A Market for Emission Reduction Credits in Western Canada

by:

Cynthia Kallio Edwards

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Abstract

In order to reach its emissions goal agreed to in Kyoto, the Canadian government must place a restriction on carbon emissions. A quota restricting the amount of allowable emissions will facilitate the development of various methods to reduce these emissions. This study analyzes a potential market for trade in carbon credits that enable carbon dioxide (CO_2) emitting companies to offset their emissions. In this market, agricultural landowners using their land as a carbon sink can provide a supply of emission reduction credits that could be sold to CO_2 emitters, such as coal burning utility companies.

Three market organization options for the development of an Emission Reduction Credit (ERC) market were presented in this study. The transaction costs involved in each option were compared in order to determine which was the most efficient with respect to transaction costs. Two carbon sequestration methods were applied to these market options, the use of permanent cover crops and the use of zero-tillage, direct-seeding technologies.

The conclusion of this study is that a market for ERC can be developed with the proper institutions in place. Factors such as the carbon sequestration activity used, the price of CO_2, and the contract size affect the relative efficiency of the market organization options. Further research is needed to determine risk levels among these three market options and how that risk may offset the benefits of reduced transaction costs between market options, contract sizes, and sequestration activity.

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1.0 Background

At the 1997 Climate Change Convention in Kyoto, the primary topic of discussion was the reduction of greenhouse gases (GHG), which are believed to be the principal cause of global warming. Developed nations agreed to reduce their GHG emission levels by an average of 5.2 percent from 1990 levels between 2008-2012. Canada agreed to reduce its GHG emissions by 6 percent from 1990 levels; this is equivalent to a 25 percent reduction from the 'Business As Usual' forecasts for 2008. If Canada is to reduce total GHG emissions, anthropogenic[1] emissions must be reduced and sequestration capacity must be increased.

The Kyoto Protocol contains several provisions for the creation of flexible emission reduction systems. One such provision is for the use of Tradable Emissions Systems that allow Annex I countries[2] to trade emission reduction units from projects where emissions are reduced or sinks[3] are enhanced (Rolfe 1998).[4] A tradable emission system involving soil carbon sequestration in western Canada is the focus of this study.

At the Kyoto conference, particular attention was paid to CO_2 because it is the gas that is the primary contributor to global warming (Markus 1997). The pre-industrial concentration of CO_2 is estimated to have been approximately 280 ppmv[5] (Agriculture and Agri-Food Canada 1999, 2). By 1984 that concentration had increased to 358 ppmv (Ibid., 2). The burning of fossil fuels and other human activity is currently generating nearly 24 billion tons of CO_2 per year; of which only half is being absorbed by natural processes and the ocean (Morrissey and Justus 1999, 4). The consequence of this human activity is atmospheric CO_2 levels that are 30 percent higher than they were a century ago (Ibid).

The time taken for the atmosphere to adjust to any change in source or sink is in the order of fifty to two hundred years and is primarily determined by the slow exchange of carbon between surface water and deep layers of the ocean (Intergovernmental Panel on Climate Change 1990). Consequently, anthropogenic emissions of CO_2 are not being fully absorbed by natural processes and the problem is compounded by the fact that the effect of any change in emissions will not be realized for some time.

On a world scale, agriculture is responsible for roughly 25 percent of anthropogenic CO_2 emissions, 60 percent of methane emissions (CH_4), and up to 80 percent of world nitrous oxide (N_20) emissions (Bunyard 1996). In Canada, GHG emissions from agricultural sources accounted

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[1] Anthropogenic GHG emissions are those that originate from human activities such as the burning of fossil fuels.
[2] Developed countries plus countries that are undergoing the process of transition to a market economy.
[3] The FCCC defines a sink as "any process, activity or mechanism that removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere." (Sinks Table 1998).
[4] Two other mechanisms that allow for flexibility are the Clean Development Mechanism and Joint Implementation.
[5] Parts per million by volume.

for approximately 9.5 percent of total emissions in 1996 (Agriculture and Agri-Food Canada 1998, 3). However, in 1996 agriculture contributed roughly 49 percent of Canada's N_2O emissions, which were primarily due to soil management activities such as fertilization (Ibid). That same year approximately 27 percent of Canada's CH_4 emissions originated from the agriculture sector, the majority of which were caused by enteric fermentation in livestock and manure management (Ibid). In contrast, CO_2 emissions from Canadian agriculture are relatively low compared to the energy and transportation sectors, and result from mainly land management practices and the burning of the fossil fuels used in agricultural production (Tyrchniewicz 1998).

In order for Canada to meet its emission reduction goal, new policies focused on the reduction of CO_2 are needed.[6] These policies could include the use of market-based instruments, such as tradable permits and allowances, and non-market economic instruments that include taxes and subsidies. If the Canadian government restricts CO_2 emissions through regulation then a demand for the emissions will emerge. Demand for a good arises when it shifts from being a free good to being a scarce commodity. The potential exists for the Canadian agricultural sector to sequester carbon when certain land management practices are used, thereby creating a supply of CO_2 that is not emitted into the atmosphere. The carbon that is sequestered in the soil can be used to offset CO_2 emissions. The evolution of a supply of and demand for CO_2 will facilitate the trade of a commodity that previously did not exist.

Property rights are assigned to the CO_2 via the development of well-defined CO_2 credits that are secure and tradable under an enforceable system. A market for CO_2 will develop and trading will take place if the gains from trading exceed the transaction costs associated with trading. The potential social gain from the creation of this market will depend on the gains from trade minus all transaction costs, including those incurred by government in the creation, regulation, and enforcement of the market.

This study proposes the development of a market for emission reduction credits (ERC) that can be created when agricultural soils are used to generate a supply of CO_2. Emitters of CO_2, such as utility companies, who need to offset their emissions, can purchase these ERC from agricultural landowners who use zero-tillage and direct-seeding technologies or place land under permanent cover. The value of the CO_2 will be captured by the ERC. The ERC market developed in this study is based on a biological system (agriculture) rather than an engineered system such as the sulphur dioxide (SO_2) market in the United States. Consequently, this quantity of credits generated in this market is more variable and less predictable, which makes this market riskier than markets where the quantity of credits and level of emissions are easily monitored.

Currently, agricultural land is not recognized as a carbon sink within the Kyoto Protocol, although the eligibility of carbon sequestration in soil is discussed in Article 3.4 of the Protocol. Negotiations surrounding the use of agricultural soil as a sink are ongoing (Sinks Table 1998). Until policy instruments that incorporate the use of carbon sinks are developed, the ability of agricultural land to sequester carbon will continue to be largely unrecognized. Studies such as this

[6] Regulation regarding the emissions of other GHG can also be conducted in a number of ways.

one that look into market feasibility can bring attention to the use of agricultural soil as a carbon sink, thereby promoting its use as such within the Kyoto Protocol.

It has been predicted that the use of agricultural soil as a carbon sink can contribute to the mitigation of Canada's GHG emissions. Janzen (1998, 7) notes that given the large amount of Canadian cropland (45.4 million hectares) even a small change in soil organic carbon levels can lead to an important proportion of Canada's emission reduction targets. An additional 0.2 tonnes of carbon per hectare can amount to 8 million tonnes of carbon, which is equivalent to roughly 6 percent of Canada's 1990 CO_2 emissions (Ibid). Another estimate for offset potential is that if the use of zero-tillage is doubled from the business as usual prediction of 25 percent participation to 50 percent participation, that alone could reduce net agricultural GHG emissions by 9 percent from the 2010 'Business As Usual' scenario (Boehm, 1999).

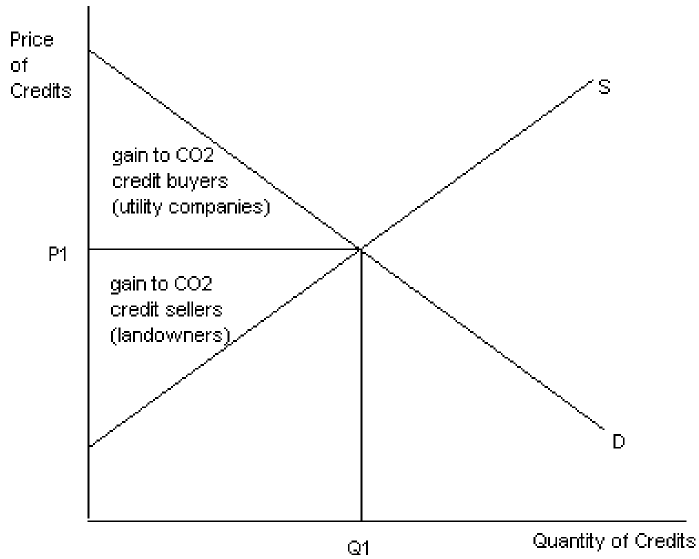
Problem Statement

The problem addressed in this study is the development of an ERC market. Three potential market organization options for an ERC market in western Canada, a bilateral market and two that make use of agents to facilitate trade, are developed and compared in this study. Transaction costs associated with each option are compared in order to determine their relative efficiency. The institutions[7] associated with each option are also indicated because they influence the transaction costs, hence efficiency. Ultimately, the effectiveness of the institutional structure will determine the success or failure of the ERC market. A successful ERC market could reduce emissions while benefiting industries and agricultural landowners in western Canada. Currently there are no emissions standards, tradable credits, or market for ERC in western Canada.[8]

The supply and demand for ERC and the resulting equilibrium price are illustrated in Figure 1.1. In a closed economy, the price of credits would be P1. If credits were traded on the world market at a price above P1, Canada would be a net exporter of CO_2 credits while a price below P1 would result in Canada being a net importer of credits. At price P1, in a closed economy, the market is in equilibrium and the gains to the buyers of credits (consumer surplus) and sellers of credits (producer surplus) can be measured using standard welfare analysis. The price of carbon, an important parameter in the demand curve for credits, will influence the size of the consumer and producer surplus.

[7] Institutions in this study are public institutions, such as law and government, as well as the rules and norms that govern society.
[8] Forest sequestration is being used as a supply carbon credits in Costa Rica and Australia. Landowners there are being paid to put their marginal land under forest.

Figure 1.1: The supply and demand of CO_2 credits in Canada



Source: Author

In Figure 1.1 the supply curve slopes upward because of technological substitutes for the control of CO_2 emissions. Using agricultural land to sequester carbon is not the only method available to reduce atmospheric CO_2 emissions.

1.2 Scope of the Study

This study deals specifically with the western Canadian prairie provinces of Alberta, Saskatchewan, and Manitoba. These provinces collectively contain the largest portion of improved farmland in Canada.[9] The focus of this study is on the creation of a market for CO_2, despite the importance of N_2O and CH_4 in the Canadian agriculture sector. The potential for agricultural land to sequester carbon when specific land management practices are used facilitates the development of a market for CO_2 credits.

1.3 Research Objectives

The primary objective of this project is to develop a market where CO_2 credits that enable CO_2 emitting companies to offset their emissions can be bought and sold. In this market, following the implementation of a quota that restricts CO_2 emissions, agricultural landowners will use their land as a carbon sink to generate carbon credits for sale to CO_2 emitting companies as emission offsets.

[9] Of the 45.5 million hectares of improved farmland in Canada in 1996, 86% was in the four western provinces (Agriculture Table 1998).

This study describes how such a market would work and the institutions needed to ensure its efficiency.
The conceptual analysis of this study incorporates the use of transaction costs, which are used to determine the efficiency of the three market options developed in this study. An empirical look at transaction costs associated with each market option is also included in order to illustrate the magnitude of the costs associated with each option and how those costs are affected by variables such as carbon sequestration practice.

Specific objectives are:

1) To develop a market that will use the carbon sequestration capability of Prairie agricultural soils as the supply of ERC.
2) To determine the type of institutional setting that is required to create this market.

1.4 Hypothesis

The hypothesis that is focused on in this study is:

Hypothesis: A market for tradable emission credits can be created with the appropriate institutions in place.

An empirical analysis of the transaction costs involved in each of the three market options is used to compare their efficiency. The development and empirical analysis of the three options for market organization allows for a sharp focus on the theoretical analysis of transaction costs, including search, negotiation, and monitoring costs.

1.5 Impact

If Canada is to meet its stated objective of reducing GHG emissions a combination of anthropogenic emission reductions and increased carbon sequestration capacity must be used. One possibility is to link carbon emitters with those who have the ability to sequester carbon through a market for tradable ERC. Agricultural landowners in Canada could gain from trade in ERC because agriculture is potentially a low cost supplier. The producer surplus illustrated in Figure 1.1 could be large and Canada could be a net exporter of carbon if it is traded on a world scale.

Policy focused on reducing GHG emissions will be linked with policy regarding the removal of marginal land from crop production and the promotion of zero-tillage and direct-seeding technologies. This policy approach has not been fully developed in Canada and will be beneficial to those concerned with the reduction of GHG. Various economic, environmental, and social impacts will result from the development of an ERC market. Policy makers will be able to analyze these impacts and use them to influence their policy decisions.

1.6 Outline

The remainder of this study is outlined as follows; Chapter Two focuses on the potential for prairie agricultural soils to sequester carbon, which is the foundation for the development of the

ERC market in this study. Chapter Three contains the conceptual framework, including the theory of transaction cost economics and the descriptions of the three market options. Chapter Four is the empirical analysis. Chapter Five, the final chapter, includes the conclusions, recommendations, policy implications, and limitations of the study.

Chapter Two: Carbon Sequestration in Prairie Agricultural Soils

2.0 Introduction

The successful development of the proposed ERC market considered in this study relies upon the potential for carbon sequestration in agricultural land, and the ability to quantify and verify changes in soil carbon stocks. This chapter overviews the role that Prairie agricultural land can play in reducing atmospheric carbon levels and the land management practices that can be used to increase carbon stocks in agricultural soils. The land management practices are particularly important because agricultural producers adopt practices not only for their ability to sequester carbon, but for other economic and agronomic reasons as well.

