUTION*			
	Year 1	Year 2	Year 3	Year 4
Gross margins ($)	-97,654.29	-129,420.26	-129,420.26	16,167.92
Farmer's labour (hr)	1,500.00	1,500.00	1,500.00	1,500.00
Hired labour (hr)	2,559.21	2,987.65	2,987.65	2,987.65
Total labour (hr)	4,059.21	4,487.65	4,487.65	4,487.65
Operating capital ($)	232,198.00	261,537.59	261,537.59	261,537.59
Soil amendment costs ($)	144,481.50	170,382.32	170,382.32	170,382.32
Compost (kg)	1,307,726.47	1,468,324.45	1,468,324.45	1,468,324.45
Compost costs ($)	117,695.38	132,149.20	132,149.20	132,149.20
Rock-phosphate (kg)	44,175.00	64,098.17	64,098.17	64,098.17
Rock-phosphate ($)	23,412.75	33,972.03	33,972.03	33,972.03
Langbeinite (kg)	6,023.86	7,609.09	7,609.09	7,609.09
Langbeinite ($)	3,373.36	4,261.09	4,261.09	4,261.09
Number of animals	0	0	0	0

ruminant compost (Table 4.13).This result can be attributed to the benefits that ruminant compost had on yields, along with the economic benefits that leguminous forages provide to soil fertility, since less nitrogen was required (i.e., less compost). On the other hand, the amount of rock-phosphate and langbeinite were quite high. In fact, the costs of soil amendments (including compost) were almost 67% of total variable costs. Over a four year period, gross margins were negative ($-161,070).

The results from Scenario 3 (Table 4.14) suggest that livestock that benefits from forages grown for fertility building purposes, can provide additional economic benefits to the whole-farm system. In fact, gross margins significantly improved by including a winter backgrounding operation into a rotation that included wheat, potato and two years of forage under ruminant compost. This was mainly due to the additional revenues from the beef enterprise, and to the significant reduction in soil amendment costs due to manure available from the farm. Soil amendment costs were only 43% of the total variable costs, and gross margins were $-22,398 over a four year period.

4.4.2 Comparisons Among Scenarios

Overall, major changes were found in gross margin, labour, operating capital, and the amount of soil amendments applied when forages and livestock were included in the model. It is important to note that for all crop rotations, gross margins were negative during the three years of transition prior to obtaining organic certification in the fourth year. By comparison, gross margins from the fourth year were relatively high, assuming that certification was granted and that organic price premiums were available. Table 4.15 outlines the comparisons between the optimal solutions of the three scenarios.

4.4.2.1 Gross Margins

Variations in gross margins (Figure 4.1) were remarkable among the optimal crop rotations, as well as within each of the optimal rotations, especially, when organic certification was granted. During the first three years of rotation, while in transition to organic agriculture, gross margins were negative, while gross margins were positive during the fourth year, when organic price premiums were accessible.

The cash crop rotation selected in Scenario 2 (i.e., WFFP grown under ruminant compost) provided 53% higher gross margins than the rotation selected in Scenario 1 (i.e., WSBP under monogastric compost). By comparison, total variable costs decreased by

Table 4.13 Optimal Solutions from Scenario 2

Rotation WFFP under ruminant compost	*OPTIMAL SOLUTION*			
	Year 1	Year 2	Year 3	Year 4
Gross margins ($)	-52,478.71	-90,237.90	-90,237.90	71,884.43
Farmer's labour (hr)	1,079.42	1,164.41	1,164.41	1,164.41
Hired labour (hr)	0	0	0	0
Total labour (hr)	1,079.42	1,164.41	1,164.41	1,164.41
Operating capital ($)	233,106.41	266,893.43	266,893.43	266,893.43
Soil amendment costs ($)	171,781.82	205,465.93	205,465.93	205,465.93
Compost (kg)	630,356.83	732,027.29	732,027.29	732,027.29
Compost costs ($)	91,401.74	106,143.96	106,143.96	106,143.96
Rock-phosphate (kg)	128,434.46	160,823.95	160,823.95	160,823.95
Rock-phosphate ($)	68,070.26	85,236.70	85,236.70	85,236.70
Langbeinite (kg)	21,981.82	25,152.27	25,152.27	25,152.27
Langbeinite ($)	12,309.82	14,085.27	14,085.27	14,085.27
Number of animals	0	0	0	0

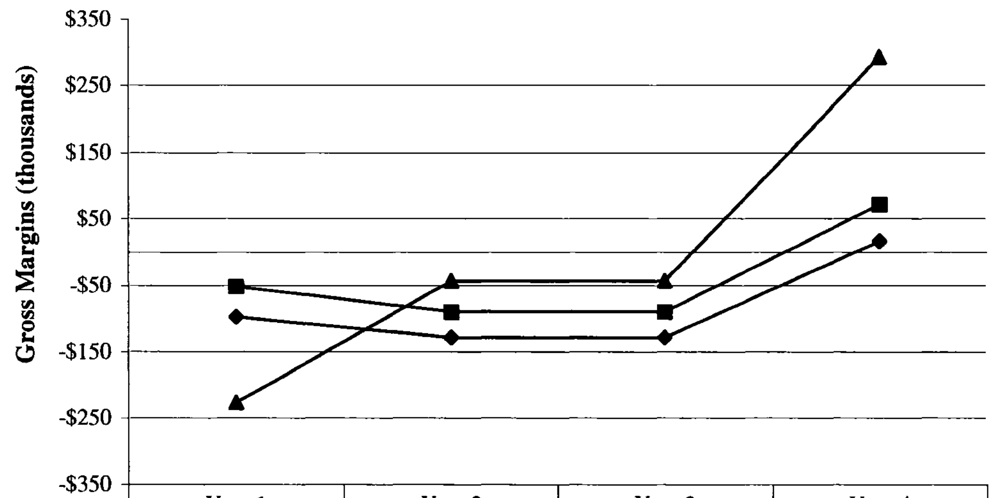
Table 4.14 Optimal Solutions from Scenario 3

Rotation WFFP under ruminant compost + beef	*OPTIMAL SOLUTION*			
	Year 1	Year 2	Year 3	Year 4
Gross margins ($)	-226,405.86	- 44,013.86	- 44,013.86	292,035.62
Farmer's labour (hr)	1,453.42	1,538.41	1,538.41	1,164.41
Hired labour (hr)	0	0	0	0
Total labour (hr)	1,453.42	1,538.41	1,538.41	1,164.41
Operating capital ($)	328,418.44	302,044.98	302,044.98	206,732.95
Soil amendment costs ($)	171,781.82	147,089.51	147,089.51	147,089.51
Compost (kg)	630,356.83	732,027.29	732,027.29	732,027.29
Compost costs ($)	91,401.74	47,767.54	47,767.54	47,767.54
Rock-phosphate (kg)	128,434.46	160,823.95	160,823.95	160,823.95
Rock-phosphate ($)	68,070.26	85,236.70	85,236.70	85,236.70
Langbeinite (kg)	21,981.82	25,152.27	25,152.27	25,152.27
Langbeinite ($)	12,309.82	14,085.27	14,085.27	14,085.27
Number of animals	187	187	187	0

