FARMERS' WILLINGNESS TO PLANT TREES ON MARGINAL AGRICULTURAL LAND IN CANADA'S GRAIN BELT

by

PAVEL SUCHÁNEK

B.Sc., The University of British Columbia, 1998

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(The Faculty of Agricultural Sciences, Programme of Agricultural Economics)

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

June 2001

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Agricultural Economics

The University of British Columbia
Vancouver, Canada

Date Aug 31, 2001

DE-6 (2/88)

Abstract

Climate change has been one of the major global environmental concerns to date. Its seriousness supported by many scientists around the world prompted the vast majority of countries to sign the Kyoto Agreement on climate change. In this document Canada committed to a six percent reduction below 1990 level of carbon dioxide emissions by the 2008-2012 commitment period. Canada has expressed its intention to use its extensive land base as a carbon sink by planting trees. However, no data are available on precisely how much of the land can be converted to trees and at what cost. This thesis uses a survey of farmers in the grain-belt region of Canada to investigate the costs of planting trees on marginal agricultural land and estimate the amount of land available for tree planting. The survey proposes a random bid to each farmer for accepting a particular tree-planting contract. Farmers' answers are analyzed using a bivariate probit model that provides an estimate of the mean willingness to accept for each farmer. Regressing the number of acres made available at this bid on the difference between the bid and the mean willingness to accept results in a supply type of schedule that provides a general estimate of the potential for tree planting in Canada for climate change mitigation purposes. The thesis concludes that Canada can rely on offsetting its emissions of carbon dioxide by means of biological mitigation only to a limited extent due to the high cost of compensation to landowners for their land.

Table of Contents

Abstract ii
Table of Contents iii
List of Tables iv
List of Figures v
Chapter 1: Background to Climate Change and the Role of Forestry 1
1.1 Introduction 1
1.2 Global Warming 2
1.3 The Kyoto Protocol 5
1.4 Climate Change Mitigation in Forestry and Agriculture 9
1.5 Tree Plantations 10
1.6 Afforestation of Marginal Agricultural Land 11
1.7 Conclusion and Thesis Outline 13
Chapter 2: Land-use Change and Afforestation: A Review of Economic Issues 14
2.1 Introduction 14
2.2 Cost-Benefit Analysis 14
2.3 Subsidies for Afforestation 15
2.4 Possible Shortcomings of Cost-Benefit Analysis 17
2.5 Identification of Economically Suitable Land for Afforestation 19
2.6 Optimal Allocation of Land Based on Results from a Dynamic Optimization Model 21
2.7 Costs of Afforestation Using a Positive Analysis 23
2.8 Estimating the Opportunity Costs of Tree Planting – Thesis Objective 24
2.9 Conclusion 26
Chapter 3: Theory 28
3.1 Introduction 28
3.2 Random Utility Model 28
3.3 The Probit Model 30
3.4 Bivariate Probit Model 33
3.5 Supply Curve 37
3.6 Conclusion 38
Chapter 4: Survey of Landowners in Canada's Grain Belt 39
4.1 Introduction 39
4.2 Use of Survey Instruments 39
4.3 Survey Content and Structure 41
4.4 Response Rate 44
4.5 Summary Descriptive Statistics 47
4.6 Conclusion 56
Chapter 5: Regression Results 57
5.1 Introduction 57
5.2 Model Modification 57
5.3 Choice of Variables 58
5.4 Bivariate Probit Results 60
5.5 Single Probit Results 62
5.6 Conclusion 69
Chapter 6: Policy Implication and Direction for Future Research 70
Bibliography 73
Appendix A Survey, Survey Cover Letter and Bid Pairs 79
Appendix B Typical Comments by Respondents 94

List of Tables

Table 1. Possible Direct Benefits and Costs Related to Afforestation. 16
Table 2. Survey Responses and Effectiveness of Delivery 45
Table 3. Definitions of Variables 59
Table 4. Opportunity Cost Values For A Given Land-Use 60
Table 5. Coefficient Estimates and T-Ratios for Bivariate Probit Model. 61
Table 6. Prediction Success Summary 64
Table 7. Coefficient Estimates and T-Ratios for Single Probit Model. 66
Table 8. Distribution of Expected Willingness to Accept Tree-Planting Program ($/acre) 67
Table 9. Basic Statistics on Number of Acres Made Available for Tree Planting 67
Table 10. Marginal Effect of Higher Compensation on Number of Acres Supplied. 68

List of Figures

Figure 1. Number of Responses by Province 40
Figure 2. Mail-out Bid Distributions. 43
Figure 3. Age Distribution of Respondents. 46
Figure 4. Post Secondary Education of Respondents. 48
Figure 5. Net Worth Distribution of Farmers. 49
Figure 6. Farmers' Attitude towards Climate Change 50
Figure 7. Esthetic Perception of Increased Tree Cover in Local Area 50
Figure 8. Benefits of Planting Trees on Agricultural Land 50
Figure 9. Reasons for Voluntary Engagements in Tree Planting. 51
Figure 10. Previous Tree Planting Initiatives. 51
Figure 11. Willingness to Participate for Adequate Compensation. 53
Figure 12. Main Reason(s) for not Considering Tree Planting Program. 54
Figure 13. Factors Possibly Preventing Tree Planting. 54
Figure 14. Preferred Contract Length. 55
Figure 15. Farmers' Post Contract Responses. 55

Chapter 1: Background to Climate Change and the Role of Forestry

1.1 Introduction

Many countries in the world have experienced profound economic progress during this century. Their rapid development was, to a large extent, due to inventions of new technologies for energy generation that ignited the current extensive use of fossil fuels. Presently, most world economies rely on the provision of energy that has become an essential determinant of their performance. Fossil fuels have been burnt at increasing rates, annually releasing tonnes of carbon dioxide and other greenhouse gases into the atmosphere to satisfy rising energy demand. Some scientists suggest that adding substantial amounts of greenhouse gases into the atmosphere may have great environmental repercussions for human development. Whether greenhouse gases presume a serious potential for negative environmental effects or not, humans will need to reduce their emissions, since nonrenewable fossil fuels are in limited supply and alternative energy sources are presently relatively expensive.

The 1992 United Nation's Earth Summit in Rio de Janeiro addressed some of the most serious environmental concerns to date. Among other objectives for this summit was the issue of climate change, in particular the contribution of emissions of carbon dioxide to global warming that could produce presumably widespread economic damages. Developed nations were challenged to reduce their carbon emissions. Since strict regulations reducing consumption of fossil fuels may cause poorer economic performance in the short run, many countries have been searching for other ways of accomplishing lower greenhouse gas emission targets at the least cost. As a result of the Kyoto Protocol to the conference of the parties to the United Nations Framework Convention on Climate Change, countries with vast amounts of land have in particular showed interest in planting trees for carbon sequestration that could to some extent offset their emissions. Tree planting can be carried out for various reasons, however. Since future climate change and its potential impacts are unknown, afforestation programs could emphasize other tangible benefits, rather than just carbon sequestration benefits. Economic analysis that takes all but carbon benefits into account could show that tree planting should be pursued regardless of concerns about climate. A meaningful afforestation analysis for Canada requires data on land available for tree planting and a formulated incentive scheme necessary to convince landowners to plant trees.

1.2 Global Warming

Throughout the last decade of the twentieth century the concern over global climate change has gained a lot of attention from members of various academic fields. The rigorous scientific debate also had an impact in the political sphere where the topic of climate change influenced the political agenda of not only many international institutions but also the governments of nearly all countries. In 1992, representatives from various countries signed the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro, Brazil. The parties to the convention defined climate change as a change of climate attributed directly or indirectly to human activity in addition to natural climate variability (United Nations, 1992). The signatories to this convention agreed to stabilize greenhouse gas emissions at 1990 levels by the year 2000 in order to modify long-term trends in their emissions and thus reduce the risks of global climate change. The UNFCCC came into force on March 21, 1994.