2.1 Agricultural Soil as a Carbon Sink

Agriculture is unique in that it not only contributes to the problem of GHG emissions, hence global warming, but it can also be part of the solution aimed at reducing atmospheric GHG concentrations (Kulshreshtha *et al.* 1998). Agriculture can be part of the solution by providing a sink for carbon, thereby reducing CO_2, which is one of the three most important GHG.

The FCCC defines *sinks* as processes or activities that remove GHG from the atmosphere (Bruce *et al.* 1998). Agricultural land is not yet recognized as a sink under the Kyoto Protocol of 1997[10], largely due to European opposition, but also because of a lack of defensible numbers pertaining to net emissions from agricultural soils (Runnalls 1998). The issue of measurement and verification is a point of contention among signers of the Protocol because emissions of other gases from soils, such as N_2O, are measured and counted toward sources even though the methods for their measurement and verification are no more certain than for CO_2. Despite the current exclusion of soils as a sink, Article 3.4 of the Kyoto Protocol does imply that they could be used as a carbon sink.

Future increases in atmospheric concentrations of CO_2 can be abated by directly reducing emissions, but removal of CO_2 from the atmosphere occurs mainly by photosynthesis and sequestration of organic carbon in different components of terrestrial, oceanic, and freshwater aquatic systems. (Bruce *et al.* 1998). Photosynthesis, which converts atmospheric CO_2 and water into organic compounds and oxygen using light energy, is the basic biochemical process of all plant growth and agriculture (Environment Canada 1996). As a result, agricultural activities such as the use of high yielding crop varieties, which enhance the photosynthetic process, increase the absorption of CO_2 from the atmosphere and reduce the risk of climate change by lowering atmospheric concentrations of GHG.

Canada’s cropland is estimated to contain a pool of soil organic carbon of approximately 6 billion tonnes to a depth of 1 meter (Bruce *et al.* 1998). Since cultivation, Prairie soils have gone from being a carbon sink under natural conditions to becoming a source of atmospheric carbon. An estimated 464 million Mg[11] of carbon have been released from prairie soils since the beginning of

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[10] Soils are currently counted as a source under the Kyoto Protocol.
[11] 1Mg = 1,000,000 grams = 1000 kg and 1000 kg = 1 tonne; therefore, 1 Mg = 1 tonne.

cultivation (Boehm 1995). A considerable percentage of this loss occurred in the first two decades following initial cultivation of the soil, after which the rate of loss slowed and soils approached a steady state where they were no longer losing carbon (Agriculture Table 1998; Sala *et al.* 1996).

Using the CENTURY model, Smith *et al.* (1997) estimated that average annual net emissions from cropland in Canada decreased from 10 million tonnes of CO_2 in 1970 to about 6 million tonnes in 1990. The decrease in net soil emissions has occurred because soil carbon is reaching a new equilibrium, due to an increase in soil-conserving, low-disturbance cropping practices and smaller increments of land being converted into cropland over the two decades from 1970 to 1990 (Sinks Table 1998).

Smith *et al.* (1997) predict that Canadian agricultural soils will become a net sink of 1.8 million tonnes of CO_2 by 2010 if current trends in farm management practices continue.[12] That is, if there are no significant changes in current farm management practices, 1.8 million tonnes of CO_2 per year will be the rate of soil organic carbon change in soils. The Saskatchewan Soil Conservation Association (SSCA) estimates that annual carbon sequestration rates for the three prairie provinces was between 2 and 3.4 million tonnes of CO_2 equivalent in 1996; they believe their estimates are conservative (Sinks Table 1998).

Soil organic carbon is a key indicator of soil health. Therefore, it is routinely measured in both local and regional soil studies (Sinks Table 1998; Acton and Gregorich 1995). Canada's national soil survey database includes information from which researchers can estimate changes in soil carbon; this database will be very beneficial when considering the possibility of using agricultural land as a sink. It is predicted that in a twenty-year period as much as 736 million tonnes of CO_2 equivalent could be sequestered using agricultural land in Canada (Soil Conservation Council of Canada 1998, 3).[13] The research on soil organic carbon provides the basis upon which to develop the relation between atmospheric carbon and soil carbon gains or losses.

Canada's agricultural land base in 1996 was approximately 68 million hectares; approximately 45.5 million hectares of which was annually cropped, summerfallowed, or in improved pasture (Sinks Table 1998, sec. 4.1.1). The four western provinces contained 86 percent of the 45.5 million hectares of improved cropland. This vast amount of agricultural land coupled with the ability of crops to remove carbon from the atmosphere and the ability to sequester carbon in soil provides a significant opportunity for western Canadian agricultural soils to store carbon.

It is important to keep in mind that by itself carbon sequestration in agricultural soils can only make a small contribution to mitigating GHG emissions (Paustian, *et al.* 1997). Relative to the amount of fossil fuels currently being burned in Canada, only small amounts of carbon can be

[12] Smith assumes that some soils are still a small source of CO_2, whereas in Bruce *et al*. (1998) soils are assumed to be at a constant carbon level so that any improvement implies a net gain of carbon.

[13] This is a much higher estimate than that given by Smith, which indicates the presence of uncertainty surrounding potential for carbon gains. The SSCA and Bruce *et al* (1998) assume high adoption rates and Bruce's estimates include 61.1 million Ha of Canadian agricultural land (most of the total agricultural land) while the CENTURY Model only covers cropland area (45.5 million hectares) (Sinks Table 1998).

sequestered in Canadian agricultural soils. Therefore, increasing carbon storage may best be thought of as a transitionary measure rather than a long-term solution (Ellert and Janzen 1996; Janzen *et al.* 1998).

The Prairie Soil Carbon Balance Project (PSCB), which is funded in part by the Greenhouse Emissions Management Consortium (GEMCo)[14], arose out of an interest in using agricultural land as a carbon sink. GEMCo has two objectives, the first is to promote carbon-sequestering practices in order to reduce atmospheric CO_2 levels, and the second is to develop a framework for measuring carbon sequestration in soils. The objective of the PSCB is to develop a 'cost-effective, scientifically defensible set of tools for estimating and verifying soil carbon changes in response to various agricultural management practices' (Frick 1999). The success of the PSCB project could further facilitate the successful development of a market for ERC because verifiable measurement of changes in soil carbon are needed to make the monitoring of soil carbon more reliable.

Despite the vast amount of research done on soil organic matter, an accurate estimation of potential carbon sequestration remains constrained by the availability of methods designed to quantify, predict and verify changes in soil carbon (Janzen 1998). If the ERC market that is proposed in this study is to be operational, there must be a verifiable, quantifiable measure of the change in soil carbon developed for use on the hectares registered in the program. There is, however, general agreement that agricultural soil can be managed in such a way as to increase the amount of carbon sequestered in it.

2.2 Land Management Practices and Carbon Sequestration Potential

2.2.1 General Land Management Practices

The net result of carbon input through the addition of plant litter and carbon loss through decomposition is reflected in the change in soil carbon content (Bruce *et al.* 1998). Therefore, in order to elicit a gain in carbon storage, a new management practice must; 1) increase the amount of carbon entering the soil as plant residues, or 2) suppress the rate of soil carbon decomposition. There are several land management practices that can increase the soil organic carbon (SOC) sequestration potential of agricultural soils. These best management practices include:

1) Reduction in summerfallow;
2) Zero and minimum-tillage;
3) Direct (low disturbance) seeding;
4) Conversion of marginal cropland to permanent cover crops;
5) Rotational grazing, and;
6) Intensive use of fertilizer on cropland and pastureland. (Sinks Table 1998; Bruce *et al.* 1998; Runnalls 1998; Dumanski *et al.* 1995; Janzen *et al.* 1998).

The adoption of these best management practices could sequester approximately 50 to 75 percent of the total agricultural emissions of CO_2 in Canada for the next 30 years (Dumanski *et al.* 1995:1).

[14] GEMCo is an affiliation of utilities and other industries using fossil fuels (Wilson 1999).

With respect to cultivated land, numerous strategies for increasing carbon sequestration have been identified. These strategies can be broadly classified into four main approaches:

1) A reduction in tillage intensity;
2) Intensification of cropping systems;
3) Adoption of yield promoting practices, including improved nutrient amendment, and;
4) The reestablishment of permanent perennial vegetation (Bruce *et al.* 1998).

Adoption of practices with reduced tillage can result in significant accumulation of soil carbon, which can be further enhanced if yield increases are also occurring.

2.2.2 Specific Management Practices and Carbon Sequestration Potential

Two land management practices that can be used to increase the carbon sequestration capacity of agricultural soils are focussed on in this study. They are; 1) the conversion of cultivated land to permanent cover, and 2) the use of zero-tillage, direct-seeding technologies.

Zero-tillage, direct-seeding systems disturb the soil only when the seed is placed directly into stubble with low disturbance air seeders and when fertilizer is banded. As a result of low soil disturbance SOC decomposition is reduced and more carbon remains in the soil than in conventional systems (Boehm 1999). Summerfallow based on chemical weed control, rather than tillage can be part of a direct seeding, zero-tillage system but continuous cropping systems that involved pre-seeding or post-harvest tillage would be classified as minimum-tillage.

On cultivated land, the average rate of carbon accumulation following the adoption of improved land management practices has been estimated to be approximately 0.3 Mg/Ha/year (Bruce *et al.* 1998, 13).[15] This is equivalent to 1.1 tonnes of CO_2 per hectare per year.[16] The rate of carbon accumulation will vary depending upon the initial carbon status of the soil, the climatic region, and other agronomic variables such as fertilizer application and crop sequence.

Although zero-tillage, direct-seeding practices provide several benefits, they cannot be used everywhere. For example, a recent PFRA survey in Saskatchewan found that more than 70 percent of cropped fields in the Dark Brown and Black soil zones are suitable for direct seeding but only half of the fields in the Brown soil zone are suitable (PFRA 1997). However, results indicated that 93 percent of all summerfallow fields can be direct seeded in the Brown and Dark Brown soil zones while generally all summerfallow fields in the Black and Grey soil zones can be direct seeded.

Zero-tillage agriculture is already expanding rapidly in the prairies because it has many advantages in addition to carbon sequestration such as improvements in soil tilth, moisture retention, and reduced erosion (Runnalls 1998; Bryce *et al.* 1999). In addition, zero-till requires less machinery use, so farm emissions of CO_2 are also reduced. However, nitrogen fertilizer applications, hence N_2O emissions, may increase. When combined with other strategies of carbon sequestration and fossil fuel emission reductions, widespread implementation of conservation tillage practices could prove to be significant in alleviating the impacts of climate change (Kern and Johnson 1993).

[15] This is a conservative estimate that has been averaged for Canadian cultivated land.
[16] The ration of CO_2:C is 44:12 = 3.67:1. Therefore, to convert from carbon to CO_2 requires multiplication of 3.67; ie. 1Mg C = 3.67 Mg CO_2.

In Saskatchewan, 22 percent of croplands were under a zero-tillage system in 1996, up from 10 percent in 1991; 10 percent of Alberta's and 9 percent of Manitoba's croplands were under a zero-tillage system in 1996 (Soil Conservation Council of Canada 1998, 2). Technology transfer programs that provide farmers with information regarding the proper techniques used in conservation tillage and the benefits concerning the use of these techniques will be fundamental in promoting the use of conservation tillage (Soil Conservation Council of Canada 1998). This in turn will promote the use of practices that improve the carbon sequestration capacity of soil.

Set-aside land provides an opportunity for the most effective way of restoring soil carbon by reestablishing and maintaining perennial vegetation (Bruce *et al.* 1998). The conversion of cultivated land to perennial grasses or forage sequesters carbon at a higher rate than the use of zero-tillage, direct-seeding systems. The higher rate of sequestration occurs because soil is not disturbed by physical tillage, little carbon is removed in harvesting, and there is a greater allocation of carbon below ground (Bruce *et al.* 1998).

Analysis of land under the U.S. Conservation Reserve Program indicates levels of soil organic matter of 0.1 to 0.4 Mg/Ha/year in addition to total below ground carbon levels of 0.25 to 1.35 Mg/Ha/year (Bruce *et al.* 1998, 13). Therefore, conversion to permanent cover can potentially sequester between 1.28 tonnes[17] and 6.42 tonnes[18] of CO_2 equivalent per hectare per year. Even though reestablishment of grasses or trees on cultivated lands may achieve the highest carbon gain per unit of land area, it requires removing land from annual crop production, which may limit the economic attractiveness of this management practice.

The crops grown and the soil type both have great impact on the ability of soil to sequester carbon when using the best management practices previously mentioned. For example, Campbell *et al.* (1996a) concluded that for coarse-textured soils located in semi-arid regions there was only limited ability to sequester additional carbon if monoculture cereal systems were used under conventional or no-tillage practices because a lack of available water constrains biomass production above current levels. It has also been found that carbon gains are related to the clay content of soils because the ability to sequester carbon is related to the production of biomass; consequently, residue input and soil clay content must be considered when estimating carbon storage in soils (Campbell *et al.* 1996b). There is also inherent variability in SOC levels, which increases as one moves from level areas to topographically variable surfaces (Pennock 1999). This variability among crops, soil type, and topography adds to the complexity of establishing initial soil carbon levels and determining carbon sequestration capacity, both of which are needed to estimate the number of CO_2 credits that can be generated using a particular parcel of land.

Unfortunately, there are problems with some of the best management practices for carbon sequestration as they are outlined above. First, there is a problem with the amount of nitrogen fertilizers that are required to achieve high rates of plant growth and photosynthetic capability in cultivated agricultural systems. Large inputs of nitrogen fertilizer can increase N_2O emissions,

[17] (O.1 + 0.25) * 3.67 = 1.28 tonnes CO_2/Ha/yr.
[18] (0.4 + 1.35) * 3.67 = 6.42 tonnes CO_2/Ha/yr.

which contribute to global warming with about 310 times the warming potential of CO_2 (Boehm 1999).