Table 4.15 Result Comparisons of the LP Model Scenarios

	Scenario 2 compared to scenario 1 (scn. 2 - scn. 1)			Scenario 3 compared to scenario 1 (scn. 3 - scn. 1)			Scenario 3 compared to scenario 2 (scn. 3 - scn. 2)		
	Change	Value Change	Percentage Change (%)	Change	Value Change	Percentage Change (%)	Change	Value Change	Percentage Change (%)
Revenues ($)	Increased	177,853.39	21.08	Increased	557,304.10	66.05	Increased	379,450.71	37.14
Var. costs ($)	Decreased	-1,403.43	0.12	Increased	239,375.16	20.22	Increased	240,778.58	20.36
Gross margins ($)	Increased	179,256.82	52.67	Increased	317,928.94	93.42	Increased	138,672.12	86.09
Farmer's labour (hr)	Decreased	-1,427.36	23.79	Decreased	- 305.36	5.09	Increased	1,122.00	24.54
Hired labour (hr)	Decreased	-11,522.16	100.00	Decreased	- 11,522.16	100.00	Unchanged	0	0
Total labour (hr)	Decreased	-12,949.52	73.90	Decreased	- 11,827.52	67.50	Increased	1,122.00	24.54
Operating capital ($)	Increased	16,975.92	1.67	Increased	122,430.56	12.04	Increased	105,454.64	10.20
Soil amendment costs ($)	Increased	132,551.13	20.22	Decreased	- 42,578.11	6.49	Decreased	- 175,129.24	22.22
Compost costs ($)	Decreased	-104,309.37	20.29	Decreased	- 279,438.62	54.35	Decreased	- 175,129.24	42.73
Rock-phosphate ($)	Increased	198,451.50	158.34	Increased	198,451.50	158.34	Unchanged	0	0
Langbeinite ($)	Increased	38,409.00	237.73	Increased	38,409.00	237.73	Unchanged	0	0
Compost (kg)	Decreased	-2,886,261.13	50.52	Decreased	- 2,886,261.13	50.52	Unchanged	0	0
Rock-phosphate (kg)	Increased	374,436.80	158.34	Increased	374,436.80	158.34	Unchanged	0	0
Langbeinite (kg)	Increased	68,587.50	237.73	Increased	68,587.50	237.73	Unchanged	0	0
Number of animals	Unchanged	0	0	Increased	561	100.00	Increased	561	100.00

Figure 4.1 Gross Margins from Optimal Rotation Systems



	Year 1	Year 2	Year 3	Year 4
Scenario 1	-97.65	-129.42	-129.42	16.17
Scenario 2	-52.48	-90.24	-90.24	71.88
Scenario 3	-226.41	-44.01	-44.01	292.04

less than 1%, while revenues increased by 21%. On the other hand, the mixed cash crop-livestock rotation selected from Scenario 3, (i.e. WFFP grown under ruminant compost) generated 93% higher gross margins than the rotation from Scenario 1. Total variable costs increased by 20%, while revenues increased by 66%. In addition, the mixed cash crop-livestock rotation WFFP generated 86% higher gross margins than the same rotation in a cash crop operation (Scenario 2). Variable costs were 20% higher, but revenues were 37% higher.

The increases in both variable costs and revenues were attributed to the beef cattle enterprise. The size of the herd was 187 stockers per year for the transition phase. The model did not select beef livestock in year 4 because the economic benefits provided by the beef enterprise relating to soil amendment costs would have been shown in year 5, and year 5 was not included in the model. A herd of 187 animals is consistent with the average herd size for Nova Scotia, where the typical herd size for a backgrounding operation is 100 animals, and ranges from 50 to 1,000 (Firth, 2005).

In Figure 4.1, it is clear that the optimal rotation in Scenario 3 (WFFP + beef), which included livestock, yielded the lowest gross margins in the first year of rotation, since livestock purchases increased variable costs considerably. However, from the second year onwards, beef sales were included each year of the rotation. Therefore, gross margins increased. On the other hand, the optimal rotations from scenarios 1 (WSBP) and 2 (WFFP) had higher gross margins during the first year, and then decreased until organic certification was granted. This can be attributed to nutrient credits in the soil from the conventional operation. Hence, about 28% less soil amendments were used in Scenario 1 (WSBP) and 18% less soil amendments were used in Scenario 2 and 3 (WFFP) during the first year of transition.

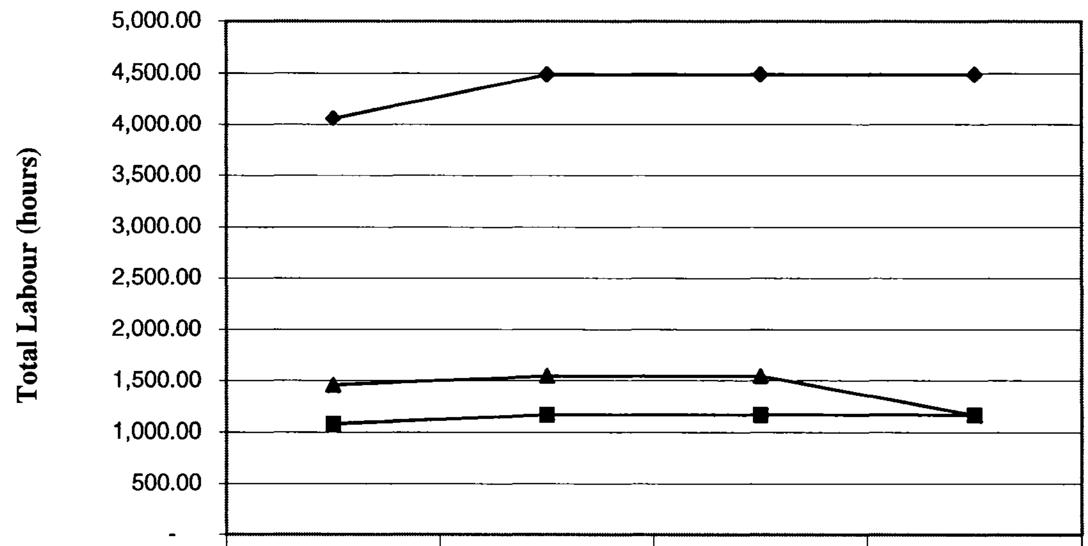
4.4.2.2 Labour

In general, labour requirements were relatively high for the optimal rotation in the first scenario (Figure 4.2). This was mainly because the cash crop rotation WSBP under monogastric compost required an average of 2,881 hours of hired labour per year, and 1,500 hours of farm operator labour. In this rotation, hired labour was required mainly to prepare monogastric compost. The most profitable optimal solution from Scenario 2 (i.e., WFFP under ruminant compost) required 24% less labour from the farm operator, and zero hired labour. The optimal rotation in Scenario 3 (WFFP + beef) required 5% less of the farmer's labour than in Scenario 1, and 25% more farm operator labour than in Scenario 2, while hired labour was not required. Labour changes were mainly attributed to livestock requirements (in scenario 3) and monogastric compost preparation (in scenario 1). Similarly, the decreases were due to less labour required for forages. It is important to note that in Scenario 3 (WFFP + beef), the farmer's labour availability was significantly higher since it was assumed that during the winter, the farm was still in operation (i.e., winter backgrounding). For the other two scenarios, labour was not required during the winter months since no field operations would take place.