Even though the UNFCCC adopted the notion that human induced emissions of greenhouse gases have an impact on global temperatures, the issue of climate change is far from unequivocally resolved. Some, yet inconclusive, evidence suggesting that global temperatures have been rising and anthropogenic activities have been the major cause of their increase has been accumulating in recent years. Most studies point out that the Earth will likely continue getting warmer, experiencing unprecedented climate patterns. Some research even warns about the possibility of irreversible and therefore dangerous climate shifts that would have an adverse effect on global welfare. However, there are serious uncertainties regarding climate change. The first uncertainty relates to whether global warming is a real, long-term phenomenon that is likely to continue, or only a relatively short-term and possibly natural variation in climate. The second uncertainty concerns the reasons for the alleged warming. In particular, how does the accumulation of greenhouse gases and their interactions with other gases impact climate?

The international agency coordinating climate change research is the Intergovernmental Panel on Climate Change (IPCC). The IPCC's most recent estimates indicate that the world will be warmer by approximately 1.0 to 3.5 degrees Celsius by the year 2100. Ten years ago, based on the assumption that emissions of greenhouse gases continue to accumulate without mitigation, this organization predicted that by the year 2100, world temperatures would rise by twice as much as current estimates (Easterbrook, 1999). According to the Canadian Forest Service (1999), there seems to be a near-unanimous scientific consensus that global temperatures have risen by about a half a degree of Celsius during the last 150 years, with the 1990s having above-average temperatures. Even though this half-degree change in global temperatures could be a significant finding, it does not provide any real insight into what causes recent global warming or whether it is bound to continue into the future.

A US National Academy of Science Panel (Hebert, 2000) confirmed in a recent report that global warming was accelerating but it could not say that it was due to human pollution. The panel examined more than 100 years of data, but that was simply too short for making any definitive statements about climate. The confirmation came despite reported discrepancies concerning temperature measurements: surface monitors recorded an increase in temperatures, while satellite and weather balloon observations showed little or no warming. While this panel was confronted with finding reasons for the temperature discrepancies between the Earth's surface and higher altitudes, it did not attempt to explain the cause of global warming or to make any predictions for the future. Indeed, it could not draw a link between changes in global temperatures and human emissions of greenhouse gases.

There have been several attempts for a valid explanation of the upward trend in recent global temperatures. The most prevailing hypothesis blames human activities, particularly fossil fuel burning, for increasing concentrations of greenhouse gases whose accumulation in the atmosphere enhances its ability to trap heat around the Earth. The evidence supporting this claim, as cited by the Canadian Forest Service (1999), is a warming trend over the last 150 years, narrowing gap between daily minimum and maximum temperatures and regional changes. Rapidly changing global climate system and greater instability between various components of this system could result in increasing weather variability. It is these consequent extreme weather events that would present the greatest challenges. The organization admits, however, that "whether extreme weather is increasing in severity and frequency remains an issue" (p.5).

The hypothesis that extreme weather is increasing in severity and frequency stems from emissions of greenhouse gases that presently cannot be accurately measured.[1] For the years to come, it is nearly impossible to predict future emissions for they depend on the rate of economic development, technological and structural change, and substitution possibilities between fuels, energy and other inputs. Scientists are also uncertain about the interactions of these gases in the atmosphere, the links between their flows and stocks, and their residence time in the atmosphere (OECD, 1995). In addition, the hypothesis fails to explain the substantial increase in temperatures during the first 40 years of this century when concentrations of greenhouse gases were insignificant (Easterbrook, 1999). Only about a half of the total warming of this century has occurred since the 1940s with a downward spike in temperatures in the 1960s. On the other hand, humans have been steadily releasing carbon dioxide throughout the whole period. It might then be plausible to suggest that this relatively small increase in global temperatures in the 1990s has been due to natural variation. Easterbrook (1999) also points out that meaningful temperature records stretch only as far back as the end of the last century. This beginning of recorded data coincides with the end of the Little Ice Age that altered the climate from about 1500 to 1850. Perhaps a reverse trend in temperatures is what one would expect after the previous cooling.

One of the alternative explanations for global warming since the 1960's is fluctuation in the output of the sun (Calder, 1999). Research by Calder (1999) into reasons for global warming was encouraged by findings that explain the rhythm of the ice ages with the Earth's behaviour in orbit, the so-called Milankovitch effect. Calder uses this solar explanation for temperature variations to address changes in climate temperature for even much shorter time periods. One of the building stones for his hypothesis has been a study by Svensmark and Friis-Christensen (1997) that links the intensity of galactic cosmic rays to variations in the Earth's cloud cover. The impact of cosmic rays can be lessened by solar wind, which has been vigorous during this century as a result of the activity of the Sun. Consequently, lower levels of cosmic rays have prohibited sufficient cloud formation and caused warming of the Earth since clouds are capable of reflecting the radiation of the sun into space. According to Calder (1999), the pattern of global temperature variations mirrors the behaviour of the Sun. Even though the actual microphysical processes of cosmic rays and cloud formation interactions have not been fully explained yet, the greenhouse hypothesis deserves further scrutiny before it is whole-heartedly endorsed. It could also be the

[1] Carbon dioxide emissions from fuel consumption can be determined with relative precision. However, emissions of this gas associated with land use change are not as straightforward. Measurements of other greenhouse gases are even less certain (OECD,1995).

case that the rising level of carbon dioxide in the atmosphere coincides with increasing temperature in recent years or that the causality between carbon concentration and temperature works in the opposite direction, with human emissions irrelevant (Calder, 1999).[2]

Both hypotheses have a common underlying problem. Reliable data for the analysis of climate change are only available for a relatively recent time period. Considerable care should be applied to the interpretation of short-term weather variations and natural fluctuations versus real signs of long-term climate change. Weather is what happens today, whereas climate patterns can only be extrapolated from data over several centuries. Unfortunately, this is a luxury that our society does not have and therefore any statement about climate change should be interpreted with a degree of reservation. Easterbrook (1999) rightly asserts that climate patterns may experience artificial or natural variations, or some combination of the two. Only the artificial causes can be influenced by human activity. Common sense suggests that continued pollution of the atmosphere with not only carbon dioxide but other chemicals as well, and mismanaging forests, agriculture and land use in general, could have an impact on climate because of the increasing intensity with which these actions are being carried out. The IPCC concluded that anthropogenic activities such as burning of fossil fuels and changing land use patterns play a role in climate but this role remains to be identified (IPCC, 1995).

1.3 The Kyoto Protocol

Facing significant scientific uncertainties, the UN (1992) took a stand by proclaiming that precautionary measures should be taken in order to "anticipate, prevent and minimize the causes of climate change and mitigate its adverse effects". The UNFCCC endorsed the view that accumulation of greenhouse gas emissions causes global climate change. According to the UN (1992), postponing action should not occur regardless of lack of full scientific certainty since serious threats of irreversible damage exist. Based on the assumption put forth by the UN, there are fundamental issues that any such action will need to address.