Secondly, intensive-grazing programs[19] that require the production of more cattle can lead to increased methane emissions. This is not to say that fertilization and intensive grazing cannot be used to reduce overall GHG emissions, but producers must be careful to use these practices so that net GHG emissions of CO_2, N_2O, and CH_4 are reduced.

Thirdly, following a change to management practices that increase the stock of soil carbon, the yearly rate of gain will diminish with time (over a period of about 15 to 30 years) as the soil reaches a new carbon balance under the new management practices (Boehm 1999). Thus, carbon sequestration in soils cannot be expected to continue at the same rate forever under a given set of production technologies.

2.3 Summary

Research has shown that if Canadian farmers can be mobilized to adopt some of the land management techniques mentioned above at a faster rate, agricultural soils could become a larger net sink than reported by Smith *et al*. (1997). The development of a market for ERC could encourage farmers to adopt these best management practices thereby benefiting the farmer, the CO_2 emitting companies and society if net emissions are reduced. The creation of this market would not be a restrictive 'stick' policy option, but rather an opportunity to receive additional benefits from management practices that improve soil tilth, soil moisture and organic carbon levels, and result in more efficient use of inputs. The combination of these benefits may help to improve agricultural sustainability.

Research focused on the development of verifiable and quantifiable measurements in soil carbon such as that being conducted in the PSCB project will promote the use of soil as a carbon sink and may result in agricultural soil becoming recognized as a sink under the Kyoto Protocol. A globally acceptable way in which to measure the amount of carbon being sequestered in soil, or to estimate these levels using computer models, is still needed.

Agricultural land in western Canada has the potential to sequester vast amounts of carbon. Land management practices such as reduced tillage, increased use of perennial forages, and more intensive use of fertilizers can increase the carbon sequestration capacity of these soils. Incentives to adopt these practices, such as a market for carbon, will promote their use. The sequestering of carbon in agricultural soil facilitates the development of the ERC market in this study.

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[19] The grazing option was not expanded upon in this study but it does provide an additional way to sequester carbon.

Chapter Three: Conceptual Framework

3.0 Introduction

The conceptual development of a market where carbon credits can be bought and sold is the focus of this chapter. Following the implementation of a quota that restricts CO_2 emissions, emitters will need to comply with the new emissions standards. They can use the credits, which are generated by sequestering carbon in agricultural soil, to offset their emissions.[20]

Three organization options for the ERC market are proposed and the advantages and disadvantages of each are indicated. First, a bilateral market where buyers and sellers interact through a commodity exchange is developed. Then two options that involve agencies, one public and one private that facilitate trade are developed. The role of the agencies is to reduce the transaction costs in the ERC market.

Two carbon sequestration practices are considered for use in the ERC market:

1) The removal of land from annual production (the use of permanent cover crops), and;
2) The use of zero-tillage and direct-seeding technologies.

Each of these two management activities sequesters a different amount of carbon per hectare and monitoring techniques used for each activity are different. Consequently, any transaction costs that are calculated per hectare as well as the monitoring costs are different between these two activities. As shown in Chapter Six, contract[21] size affects transaction costs that are calculated per contract, such as time costs and brokerage fees.

3.1 Transaction Costs and Efficiency Criteria

Williamson (1981) says that a transaction takes place when a good or service is transferred across a technologically separable interface, such as from one stage of production to another. Transaction costs are the costs associated with this transfer. Arrow (1969, 48) defines transaction costs as the “cost of running the economic system”, and compares transaction costs to the friction that is found in physical systems.

The criteria used to evaluate the efficiency of the three market options are the total transaction costs involved, which include the contracting, consummating, and monitoring of the agreement between the seller of carbon credits (the landowner) and the buyer of those credits (the utility company). As Dudek and Wiener (1996) note, transaction costs are not only the out-of-pocket expenses incurred by the parties but also include the opportunity costs, such as lost time and resources, that could have been dedicated to the next best opportunity. These opportunity costs are not included in this study; however, it is important to remember that they do exist.

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[20] Landowners (producers) may also need to use credits if their emissions increase.
[21] Transaction costs are calculated for contract sizes of 20, 100, and 1000 tonnes of CO_2

Transaction costs differ from one another in three principal dimensions (Malla *et. al* 1998). Each of these dimensions defines the essential characteristics of a transaction by answering three questions; "*Why are certain participants involved?"; "Is this mutually satisfying exchange a one time event?";* and *"Does the nature of the exchange preclude interest from other parties, for other purposes, or is it specific to only this instance?"* (Malla *et al.* 1998, 4). Williamson (1979) defines these three characteristics as uncertainty, frequency, and asset specificity.

Uncertainty in the transaction can arise from a lack of communication or from strategic behaviour. Uncertainty in the ERC market may also arise because of the agronomic uncertainties that are associated with carbon sequestration using zero-tillage and direct-seeding technologies. Frequency of the transaction can be classified as either occasional or recurring; frequency in this market varies depending upon which option is chosen. Finally, asset specificity refers to [capital] investments that have a lower value in an alternative use, or the salvage value of the asset is low. Asset specificity will not play a large role in this market because the machinery used in the farming practices is salvageable and no other specific assets are used.[22] In addition, asset specificity does not apply to the credits themselves, as the credits earned on over a set time period and are easily transferable, assuming that no arbitrary legal restrictions apply to the credits.

Transaction costs include search, negotiation, and enforcement costs (Dahlman 1979).[23] Search costs are those involved in locating individuals whose interests make them likely candidates for a transaction (Malla *et al.* 1998). In the market for ERC the candidates are primarily the utility companies that are interested in offsetting CO_2 emissions[24] and landowners who are interested in being compensated for sequestering carbon. *Ex ante* search costs also include the costs involved in obtaining the pertinent information needed to plan a long-term project (Ostrom *et al.* 1993). Solomon (1998) points out that in an offset market, such as the one for ERC, search costs may be more significant than in allowance markets because fewer emission sources are covered in offset markets, which tends to make the search for suitable trading partners more costly.

Negotiation costs are the costs of negotiating agreements among participants who may differ with respect to their preferences, resources, and information, and then achieving an agreement upon the terms of sale (Ostrom *et al.* 1993). These costs include the drafting of the contracts and the conservation easements. The use of standardized contracts and sales made in standardized job and board lot[25] sizes will reduce the negotiation costs involved in the market. Negotiation involves communication with all relevant parties, including buyers, sellers, and regulators.

Enforcement costs are those associated with ensuring that participants are living up to their contractual obligations; these are primarily *ex post* costs. These costs include those involved in the monitoring of participant performance, the sanctioning and governance of the project, and the renegotiation of the agreement if needed (Ostrom *et al.* 1993). Which carbon sequestration

[22] One could consider the land under a conservation easement to be a site-specific asset.
[23] Dudek and Winer (1996) also include approval, monitoring, and insurance costs. Insurance costs may be important in this market as there are numerous reasons why a certain amount of carbon cannot be delivered.
[24] Other candidates could include environmental groups or governments interested in reducing emissions.
[25] Following the WCE, one job lot equals 20 tonnes; one board lot is equivalent to 5 job lots (100 tonnes).

practice is used and which monitoring method is chosen affects the enforcement costs for the ERC market.

Approval costs arise when the transaction in question must be approved by a government agency (Dudek and Wiener 1996). Approval costs could apply to the ERC market depending upon the level of government involvement in the market and the market option used. Approval costs are also affected by the need for Kyoto verification of soil carbon levels and approval of the market by the international community. If approval costs are high, negotiation costs will increase if trading partners are less confident that government approval of a trade will be secured (Solomon 1998).

All costs associated with the adoption of carbon sequestration practices, verifying changes in soil carbon levels and selling the credits are included in the seller's price, which must not exceed what the buyer is willing to pay (Sinks Table 1998). Research is currently being done on what a tonne of sequestered carbon may be worth, estimates range from U.S. \$3.00 to U.S. \$31.50 per tonne of CO_2 equivalent, which is approximately \$4 to \$50 Canadian per tonne (Haites 1999, 32). If the price of CO_2 cannot cover the transaction costs involved in this market, then the market will never become operational. No matter which market option developed is most efficient, its implementation and endurance will ultimately depend upon the price of carbon.

3.2 Options for ERC Market Organization

There is a range of options available for the organization of the ERC market. Two options looked at in this study incorporate the use of conservation easements[26] while the third uses a system of short-term contracts. The purpose of this study is to discover the market organization option that is most efficient, given transaction costs. This is not to say that only one option can be used; there could be several market organizations being used at one time. Different market participants may prefer a market option on the basis of transaction costs alone, or on the basis of some other criteria such as risk.

The ERC market involves trade in paper credit certificates instead of trade in a tangible product. The buyers of the credits need not necessarily be utility companies but may be some type of environmental organization. In addition, utility companies themselves may be in a selling position if they find they have purchased an excess amount of credits. The need to monitor landowner behaviour and the problems associated with verifying soil carbon levels add to the complexity of the ERC market.

[26] Although the use of conservation easements is examined in this study, the use of restrictive covenants may be beneficial in certain situations such as when a utility company wants to place a restrictive covenant on land adjoining its own land. The fact that land under a restrictive covenant must be adjoining the land of the party benefiting from the covenant greatly limits the use of restrictive covenants. In addition, restrictive covenants cannot be used to impose a positive obligation; i.e. one cannot use a restrictive covenant to force a landowner to put cultivated land under permanent cover; rather, it can only be used to prevent a landowner from breaking land that is already under permanent cover.

The contracts used in each option must stipulate what land is to be part of the ERC market, the classification of that land, and the initial characteristics of the land. The initial characteristics of the land under contract, such as the soil zone and soil type, must be known prior to contracting in order to determine how much carbon is expected to be sequestered by that particular piece of land.[27] All contracts must be negotiated on the basis of observable behaviour, which includes the use of zero-tillage and direct-seeding land management practices and the use of permanent cover crops.

One method that can be used to verify soil carbon levels is modeling. If this method is used, it is important that at the beginning of the negotiation for CO_2 credits it is understood by both parties that model verification can be conducted intermittently. These models may be improved upon as knowledge of the impact of specific production practices improves. The expected amount of carbon sequestration also changes if extreme weather conditions occur.[28] The soil carbon estimates can later be verified through updated sampling or improved modeling methods.[29] In order to avoid costly legal complications, the terms under which soil carbon modeling is to be used for the purpose of verification must be agreed to *ex ante*.

The contracts used in each option also state who has the right to monitor the landowner and how that monitoring will be done. For each option, the contract is specified on the delivery of soil carbon in a specific year so that a contract for carbon sequestration done in 2000 would be separate from a contract for carbon sequestration done in 2001. This is done for analytical simplicity since otherwise questions of discounting and adding up carbon sequestration services over time would need to be addressed. In a market it might be simpler to bundle delivery of carbon services over a range of years into one contract since transactions costs per unit of carbon sequestered will be lowered.

Monitoring procedures are similar for all market options but differ between the two sequestration activities. Aerial photographs will be used to monitor permanent cover crops while on-farm inspections will be used to monitor land managed using zero-tillage and direct-seeding technologies. Monitoring in this case implies determining if the land management practices agreed to in the contract are being done. Satellite images and using the Global Positioning System (GPS) could eventually be used to monitor permanent cover crops. The Saskatchewan Crop Insurance Corporation (SCIC) has recently begun to use GPS in its insurance adjusting procedures (SCIC 1999).

Contracts must also specify if the landowner is to be paid on an *ex ante* basis for a stream of future soil carbon sequestration services, or on an *ex post* basis following observed carbon sequestration for a certain time period. The *ex ante* payment option provides the landowner with

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[27] The estimation of carbon sequestration potential is a difficult process that depends upon many factors; however, for this study the main point is that both parties to the contract must agree on factors that affect sequestration capacity before the contract is signed. This is part of the contract negotiation.

[28] Because of climate variability, the time period over which delivery can be guaranteed needs to be many years (10-20) to avoid this problem.

[29] Uncertainty regarding the amount of carbon sequestered, and whether or not that amount will change, may limit participation in the ERC market. Uncertainty in program design causes problems in the development of public policy.

money up front but may restrict land use practices. For example, limitations on the use of chemical fallow might prevent a producer from fallowing when weather conditions warrant. The problem with the *ex post* payment option is that administration costs might be higher and yearly fluctuations in both the value of CO_2 credits and crop yields may expose the landowner to a variable rate of return. Either payment method could be applied to any market organization option.

The development of a credit buy-back option is necessary so that if, for some reason such as economic downturn or weather, the producer[30] has to discontinue the sequestration practice agreed to in the original contract, the credits originally sold can be bought back. The landowner, or producer, must buy credits to cover the amount of carbon released when the land is disturbed.[31] The buy-back of credits would occur at the current market price, rather than the price the credits were originally sold for, in order to avoid a situation where massive buybacks could occur if credit prices were to rise.

In the two options where conservation easements are used, the party who holds the easement (the grantee) may have to give it up if land management practices were altered and credits had to be bought-back. It is very difficult to remove a conservation easement once it has been registered. The easement has to be removed by a court order, which is difficult to obtain if it is drafted and registered properly. However, conservation easements can be flexible, as long as they are used to satisfy the conservation purpose set out in the original agreement. It is possible to include a clause for variability, such as the postponement of certain rights under the conservation easement.[32] The postponement of rights allows producers to alter management practices.