4.4.2.3 Capital

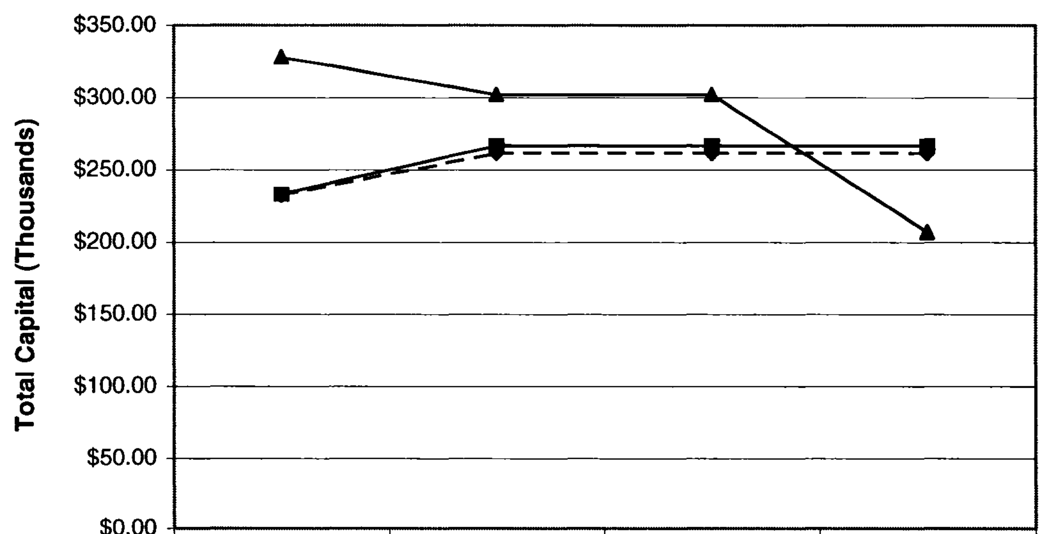
Capital requirements were quite high, but relatively consistent among the optimal rotations. The changes in capital requirements are presented in Figure 4.3. The optimal rotation from Scenario 2 (WFFP) required almost 2% more capital than the optimal rotation from Scenario 1 (WSBP). This was due to the cost of soil amendments discussed

Figure 4.2 Total Labour Requirements from Optimal Solutions



	Year 1	Year 2	Year 3	Year 4
Scenario 1	4,059.21	4,487.65	4,487.65	4,487.65
Scenario 2	1,079.42	1,164.41	1,164.41	1,164.41
Scenario 3	1,453.42	1,538.41	1,538.41	1,164.41

Figure 4.3 Total Capital Requirements from Optimal Solutions



	Year 1	Year 2	Year 3	Year 4
Scenario 1	232.20	261.54	261.54	261.54
Scenario 2	233.11	266.89	266.89	266.89
Scenario 3	328.42	302.04	302.04	206.73

in the next section. The optimal rotation (WFFP) in the mixed cash crop-livestock operation required 12% more capital than the rotation WSBP, and 10% more than the stockless rotation WFFP. The relatively high capital requirements for the beef operation were reduced by the low capital requirements for compost preparation, since the livestock produced most of the manure.

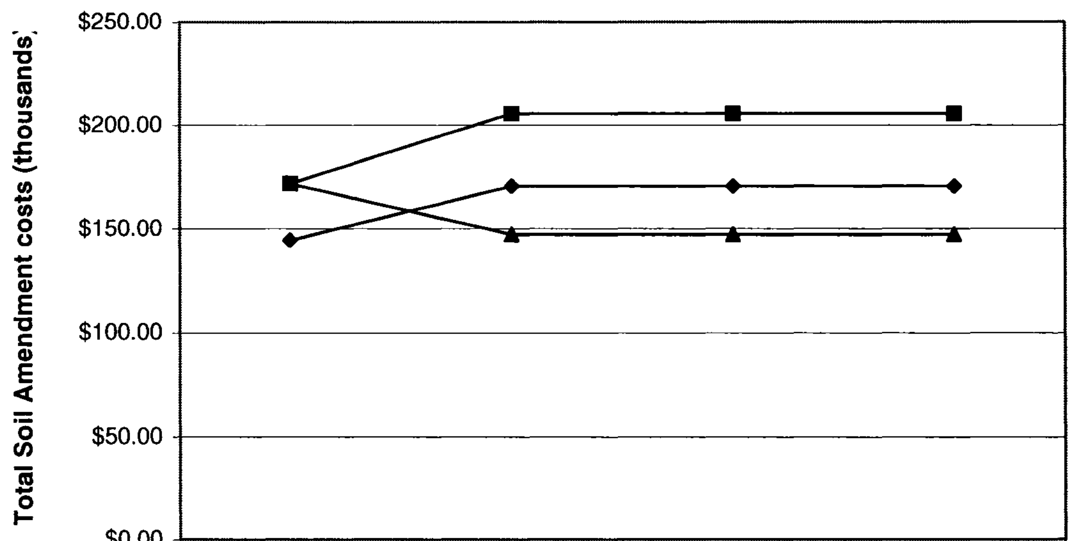
4.4.2.4 Soil Amendments

Soil amendment expenses were lower when livestock were included in the model, in particular compost costs. This was because the manure produced on the farm would be used for compost. The optimal rotation from Scenario 3 (WFFP + beef) had 6% lower soil amendment costs compared to the solution from Scenario 1 (WSBP), and 22% lower than the solution from Scenario 2 (WFFP). In turn, the latter had 20% higher soil amendment costs compared to the optimal rotation from Scenario 1 (WSBP). The changes in soil amendment costs are presented in Figure 4.4

The optimal rotation from Scenario 2 (WFFP) required 51% less ruminant compost than what the optimal rotation from Scenario 1 (WSBP) required of monogastric compost. This was not only because legume forages fix nitrogen from the atmosphere, but also because, on average, ruminant compost provided slightly more nitrogen than monogastric compost (i.e., 0.065%). The amount of compost used in the rotation WFFP in Scenario 2, was exactly the same for Scenario 3. However, ruminant compost costs in the cash crop-livestock rotation WFFP (Scenario 3) were 43% lower than in the stockless rotation WFFP (Scenario 2), because most of the manure was produced on the farm. Nevertheless, it is important to note that compost produced on the farm was not credited until the second year of rotation, and compost used in the first year was prepared from purchased manure. For these reasons, soil amendment costs in Scenario 2 and 3 are the same in the first year.