First, greenhouse gases are contained in the atmosphere around the globe. Therefore, any uptake or measure taken to prevent or reduce greenhouse gas emissions can be considered a pure public

[2] Data for carbon levels in the atmosphere have only been available for roughly the last 40 years.

good with benefits extending to all inhabitants regardless of their place of residence.[3] As Ley and Sedjo (1997) argue, different people will be affected in different ways and such impact will also vary across countries and continents, thereby presenting an enormous challenge to economists to determine any global welfare shifts. The change in welfare would involve its redistribution not only across the planet but also across the generations and inevitably require moral or ethical considerations that would move the issue of climate change out of the realm of science. Second, any policy change that takes climate change into account should be cost-effective in order to provide the greatest benefits at the lowest possible cost. In this context, future benefits of lower carbon concentrations, and to a lesser extent some costs, are uncertain since future damage is uncertain. If marginal damage associated with higher carbon concentrations were known, the value of keeping marginal carbon tied up in the terrestrial ecosystems could be determined (Sampson & Sedjo, 1997). The value of a physical unit of carbon could then be used in evaluating any carbon reduction or sequestration projects.

In light of the commitments agreed upon in Rio de Janeiro, the parties to the UNFCCC met in Kyoto, Japan, and adopted the Kyoto Protocol. On December 11, 1997, nearly 160 countries signed an agreement committing industrialized countries collectively to reduce greenhouse gas emissions by 5.2 percent during the 2008-2012 period compared to the 1990 baseline.[4] Canada agreed to reduce emissions to 6 percent below the 1990 level. The Kyoto Protocol was meant to ensure that greenhouse gas concentrations in the atmosphere do not reach critical levels with irreversible consequences potentially dangerous to human development. The focus was on reducing emissions to the atmosphere from energy production and consumption, industrial processes, and other activities, particularly those related to carbon dioxide (Schlamadinger, 1999).

Carbon dioxide, presumably the most important greenhouse gas, is linked directly to terrestrial ecosystems through the carbon cycle. This provides an opportunity for various land use policies to be implemented in order to reduce the concentration of atmospheric carbon. The potential for carbon emission mitigation from activities related to forestry, agriculture and land use in general was a reason for controversy during the Kyoto negotiations. The challenge has been to define

---

[3] See Ley and Sedjo (1997) for a definition of a pure public good.

[4] At this point only industrialized countries committed to reductions. From an equity point of view, no emission limits were imposed on developing countries.

terms such as sinks, sources and reservoirs, and issues related to carbon accounting.[5] Marland and Schlamadinger (1999) use the GORCAM model to illustrate that the Kyoto Protocol may not necessarily promote the most optimal carbon mitigation strategy based on forests because not all carbon credits for forest uptake are presently taken into account. The Protocol does not allow for soil carbon credits and debits. This provides a preferential base for projects that could produce the most emission reduction credits, but not the most benefits of lower carbon concentrations in the atmosphere. Interpretation of the Kyoto terminology is also not clear and needs to be more precisely defined in order to ensure that no incentives are provided for projects that do not follow the objectives of the Protocol (Marland & Schlamadinger, 1999).

In order to meet national emission targets, carbon dioxide removing activities associated with land-use change need to provide valid means for climate mitigation. Article 3.3 of the Kyoto Protocol states that only "measured as verifiable changes in carbon stocks during each commitment period, shall be used to meet the commitments" (UN, 1997, p. 20) by offsetting a portion of the gross emissions. Only direct human-induced land-use changes that impact the carbon cycle in addition to 'business as usual' scenario count under the Kyoto Protocol. An underlying problem in this discussion is the concept of the addition of direct, human-induced changes. Natural changes take place simultaneously with human-induced activities designed to sequester carbon, and it is therefore difficult to separate the two effects. In the forestry context, the Protocol permits afforestation, reforestation and deforestation activities initiated since 1990 and carried out during the 2008-2012 commitment period to account for carbon stock changes.[6] Nevertheless, it has been recognized that decisions on land-use related to forestry and agriculture can have an impact on the global carbon cycle.

Land use mitigation strategies can accomplish a slowdown of net greenhouse gas emissions. Eventually, however, fossil fuels will need to be replaced "as the prime energy sources in order to secure a continuing economic and social development in the world" (Marland & Schlamadinger, 1999, p. 34). Diminishing the role of fossil fuels in the current global economy will require extensive capital investments and take many years. Carbon sequestration policies could play a role in this transition by mitigating carbon accumulation in the atmosphere in a cost-effective

[5] See Lund (1999) for discussion of the Kyoto terminology.

[6] For illustration, carbon that is sequestered in biotic stocks is to be subtracted from the national emission target whereas the loss of carbon during deforestation is to be added. The upcoming discussion provides more detail on what flows of carbon can be used.

fashion (Sampson & Sedjo, 1997), while providing time for evaluation of alternatives. Among others these contain abrupt restrictions on the use of fossil fuels that could presently prove costly. Not only would these restrictions be difficult to enforce on a global level but also could create a possibly dramatic economic downturn accompanied by reduced political stability.

Mitigation policies have the potential to moderate the economic impact of global climate change in the short term, while allowing for investments in technology research that in turn could provide for new and cheaper ways of dealing with greenhouse gases. Not only is the effect of carbon dioxide on climate unknown, but the effect of possible warming on production processes is uncertain (Ley & Sedjo, 1997). Van Kooten and Folmer (1997) focus on adaptation to climate change in agriculture, reporting that agricultural output may not necessarily decrease on a global scale if climate change follows the IPCC prediction.[7] Time will also show whether greenhouse gases pose a global threat or not. Proceeding in this direction will not only allow for present economic development but also provide for future development toward a clean-energy economy. The desirable clean-energy policies could involve economic incentives for the reduction in demand for fossil fuels through increasing energy efficiency, substitution of biomass for fossil fuels and technological innovation.[8] Because of the limited stock of fossil fuels, this shift will be inevitable regardless of global temperatures.

Diverting substantial investments, however, away from innovation and technology research to carbon sequestration projects may impose unnecessary costs on society, however. Lashof and Hare (1999) argue that, by implementing the method of significant carbon offset credits as means for warming mitigation, more fossil fuels than would otherwise be the case be utilized for the same emission limit. Countries would be slower in adopting new energy efficient technologies if a large part of their emission reduction commitment came from carbon offsets. Relying on carbon sequestration in essence delays the technological shift, which could impose larger emissions reduction in the future. The cost of the agreed upon emission reductions is likely to be higher if early investments are diverted away from technology innovative industries (i.e.,

[7] Some recent studies assume reductions in yields of agricultural commodities with increasing concentrations of carbon dioxide in the atmosphere. According to the authors, these studies often leave out the fertilization effect of higher carbon concentrations and don't provide any room for technological and technical advances.

[8] Easterbrook (1999) uses the example of marked-based, pollution control trading program in the U.S. that successfully stimulated the innovation of new technologies in order to reduce acid rain emissions.

renewable energy) toward industries with slower technological change (i.e., forestry).[9] This would also imply slower transfer of technologies to less developed countries causing them to emit more carbon than necessary. In Lashof and Hare's (1999) view, the Protocol downplays the role of progress, technological change and innovation, which could have a profound effect on the energy paradigm of the future.

1.4 Climate Change Mitigation in Forestry and Agriculture

Policy makers in countries concerned with mitigating global climate change have tended to encourage the use of forests for carbon sequestration (Sampson & Sedjo, 1997). Growing forests are able to sequester carbon in biomass and enhance carbon accumulation in forest soils, and store that carbon for substantial periods of time. Timber harvest will disrupt the carbon flows and reduce the amount of stored carbon, as will any natural event such as fire, spread of disease or an insect epidemic.[10] Birdsey (1992) attempts to quantify changes in forest carbon flows and stocks. Birdsey's results suggest that mitigation policies associated with forestry are capable of reducing the amount of atmospheric carbon by:

- providing viable alternatives for the production of biomass that replaces the use of fossil fuels as energy source;
- storing carbon in terrestrial ecosystems;
- storing carbon in durable wood products and landfills; and
- replacing energy-intensive products that rely on burning of fossil fuels with ones that rely on forest products, for example, aluminum versus lumber studs or concrete as a building material in place of wood (Marland & Schlamadinger, 1999).