With respect to enforcement of the contracts used in the following market options, only civil remedies, such as suing, can be used, as there is no criminal offence attached to breaking a contract (Kallio 1999). Although a penalty clause in the contract is not enforceable under the court system,[33] the court and legal costs incurred when cheating is detected may be high enough to deter it. The threat of successful legal action may be used to obtain out of court settlements. Instead of prosecution in a civil court system if violations against either party in the ERC market are found, a system of administrative penalties, which are imposed by government tribunals or officials, may be more appropriate for a credit-trading program (Rolfe 1998). Administrative penalties efficiently deter violations that are too minor for the civil courts. Legislation authorizing

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[30] The producer makes the agronomic decisions but it is the landowner that enters into the contract used in this market. In the case of land rental, an agreement would have to be worked out between the owner and the renter. This results in an additional negotiation cost; however, since each rental agreement is different this cost is not directly addressed in this study.

[31] The amount of carbon sequestered by a practice is not necessarily equal to the amount released by another practice, such as summer fallowing; therefore the landowner may have to buy-back more credits than were originally sold depending upon the specific change in the management practice.

[32] Legal drafting issues, such as who decides when the easement will be postponed, how long it will be postponed, and what compensation will be required, will need to be decided prior to registration of the conservation easement (Annand 1999).

[33] An example of a penalty clause is if the utility company tries to penalize the landowner $100 per hectare for non-compliance when the landowner was only paid $5 per hectare to use the sequestration practice.

the use of a strict penalty may reduce the need to monitor landowners because the penalty for non-compliance is greater under a legislated penalty system than under a civil system[34].

The Kyoto baseline year is 1990[35] and a small percentage of producers were already using land management practices that sequestered carbon at that time; therefore, the organizers of this market must be careful that credit under Kyoto is not being given for something that was done prior to 1990. For example, if enough land is registered to sequester one million tonnes of CO_2 but 10% of that area was already being managed under a zero-tillage, direct-seeding system in 1990 then in reality only 900,000 tonnes have been sequestered since the baseline year because 10% was sequestered prior to 1990. Organizers must be careful to ensure that there is not a 'dirty base' upon which the market is built. This problem is referred to as 'slippage' and is common in acreage reduction programs. Slippage can be thought of as the price paid for the use of a voluntary, as opposed to compulsory, program. Following the protocol of the Emission Trading Program in the United States, the ERCs must be real, permanent[36], quantifiable, enforceable, and surplus (Solomon 1998).

3.2.1 Market Option A

This option is direct entry[37] into the market, similar to the EPA's market for SO_2 allowances in the U. S. where the allowances are traded on the CBOT. CO_2 credits become a commodity like any other commodity traded on the Winnipeg Commodity Exchange (WCE).[38] Normally, credits would initially be traded in a spot[39] or forward cash market[40] situation, and as these spot and forward cash markets become more developed the chance to introduce cash-settled CO_2 credits as futures derivatives exists (Agralink 1999). However, for the case of CO_2 credits, it is likely that trading will begin through the use of futures contracts[41] because reductions in GHG prior to 2008 have no value under the Kyoto Protocol[42].

If the market for ERC is in place prior to the 2008 start for Kyoto accounting then it is possible that futures may be traded years before the emission reductions are counted under the Kyoto

[34] Though tobacco companies in the U.S. have preferred to seek the certain punishment of administrative penalties to the ravages of civil suits where extraordinary levels of compensatory damages might be awarded. Tobacco company stock prices went up when a preliminary announcement was made of a $200 billion deal with U.S. governments in return for protection from civil suits (Tobacco Task Force Report of November 6, 1999, Office of the Attorney General, Washington State).
[35] GHG reductions are from 1990 levels, not that 1990 is the start date of the agreement.
[36] Excluding the short-term contracts for sequestration in Market Option C.
[37] Direct entry in this context is entry into the market without having to use a middleman or agent.
[38] The credits could be traded on any exchange however, the WCE is in Western Canada, which is the area of focus for this study; and the WCE specializes in futures trading.
[39] Spot markets are characterized by the purchase and sale of a commodity for immediate delivery (United Nations 1995)
[40] Forward contracts where the buyer and seller agree today on a product that will be delivered at some future date; there is a credit risk involved (CFTC 1998; United Nations 1995).
[41] A futures market involves the trade in agreements to buy or sell an asset at a certain price at a future date; the contract is usually standardized (United Nations 1995).
[42]Negotiations at IPCC are in progress to see if any credit will be provided for early action. The Canadian government has committed itself to creating a system to provide credit for early voluntary action.

agreement. Therefore, in this special case the market would begin with forward contracts and futures prior to the development of the cash market in 2008. Regardless of when futures trading begin, the New Product Committee at the WCE must conduct a preliminary economic assessment of the commodity (Love 1999).

The preliminary assessment normally includes an extensive examination of the underlying cash market, which may not be possible in the case of CO_2. In addition to the examination of the cash market, the following conditions must be met in order for the commodity to pass the initial assessment:

1) Existence of an active spot and forward cash market;
2) Widely distributed market participants;[43]
3) Sufficient volumes of the underlying commodity;
4) Variability of supply;
5) The need for price discovery;
6) Price volatility, and;
7) Ongoing access to cash market information.[44]

The creation of the futures contract for a new commodity must provide economic benefits such as price discovery and the more efficient use of available resources. Once the commodity has passed the initial economic assessment, a complete feasibility study of the commodity is conducted at a (minimum) cost of $150,000 (Love 1999).

Although most commodities approved for futures trading are initially traded in a well-developed cash market, there are exceptions to this rule for some new commodities. In particular, for the case of ERC, the need for price discovery and the lack of a viable hedging alternative may outweigh the disadvantage associated with the lack of a well-established cash market. Trade in the cash market would begin in 2008; therefore, the condition stipulating ongoing access to cash market information will be met at that time.

The trades conducted through the WCE are used to determine price in the marketplace. If the market is too thin, which may or may not be the case, there could be a problem with price discovery under this market option. Not all transactions under this option would need to go through the WCE; spot cash and forward cash transactions could be conducted directly from seller to buyer. This is similar to a cash market situation such as selling feed barley to your neighbor, it is sold directly but the price is determined in a larger market. Buyers and sellers can use the WCE but they do not have to.

Conservation easements are used in this option to legally bind the landowner to sequester carbon in perpetuity. The grantor of the easement in this option is the landowner, while the grantee of the easement is an organization such as the Saskatchewan Soil Conservation Association (SSCA).[45] The grantee of the easement is ultimately responsible for monitoring the grantor's

[43] This is a regulatory concern; one or two firms cannot be allowed to dominate the market.
[44] This is needed for maintenance of the contract.
[45] The SSCA is used for illustrative purposes only. As the law currently stands, the holder of the conservation easement (the grantee) must be one of only a handful of approved agents, all of who must have an interest in the conservation of the land.

behaviour.[46] The SSCA has the knowledge and infrastructure to monitor the practices used in this market that not only sequester carbon but conserve soil as well. The burden of enforcement in this option, as well as in Option B, is on the grantee of the conservation easement.

Contracts and easements can be negotiated between the landowner and the utility company for sales that are made directly from seller to buyer. However, following the registration of the conservation easement, most sales would be done through a broker. This would be similar to the use of WCE long-term contracts wherein the seller of the credit agrees to supply X tonnes of carbon over a certain time period and the value of each tonne is negotiated prior to delivery date.[47] The contract between the landowner and the broker would stipulate the amount of carbon to be sequestered by the landowner; after this amount has been agreed to the landowner is allowed to trade futures.[48]

Due to the use of conservation easements, the majority of the risk will be borne by the grantor of the easement, the landowner, because they are responsible for maintaining the farm management practices agreed to in the original contract. The penalty for non-compliance with the agreement made under the conservation easement will fall upon the current landowner because conservation easements run with the land.[49]

One advantage of this market is that the costs associated with conducting transactions through a central agency, such as commission costs, are eliminated. However, there are costs associated with using the WCE and brokers. This bilateral market is desirable for the utility companies because they would simply buy CO_2 credits and futures as they would any other commodity. Another advantage is the free market price discovery process that would occur in this market setting. This market option could co-exist with the other options so that the price of CO_2 can be determined in an open-market setting. The active buying and selling of futures contracts results in the market determining the best estimate of both today and tomorrow's prices for the underlying commodity (CFTC 1997). In an active futures market, price discovery, which is the process of arriving at a figure where one person will buy and another will sell, continues from the opening of the market until that day's close.

The WCE facilitates trade by providing the infrastructure and rules needed for the market (Love 1999). Tracking the ownership of [CO_2] futures contracts, which is very important because of the need for Kyoto verification, is the specialty of the WCE. Furthermore, futures markets encourage wide participation, which lessens the opportunity for control by a few buyers and sellers. This

[46] Because it is the Government of Canada who is ultimately responsible for abiding by the agreement made in Kyoto, a public agency may be set up to conduct all monitoring of GHG emissions. In this case the responsibility of monitoring would fall upon the government rather than an organization like the SSCA, which can be considered an agent of civil society rather than a public or private agent.
[47] Although the carbon does not actually get 'delivered' a pre-arranged date, such as the start of the crop year, could be used as a reference point indicating when the next years' carbon is to start being sequestered.
[48] This is the case if the broker is responsible for insuring that credits have been generated and verified; this may be done by a separate agency whose purpose is to monitor and verify the existence of carbon credits.
[49] In the case of land rental, an agreement between the renter and owner will have to be negotiated and made part of the rental contract. This would be similar to cases where the owner stipulates that a certain amount of the land under contract must be summerfallowed.

participation is encouraged because of relatively low transaction costs and frequent trading (CFTC 1997).

Disadvantages of this option for the landowner are the risks associated with restricting land use through a conservation easement, which may prevent agronomically correct practices from being performed. A conservation easement restricts not only the current landowner, but future landowners as well, which may cause the value of the land to depreciate and may discourage landowners from entering the market. The agronomic risks associated with the use of zero-tillage, direct-seeding technologies are compounded because of the limitations placed on the land by the conservation easement. It is also very expensive to get small farmers into this type of market because stock brokers charge higher prices for small transactions. Negotiation costs are high for a landowner that is sequestering a relatively low amount of carbon.

The following flowchart depicts the chain of events that must occur in this market option in order for the CO_2 credit to be created and transferred from seller to buyer.

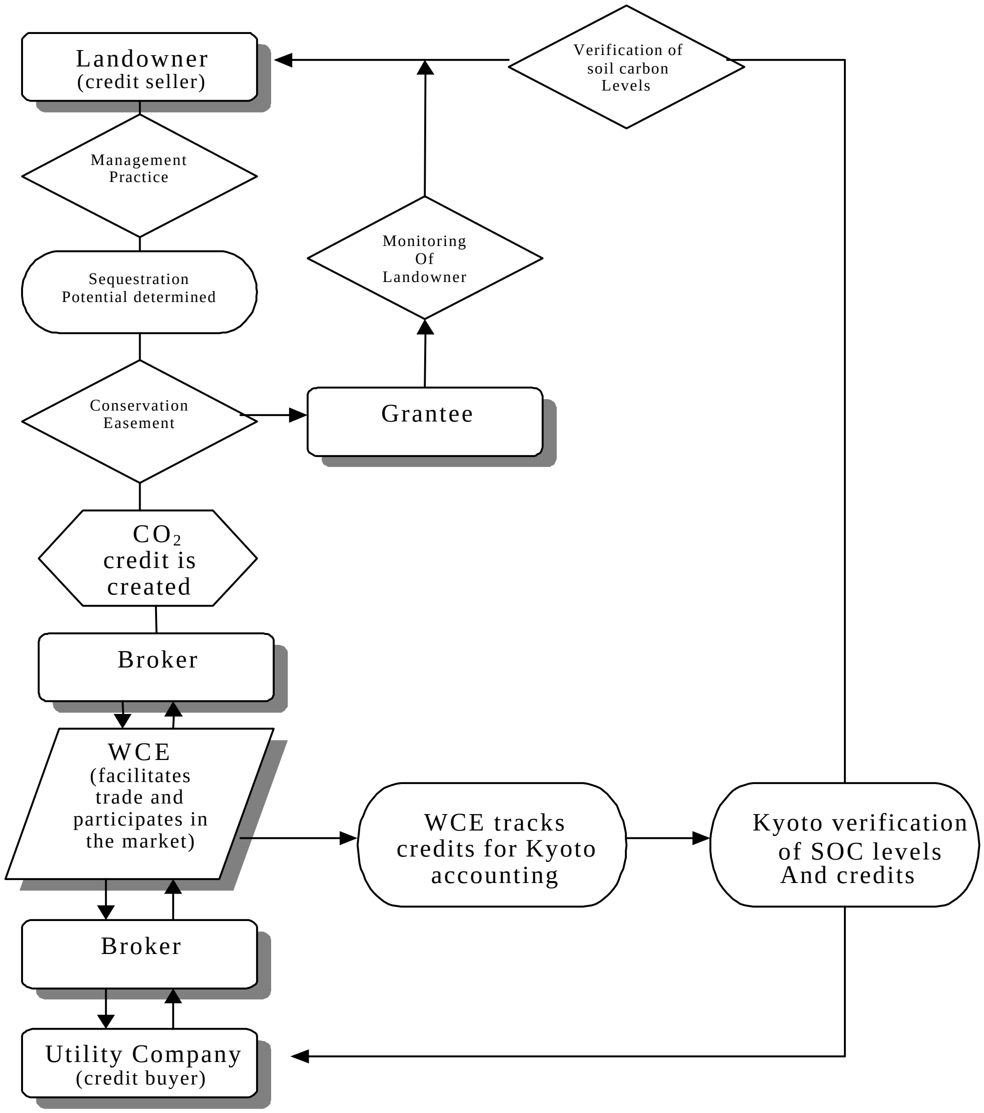

Figure 3.1: Market Option A - Chain of Events

3.2.2 Market Option B

Transactions in this market option are conducted through a central agency such as PFRA.[50] Conservation easements are used to ensure that carbon is sequestered in perpetuity and that the landowner is responsible for obliging by the terms set out in the easement. Once again, CO_2 could be traded in standardized job and board lot sizes in order to increase simplicity and reduce negotiation costs. Because of the rules regarding who the grantee of a conservation

[50] PFRA is referred to for illustrative purposes only.

easement can be, the agency in this case will have to be a public central agency[51] (Kwasniak 1997; Annand and Curry 1999). The central agent is responsible for monitoring landowner behaviour because the burden of enforcement is on the grantee of the conservation easement.