Both the amount and cost of rock-phosphate were 158% higher for WFFP rotation in Scenarios 2 and 3 compared to WSBP in Scenario 1. Similarly, the amount of langbeinite and its cost were 238% higher for WFFP in Scenario 2 and 3 compared to WSBP in Scenario 1. In both cases, the amounts and costs of rock-phosphate and langbeinite were higher because forages (in WFFP) required more demanding in phosphorus and potassium than soybean and barley (in WSBP).

Figure 4.4 Soil amendment Costs from Optimal Rotation Systems



	Year 1	Year 2	Year 3	Year 4
Scenario 1	144.48	170.38	170.38	170.38
Scenario 2	171.78	205.47	205.47	205.47
Scenario 3	171.78	147.09	147.09	147.09

4.5 Summary

In this chapter, a linear programming model was developed and analyzed to compare the economic impacts of including forages and livestock into cash crop rotations during the transition to organic agriculture in Eastern Canada. For a given set of crop rotations grown under monogastric and ruminant compost, the model selected a rotation that maximized gross margins on a whole-farm basis and investigated whether feeding forages to beef in a winter backgounding operation provided higher gross margins than selling forages as a cash crop.

The enterprise budgets developed from the Truro experiment were modified to better reflect a commercial operation for the LP model. Such modifications included changes to the number of passes per field operation, and a soil fertility management scheme planned from an economic perspective. The fertility management plan included the development of individual LP models to determine an optimum soil amendment mix suitable to meet soil test recommendations in each rotation.

The model considered a multi-period framework for a 4-year crop rotation and livestock production system. Price premiums were not included during the first three years of rotation, but were included for the fourth. The objective function was set to maximize gross margins over a four year period. Variations of the model were run in three different scenarios. The base scenario included non-forage based crop rotations. The second scenario included forage-based rotations, and the third added ruminant livestock.

The results suggest that, the profitability of the transition to organic agriculture can improve considerably when a mixed cash crop-livestock operation included two years of forage in the rotation. It was also found that growing crops under ruminant compost provided higher gross margins than under monogastric compost. However, when the model was run in the first scenario, (i.e., cash crop rotations with either monogastric or ruminant compost) WSBP rotation under monogastric compost provided higher gross margins than the same rotation under ruminant compost. Nevertheless, gross margins were negative over a four year period. When forages were included in the second scenario, WFFP rotation under ruminant compost yielded the highest gross margins. When ruminant livestock entered the plan, gross margins were considerably higher compared to the optimal solutions in the other two scenarios. It is important to note that gross margins of the three optimal rotations were negative throughout the first 3 years of transition to organic agriculture. However gross margins were consistently positive once organic certification was granted.

In conclusion, rotations that include forages and beef can ease the financial difficulties of the three years of conversion from conventional to organic agriculture, if ruminant compost is used.

CHAPTER 5. SUMMARY AND CONCLUSIONS

5.1 Summary

The economic feasibility of organic agriculture has been studied in many parts of the US and in several Canadian regions. However, little information is available for Atlantic Canada. With a few exceptions, most of the studies conclude that organic agriculture can be profitable, especially when the system is fully established. On the other hand, during the transition to organic agriculture, farmers may encounter financial losses because yields may decline, price premiums are not accessible, and farmers incur significant production costs. However, it has been proposed that forage-based crop rotations might help reduce losses, in particular when leguminous forages, grown to improve soil fertility, are used for feeding cattle.

The purpose of this study was to investigate the economic feasibility of alternative crop rotations, and to determine the economic implications of including forages and livestock during the transition to organic agriculture. The rotations were distinguished by: i) the frequency of forage in rotation, ii) the source of nutrients, and iii) the type of farming operation. The economic analyzes presented in this study included enterprise budgeting, statistical analysis, and multi-period linear programming.

The economic analysis was divided in two parts. In the first, data from a four-year crop rotation experiment in Truro, Nova Scotia, were analyzed using enterprise budgeting and parametric statistical methods. Three types of soil amendment (i.e., stockless, monogastric, and ruminant) were combined with three levels of forage-based crop rotations (i.e., 0, 1, and 2 years of forage). The baseline four-year rotation was wheat (W), soybean (S), barley (B) and potato (P), and forage (F) replaced soybean and/or barley depending on the level of forage in the rotation. The experiment was divided into core and extra experimental plots. Crops in core plots were grown using three types of soil amendment in the following rotations: WSBP, WBFP, and WFFP. On the other hand, crops in extra experimental plots were grown only under a stockless system with 6 rotations: BFPW, FPWB, PWBF, FFPW, FPWF, and PWFF.

The second part of the economic analysis involved the development of a multi-period linear programming (LP) model, based on information from the core plots of the Truro experiment. The enterprise budgets generated from the experiment were modified to represent a typical commercial operation in Nova Scotia. The LP model included the three rotations studied in the core experimental plots and two of the soil amendment treatments (i.e., monogastric and ruminant compost). In addition, the model included the potential for a backgrounding beef operation.

5.2 Results and Conclusions

5.2.1 Results

Results from the statistical analysis suggest significant differences in yield for wheat, forage, and potatoes. Wheat and potato yields tended to be higher under ruminant compost. In addition, regardless of the type of soil amendment, the highest forage yield was found in the rotation with two consecutive years of forage (i.e., WF<u>F</u>P).

Fixed costs varied by rotation, because the machinery complement was different among rotations. In general, higher fixed costs were found in forage-based crop rotations, and rotations involving compost applications. Variable costs were quite high and varied widely. High variable costs were mainly attributed to: the amount of soil amendment required to meet soil test recommendations, and the costs of soil amendments. In general, variable costs in the core plots were lower under monogastric systems and two years of forage in rotation.

Net returns were greatly influenced by nutrient supply costs. On average, most crops generated losses during the transition period. However, certified organic potatoes with a price premium of 87% above the conventional price, generated positive net returns in the fourth year. In general, crop net returns tended to be higher in forage-based crop rotations and in livestock systems, compared to rotations with no forage and in the stockless system. In particular, rotations with two years of forage and rotations under monogastric system yielded higher net returns. The highest wheat net returns were found in the WFFP rotation under the monogastric system. By comparison, the highest forage net returns from 2003 to 2004 were found for the stockless system, while the highest barley net returns were found in the WSBP rotation under monogastric compost. In 2005, the highest potato net returns were generated from the ruminant system.

The results from the LP model suggest that forages and livestock can provide considerable economic benefits, especially when crops are grown under ruminant compost. The model was run in three different scenarios. The first scenario or base model considered only cash crops and no forage. The best alternative for Scenario 1 was to manage a rotation consisting of wheat, soybean, barley and potato (WSBP) under monogastric compost. In spite of positive gross margins obtained once organic certification was granted (i.e., $16,168), gross margins were negative over a four-year period (i.e., $-340,327).

The second scenario included forage-based rotations (i.e., WBFP, and WFFP) in the model and the best alternative was to grow wheat and potato in rotation with two years of forage under ruminant compost. This result was mainly due to higher wheat and potato yields, and to additional nitrogen provided by leguminous forages. Positive gross margins were obtained only in the last year of rotation (i.e., the first year under organic certification) (i.e., $71,884). Nevertheless, the sum of gross margins for the whole rotation were still negative (i.e., $-161,070).