Further, the effect of carbon sequestration in forests can be enhanced by higher forest productivity, increasing the stock of standing timber, intensification of timber management, and investment and expansion of forest area (Sampson & Sedjo, 1997).[11] There are also various

[9] That is not to suggest that technologies related to biomass burning should be ignored.

[10] The issue of carbon stocks and fluxes will be dealt with in more detail in later sections.

[11] Forest area can be expanded by reducing the rate of forest loss and/or conversion to other uses, and through afforestation.

agricultural programs that reduce emissions of carbon dioxide into the atmosphere. Such programs, for example, entail prevention of converting wetlands and ability to maintain grasslands. In addition, various farm practices such as reduction in summer fallow, use of conservation tillage and creation of permanent grasslands can promote carbon storage in soils (van Kooten & Folmer, 1997).

1.5 Tree Plantations

In agriculture and forestry, research has focused on using agricultural land for tree planting in order to mitigate climate change. Parks et al. (1997) distinguish among a few other types of forest plantations, depending on the purpose of establishment:

- restoration for obtaining recreational and environmental amenities, such as reduced soil erosion, and provision of shelter and biologically-diverse wildlife habitat;
- roundwood production for the supply of raw materials, such as pulp wood and sawnwood;
- bioenergy plantations for the production of fuelwood or charcoal for use as an energy source; and
- plantations for non-wood purposes, such as rubber, nuts or fruits.

Trees can also be integrated into urban settings to serve as windbreaks and shelterbelts, and simply to provide esthetic values. Broadly speaking, a forest plantation can be defined as growing trees providing at least 20% crown cover for contiguous area greater than one hectare. This definition is consistent with the FAO terminology for tree planting (Parks et al., 1997). The dynamics of land-use changes involve shifts due to technical change, demand growth, public policies and external impacts (Alig, Adams & McCarl, 1998). Shifting land use out of agriculture into forestry by planting trees on marginal agricultural land, pasture or cropland plays an important role in meeting policy targets (Alig, Adams, McCarl, Callaway & Winnett, 1997).[12]

1.6 Afforestation of Marginal Agricultural Land

Despite the unknown effect of climate change and random natural disturbances on forest growth and productivity, forests are expected to sequester carbon at a decreasing rate over time mainly due to urbanization and increasing population growth. Policy makers became interested in the costs and implications of reversing this expectation in the face of the likely increase in greenhouse gas emissions due to rising population and energy use. Even though Canada has agreed to cut back its emissions to 6 per cent below the 1990 level by the end of the commitment period, a recent proclamation by the Canadian Environment Minister, Mr. David Anderson ("Anderson Hints," 2000) indicates that Canada's emission reduction target may be unattainable. According to Anderson, the Canadian government lacks data on both emission and sequestration activities. Properly administered government afforestation programs could aid in collecting some of the missing information and contribute to the goal of higher carbon sequestration rates from increased forest area. In addition, many studies reveal that afforestation appears to be one of the most cost-effective options for carbon sequestration (Sampson & Sedjo, 1997; Sohngen, Mendelsohn & Sedjo, 1998; Sedjo, Wisniewski, Sample & Kinsman, 1995).

Conversion of marginal agricultural land into forestry could include land that is not suitable for growing crops or used as pasture because of high erodibility, climate, terrain or adverse soil characteristics, such as poor drainage, wetness, low moisture holding capacity, stoniness and low fertility (Parks, Brame & Mitchell, 1992). Other land that can be used for both agricultural and timber production could also be shifted from crop to timber production, but only if the net present

[12] On the other hand, changing climate may also cause shifts in land use. Van Kooten and Folmer (1997) raise an important question: "Should land uses be modified now in an effort to mitigate climate change or should policies be implemented to prepare landowners to adapt to climate change in optimal fashion"? In the context of adaptation, the roles of government and institutional design have often been neglected. Policies should be designed so that farmers can efficiently respond and adapt to climate change. "Institutional rigidity, therefore, discourages owners from adopting land uses that are preferred in the context of global change" (van Kooten & Folmer, 1997). Van Kooten and Folmer (1997) bring attention to the program of agricultural subsidies in the EU as an example of such rigidity, where policy design prevents efficient reduction in agriculture's emissions of greenhouse gases.

value of the forgone agricultural use is smaller than that of forestry. However, not all land is suitable for use in both the agricultural and forestry sectors. A policy designed to move this land between the sectors would most likely be sub-optimal and result in substantial losses. As a result, the land available for conversion has to be able to support growing of trees. Successful implementation of a policy that aims at tree planting on marginal agricultural land requires that the land is planted to a suitable type of tree. The actual selection of a tree species highly depends on the local conditions of the land in question, the perception of the landowner and possibly the rate at which it can sequester carbon.

Carbon sequestration rates are relatively simple to determine since growth models for various species and sites exist. These models assist in estimating timber yields that determine the marketable timber volume. By converting this timber volume into total biomass weight, the stock of carbon sequestered during a specified time horizon can be calculated (Birdsey, 1992). Carbon can be accumulated not only in timber but also in forest soils depending on the soil conditions and time of planting (Sampson & Sedjo, 1997). However, the Kyoto Protocol allows for only carbon sequestered in timber to be offset against carbon emissions from other sources. More generally, the dynamics of total carbon storage can be arranged into the following categories according to carbon contained in:

- vegetation above and below the ground;
- decomposing matter such as litter, coarse woody debris, dead trees, branches and leaves;
- soils in the form of humus and soil organic matter;
- wood products such as furniture, lumber and paper; and
- wood materials for burning as substitutes for fossil fuels (Parks et al., 1997).

Proper accounting for changes in legitimate stocks of sequestered carbon requires establishing a reference scenario. This is often called the "with-without" project principle. Such a scenario should correspond to a state of carbon stocks in the absence of a sequestration project – the converted agricultural land continues to be used in the pre-conversion state (Sampson & Sedjo, 1997). Meaningful carbon accounting is a crucial part of any carbon sequestration project and plays an important role in decision making.[13] Nevertheless, it is important to evaluate the

[13] Meaningful in a sense that not only relevant stocks and fluxes of carbon should be accounted for but also that physical carbon should be discounted in order to make intertemporal comparisons (van Kooten, Grainger, Ley, Marland & Solberg, 1997).

economic and social aspects of a tree-planting program. The appraisal can be carried out using a cost-benefit-analysis that takes into account all relevant project costs and benefits and their distribution over time.

1.7 Conclusion and Thesis Outline

Relatively late concerns about emissions of greenhouse gases and their impact on climate have given rise to the possibility for offsetting some of the emissions by planting trees. Trees can effectively sequester carbon in a reasonably inexpensive way in comparison to other current alternatives. Since trees can also provide other than carbon benefits, their planting should be pursued given that the opportunity cost of doing so is less than the net benefit of planting trees.

The objective of this thesis is to examine possibilities for planting trees on marginal agricultural land in Western Canada. In particular, I determine the perceived value of land suitable for conversion in terms of the landowners' willingness to accept compensation for participating in a tree-planting project. I thereby obtain a supply curve for this marginal agricultural land. The land value is crucial for estimating the impact and possible costs of the project that could further be reduced by implementing various extension and support services. The actual implementation of the project will also depend on local conditions and the landowner's attitude towards afforestation.