The transactions in this option are made from seller to buyer through the central agent, which can be thought of as a real estate agent that brings together the buyers and sellers of the CO_2 credits, or an agent who sells goods on consignment. The agent has a standardized contract that can be used for each transaction; the only factors that need to be negotiated are the size of the transaction and the price paid per tonne of CO_2. The intermediary agent is responsible for registering the conservation easements, and is also the grantee of the conservation easements. Although the agent is the grantee of the easement, the credit will be sold from the landowner to the utility company; there is no transfer of the CO_2 credit from the seller to the agent.

The value of the easement is determined by how much the utility company is paying for a tonne of CO_2. If the landowner is being paid $20 per tonne of CO_2 sequestered per year then the value of the easement to the owner of that land is $20 times the amount of carbon being sequestered on the land registered under the easement. The easiest way to pay for the carbon being sequestered is to pay *ex ante* for a future stream of carbon.[52] Although the price paid per tonne of CO_2 is negotiated on signing day, it could be stipulated in the contract that the price paid be renegotiated in, for example, ten-year intervals. This way the price reflects the value of the sequestered carbon closer than if a certain price was agreed upon at the onset of the contract to be paid in perpetuity.[53]

There is an incentive for the central agent to attract new landowners to the program because the agent earns a commission on each credit sold.[54] The agent may attract landowners by informing them of the current price for CO_2, promoting soil conservation through zero-tillage, direct-seeding technologies and proclaiming the benefits of putting marginal land under permanent cover.[55,56]
In return for advertising, negotiating and legal services, the intermediary agent earns a commission based on the value of the sale, which could range for 5-10% of the transaction value. Just as in real estate, the commission is paid by the seller, which should in principle affect the price the seller is willing to sell for. In essence the commission is shared between buyer and seller because the selling price is higher than it would have been in the absence of the commission.

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[51] The grantee of a conservation easement must be a qualified organization. A qualified organization is defined to be; a government or government agency, a local authority, or a nonprofit organization that has charitable status with Revenue Canada (Kwasniak 1997; Annand and Curry 1999).
[52] This assumes that inflation is built into the price; however, if inflation significantly rises it could cause a problem if this payment method is used.
[53] The problem of the price being paid for CO_2 not reflecting its current value could be eliminated if the futures market described in Option A existed along with this market option that uses a central agent.
[54] The central agent will advertise for the same reason a real estate agent advertises; more sellers means more commissions.
[55] The benefits of permanent cover include soil conservation, reduced input costs, and increased on-farm diversification.
[56] The project focussed on the use of zero-tillage that is currently being undertaken by TransAlta, the SSCA, and Monsanto promotes the benefits of zero-tillage and is similar to this idea of project promotion being undertaken by the central agency.

One advantage of this market option is that the central agent can link several sellers with a larger buyer. The linking of sellers makes it less expensive for smaller landowners to enter the market because commission costs will be reduced.[57] If smaller landowners find it less expensive to become part of the market when a central agency is used, more acres will be used to sequester carbon, thereby reducing more GHG.

Another potential advantage is that monitoring costs may be reduced if a central agent can monitor more efficiently than an organization such as the SSCA in the previous market option.[58] In this option, which makes use of a public central agent, legislation to permit the use of a penalty system for non-compliance could be passed.[59] Larger penalties such as fines, probation, or jail time, allowed under the legislated penalty system would reduce the need to monitor; therefore, transaction costs may be reduced.

The disadvantages of this market include the costs associated with having to use a public central agency, such as approval costs.[60] There are also costs now associated with the central agent, such as commission costs, which are potentially disadvantageous.[61] The disadvantages previously mentioned regarding the use of conservation easements are also applicable to this option. There is risk associated with setting a price for CO_2 if the landowner is paid for a future stream of carbon without there being a period when re-negotiation of the price occurs; this problem is exaggerated if no futures market exists.

The following flowchart depicts the chain of events that occurs in this option in order for the credit to be created and transferred from seller to buyer via the public agent.

Figure 3.2: Market Option B - Chain of Events

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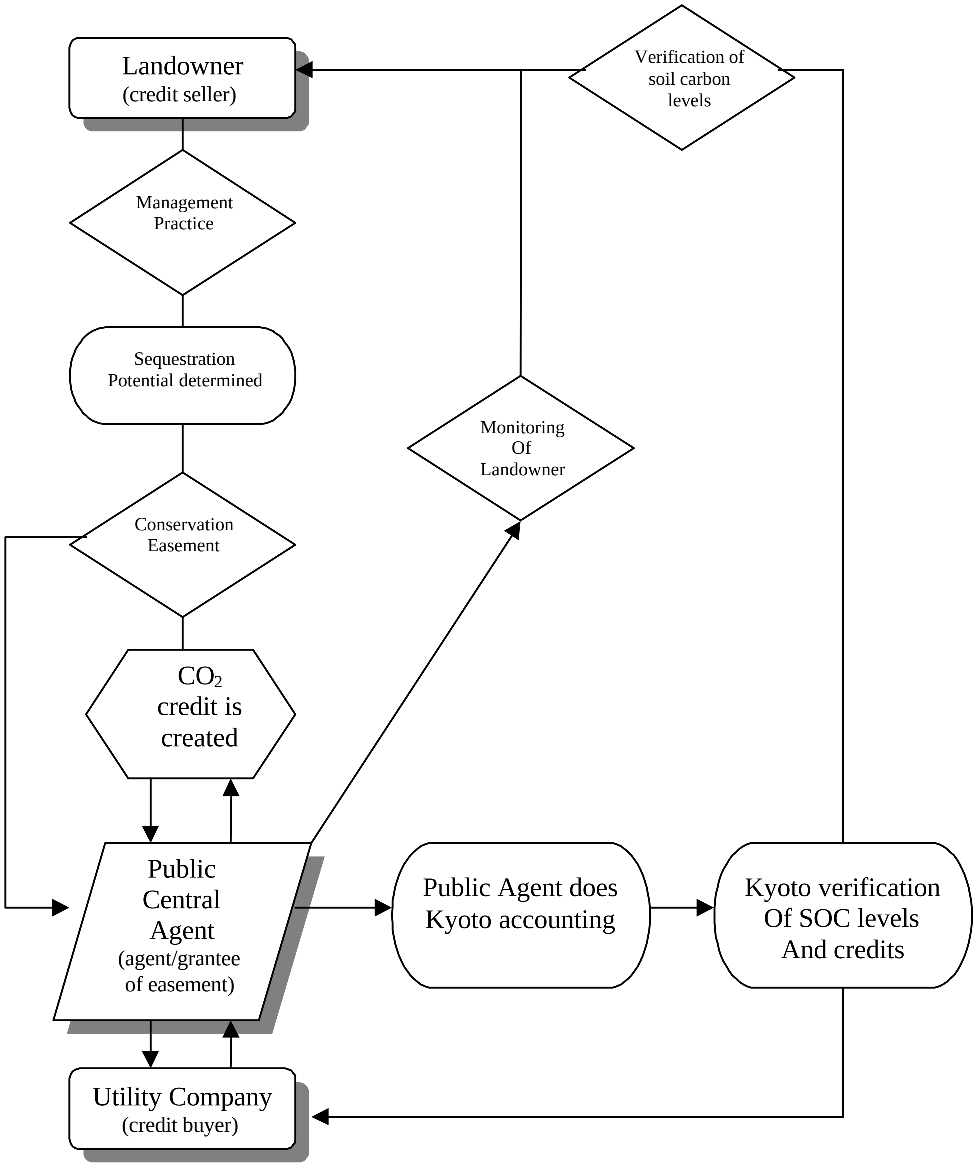
[57] Commission costs are calculated per sale, so one group of landowners selling to one utility company would only be one sale; as opposed to several landowners selling individually to one utility company.

[58] One of the first features standardized in the ERC market will be monitoring; if a commodity exchange is created, as in Option A, the commodity will have to be standardized, including monitoring procedures. If this is the case then Option B will have no advantage over Option A in terms of monitoring procedures.

[59] This type of legislation can be compared to the Crop Insurance Act in Saskatchewan that enables SCIC to distribute crop insurance, monitor producers, and penalize those who do not comply with their agreement.

[60] These costs are the costs associated with government having to approve the transactions; which may or may not be necessary depending upon the structure of the central agency (See Dudek and Wiener 1996).

[61] These costs are not a disadvantage if the central agency can conduct the transaction more efficiently than the direct buyer-seller negotiation. The commission paid to the central agent may be less than the cost of conducting the transaction without the agent.



Source: Author

3.2.3 Market Option C

Transactions in this option are conducted through a private agency and no conservation easements are used. Instead, short-term contracts are negotiated between the agent and the landowner wherein the landowner agrees to use a certain carbon sequestering management practice for a period of 3, 5, or 10 years.[62] The value of the contract, depending upon its duration, is a fraction of the value associated with trading a permanent reduction of CO_2 emissions.

[62] These are guidelines; however, three contract term options would provide enough choice without delaying the contract negotiations by providing too many choices.

It can be determined through modeling how much carbon is being sequestered per hectare, which depends on practice and soil zone. The estimated amount of carbon to be sequestered influences the amount the landowner is paid per hectare. The agency, via the use of a separate contract, then sells the CO_2 credits generated via carbon sequestration to the utility company who can then use the credit to offset their emissions.[63] The private agent can sell the credits generated by any number of landowners to an individual utility company, which will reduce the overall transaction costs because only one contract is needed instead of each landowner's credits being sold to one buyer.

The contract between the agency and the landowner specifies the amount the agent will pay the landowner per hectare to use the carbon sequestering practice agreed to by both parties. This is opposed to the previous market options wherein the landowner is paid for the credit created when the carbon is sequestered, rather than being paid to use a certain practice. This part of the market would be structured in a manner similar to how PFRA or Ducks Unlimited pay landowners to put land under permanent cover or forage.

In this market option there could be any number of private agents. In order to keep track of the CO_2 credits, hence GHG, for Kyoto accounting purposes, once a particular parcel of land is registered under contract to the agent it will become part of that agent's 'Kyoto Area'. This implies that the agent is responsible for the net carbon sequestration in that area, as well as in each individual parcel of land. If, for example, a landowner does not renew a contract with an agent, resulting in a loss of sequestration acreage, the agent is responsible for finding another landowner to sequester carbon equivalent to that which was lost. Monitoring of landowner behaviour is the responsibility of the private agent in this option. The agent must be able to verify that carbon is being sequestered and that the credits are valid.[64] The agent will be accountable to the government and credits must be real and quantifiable.

A mechanism is needed that can define the area for which the agent is responsible. These areas could be specific areas within a province or could spread across borders. The size of any one Kyoto Area will depend upon how many private agents are in the market and how successful they are at attracting landowners to register their land with them. The use of Kyoto Areas creates a competitive market among agents. However, the registering of land under two or more agents must be avoided. A system similar to the use of permit books that specify delivery points could be used to keep track of which land is registered under which agent's Kyoto Area.[65]

Contracts in this option must specify which land is in the agent's Kyoto Area; the first time that land is registered in the ERC market it will become part of the initial agent's Kyoto base. The contract must specify that if the landowner does X he will receive $Y per hectare for that action. The agent, by estimating how much carbon is sequestered on a particular parcel of land

[63] Use of this option depends upon whether or not a permanent reduction of GHG is needed, or if the reduction could be only for a certain period such as the 2008-2012 period addressed in the Kyoto Protocol.
[64] There will need to be an additional level of monitoring here to monitor the private agents.
[65] A system of competitive bidding similar to that used for mineral rights could be applied in this option.

determines how many credits are generated and then sells those credits to the utility companies that must offset their emissions.

The money to pay the landowners at the onset of the project could come from other investments the private agent has, or forward contracts could be made between the agent and utility companies where money changes hands that can be used to pay the landowners. After the program is fully operational, the money that the utility companies use to purchase the credits can be used to pay the landowners.

The private agent is essentially speculating on the market like a grain merchant who buys the grain from the producer and later sells it to the processor speculates on the grain market. The agent takes a long open position in the market, which is very risky. The basis associated with this option, which is made up of carrying costs, commission costs, and time value, is large. The private agent in this case must have vast monetary resources so that they are able to take on the risk involved in taking this long open position.[66] There are, however, potential gains to be made for the agent depending upon the price of CO_2 and market fluctuations. The agent bears the risk of price fluctuations in the carbon market for a certain period of time just as the grain merchant bears the risk of price changes while he has possession of the grain itself.

The landowner bears less risk in this option, even though climate variability poses a risk. There is less financial risk because payment is dependent only upon the practice used rather than the price of CO_2, and less agronomic risk because short-term contracts instead of conservation easements are used. More landowners may be attracted to the market if this option is available because their risk will be lower.

The primary advantage of this market option for the landowner is that there are fewer long-term restrictions on land use due to the absence of conservation easements. This allows the landowner to make more agronomically sound decisions without having to break a conservation easement agreement. Furthermore, the value of the land is not affected as much as with the conservation easement. The flexibility of short-term contracts may attract more landowners to the program. Another potential advantage for the landowner is that private agents will compete to get landowners registered under their Kyoto Area and to keep them in their Kyoto Area; therefore, the landowner may receive a higher price than if there was only one private agent in this type of market organization.