In the third scenario, the sum of gross margins, over a period of four years, was substantially higher compared to Scenarios 1 and 2 (i.e., $-22,398). The sum of gross margins during the first three years of transition to organic agriculture were negative (i.e., $-314,434). However, positive gross margins were much higher once organic certification was granted (i.e., $292,036), primarily because beef cattle were added to the model. The best alternative in Scenario 3 was to grow wheat and potato in rotation with two years of forage under ruminant compost in a mixed cash crop-livestock operation. This result can be attributed to the higher wheat and potato yields, as well as to a considerable reduction in soil amendment costs and revenues obtained from the beef enterprise.

5.2.2 Conclusions

Overall, organic agriculture can be comparable to conventional agriculture in terms of its economic feasibility. However, organic farming could potentially generate externalities that may not have a direct monetary value, such as health, diversity, better tasting food, animal welfare, and environmental stewardship. In addition, there is a wide variation in terms of the number of successful organic farms. However, as in conventional agriculture, the success of farming can be site specific, and subject to management skills, history of the fields, and farmer's experience.

Results of the statistical analysis of the Truro experiment indicate that ruminant compost can provide additional economic benefits to a farming operation during the transition to organic agriculture, since yields tend to be higher. In addition, forage-based crop rotations may be needed to build soil organic matter.

From the optimal solution obtained in the multi-period LP model, it can be concluded that including forages and livestock with a cash crop rotation system can provide economic benefits to ease the financial difficulties during the transition to organic agriculture. Therefore, including forages and beef into a farming operation could be a good strategy.

Within the scope of this study, it was found that the most important economic implication during the transition to organic agriculture was related to substituting organic soil amendments for synthetic fertilizers. Production costs related to maintaining soil fertility can be high, especially if soil amendments are applied to meet standard soil nutrient recommendations. However, once the system is implemented, the results of this study support the view that organic farming can be profitable.

5.3 Limitations of the Study

The scarce information on organic agriculture in Nova Scotia was one of the main limitations of this study. Yield data were restricted to four years of field experiments, where only one of the treatments represented a fully-phased rotation. Ideally, all of the crops should have been grown every year for the three treatments investigated in order to capture rotation effects. In addition, more replications could have improved the reliability of the results.

Conventional and organic price information were also limited. Even though price information obtained from other provinces was only used to estimate percentage price premiums, this information may not accurately represent the market in Nova Scotia. In addition, many assumptions were needed to estimate production costs, and these might not represent those of a real farm in transition to organic agriculture in Nova Scotia.

The field experiments were not planned from an economic perspective. For example, the cost of various nutrient sources was not taken into account when the amounts of soil amendments were determined. Therefore, the enterprise budget analysis yielded substantial negative net returns. The soil fertility management plan for the Truro experiment could have been prepared using a blending linear programming model so that soil test recommendations were met at a minimum cost. Such a procedure was carried out for the second part of the economic analysis.

The scope of this study was limited to the time frame required by the Canadian Organic Standard to obtain certification (i.e., 3 years). In reality, the biophysical transition to organic farming can be longer or shorter depending on factors that are specific to a farm. Yield reductions are often expected during transition. However, yield depressions were not included in this study. Furthermore, the experimental plots used land of relatively high fertility, so little yield depression was observed.

5.4 Recommendations for Further Research

More research is needed to support the development of organic agricultural practices in Eastern Canada. Information on yields, prices, and production costs should be available for farmers willing to convert. A long-term rotation experiment may be required to provide a larger yield data set. Similarly, prices paid to producers, as well as retail price information, should be collected as a permanent initiative. Crop and livestock budgets should be generated and updated regularly for organic agriculture

Data for this study were collected from experimental trials conducted in Nova Scotia. However, the experiment was simultaneously replicated in Manitoba. Therefore, the data from the Manitoba trials should also be analyzed from an economic perspective, and then compared with the results from this study to determine differences and similarities at the provincial level. Conventional farmers willing to convert to organic agriculture will benefit from similar studies conducted in other provinces or regions.

Further research should focus on risk analysis during the transition to organic. For example, the probability of obtaining a particular yield should be analyzed along with output prices at various levels and different farmers' attitudes towards risk.

The economic implications of including other types of livestock with crop rotations should also be investigated. In addition, this study focused on three nutrient sources to maintain soil fertility. However the economic implications of maintaining soil fertility with other alternatives such as brancheal wood chip (BWC) should be evaluated.

Finally, because of concerns with the economic feasibility of meeting soil test recommendations with organic nutrients, more extensive analysis at the provincial level would be required to address this issue. An investigation of the agronomic characteristics of representative soil types, as well as typical organic nutrient sources in the province should be analyzed, along with their implications on yields and net returns.

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APPENDIX 1. NUTRIENT APPLICATION RATES IN THE TRURO EXPERIMENT

1.1 Nutrient Application in Core plots, 2002

Rotation	Block	Crop	Treatment	Organic soil amendment application (kg/ha)	Estimated Nutrient Availability from Organic Soil Amendment (kg/ha)			Rock Phosphate application (kg/ha)	Phosphorus Availability from Rock Phosphate (kg/ha)	Total Phosphorus availability (P2O5) (kg/ha)
					Nitrogen	Phosphorus (P2O5)	Potassium (K2O)			
WSBP	1	Wheat	St	26,480	170	23.89	510.41	1,421	42.63	66.52
	1		M	20,859	170	140.43	308.93	N/A	N/A	140.43
	1		R	25,856	170	113.09	903.55	N/A	N/A	113.09
	2		St	26,480	170	23.89	510.41	2,588	77.63	101.52
	2		M	20,859	170	140.43	308.93	343	10.28	150.72
	2		R	25,856	170	113.09	903.55	N/A	N/A	113.09
	3		St	26,480	170	23.89	510.41	2,588	77.63	101.52
	3		M	20,859	170	140.43	308.93	343	10.28	150.72
	3		R	25,856	170	113.09	903.55	N/A	N/A	113.09
WBFP	1	Wheat	St	26,480	170	23.89	510.41	1,421	42.63	66.52
	1		M	20,859	170	140.43	308.93	N/A	N/A	140.43
	1		R	25,856	170	113.09	903.55	N/A	N/A	113.09
	2		St	26,480	170	23.89	510.41	2,588	77.63	101.52
	2		M	20,859	170	140.43	308.93	343	10.28	150.72
	2		R	25,856	170	113.09	903.55	N/A	N/A	113.09
	3		St	26,480	170	23.89	510.41	2,588	77.63	101.52
	3		M	20,859	170	140.43	308.93	343	10.28	150.72
	3		R	25,856	170	113.09	903.55	N/A	N/A	113.09
WFFP	1	Wheat underseeded	St	13,240	85	11.95	255.20	2,127	63.82	75.76
	1		M	10,430	85	70.22	154.46	1,005	30.14	100.36
	1		R	12,928	85	56.54	451.77	567	17.00	73.54
	2		St	13,240	85	11.95	255.20	3,294	98.82	110.76
	2		M	10,430	85	70.22	154.46	2,171	65.14	135.36
	2		R	12,928	85	56.54	451.77	1,733	52.00	108.54
	3		St	13,240	85	11.95	255.20	3,294	98.82	110.76
	3		M	10,430	85	70.22	154.46	2,171	65.14	135.36
	3		R	12,928	85	56.54	451.77	1,733	52.00	108.54

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.