In the next chapter, I review the literature on the costs and benefits of tree planting programs, and provide a clearer statement of what I accomplish in this research. Then, in Chapter 3, I present the model for estimating the willingness of farmers to provide their land for tree planting. The model is applied to data whose collection and descriptive statistics I discuss in Chapter 4. I analyze the data in Chapter 5, which is followed by discussion of thesis results and final remarks in Chapter 6. Finally, I include references and appendices, which contain the survey and the computer program used in this research.

Chapter 2: Land-use Change and Afforestation: A Review of Economic Issues

2.1 Introduction

The expansion of forest area onto marginal agricultural land has been identified as one of the most cost-effective opportunities for carbon sequestration to help mitigate climate change. A number of studies explore the economics of afforestation; in this chapter, I consider a few studies focused on tree planting for carbon uptake in North America. The studies in this section relate to land-use data from a variety of sources that often incorporate averages over large geographic areas. While some studies focus on normative criteria for changes in land use, others attempt to explain factors and the hidden rationale influencing the status quo (i.e., land remaining in agricultural use despite normative economic analysis indicating otherwise). Farmers may decide to retain their marginal land in agriculture for reasons of risk-aversion, existence of high option value or other private non-market benefits, or simply for lack of information related to the knowledge of growing trees or obtaining forest capital. Traditionally, normative studies consider only compensation for forgone agricultural benefits and forest establishment costs, while assuming that gains from consequent forestry practices should be used to offset the level of potential compensation.[14]

2.2 Cost-Benefit Analysis

Cost-benefit analysis (CBA) is one of the most widely used tools of applied economics. A proper CBA can assist landowners as well as policy makers in their decision making. In the afforestation/carbon sequestration context, CBA is based on a comparison of two alternative land uses – forestry versus agriculture. By making such a comparison, the CBA explicitly considers the opportunity costs of the alternative land use. As Parks et al. (1997) indicate, the social decision-making process comprises not only considerations regarding land and public funds

[14] Private non-market forest benefits may also exist that reduce the level of compensation.

availability, but also preferred levels of socio-cultural, infrastructure and political benefits. Each land use can be compared on the basis of (Parks et al., 1997):

- net present value of all quantifiable benefits and costs;
- stored discounted carbon;[15]
- net present value of all non-quantifiable benefits and costs; and
- socio-cultural, infrastructure and political benefits.

Table 1 summarizes the benefits and costs associated with afforesting agricultural land. Following Parks et al. (1997), the decision-maker seeks to maximize welfare, or obtain the net present value (NPV) of all the benefits and costs of land in forestry. A positive NPV for land planted to trees suggests that this land be utilized in growing trees.

2.3 Subsidies for Afforestation

Most agricultural land in Canada is privately owned and will likely require some form of subsidy to compensate landowners for all their costs of converting land to forestry. Farmers' bids in the Conservation Reserve Program in the U.S. divulge farmers' willingness to accept a further 25 per cent of the sum of forgone agricultural benefits and total conversion costs, in addition to compensation for all these costs, in return for participating in the program. This observation strongly implies that farmers need to be paid in order to shift their land into forestry and suggests that the actual cost of afforestation policies may be higher than expected (Parks, 1995). Parks' (1995) study reveals that some land conversion costs cannot be explicitly embedded in profit maximization analysis and brings attention to the fact that millions of acres of marginal land in the U.S. continue to be retained by farmers for agricultural purposes in spite of a purely economic analysis suggesting otherwise. Such apparent "irrational" behavior has been observed in the U.S. for over 15 years and, according to Parks (1995), can be explained by:

- farmers' expectations of capital gains associated with the land;
- non-existence of perfect timber capital markets;

[15] Most studies ignore the negligible amount of carbon that is being released by burning fossil fuels during cultivation and harvest.

- omitted benefits from open space as part of agricultural benefits;
- subjective uncertainty about the land benefits and random potential profits; and,
- most importantly, farmers' risk aversion influenced by the asymmetry of information related to knowledge of production practices (i.e., farmers have a comparative advantage in farming versus forestry).

Table 1. Possible Direct Benefits and Costs Related to Afforestation.

Item	Description
Benefits	
Marketable wood products and other monetary benefits	Lumber, pulp, fuelwood, improvements in agricultural yields (in the case of shelterbelts)
Non-marketable products	Reduced soil erosion, protection and enhancement of biodiversity, enhanced wildlife habitat, recreation, aesthetic and scenic amenities, provision of shelter for livestock, water quality and quantity improvements, noise reduction, sun, wind and cold protection (i.e. improved energy efficiency)
Socio-cultural benefits	Employment and equity
Infrastructure	Human and capital
Political benefits	Domestic and international
Carbon	Carbon uptake (may not be readily observable, however, susceptible to deliberate fires, damage by animals, abandoning plantations or degradation via open access)
Costs	
Establishment	Seeds, seedlings and other material; Labour for site preparation, planting, improving and/or building access roads; Materials and labour for replanting trees that do not survive the first year after planting
Management	Overall administration and technical supervision, training, technical assistance and extension services
Maintenance	Weeding, thinning, road maintenance, fire protection, harvesting and transport
Monitoring	Site surveys, soil testing, tree measurements and feedback
Adverse environmental effects	These could primarily result from planting monocultures of hybrid poplar and could include increase in the use of pesticides and fertilizers, higher susceptibility to insects and diseases, and reduced biodiversity
Transaction	Conversion and other transactions

Source: Parks et al. (1997).

There might also be other factors influencing landowners' decision-making processes that need to be considered. Plantinga (1997) refers to the existence of option value associated with the decision to convert agricultural land to forestry. If conversion to forestry is perceived or otherwise regarded as irreversible, then there is value to delaying the conversion and landowners will need to be provided additional compensation in return for keeping their land in forestry. Parks (1995) alludes to the establishment of financing mechanisms such as cost-sharing, rental payments and/or technical assistance programs designed to reduce uncertainty in order to enhance farmers' willingness to convert land. By the same token, Canada's Forest Sector Table (1999) points out the importance of providing an insurance program. On the other hand, the rate of afforestation is likely to be affected by the scope of publicity, growing and providing adequate nursery stock, and the time required for developing, implementing and operating an effective afforestation policy (Forest Sector Table, 1999). Afforestation programs designed for carbon sequestration and sponsored by, perhaps, the federal government could increase the NPV for the most desired lands available and suitable for conversion by providing their owners with subsidies. Ideally, for meeting a policy objective, the incentives for conversion should only be provided to the most efficient and effective players (Sampson & Sedjo, 1997).

2.4 Possible Shortcomings of Cost-Benefit Analysis

There are some problems with cost-benefit analysis in the context of afforestation. Obtaining precise valuation of likely costs of climate change and all potential benefits and costs related to afforestation is difficult. The effects of climate change on the economic and ecological systems are unknown and uncertainty involves not only the scope of impact, but also its timing. Making matters more complicated, the probability of natural disturbance is also not known. Moreover, when benefits of afforestation involve lumber, pulp or fuelwood, the extent of these benefits depends on appraised timber yields due to uncertainty of the degree of applied forest management (Parks, Brame & Mitchell, 1992). Finally, other political, legal and cultural uncertainties also exist.

An optimal decision based on CBA can also be potentially difficult to select due to factors such as conversion and sunk costs, and farmers' risk perception. Conversion costs can be deemed a real conversion deterrent. Van Kooten and Folmer (1997) indicate that a change in land use will not occur at a single point but rather over a range of values for a deterministic variable. For example, the cost of establishing a crop plantation when land is converted from range production could prevent point shifts in land use. Similarly, sunk investment in agricultural machinery may cause further investment in irrigation systems before abandoning agricultural activities altogether, given that the former has a higher present value than the latter (van Kooten & Folmer, 1997).