Disadvantages of this option are the costs associated with the negotiation of two contracts, one between the landowner and agent and one between the agent and the utility company. In addition, because of the short-term contracts, negotiations must take place more often, which ultimately results in higher costs. However, these costs could be offset by economies of scale in contract negotiation that are realized when a standard contract is used. Advertising costs may be higher because of competition; however, the net effect of these increased costs is likely to be minor. There is also a large amount of risk borne by the agent. The agent will require a premium to take on this risk, which will ultimately be paid by the participants in the market.

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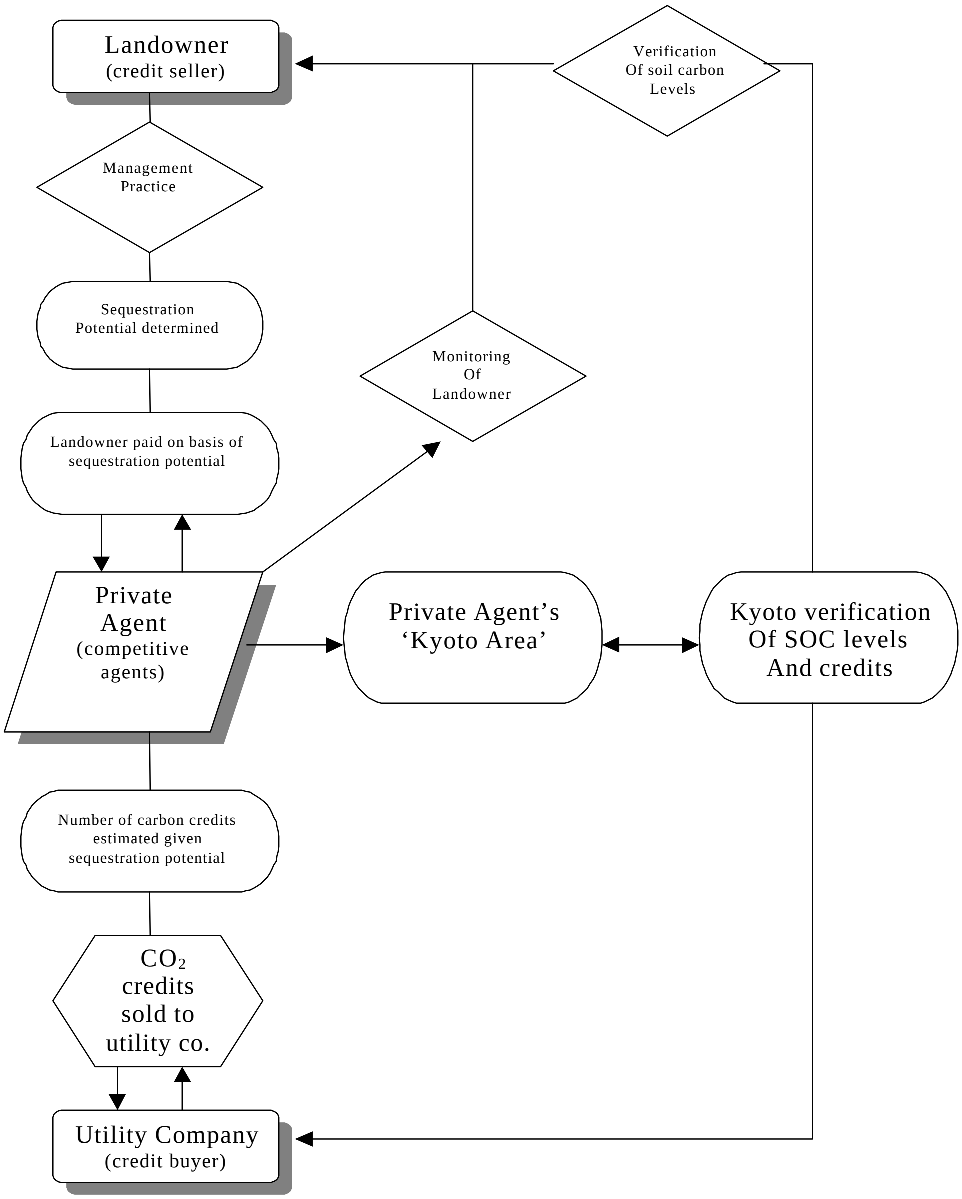
[66] The agent may be able to hedge credits if the market in Option A also exists, which would reduce the risk associated with the central agent holding the credits for an extended period of time.

The following flowchart depicts the chain of events that must occur in this option for the landowner to receive payment and for the credits to be created and sold.

Figure 3.3: Market Option C – Chain of Events



Source: Author

3.2.4 Summary of Options for Market Organization

Three market organization options have been described; one bilateral market that makes use of conservation easements and two markets that use intermediary agencies - one that uses conservation easements and one that does not. For each option there are two potential sequestration activities, the removal of land from production to be put under permanent cover and the use of zero-tillage, direct-seeding technologies.

The two options that involve the use of conservation easements are fundamentally different from the third option that uses contracts. The use of an easement ensures that the carbon sequestration is permanent[67] and that the practices used to sequester carbon are used in perpetuity. Depending upon the rules for Kyoto verification of sinks, the two options that involve the easements may be more credible under the Kyoto Protocol because the carbon is sequestered permanently.

In the two options where intermediary agents are used, these agents need to have the financial reserves necessary to take on the risks associated with the market. This is particularly important in Market Option C where the majority of the risk is passed from the landowner to the private agent.

The bilateral market outlined in Market Option A may have to exist in addition to either of the other options in order to discover a price for CO_2. Following the development of a futures, and later a cash, market the other two options may simply evolve to increase the efficiency of the market for ERC in western Canada.

With respect to the defining of Kyoto and non-Kyoto farms, land registered under the conservation easements used in Options A and B would be considered Kyoto farms because they have agreed to be monitored for the long term and have entered into a contract to sequester carbon. The land under short-term contracts in Option C will not likely be considered true Kyoto farms because they have not entered into a long-term commitment to sequester carbon. However, these farms would be accounted for under the private agent's Kyoto Area because there has been a commitment to sequester carbon and to have that land monitored, even if only for a short period of time.

All agricultural land involved in the market for ERC will be contributing to the reduction of GHG under the Kyoto Protocol. However, non-Kyoto farms could make a contribution to Kyoto if, for example, a fuel tax resulted in less fuel use on those farms. In addition, land management practices used on non-Kyoto farms will affect the levels of GHG in the atmosphere. The difference is that on non-Kyoto farms the practices used and the resulting changes in GHG levels will not be monitored or verified, contrary to those on the Kyoto farms.

Although only three market organization options were developed, there could be various combinations of these market options put into place, or entirely different options may be developed that are more efficient. There could, for example, be trading through private agents

[67] Even though a clause that allows for some agronomic freedom can be built into the easement; the long-term (permanent) objective of carbon sequestration is still met.

wherein landowners have made use of conservation easements. Variations in risk levels will also influence the acceptance of a particular market organization option.

Chapter Four: Empirical Analysis

4.0 Introduction

This chapter includes the empirical analysis of the transactions costs associated with each ERC market organization option. These costs have been put into matrices so that it can be clearly seen where the options differ with respect to transaction costs, and how the costs in each option differ with respect to sequestration activity and contract size.

The second section in this chapter is the sensitivity analysis, which illustrates how the price of CO_2 influences which market option, A or B, is most efficient. Also included in this chapter are the Transaction Abatement Cost curves that illustrate how the costs per tonne of CO_2 decrease as contract size increases.

4.1 Transaction Cost Analysis

The costs used in this section were estimated given data from a number of sources including PFRA, Ducks Unlimited, and the Winnipeg Commodity Exchange.[68] In the United Nations (1995) booklet on the precedents for tradable permits, one conclusion was that permits (credits) should be defined in terms of a homogeneous product, such as a metric tonne of CO_2 emissions.[69] Therefore, the transaction costs in the following matrices are quantified per tonne of CO_2 equivalent. Given that several of the costs were initially calculated on a per hectare basis, the more carbon that can be sequestered on a single hectare, which varies between the two sequestration activities, the less expensive the cost per tonne of CO_2 equivalent. The sequestration capacity of an individual parcel of land is also affected by soil zone, soil type, crops grown, yield, and weather. The more CO_2 equivalent sequestered in a single contract, hence the larger the contract, the less expensive the transaction on a per tonne basis. This is because many costs, such as the monitoring costs, are calculated per contract and are the same regardless of contract size.

The following matrices indicate two types of costs; infrastructure development costs (IDC) that are given in dollars and transaction costs that are quantified in dollars per tonne of CO_2 equivalent traded. Following Dahlman (1979) the transaction costs are separated into search, negotiation, and enforcement costs. IDC are encountered regardless of the number of market participants, the amount of land under contract in the market, or the sequestration practice used. One such fixed cost is the monitoring of the utility companies that purchase the credits; some agent responsible for monitoring all GHG emissions to ensure Canada is in accordance with the Kyoto Protocol must monitor these companies. Several IDC have been estimated in terms of their minimum cost

[68] It is assumed that the utility companies are acting individually and not as a group.
[69] It was decided by the UN/FCCC that a tradeable unit of GHG should be one metric tonne of CO_2 equivalent (Carpenter *et al.* 1999).

as the maximum costs depend upon the market organization and factors such as competition and regulation.

The costs that appear in the following matrices were taken from the calculations shown in Appendix A where detailed matrices for each market option are presented. The three contract sizes; 20, 100 and 1000 tonnes are roughly converted into hectares in order to show approximately how much land would be involved in a certain contract; the estimates of sequestration potential by Bruce *et al.* (1998) were used for the conversions.

4.1.1 Market Option A - Cost Matrix

Recall that this is the bilateral market between buyers and sellers wherein the WCE facilitates trade; conservation easements are also used in this market option.

Table 4.1: Market Option A - Infrastructure Development and Transaction Cost Matrix

	Carbon Sequestration Activity					
	Permanent Cover			**Direct-seeding/ Zero-tillage**		
	20 t (5 Ha)	**100 t** (26 Ha)	**1000 t** (260 Ha)	**20 t** (18Ha)	**100 t** (90 Ha)	**1000 t** (909 Ha)
Infrastructure Development Costs			**($)**			
Market Set-up	$150,500 minimum for feasibility study and contract drafting.					
Advertising	$100,000 minimum for additions to publications, pamphlets, etc.					
Sequestration Potential and Kyoto Verification	$12 million for development of measuring and monitoring Framework.					
Dispute Settlement	These costs will vary among individual situations.					
Transaction Costs			**($/tonne)**			
A. Search Costs						
Sales Costs	These costs are not applicable to this market option.					
Subtotal 1						
B. Negotiation Costs						
Time Costs	4.18	0.84	0.08	4.18	0.84	0.08
Contract Negotiation	0.97	0.97	0.97	3.41	3.41	3.41
WCE transaction fees	0.14	0.14	0.14	0.14	0.14	0.14
Brokerage fees	5.80	1.45	0.89	5.80	1.45	0.89
Conservation Easement Reg.	1.00	0.20	0.02	1.00	0.20	0.02
GST on WCE & Brokerage	0.42	0.11	0.07	0.42	0.11	0.07
Miscellaneous	2.50	0.50	0.05	2.50	0.50	0.05
Subtotal 2	**15.01**	**4.21**	**2.23**	**17.45**	**6.65**	**4.66**
C. Enforcement Costs						
Monitoring	0.50	0.10	0.01	1.45	0.29	0.03
Subtotal 3	**0.50**	**0.10**	**0.01**	**1.45**	**0.29**	**0.03**
Total Variable Costs =1+2+3	**15.51**	**4.31**	**2.24**	**18.90**	**6.94**	**4.69**

Source: Author's estimates and calculations.

The time costs and the brokerage fees are very high for a small (20 tonne) contract. Consequently, smaller landowners will have difficulty entering the market because the transaction costs are simply too high. Costs decrease for both sequestration activities as contract size increases, and differ between the two sequestration activities in both negotiation and monitoring costs.

4.1.2 Market Option B - Cost Matrix

This option makes use of a public agent that acts as an intermediary between the buyers and sellers of carbon credits. Conservation easements are used in this option.

Table 1: Market Option B - Infrastructure Development and Transaction Cost Matrix

	Carbon Sequestration Activity					
	Permanent Cover			Direct-seeding/ Zero-tillage		
	20 t (5 Ha)	100 t (26 Ha)	1000 t (260 Ha)	20 t (18Ha)	100 t (90 Ha)	1000 t (909 Ha)
Infrastructure Development Costs			**($)**			
Market Set-up	$500 for contract drafting plus additional set-up and training costs.					
Advertising	$606,297					
Sequestration Potential and Kyoto Verification	$12 million for development of measuring and monitoring Framework.					
Dispute Settlement	These costs will vary among individual situations.					
Transaction Costs			**($/tonne)**			
A. Search Costs						
Sales Agent Costs	2.88	0.58	0.06	2.88	0.58	0.06
Subtotal 1	**2.88**	**0.58**	**0.06**	**2.88**	**0.58**	**0.06**
B. Negotiation Costs						
Time Costs	4.18	0.84	0.08	4.18	0.84	0.08
Contract Negotiation	0.97	0.97	0.97	3.41	3.41	3.41
Conservation Easement Reg.	1.00	0.20	0.02	1.00	0.20	0.02
Commission Costs	0.75	0.75	0.75	0.75	0.75	0.75
Miscellaneous	2.50	0.50	0.05	2.50	0.50	0.05
Subtotal 2	**9.41**	**3.26**	**1.88**	**11.84**	**5.70**	**4.31**
C. Enforcement Costs						
Monitoring	0.50	0.10	0.01	1.45	0.29	0.03
Subtotal 3	**0.50**	**0.10**	**0.01**	**1.45**	**0.29**	**0.03**
Total Variable Costs =1+2+3	**12.79**	**3.94**	**1.95**	**16.18**	**6.56**	**4.40**

Source: Author's estimates and calculations.