Note: St=Stockless system, M=Monogastric system R=Ruminant system. Potassium recommendation was already met, so no langbeinite application was required.

1.2 Nutrient Application in Core plots, 2003

Rotation	Block	Treatment	Crop	Rock Phosphate application (kg/ha)	Phosphorus Availability from Rock Phosphate (kg/ha)
WSBP	1	Stockless	Soybean	1,833	55
	1	Monogastric		200	6
	1	Ruminant		1,333	40
	2	Stockless		1,833	55
	2	Monogastric		0	0
	2	Ruminant		1,333	40
	3	Stockless		1,833	55
	3	Monogastric		333	10
	3	Ruminant		1,333	40
WBFP	1	Stockless	Barley underseeded	1,333	40
	1	Monogastric		1,100	33
	1	Ruminant		1,333	40
	2	Stockless		1,333	40
	2	Monogastric		1,133	34
	2	Ruminant		1,333	40
	3	Stockless		1,333	40
	3	Monogastric		933	28
	3	Ruminant		1,333	40
WFFP	1	Stockless	Forage	2,166	65
	1	Monogastric		1,333	40
	1	Ruminant		1,833	55
	2	Stockless		2,166	65
	2	Monogastric		1,333	40
	2	Ruminant		1,833	55
	3	Stockless		2,166	65
	3	Monogastric		1,333	40
	3	Ruminant		1,833	55

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage, St=Stockless system, M=Monogastric system R=Ruminant system. Nitrogen and Potassium recommendations were already met.

1.3 Nutrient Application in Core plots, 2004

Rotation	Block	Treatment	Crop	Organic soil amendment application (kg/ha)	Estimated Nutrient Availability from Organic Soil Amendment (kg/ha)			Rock Phosphate application (kg/ha)	Phosphorus Availability from Rock Phosphate (kg/ha)	Total Phosphorus availability (P2O5) (kg/ha)
					Nitrogen	Phosphorus (P2O5)	Potassium (K2O)			
WSBP	1	St	B	5,566	49.93	6.55	141.27	2,113	63.39	69.94
	1	M	B	16,887	57.42	40.05	58.57	N/A	N/A	40.05
	1	R	B	9,141	47.76	29.69	163.10	843	25.29	54.98
	2	St	B	5,566	49.93	6.55	141.27	3,113	93.39	99.94
	2	M	B	14,720	50.05	34.91	51.05	170	5.10	40.01
	2	R	B	16,635	86.92	54.02	296.83	1,530	45.90	99.92
	3	St	B	5,566	49.93	6.55	141.27	3,113	93.39	99.94
	3	M	B	23,363	79.43	55.41	81.03	986	29.58	84.99
	3	R	B	16,635	86.92	54.02	296.83	1,532	45.96	99.98
WBFP	1	St	F	N/A	N/A	N/A	N/A	2,500	75	75
	1	M	F	32,863	111.73	77.93	113.97	N/A	N/A	77.93
	1	R	F	29,982	124.24	83.22	385.52	N/A	N/A	83.22
	2	St	F	N/A	N/A	N/A	N/A	4,000	120	120
	2	M	F	37,245	126.63	88.33	129.17	N/A	N/A	88.33
	2	R	F	42,328	175.40	117.49	544.26	N/A	N/A	117.49
	3	St	F	N/A	N/A	N/A	N/A	4,000	120	120
	3	M	F	52,581	178.78	124.70	182.36	N/A	N/A	124.70
	3	R	F	42,328	175.40	117.49	544.26	N/A	N/A	117.49
WFFP	1	St	F	N/A	N/A	N/A	N/A	4,000	120	120
	1	M	F	37,245	126.63	88.33	129.17	N/A	N/A	88.33
	1	R	F	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2	St	F	N/A	N/A	N/A	N/A	4,000	120	120
	2	M	F	41,627	141.53	98.72	144.37	N/A	N/A	98.72
	2	R	F	42,328	175.40	117.49	544.26	N/A	N/A	117.49
	3	St	F	N/A	N/A	N/A	N/A	4,000	120	120
	3	M	F	48,199	163.88	114.30	167.16	N/A	N/A	114.30
	3	R	F	42,328	175.40	117.49	544.26	N/A	N/A	117.49

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.

Note: W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage, St=Stockless system, M=Monogastric system R=Ruminant system.

1.4 Nutrient Application in Core plots, 2005

Rotation	Block	Treatment	Crop	Organic soil amendment application (kg/ha)	Estimated Nutrient Availability from Organic Soil Amendment (kg/ha)			Rock Phosphate application (kg/ha)	Phosphorus Availability from Rock Phosphate (kg/ha)	Total Phosphorus availability (P2O5) (kg/ha)
					Nitrogen	Phosphorus (P2O5)	Potassium (K2O)			
WSBP	1	St	P	8,412	57.79	8.24	196.09	4,998	149.95	158.20
	1	M	P	24,222	85.99	59.10	74.12	2,529	75.86	134.96
	1	R	P	10,080	63.00	38.51	171.46	3,569	107.08	145.58
	2	St	P	8,412	57.79	8.24	196.09	4,998	149.95	158.20
	2	M	P	24,222	85.99	59.10	74.12	2,529	75.86	134.96
	2	R	P	10,080	63.00	38.51	171.46	3,569	107.08	145.58
	3	St	P	8,412	57.79	8.24	196.09	4,998	149.95	158.20
	3	M	P	24,222	85.99	59.10	74.12	2,529	75.86	134.96
	3	R	P	10,080	63.00	38.51	171.46	3,569	107.08	145.58
WBFP	1	St	P	6,880	47.27	6.74	160.38	5,059	151.78	158.53
	1	M	P	22,641	80.38	55.24	69.28	2,657	79.72	134.96
	1	R	P	9,997	62.48	38.19	170.05	3,580	107.39	145.58
	2	St	P	6,880	47.27	6.74	160.38	5,059	151.78	158.53
	2	M	P	22,641	80.38	55.24	69.28	2,657	79.72	134.96
	2	R	P	9,997	62.48	38.19	170.05	3,580	107.39	145.58
	3	St	P	6,880	47.27	6.74	160.38	5,059	151.78	158.53
	3	M	P	22,641	80.38	55.24	69.28	2,657	79.72	134.96
	3	R	P	9,997	62.48	38.19	170.05	3,580	107.39	145.58
WFFP	1	St	P	8,891	61.08	8.71	207.24	4,979	149.38	158.09
	1	M	P	18,416	65.38	44.94	56.35	3,001	90.04	134.97
	1	R	P	9,437	58.98	36.05	160.52	3,650	109.49	145.54
	2	St	P	8,891	61.08	8.71	207.24	4,979	149.38	158.09
	2	M	P	18,416	65.38	44.94	56.35	3,001	90.04	134.97
	2	R	P	9,437	58.98	36.05	160.52	3,650	109.49	145.54
	3	St	P	8,891	61.08	8.71	207.24	4,979	149.38	158.09
	3	M	P	18,416	65.38	44.94	56.35	3,001	90.04	134.97
	3	R	P	9,437	58.98	36.05	160.52	3,650	109.49	145.54

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, S= Soybean, B= Barley, P=Potato, F= Forage, St=Stockless system, M=Monogastric system R=Ruminant system.