Finally, since forestry and agriculture are linked by land exchanges, equilibria in both land markets are determined simultaneously on a spatial and intertemporal basis. Time implications play an important role in land allocation. Most returns in agriculture are realized within one to two years in comparison to distant future returns in forestry. The spatial considerations involve the potential impact of the adjustment process in agricultural and timber markets on carbon storage and fluxes. In particular, conversion of suitable agricultural land to forest could cause shifts in the product and land markets that would stimulate both present and future countervailing transfers of land. Alig, Adams and McCarl (1998) argue that such shifts will hamper the total effectiveness of a policy that promotes afforestation by making it more costly and sequestering less carbon. Alig et al. (1997) empirically estimated the welfare impacts of afforestation in the U.S. They concluded that, with afforestation, intersectoral responses might lead to outcomes that diverge from those intended by the policy. In particular, most afforested land is likely to revert back to agriculture as soon as the timber reaches minimum harvest age, implying that a smooth change in land use may not be optimal. Some of the authors' projections show shifts of large areas of land from agriculture to forestry early on, but this encourages some forestland to revert to agriculture. In the literature, this is often referred to as a carbon leakage. Afforestation subsidies could have a dampening effect on stumpage prices and cause landowners to get out of existing forests in response to future expectations of lower timber prices. Overshooting flux targets (through increased afforestation or intensive management) may be necessary in some periods in order to achieve some aggregate target for all periods. This overshooting will have more complex intersectoral welfare implications.

Undoubtedly, extensive shifts in land use are likely to result in changes in welfare. There will be winners and losers, for a large amount of Canadian economic activity stems from land use. In the forestry sector, consumers could benefit from lower lumber prices resulting from a higher timber supply. Producers, on the other hand, might lose if lumber prices go down. In agriculture, afforestation will likely increase the prices of agricultural products through reduction in land available for cultivation. Consumers could pay more for domestically supplied agricultural commodities that, for physical reasons or government regulation, have no market substitutes, thereby reducing the need for agricultural support programs, mainly minimum price requirements. Further, less agricultural land would be eligible for government support that could be shifted to afforestation programs. An economic analysis designed to assist in creating effective policies needs to outline not only economic and carbon storage impacts of such policies, but also their effect on agricultural, forestry, environmental, energy and trade policies (Sampson & Sedjo, 1997). Such an extensive analysis is beyond the scope of this study, however.

2.5 *Identification of Economically Suitable Land for Afforestation*

Any successful afforestation policy has to ensure that the land is capable of not only growing trees (physiographically suited), but also of providing economic benefits (economically suited). Parks et al. (1992) analyze the suitability of marginal agricultural land in the United States for conversion to forests. The authors exclude roads and farmsteads. Land identified as suitable for conversion is not prime farmland, but rather non-irrigated crop and pasture land, and possibly idle land. This marginal land is identified by soil characteristics and uses Land Capability Subclasses e, w, s and c in Land Capability Classes III, IV and VII to create a map of physiographically, suitable-for-conversion land.[16] Parks et al. (1992) conclude that large areas of these lands are economically marginal due to their susceptibility to erosion, wetness, poor soil drainage, high water table, shallowness, low moisture-holding capacity and fertility, stoniness and climate or terrain, that make them impractical for cultivation.

Roughly half of this marginal land is currently planted to crops (row crops, close-grow crops, hay and other crops), with the other half used for pasture (warm and cool season grasses, legumes, mixed legumes-grasses, mixed grasses-forbs, and mixed grasses-forbs-legumes). Parks et al. (1992) recognize some 116 million acres of suitable-for-conversion marginal agricultural land capable of growing softwoods (62.6 million acres) and hardwoods (53.5 million acres). To determine such capability, the authors use the work published by the U.S. Forest Service that identifies the range of tree species over Major Land Resource Area boundaries. These Major Land Resource Areas are land units of specific geographical and physical characteristics such as land use, elevation, topography, climate, water, soil, and potential natural vegetation. Parks et al. (1992) restrict their study to only the Major Land Resource Areas capable of growing more than

[16] The U.S. Department of Agriculture, Soil Conservation Service, uses this soil classification for creating and maintaining national resource inventories.

trace amounts of both softwood (southern pine, white and red pine, spruce, fir, Douglas-fir, and ponderosa pine) and hardwood species (oak-hickory, maple-beech-birch, and aspen-birch).

With economic criteria entering the analysis, the authors recognize only some 23.4 million acres out of the total of 116 million acres as marginal agricultural land (only about 20 percent) to have potential for conversion to softwood forests. Lack of data for hardwood species prevented their inclusion. The economic analysis carried out in Parks et al. (1992) compares the net present values from agricultural and forestry activities using a 4-percent real discount rate. It assumes perfect markets for forest capital and risk-free decision-making on the part of landowners. Forestry benefits only encompass returns from timber whose maximum NPV yields are calculated based on timber rotations and a mix of all management intensities from medium sites as documented by Birdsey (1992). On the other hand, crop benefits are obtained from crop budgets denoting average returns across 16 major crops from average-quality non-irrigated lands, with price supports not included.[17] Pasture benefits for land with little potential for conversion to cropland are represented by annual cash rents received by the State. For medium and high potential for conversion to cropland, equivalent crop benefits are used. Some 20.7 million of the 23.4 million acres of economically marginal land suitable for conversion to softwoods is accounted for by pastureland with little potential for conversion to cropland, with the remaining 2.7 million acres suitable for cropping.

Parks et al. (1992) recognize that conversion of crop and pasture land to forests without subsidy requires that forest establishment and forgone agricultural benefits be compensated for by the gains in forestry. Even though this is true for the 23.4 million acres of marginal agricultural land in the United States, the land remains in agricultural use. This fact poses a question: Do agricultural producers need to be paid a conversion premium in addition to compensation for lost opportunity costs from agricultural production and forest establishment costs? Parks et al. (1992) conclude that research on the success of afforestation policies needs to investigate the value and nature of this conversion premium considering risk averse landowners facing imperfect forest capital markets. The existence of other environmental and social benefits associated with tree planting and land preservation may also warrant government's intervention. The authors use unpublished data by the U.S. Department of Agriculture to bring attention to the Conservation Reserve Program (CRP). CRP accomplished conversion of 33.9 million acres of highly marginal

[17] These crops include barley, corn, corn silage, cotton, legume-hay, nonlegume-hay, oats, peanuts, sorghum, sorghum silage, soybeans, summer fallow, sunflowers, summer wheat and winter wheat.

agricultural land to a more-environmentally-friendly state (mainly to prevent erosion of fragile farmland) for a total subsidy cost of $US 1.7 billion per year and a establishment-cost share of $US 1.2 billion.[18] Parks and Hardie (1995) use analysis developed by Parks et. al. (1992) to simulate land conversion costs for a 10-year program similar to the CRP. Parks and Hardie (1995) estimate that such a program would require a total discounted compensation of $US 3.7 billion in land rental costs and tree-planting costs to convert 22.2 million acres of land for carbon sequestration.