Other than the sales costs involved in this option, the transaction costs in this option only differ from Market Option A in that, instead of WCE and brokerage fees, there are commission costs involved in this option. The commission costs depend upon the price of carbon; therefore, the price of carbon influences which of market option A or B, is more efficient. In the above matrix the commission costs are calculated as 7.5 percent of the price of one tonne of CO_2, which is assumed for illustrative purposes to be $10. Under this assumption, transaction costs are lowest for contract sizes in Market Option B; therefore, it the most efficient market with respect to transaction costs.

The sensitivity analysis is included later to illustrate how the price of CO_2 influences this conclusion; for certain prices Option A is more efficient than Option B.

4.1.3 Market Option C - Cost Matrix

Short-term contracts are used in this option. Two sets of contracts are needed; the first is between the landowner and the private agent while the second is between the private agent and the utility company wherein the agent sells the credits, which are generated via the land management practices, to the utility company.

Market Option C is the most expensive option, primarily due to the program administration costs. These costs were estimated using Ducks Unlimited administration costs and may or may not be relevant to the market option depending upon how it is organized. However, since Ducks Unlimited is a private organization that deals with landowners on land leases for various projects, their costs were used to estimate costs for this option. Ducks Unlimited budgets $6000 per land lease; although several of these costs were not relevant to this market option, their program administration and contract preparation were applicable (Ducks Unlimited 1999).

Table 4.3: Market Option C – Infrastructure Development and Transaction Cost Matrix

	Carbon Sequestration Activity					
	Permanent Cover			**Direct-seeding/ Zero-tillage**		
Transaction Costs	**20 t** (5 Ha)	**100 t** (26 Ha)	**1000 t** (260 Ha)	**20 t** (18Ha)	**100 t** (90 Ha)	**1000 t** (909 Ha)
Infrastructure Development Costs			**($)**			
Market Set-up	$600 for contract drafting plus additional set-up and training costs.					
Advertising	$606,297					
Sequestration Potential and Kyoto Verification	$12 million for development of measuring and monitoring Framework.					
Kyoto Area Establishment	Costs associated with defining and verifying private agent's area.					
Dispute Settlement	These costs will vary among individual situations.					
Transaction Costs			**($/tonne)**			
A. Search Costs						
Sales Agent Costs	17.50	3.50	0.35	17.50	3.50	0.35
Subtotal 1	**17.50**	**3.50**	**0.35**	**17.50**	**3.50**	**0.35**
B. Negotiation Costs						
Time Costs	4.18	0.84	0.08	4.18	0.84	0.08
Program Administration	60.00	12.00	1.20	60.00	12.00	1.20
Contract Negotiation 1	0.97	0.97	0.97	3.41	3.41	3.41
Contract Negotiation 2	0.97	0.97	0.97	3.41	3.41	3.41
Subtotal 2	**66.13**	**14.78**	**3.23**	**71.00**	**19.65**	**8.10**
C. Enforcement Costs						
Monitoring	0.50	0.10	0.01	1.45	0.29	0.03
Re-negotiation 1	0.49	0.49	0.49	1.70	1.70	1.70
Re-negotiation 2	0.49	0.49	0.49	1.70	1.70	1.70
Subtotal 3	**1.47**	**1.07**	**0.98**	**4.86**	**3.70**	**3.44**

Total Variable Costs =1+2+3	**85.10**	**19.36**	**4.57**	**93.36**	**26.85**	**11.98**

Source: Authors estimates and calculations.

It is apparent from the previous matrices that transaction costs are a function of the size of the individual contracts. It is relatively expensive to contract with a landowner to sequester 20 tonnes of CO_2 equivalent, while it appears to be relatively inexpensive to contract with an individual who is going to sequester 1000 tonnes. However, putting the amount of land needed to sequester 1000 tonnes of CO_2 equivalent is riskier for the landowner because agronomic flexibility is limited on a greater area of land. Although it is less expensive per tonne to contract 1000 tonnes, the increased risk level may offset some of the monetary gain of contracting 1000 tonnes versus 100 tonnes.

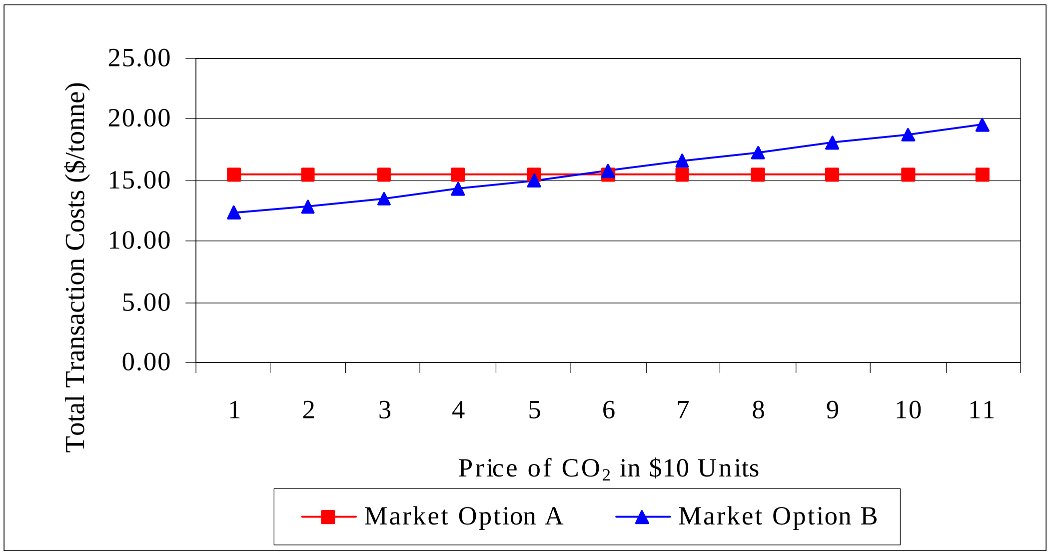
4.2 Sensitivity Analysis

This sensitivity analysis is included to illustrate how the price of CO_2, which is unknown at this time, influences the commission costs associated with Market Option B. Commission costs are calculated as a percentage of the contract value, which depends upon the price of CO_2. In the previous section, the cost matrix for Option B had commission costs of $0.75 per tonne of CO_2, or 7.5 percent of $10 per tonne, which are not influenced by contract size. The price was assumed to be $10 per tonne for illustrative purposes. The total transaction costs of Market Options A and B are similar in the cost matrices previously indicated. Therefore, the price of CO_2, hence the commission costs, can influence which of these two options is more efficient.

The sensitivity analysis was used to discover at which price of CO_2 market Options A and B have the same transaction costs, and at which price one is more (less) efficient than the other. The transaction costs associated with Market Option A do not depend upon the price of CO_2; therefore, they are constant for a 20 tonne contract. However, as the price of CO_2 rises, the total transaction costs for Market Option B also rise. The total transaction costs of these two market options are used in this sensitivity analysis. The costs were calculated for a 20 tonne contract for the permanent cover sequestration activity.

As shown in Figure 4.1, when the price of CO_2 is lower than $50 per tonne Market Option B is the most efficient because total transaction costs are below those of Market Option A. When the price of CO_2 is $50 per tonne and higher, Market Option A has lower total transaction costs than Market Option B; consequently, it is the most efficient option for the higher CO_2 prices looked at in this analysis.

Figure 4.1: Market Options A and B - sensitivity analysis for a 20 tonne contract under permanent cover



Source: Author

This graph illustrates the transaction costs for market options A and B for the use of permanent cover for a 20 tonne contract. The graph shows that the price of CO_2 can influence the efficiency (ie. the transaction costs) of market options A and B. A similar comparison can be made for the larger contract sizes as well as for alternative sequestration methods. The results of the alternative methods and different contract sizes are similar to those illustrated above; the price of CO_2 reaches a certain point that results in Market Option B becoming less efficient than Market Option A.

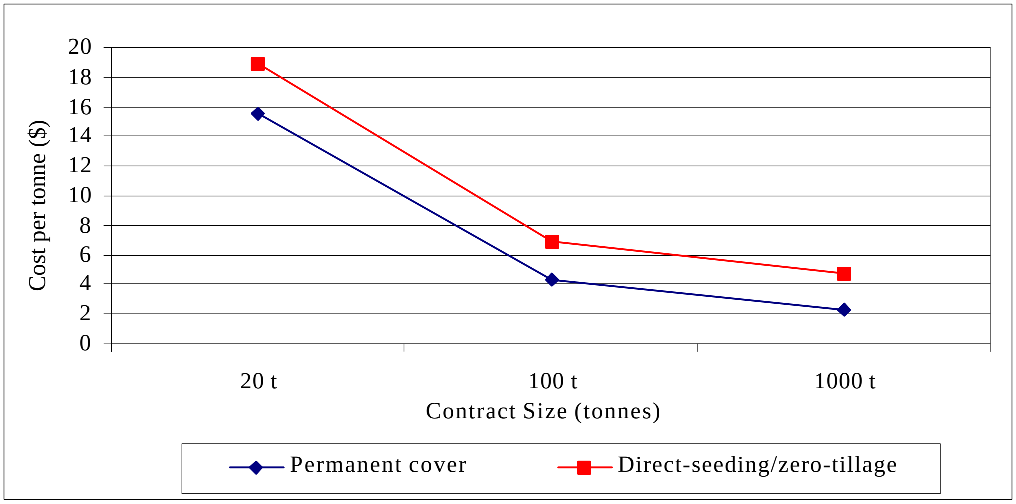
The commission costs involved in Market Option B are constant among all contract sizes. However, the brokerage fees involved in Market Option A decrease as contract size increases. As contract size increases the price of CO_2 does not have to be as high for Market Option A to become more efficient than B. For example, in Figure 4.1 CO_2 had to be worth $50 per tonne before Market Option A becomes more efficient than B. However, for a 1000 tonne contract under permanent cover, Market Option A becomes more efficient than B at a CO_2 price of approximately $15 per tonne.

The results of this sensitivity analysis must be considered when choosing one of these market options, A or B, over the other because the price of CO_2 directly affects which is more efficient with respect to transaction costs.

4.3 Transaction Cost Curves

The transaction cost curves show how average costs decrease as the size of the individual contract increases, which occurs in all market options. The spread between the two sequestration activities in each market option is attributable to monitoring and contracting costs. Monitoring techniques are different for each sequestration activity; therefore, the monitoring costs are different. In addition, costs calculated on a per hectare basis are less expensive per tonne of CO_2 equivalent when permanent cover crops are used.

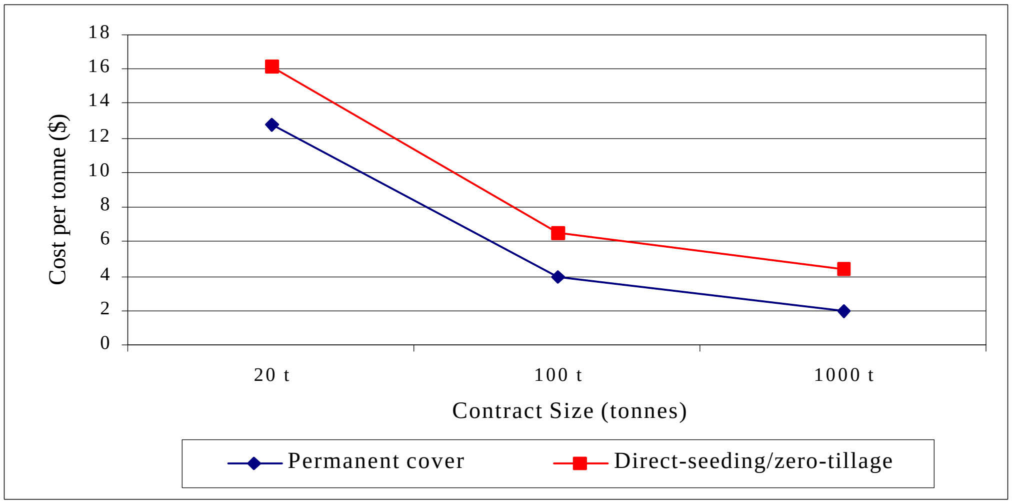
Figure 4.2: Market Option A - transaction cost curves



Source: Author

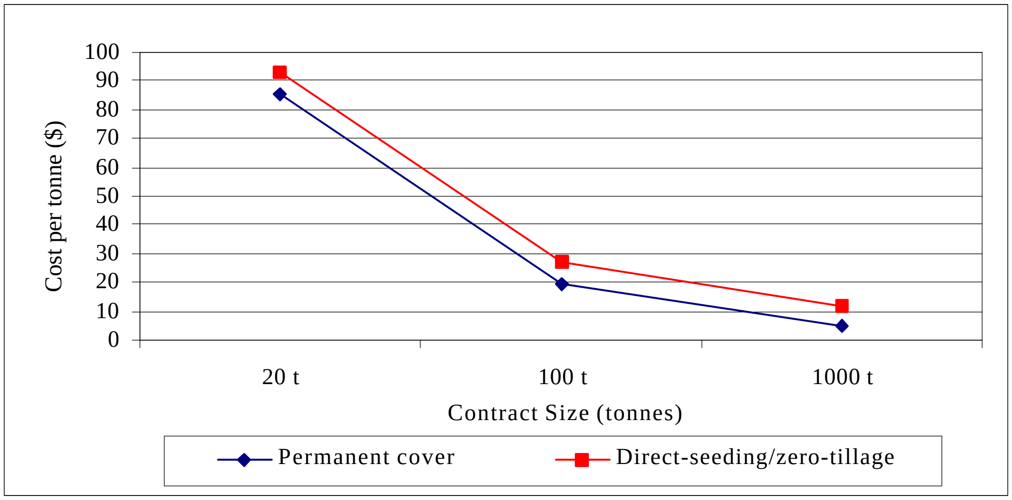
Transaction costs per tonne of carbon dioxide are lowest with the largest transaction size. The transaction costs go up at an increasing rate as the size of the contract declines. This is true for all Market Options and whether one considers permanent cover programs or zero tillage. For example, transaction costs for permanent cover under option A increase by 90% when the contract size declines from 1000 tonnes to 100 tonnes. The increase is far larger when the contract size is reduced from 100 tonnes to 20 tonnes as the transactions costs go up by 260%.