1.5 Nutrient Application in Extra Experimental Plots, 2002

Rotation	Block	Crop	Organic soil amendment application (kg/ha)	Estimated Nutrient Availability from Organic Soil Amendment (kg/ha)			Rock Phosphate application (kg/ha)	Phosphorus Availability from Rock Phosphate (kg/ha)	Total Phosphorus availability (P2O5) (kg/ha)	Langbeinite application Rate (kg/ha)	Potassium Availability from langbeinite (kg/ha)	Total Potassium available (K2O) (kg/ha)
				N	P	K						
BFPoW	1	B	5,452	35	4.92	105.1	2,043	61.28	66.20	0	0	105.1
FPoWB	1	F	0	0	0	0	3,333	100	100	477	105	105
PoWBF	1	Po	20,249	130	18.3	390.3	4,253	127.60	145.87	0	0	390.3
FFPoW	1	F	0	0	0	0	3,333	100	100	477	105	105
FPoWF	1	F	0	0	0	0	3,333	100	100	477	105	105
PoWFF	1	Po	20,249	130	18.3	390.3	4,253	127.60	145.87	0	0	390.3
BFPoW	2	B	5,452	35	4.92	105.1	2,043	61.28	66.20	0	0	105.1
FPoWB	2	F	0	0	0	0	3,333	100	100	477	105	105
PoWBF	2	Po	20,249	130	18.3	390.3	4,253	127.60	145.87	0	0	390.3
FFPoW	2	F	0	0	0	0	3,333	100	100	477	105	105
FPoWF	2	F	0	0	0	0	3,333	100	100	477	105	105
PoWFF	2	Po	20,249	130	18.3	390.3	4,253	127.60	145.87	0	0	390.3
BFPoW	3	B	5,452	35	4.92	105.1	2,043	61.28	66.20	0	0	105.1
FPoWB	3	F	0	0	0	0	3,333	100	100	477	105	105.
PoWBF	3	Po	20,249	130	18.3	390.3	4,253	127.60	145.87	0	0	390.3
FFPoW	3	F	0	0	0	0	3,333	100	100	477	105	105
FPoWF	3	F	0	0	0	0	3,333	100	100	477	105	105
PoWFF	3	Po	20,249	130	18.3	390.3	4,253	127.60	145.87	0	0	390.3

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, B= Barley, Po=Potato, F= Forage, N=Nitrogen, P=Phosphorus, K=Potassium.

1.6 Nutrient Application in Extra Experimental Plots, 2003

Rotation sequence	Block	Crop	Organic soil amendment application (kg/ha	Estimated Nutrient Availability from Organic Soil Amendment (kg/ha)			Rock Phosphate application (kg/ha)	Phosphorus Availability from Rock Phosphate (kg/ha)	Total Phosphorus availability (P2O5) (kg/ha)
				N	P	K			
BFPoW	1	F	0	0	0	0	1,667	50	50
FPoWB	1	Po	13,935	125	16.39	353.7	2,120	63.59	79.98
PoWBF	1	W	15,050	135	17.70	382	1,243	37.28	54.98
FFPoW	1	F	0	0	0	0	1,667	50	50
FPoWF	1	Po	13,935	125	16.39	353.7	2,120	63.59	79.98
PoWFF	1	W	5,574	50	6.56	141.5	1,615	48.44	54.99
BFPoW	2	F	0	0	0	0	1,667	50	50
FPoWB	2	Po	13,935	125	16.39	353.7	2,120	63.59	79.98
PoWBF	2	W	15,050	135	17.70	382	1,243	37.28	54.98
FFPoW	2	F	0	0	0	0	1,667	50	50
FPoWF	2	Po	13,935	125	16.39	353.7	2,120	63.59	79.98
PoWFF	2	W	5,574	50	6.56	141.5	1,615	48.44	54.99
BFPoW	3	F	0	0	0	0	1,667	50	50
FPoWB	3	Po	13,935	125	16.39	353.7	2,120	63.59	79.98
PoWBF	3	W	15,050	135	17.70	382	1,243	37.28	54.98
FFPoW	3	F	0	0	0	0	1,667	50	50
FPoWF	3	Po	13,935	125	16.39	353.7	2,120	63.59	79.98
PoWFF	3	W	5,574	50	6.56	141.5	1,615	48.44	54.99

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, B= Barley, Po=Potato, F= Forage, N=Nitrogen, P=Phosphorus, K=Potassium.

1.7 Nutrient Application in Extra Experimental Plots, 2004

Rotation sequence	Block	Crop	Organic soil amendment application (kg/ha	Estimated Nutrient Availability from Organic Soil Amendment (kg/ha)			Rock Phosphate application (kg/ha)	Phosphorus Availability from Rock Phosphate (kg/ha)	Total Phosphorus availability (P2O5) (kg/ha)
				N	P	K			
BFPoW	1	Po	8,919	80	10.49	226.35	4,983	149.50	159.99
FpoWB	1	W	13,378	120	15.73	339.53	3,142	94.25	109.98
PoWBF	1	B	0	0	0	0	2,833	85	85
FFPoW	1	Po	8,9189	80	10.49	226.35	4,983	149.50	159.99
FpoWF	1	W	3,902	35	4.59	99.03	3,514	105.41	109.99
PoWFF	1	F	0	0	0	0	3,6667	110	110
BFPoW	2	Po	8,919	80	10.49	226.35	4,983	149.50	159.99
FpoWB	2	W	13,378	120	15.73	339.53	3,142	94.25	109.98
PoWBF	2	B	0	0	0	0	2,833	85	85
FFPoW	2	Po	8,919	80	10.49	226.35	4,983	149.50	159.99
FpoWF	2	W	3,902	35	4.59	99.03	3,514	105.41	109.99
PoWFF	2	F	0	0	0	0	3,6667	110	110
BFPoW	3	Po	8,919	80	10.49	226.35	4,983	149.50	159.99
FpoWB	3	W	13,378	120	15.73	339.53	3,142	94.25	109.98
PoWBF	3	B	0	0	0	0	2,833	85	85
FFPoW	3	Po	8,919	80	10.49	226.35	4,983	149.50	159.99
FpoWF	3	W	3,902	35	4.59	99.03	3,180	95.41	99.99
PoWFF	3	F	0	0	0	0	3,333	100	100

Source: Hammermeister, A., Research Associate OACC, 2005, personal communication.
Note: W= Wheat, B= Barley, Po=Potato, F= Forage, N=Nitrogen, P=Phosphorus, K=Potassium.