2.6 Optimal Allocation of Land Based on Results from a Dynamic Optimization Model

In a study that relates geographically to this thesis, van Kooten (2000) considers marginal agricultural land in Alberta and the Peace River region of British Columbia as potentially available for afforestation.[19] Van Kooten (2000) identifies agricultural land according to its current use as either improved land (non-forage crops, forage, fallow, pasture and other) or unimproved land (pasture and other), and considers land in forage production (hay and alfalfa) and pasture (both improve and unimproved) in particular, as marginal agricultural lands suitable for tree plantations. Non-forage crops, fallow and irrigated forage land are excluded from the analysis for their relatively high opportunity costs associated with forestry use, as is land in the 'other' categories for lack of data. In total, some 7.033 million hectares of agricultural land with least opportunity cost are recognized as potentially capable of growing trees. Van Kooten specifically considers hybrid poplar as the only tree species suitable for carbon sequestration in this study area. Agricultural rents are represented by the net returns from both forage production (using data on representative yields and prices) and pasture use (using estimated data on stocking rates and private market value for pasture). Biomass yields and establishment costs for

[18] The compensation rates in this program were based on submitted bids. These bids were compared with "maximum allowable rental rates" determined by a local official body comprised of government and farmer representatives using farm budgets and crop rental rates. Compensation was allowed for forgone agricultural returns and part of establishment costs. Such locally specific compensation rates avoided applying an average rate of compensation to all farmers eligible under the program, which likely reduced the amount of required government subsidy for reaching the goal of converting 16 to 18 million hectares of agricultural land (Plantinga, 1997).

[19] See also van Kooten and Bulte (2000, p.420-27).

plantations of hybrid poplar are explicitly accounted for using estimated values reported by others.

The dynamic optimization model used by van Kooten (2000) maximizes "the discounted flows of present and all future net benefits, including benefits of carbon uptake" (p. 8). A 4-percent rate of discount is used for both monetary and physical carbon values. The model allocates the initial stock of 7.033 million hectares of marginal agricultural land between forestry and agricultural activities based on their most profitable use over time by converting the most marginal land to forestry first. As more land in any given year is converted, the cost of doing so rises, while costs of reverse conversion (from forestry to agriculture) are ignored. Marginal commercial timber and carbon uptake benefits decline as more land is converted to forestry. The solution to this model is an equilibrium state where the net present benefits of conversion to forestry equal the net present benefits of agricultural use for the marginal hectare. Depending on the shadow price of carbon in the sensitivity analysis, van Kooten concludes that, for shadow prices of carbon of $20 and $50 per tonne, only half and about three-quarters, respectively, of the total land area should be converted to trees. The most significant impact on the extent of afforestation of marginal agricultural land is direct establishment costs.

Using an optimal approach path, van Kooten shows that reaching the equilibrium of 3.5 million hectares of converted land for a $20 per tonne shadow price of carbon would take 20 years. This would require an average of 175,000 hectares to be planted annually whereas, more realistically, only about 85,000 hectares could be planted, in which case it would take more than 40 years to reach the equilibrium. Even though, with respect to identifying marginal agricultural land and relevant benefits and costs of afforestation, van Kooten's (2000) work does not differ significantly from Parks et al. (1992), it considers some of the practical limitations associated with planting trees by treating afforestation as a dynamic activity occurring over time (i.e., a dynamic as opposed to static problem).

It also presents the idea that extension and support programs need to be put in place in order to increase the efficiency and effectiveness of an afforestation program so that higher rates of afforestation can be achieved. However, establishing such programs will not be costless and the government will need to show a substantial initiative and dedication of human and financial resources to the task. Van Kooten's study fails to take transaction costs associated with landowners' decision-making processes and other environmental benefits/costs into account.

These could put further financial pressure on the government and prove to reduce fundamentally the contribution of afforestation programs to Canada's Kyoto commitment.

2.7 Costs of Afforestation Using a Positive Analysis

The previous studies employed normative criteria for dealing with the estimation of tree planting costs. Landowners convert their land to forestry immediately once discounted net benefits from forestry exceed those from agriculture. Plantinga (1997) takes a positive approach by estimating afforestation costs using land-use elasticities derived from an econometric analysis for both forestry and agriculture. This approach investigates the actual behaviour of landowners in response to changes in returns from alternative land uses. It is able to account implicitly for other unobservable landowner-specific factors possibly affecting a landowner's decision-making process, such as skill and knowledge level, option value, and private non-market benefits, that would otherwise need to be specified explicitly.

Plantinga (1997) examines data for 1968 and 1983 for four land productivity classes, stumpage prices and milk (grade) prices in Wisconsin. The author's model employs a maximum likelihood approach to determine the land-use elasticity for a given land productivity class with respect to changes in returns in the two sectors. Given these elasticities, the cost of an afforestation program using Plantinga's (1997) approach can be calculated by finding out how much returns from forestry need to increase to stimulate land conversion to forests. Plantinga (1997) concludes that, at least in the study region of Wisconsin, the cost estimates from normative studies are significantly lower, thus underestimating actual afforestation costs. This is because the econometric analysis implicitly accounts for some other factors that tend to increase the true costs of afforestation.

2.8 Estimating the Opportunity Costs of Tree Planting – Thesis Objective

In this thesis, I consider tree planting for environmental, social and climate change mitigation benefits in the grain belt region of Canada's four western provinces, British Columbia, Alberta, Saskatchewan and Manitoba. The objective is to estimate the level of compensation required by farmers for planting trees and the area of marginal agricultural land they would supply. Marginal agricultural land is considered because of its relatively low opportunity cost and its potential to provide farmers with other private, mainly environmental, benefits. The efficiency of the conversion is evaluated based on the least-cost-per-acre approach.[20]

The analysis makes use of the results from a contingent valuation (CV) survey sent to farmers in the four Canadian provinces. In order to encourage effective tree planting, the level of offered compensation has to account for the forgone agricultural returns as well as a number of other factors. A positive analysis by Plantinga (1997) suggests the possibility of land remaining in agriculture because of farmers' risk-aversion, high option value, private non-market benefits, or simple lack of knowledge about growing trees or obtaining forest capital. Transaction costs, the institutional setting and incentive mechanisms can also increase the opportunity cost of planting trees.[21]

The growing acceptance of the contingent valuation method is primarily due to its ability to value goods and services not provided by the market. Transaction costs are often ignored in behavioural models based on changes in agricultural and forestry rents. As a result, these models provide only a partial explanation of the shifts in observed land-use patterns. With the use of the CV survey, proper account can be made for the opportunity costs of tree planting on marginal agricultural land. Since data on the amount of marginal agricultural land in Canada is not precise,

[20] Parks and Hardie (1995) evaluate afforestation costs for the purpose of carbon uptake and conclude that carbon subsidies on a per ton of carbon basis are almost as cost-effective as those based on per acre conversion costs. The authors also point out that the latter would imply lower government information requirements than the former since data on carbon in forests are still somewhat imprecise. This finding provides further justification for choosing cost-effective criteria on a per acre basis since carbon sequestration is not regarded as the primary focus of this study.

[21] Bell, Roberts, English & Park (1994) notice that historically farmers have often been provided with only monetary incentives in order to change the current agronomic practices. Their study, however, reveals that indirect incentives aimed at improving attitudes, providing technical assistance and increasing knowledge and experience as opposed to increasing payments can significantly contribute to the effectiveness of a stewardship program.

the survey also provides an estimate of the amount of this land potentially available for tree planting.

The survey presents farmers with carefully worded, dichotomous choice questions that attempt to evoke their willingness to provide land for a tree-planting program. Assuming that farmers know the value of their marginal land, they need only to accept or reject the bid amount. The random utility framework applied to a bivariate probit is used for estimating the parameters of the underlying utility function. The determined willingness to accept (WTA) compensation is related to the area made available for tree planting to derive a supply curve for marginal agricultural land. The supply curve is not a true supply curve since all exogenous variables are only implicitly accounted for and the level of compensation is elicited from landowners' responses as opposed to observed behaviour.[22] Their desired level of compensation will be affected primarily by the current land use and its economic returns, type of ownership, and characteristics and motivations of landowners (Forest Sector Table, 1999), as well as the type of afforestation program and the support mechanism put in place.