Figure 4.3: Market Option B - transaction cost curves



Source: Author

Figure 4.4: Market Option C - transaction cost curves



Source: Author

It is the price of carbon that will ultimately dictate whether or not any of these market options are feasible, as well as which option, A or B, is most efficient with respect to transaction costs. For a 20 tonne contract using the permanent cover sequestration method, low CO_2 prices (under $50 per tonne) result in Market Option B being the most efficient while for high CO_2 prices ($50 per tonne and over), Market Option A is the most efficient. The results for other contract sizes and sequestration methods are similar in that a price of CO_2 does exist that causes Market Option A to become more efficient than Market Option B.

4.4 Summary of Results

The transaction costs associated with each of the three market options described in Chapter Three were estimated in this chapter. Under the assumption that CO_2 is priced at $10 per tonne, Market Option B had the lowest overall transaction costs, hence the highest relative efficiency. However, the sensitivity analysis indicates that for a 20 tonne contract using permanent cover to sequester carbon, as the price of CO_2 surpasses $50 per tonne, the total transaction costs in Market Option B are greater than those in Market Option A.[70] Therefore, the price of CO_2 directly influences which option is most efficient.

Using the transaction costs from each option, a transaction cost curve for each market option was developed in order to show that the contract size affects the transaction costs per tonne of CO_2 equivalent sequestered. Furthermore, there is a greater cost saving, per tonne of CO_2, when increasing contract size from 20 to 100 tonnes than there is when increasing from 100 to 1000 tonnes for both sequestration activities in all market options. Total transaction costs differ among the two sequestration activities because of the monitoring and contract negotiation costs; this spread is illustrated in the transaction curves.

[70] For a 1000 tonne contract, the price of CO_2 only has to be approximately $15 per tonne in order for Option A to be relatively more efficient than Option B.

Even though the infrastructure development costs were not specifically analyzed, the cost per transaction will tend to decrease as the size of the market grows. For example, the feasibility study that must be conducted by the WCE prior to trading futures would ultimately be spread over the number of market participants. Therefore, if only one hundred individuals enter the market the effective cost per transaction is $1500 whereas if one thousand individuals trade carbon credits this cost falls to $150 per transaction.

Chapter Five: Conclusions, Recommendations, Policy Implications, and Limitations

5.0 Introduction

The problems of climate change and global warming, which are potentially brought about by an increase in anthropogenic GHG emissions, have become significant concerns of the Canadian governments and governments throughout the world. In order for Canada to be in compliance with the 6 percent reduction in GHG from 1990 levels that it committed to in the Kyoto Protocol, anthropogenic emissions of GHG must be decreased and carbon sequestration capacity must be increased. Research is currently underway to determine how best to reduce emissions and increase carbon sink capacity.

Canadian agricultural soil can be used to sequester carbon, thereby decreasing the amount of CO_2 that is emitted into the atmosphere. Agricultural soils are not currently recognized as a sink under the Kyoto Protocol, although its use as such is discussed in Article 3.4 of the Protocol. Further research is needed into methods that can be used to measure and quantify soil carbon levels if soil is to be officially recognized as a sink. These improved methods, along with the development of efficient markets for GHG emissions that incorporate the use of sinks, will bring the sequestration potential of soil to the attention of environmental policy makers throughout the world.

The use of economic instruments, such as tradable credits, to address environmental problems has gained attention because the traditional command and control approach to environmental policy has not been effective. The use of tradable emission permits and credits effectively reduces emissions while minimizing costs. A prime example is the market for SO_2 in the United States that was introduced under the Acid Rain Program. The market for ERC developed in this study, which is based on a biological system, is fundamentally different from the SO_2 market in the United States that is based on an engineered system. The biological system is much more variable with respect to supply, and is less predictable; therefore much more risky.

5.1 Conclusions

To reach their emissions goals agreed to in Kyoto, the Canadian government must provide incentives for reduced GHG, which could include placing a restriction on carbon emissions. A quota restricting the amount of emissions allowed will facilitate the development of various methods to reduce them. The primary objective of this study was to analyze the potential of a market for carbon credits. Agricultural landowners using their land as a carbon sink could provide a supply of emission reduction credits to CO_2 emitting companies to offset their emissions.

The hypothesis addressed in this study was:

> *Hypothesis: A market for tradable emission credits can be created with the appropriate institutions in place.*

Three organization options for the development of an Emission Reduction Credit (ERC) market were presented in this study. The transaction costs involved in each option were compared to determine which option was most efficient.

Two carbon sequestration methods were analyzed in this study, the use of permanent cover crops and the use of zero-tillage, direct-seeding technologies. It was found that the total transaction costs differ between the two carbon sequestration methods. Monitoring procedures differ between the two methods, with permanent cover crops less expensive to monitor. In addition, because permanent cover sequesters more carbon per hectare, the transaction costs per tonne of CO_2 were lower under permanent cover for costs calculated on a per hectare basis, such as contract negotiation costs.

Transaction cost curves were used to illustrate that the size of the contract, 20, 100, or 1000 tonnes, affects the transaction costs per tonne of CO_2. As the size of the transaction increases, transaction costs per tonne decrease. In the three market options there was a significant decrease in costs when contract size was increased from 20 tonnes to 1000 tonnes. It is relatively expensive to get a small landowner into the ERC market under any of the market organization options. In order to determine the optimal contract size, the marginal benefit would be equated with marginal cost, which could be done in an additional study.

Under the assumption that the price of CO_2 is $10 per tonne, the most efficient market option developed in this study was Market Option B. This option incorporates the use of conservation easements to ensure that carbon is sequestered in perpetuity, and a public central agent that brings together the buyers and sellers of carbon credits. Market Option B involves a commission cost based on the value of the contract that is paid to the central agent; therefore, the transaction costs, hence efficiency of this market option, depends upon the price of CO_2.

If CO_2 prices are low, under $50 per tonne for the small contract size (20 tonnes) and under $15 per tonne for large contracts (1000 tonnes), then Market Option B is relatively more efficient than the other two options. Therefore, the institutions needed to ensure the efficiency of this market are a public central agent to facilitate trade and conservation easements to ensure that carbon is sequestered in perpetuity. However, if CO_2 prices are higher, over $50 per tonne for small contract sizes and over $15 per tonne for large contracts, Market Option A is relatively more efficient. Consequently, for higher prices the bilateral market that uses the WCE and incorporates the use of conservation easements is the most efficient option.

With respect to transaction costs, market options A and B were more efficient than option C. However, further study into the risk involved in each proposed market option is needed to determine if the benefits from low transaction costs are out-weighed by the risk associated with the use of conservation easements and contracts that limit management practices, hence agronomic flexibility. Various combinations of the options presented here, or entirely new market organization options, may be more efficient and may reduce landowner and/or agent risk.

A market for tradable emission credits can be created if institutions are in place that minimize transaction costs. From the evidence presented here, a public central agent or use of a commodity exchange will benefit the parties involved in trading carbon by minimizing transaction costs. Conservation easements may also be required, not only to reduce the costs of transacting, but to insure that the credits are credible under the Kyoto Protocol.

The ultimate conclusion of this study is that an efficient market for ERC can be developed with the proper institutions in place[71]. Factors such as the carbon sequestration activity used, the price of CO_2, and the contract size affect the relative efficiency of the market options. Further research is needed to determine risk levels between these three market options and how that risk may offset the benefits of reduced transaction costs between market options, contract sizes, and sequestration activities. It is much riskier for a landowner to put a large portion of his land under contract, even though doing so may minimize transaction costs. It is also riskier, due to higher costs and agronomic factors, to use the zero-tillage, direct-seeding option than it is to put land under permanent cover.

In addition to the reduction of GHG levels, the successful development of an ERC market will encourage landowners to use carbon sequestering land management practices. Many of the practices also reduce erosion, increase soil organic matter levels, and encourage the efficient use of inputs; hence, encourage sustainable agricultural practices. Therefore, a policy approach that reduces GHG emissions and increases agricultural sustainability can be developed.

There are various economic, environmental, and social impacts that will be realized following the development of and ERC market. Economic impacts include additional income for landowners who sequester carbon and sell the credits generated by sequestration. For the buyers of credits, which include coal-burning utility companies, the development of a tradeable credit market will enable them to efficiently offset their CO_2 emissions. With respect to environmental impacts, the sequestering of carbon can reduce atmospheric CO_2 levels and help Canada reach its emission reduction goals. In addition, agricultural sustainability may be improved due to the use of the best-management practices of zero-tillage, direct-seeding and the placement of marginal land under permanent cover.

Society will benefit from the development of this market. GHG will be reduced at a relatively low cost, landowner income will increase, which benefits the economy as a whole, and utility companies will be able to reduce their emissions in a low-cost manner resulting in less of a burden being placed on utility users.

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[71] In order for the ERC market to be efficient, the transaction costs involved in the buying and selling of the credits must be less than the value of the credits themselves. It may be possible that the market for credits will not be rich enough to prompt landowners to switch practices. However, those who are already using zero-tillage or permanent cover can benefit by selling the carbon credits generated via the use of these practices. Landowners will enter into the market when the price of the credit covers transaction costs and provides a reasonable return. Buyers of credits will purchase them when it is more cost efficient to purchase them than to pursue another alternative for CO2 abatement

5.2 Recommendations

This study is a basis for further research into the use of ERC to reduce GHG thereby aiding Canada in its commitment to the Kyoto Protocol. It serves as a preliminary look at the transaction costs involved in three market organization options that have been developed for an ERC market in western Canada. The primary recommendation of this study is that further research be conducted into the potential development of these market options, their associated transaction and infrastructure development costs, and into other factors, such as risk, that may affect their use in Canada's commitment to reduce GHG.

The research currently underway to improve verifiable changes in soil carbon stocks must also continue. The development of the market for ERC as it is proposed in this study depends upon the ability to estimate initial soil carbon levels and to model how factors such as soil type, crops grown and weather affect soil carbon changes. In order for agricultural land to be recognized under the Kyoto Protocol there must be an internationally acceptable soil carbon verification method. As soon as doubts surrounding the use of carbon sinks have been alleviated, markets that incorporate their use can be introduced to society.

5.3 Policy Implications

Canada has committed to reduce GHG emissions by 6 percent from 1990 levels by the period between 2008 and 2012; this is a 25 percent reduction from 'business as usual' scenarios. Therefore, policies must be put in place to encourage these reductions and encourage the use of sinks. The government has placed great emphasis on the use of voluntary measures to reduce emissions rather than the implementation of restrictive 'stick' policies.

An efficient market for tradable ERC can be developed with the proper institutions in place. The primary policy implication of this study is that legislation must be implemented that restricts GHG emissions, thereby facilitating the development of the ERC market. The rules pertaining to credit generation via the use of agricultural land, trade of the credits, and Kyoto verification must be specified. Policy makers must now begin to draft these rules and begin looking at the potential options for market organization. Following further research into the risk associated with each option, the market can be designed. Legislation regarding emissions restrictions and the rules needed to ensure efficiency must be in place prior to initiating the trade of ERC.

Just as in the development of any new program or policy the costs and benefits of the development of an ERC market must be analyzed. The transactions costs looked at in this study provide a preliminary look at the costs associated with the development of such a market. Policy makers can examine results presented here, which will aid them in their development of cost-effective, no-regrets policies to reduce GHG.

5.4 Limitations

Although agricultural soil can potentially be used as a carbon sink, there are some limitations to its use as such. Carbon sequestration capacity varies for individual sites and is affected by producer behaviour, which may change over time, and by specific factors such as weather. Secondly, carbon can be released faster than it is sequestered. Thirdly, carbon sequestration is not limitless. Finally, some critics suggest that carbon credits based on early forecasts will be inconsistent with reality during the Kyoto accounting period of 2008-2012. In addition, there may be a problem in the definition of a credit because producers are already adopting practices that sequester carbon for reasons other than carbon sequestration.

With respect to legal limitations, the court and legal system as it is today may not be adequate to define the property rights required for the ERC market. However, the enactment of *The Conservation Easements Act* in Saskatchewan in 1997 and a similar Act in Alberta will be beneficial in the enforcement of the conservation easements used in the market. The contracts involved in the ERC market can be enforced by the legal and court system; however, new laws may be required depending upon the specifics involved in the market regarding elements such as monitoring rights. Legislation may also be needed to set up the public or private agencies that are required if certain market design options are used. This legislation will provide the agent with the power to trade credits, and will allow them to be grantees of the conservation easements if necessary.

A third limitation is the quality of the data used to calculate the transaction costs analyzed in this study. The costs used have been estimated from the operating costs of existing agencies and organizations and the ERC market may or may not have an operating cost structure that follows these existing agencies. It is important, though, to look at existing organizations in order to estimate potential costs. These costs do provide a basis upon which to determine the efficiency of the market options presented in this study. More important than the costs themselves is the fact that the transaction costs involved in the options have been identified.

Finally, there are other options for market organization that have not been considered in this study. Other potential options could be hybrids of the options developed here, or completely different market organizations. Further research into the optimal market design is needed.

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Appendix A: Market Option Cost Matrices