APPENDIX 2. EXAMPLES OF CROP BUDGETS USED IN THE TRURO EXPERIMENT

2.1 Wheat Budget

Crop: Wheat Year: 2002				
Rotation: WSBP				
Treatment: Stockless				
INPUTS				
VARIABLE COSTS	Unit	Price/unit	Quantity	Total ($)
NUTRIENT SUPPLY AND OTHERS				
Alfalfa pellets	kg/ha	0.52	26,479.50	13,769.34
Rock-P	kg/ha	0.53	2,198.86	1,165.40
Wheat seed	kg/ha	0.525	170.00	89.25
FIELD OPERATIONS				
Ploughing	# Passes	31.2	1.00	31.20
Disk harrow	# Passes	12.4	4.00	49.60
S-tine	# Passes	9.7	3.00	29.10
Seeding	# Passes	10.3	1.00	10.30
Wheat harvesting	per ha	76.6	1.00	76.60
Grain grading and cleaning	per kg	0.05	3,340.58	167.03
Alfalfa meal application	per kg	0.0034	26,479.50	90.03
Rock-P application	per kg	0.0034	2,198.86	7.48
Operating Expenses	per ha	N/A	$15,359.27	N/A
Interests on operating expenses	per ha	3%	N/A	460.78
TOTAL VARIABLE COSTS				15,946.10
FIXED COSTS				
Machinery depreciation	per ha	110.04	1.00	110.04
Interests on investment	per ha	73.64	1.00	73.64
Insurance and storage	per ha	16.08	1.00	16.08
TOTAL FIXED COSTS				199.76
TOTAL COSTS				16,145.86
OUTPUT	Unit	Price/unit		
TOTAL REVENUE	kg/ha	0.257073	3,340.58	858.77
TOTAL NET RETURN				- 15,287.08

Note: W= wheat, S= soybean, B= barley, P= potato

2.2 Forage Budget

Crop: Forage (2nd year) Year: 2004 **Rotation: WFFP** **Treatment: Ruminant**				
INPUTS				
VARIABLE COSTS NUTRIENT SUPPLY AND OTHERS	Unit	Price/unit	Quantity	Total ($)
Ruminant compost	kg/ha	0.151	0	0.00
Rock-P	kg/ha	0.53	1,833.00	971.49
FIELD OPERATIONS				
Forage harvesting	per ha	31.7	2.00	63.40
Rock-P application	per kg	0.0034	1,833.00	6.23
Ensiling	per ha	7.44	2.00	14.88
Operating Expenses	per ha	N/A	$1,009.68	N/A
Interests on operating expenses	per ha	3%	N/A	30.29
TOTAL VARIABLE COSTS				1,086.29
FIXED COSTS				
Machinery depreciation	per ha	187.06	1	187.06
Interests on investment	per ha	127.42	1	127.42
Insurance and storage	per ha	27.82	1	27.82
TOTAL FIXED COSTS				342.30
TOTAL COSTS				1,428.59
OUTPUT	Unit	Price/unit		
TOTAL REVENUE	Kg	0.0760627	7,643.30	581.37
TOTAL NET RETURNS				- 847.22

Note: W= wheat, F= forage, P= potato

2.3 Barley Budget

Crop: Barley Year: 2004 **Rotation: WSBP** **Treatment: Monogastric**				
INPUTS				
VARIABLE COSTS	Unit	Price/unit	Quantity	Total ($)
NUTRIENT SUPPLY AND OTHERS				
Monogastric compost	kg/ha	0.11	18,323.35	2,015.57
Rock-P	kg/ha	0.53	385.33	204.23
Barley seed	kg/ha	0.425	175	74.38
FIELD OPERATIONS				
Ploughing	# Passes	31.2	1	31.20
Disk harrow	# Passes	12.4	2	24.80
S-tine	# Passes	9.7	2	19.40
Weeding	# Passes	7.9	1	7.90
Seeding	# Passes	10.3	1	10.30
Barley harvesting	per ha	76.6	1	76.60
Raking and bailing	per ha	28.3	1	28.30
Grain grading and cleaning	per kg	0.05	2,813.95	140.70
Compost application	per kg	0.00122	18,323.35	22.40
Rock-P application	per kg	0.0034	385.33	1.31
Operating Expenses	per ha	N/A	$2,570.31	N/A
Interests on operating expenses	per ha	3%	N/A	77.11
TOTAL VARIABLE COSTS				2,734.18
FIXED COSTS				
Machinery depreciation	per ha	145.64	1	145.64
Interests on investment	per ha	98.49	1	98.49
Insurance and storage	per ha	21.50	1	21.50
TOTAL FIXED COSTS				265.63
TOTAL COSTS				2,999.81
OUTPUT	Unit	Price/unit		
TOTAL REVENUE	kg	0.200083	2,813.95	563.03
TOTAL NET RETURNS				-2,436.79

Note: W= wheat, S= soybean, B= barley, P= potato

2.4 Potato Budget

Crop: Potato Year: 2005 **Rotation: WFFP** **Treatment: Ruminant**				
INPUTS				
VARIABLE COSTS	Unit	Price/unit	Quantity	Total ($)
NUTRIENT SUPPLY AND OTHERS				
Ruminant compost	kg/ha	0.151	9,437.00	1,424.99
Rock-P	kg/ha	0.53	3,650.00	1,934.50
Entrust	ha	115.5	4.00	462.00
Copper Hydroxide	ha	46.2	2.00	92.40
Potato seed	kg/ha	0.57	1,100.00	627.00
FIELD OPERATIONS				
Ploughing	# Passes	31.2	1.00	31.20
Disk harrow	# Passes	12.4	2.00	24.80
Weeding	# Passes	7.9	4.00	31.60
Hilling	# Passes	29.4	1.00	29.40
Colorado Potato Beetle control	# Passes	22	4.00	88.00
Fungus control	# Passes	22	2.00	44.00
Planting	per ha	29.4	1.00	29.40
Potato harvesting	per ha	111.8	1.00	111.80
Potato grading and cleaning	per kg	0.02	33,116.77	662.34
Compost application	per kg	0.00122	9,437.00	11.53
Rock-P application	per kg	0.0034	3,650.00	12.41
Operating Expenses	per ha	N/A	$5,447.72	N/A
Interests on operating expenses	per ha	3%	N/A	163.43
TOTAL VARIABLE COSTS				5,780.80
FIXED COSTS				
Machinery depreciation	per ha	187.06	1	187.06
Interests on investment	per ha	127.42	1	127.42
Insurance and storage	per ha	27.82	1	27.82
TOTAL FIXED COSTS				342.30
TOTAL COSTS				6,123.1
OUTPUT	Unit	Price/unit		
TOTAL REVENUE	kg	0.399	33,116.77	13,213.59
TOTAL NET RETURNS				7,090.49

Note: W= wheat, F= forage, P= potato