Performing the analysis for various levels of government support, the decision-maker will be able to compare the costs of an afforestation program with various other non-monetary benefits and the amount of carbon sequestered.[23] Upon shifting the land, irreversibility of the conversion can be expected when 1) the land is not productive enough to offset the costs of reverse conversion, 2) the forestry benefits are higher than those from agriculture, or 3) the aforementioned afforestation policy does not allow for any land to revert back to agriculture (Parks, 1995). The extent to which Canada can rely on offsets from afforestation to reduce its carbon emissions is determined in later chapters.

[22] Plantinga (1997) points out that, due to asymmetric information between farmers and the government, the requested compensation may be a lot higher than it would otherwise be under perfect information.

[23] If an afforestation program is implemented with focus on carbon, the subsidies required to convince farmers to plant trees have to be less than or equal to the minimum marginal cost of reducing emissions elsewhere or the market price of other available carbon offsets, unless other afforestation benefits exist that could make up the difference.

2.9 Conclusion

Economists are often called upon to provide welfare estimates of proposed government programs. These welfare estimates require an explicit comparison among the components of a given welfare function, since their relative importance matters. When uncertainties such as those surrounding the climate change issue exist, this comparison becomes even more complicated. It is the decision-maker's responsibility to determine the weighting scheme among the welfare elements in order to present the public with a meaningful policy.

A welfare analysis of a tree-planting project could possibly shift focus away from the benefits of carbon sequestration, which will almost certainly not be the primary objective of a national forest policy (Sampson & Sedjo, 1997). The possibility for adaptation and potential future technological developments, and resolution of uncertainty of the potential damage caused by climate change, are factors that could reduce the risk of damage caused by global changes in temperatures. In addition, the forest stocks have value far greater than that of the carbon sequestered and can serve to meet other policy objectives, such as recreation, wildlife habitat or biodiversity. Accounting for these non-carbon benefits of growing trees, a government could entice farmers to engage in tree planting by providing them with a subsidy for land conversion even if carbon dioxide was not the cause of the alleged global warming. The Canadian government has demonstrated a concern for rising global temperatures ranging from allocating a substantial share of university funding to climate change research to signing international treaties that could result in committing to greenhouse gas emissions reduction. The potential existence of carbon-uptake benefits from forests might then provide further justification for government subsidies for planting trees on some agricultural lands.

Potential climate change is a global phenomenon surrounded by various uncertainty issues and possibly having an impact on all people. A single farmer is likely to express no interest in mitigating global temperatures, unless it provides him or her with a higher utility. Ignoring the unknown benefits and costs of a warmer climate, a farmer's utility level could increase as a result of government payments as well as various private benefits of tree planting. In addition to environmental benefits, farmers could gain from tree planting by diversifying their production and reducing crop supply (if substantial acreage reduction is accomplished). Recent declines in commodity prices and upward pressure on transportation costs, in addition to mitigation-related government payments, could further entice farmers to plant trees. To facilitate effective tree-planting programs, land-use policies such as agricultural subsidies and taxes will need to be coordinated.

Chapter 3: Theory

3.1 Introduction

Economists have long made use of contingent valuation method (CVM) to value environmental amenities and model human behaviour. Use of dichotomous choice (DC) questions in CVM was first popularized by Bishop and Heberlein in their valuation of goose hunting in 1979 (McConnell, 1990). As McConnell (1990) points out, DC questions make respondents more comfortable than open-ended questions since they are not required to formulate their own valuation. Econometrically, the DC responses can be assumed random and modeled in a discrete choice (probit or logit) framework facilitated by an underlying random utility setting. This results, in this case, in estimating a probability of accepting a contract at a certain bid amount and allows computation of a minimum willingness to accept for each farmer.

3.2 Random Utility Model

Neoclassical economic theory suggests that individuals get higher utility from increased consumption. For example, the more shirts one has the better off he or she is. In some cases, however, people buy only one unit of a given good such as house or car. An individual either buys the good or does not, depending on the outcome of his or her evaluation of the purchase. Economists can represent the decision as binary (yes/no) data. When an individual decides to purchase the good, it is assumed that such decision yields him or her higher utility than forgoing the purchase. On the other hand, when an individual decides not to purchase the good, the individual is better off by not buying the good since it yields higher utility. An economist can assume that an individual knows his or her valuation with certainty, but to the economist the individual's valuation is unknown. Nevertheless, since the binary responses are observable, this valuation can be estimated to some extent using personal and economic characteristics of an individual, with some degree of error. This thesis involves modeling farmers' yes/no responses to accepting a tree-planting program.

Hanemann (1984) derives a theoretical random utility maximization (RUM) framework for analyzing binary data. A dichotomous choice question is similar to a referendum due to its vote-like character. Researchers often think of utility as the underlying index function in discrete dependent variable models (Greene, 1997). Hanemann's RUM model has been chosen for the purpose of this thesis since its use of an indirect utility function readily accommodates the environmental attributes of tree planting and does not require their monetary evaluation as is necessary for the dual, expenditure function approach.[24] The deterministic nature of a random utility function requires specification of its functional form in order to be able to estimate the farmers' willingness-to-accept (WTA) compensation. The welfare measure that this WTA seeks to determine is compensating surplus.

Assuming constant prices, the utility of a farmer can be written as

(1) $u_{i,a}(m,s)$,

where i indicates an individual farmer, a the discrete decision to accept or not to accept compensation, $\{a = 1$ if yes; $a = 0$ if no$\}$; m is income; and, s represents other observable attributes that set individuals apart such as personal and farm characteristics.

Hanemann (1984) assumes that the individual knows his or her utility with certainty, but the yes/no outcome is probabilistic since the researcher will never be able to account for all relevant exogenous variables and variations among individuals. Therefore, part of the utility function is not known to the researcher. The utility function $u_{i,a}(m,s)$ can be specified as a function of a deterministic component $v_{i,a}(m,s)$, and an additive stochastic component $\varepsilon_{i,a}$,

(2) $$u_{i,a}(m,s) = v_{i,a}(m,s) + \varepsilon_{i,a}, \qquad a = 0,1$$

where $\varepsilon_{i,0}$ and $\varepsilon_{i,1}$ are i.i.d. random variables with zero means. The utility function (2) is itself a random variable with mean $\bar{u}_a(m,s)$. The basic assumption of random utility maximization is that a farmer chooses rationally the option that yields the highest utility. Given that a farmer

[24] McConnell (1990) provides a detailed exposition of the primal and dual approaches to welfare estimation.

derives his or her utility from income and either tree planting or current agricultural activities, farmer i will say "yes" ($a = 1$) to tree planting with a proposed compensation if

(3) $v_{i,1}(m+\Delta m, s)+\varepsilon_{i,1} \geq v_{i,0}(m, s)+\varepsilon_{i,0}$,

and "no" otherwise. The observed change in income when tree planting is accepted, Δm, is comprised of the compensation (bid) amount (B) plus annualized future timber harvest benefits minus the forgone annual agricultural benefits (OC), all discounted over the contract period. Randomness of the error term resulting from the inability of a researcher to include some unobservable and/or individual specific factors in the econometric analysis implies the use of a probabilistic model. One type of a whole range of these models is the probit model.

3.3 The Probit Model

Any probabilistic model based on dichotomous choice data requires specification of the probability of either alternative occurring. Since utility is a random variable, the probability distribution of a farmer's choice to accept the bid amount can be written (suppressing subscript i) as

(4) $\Pr\{a=1\}=\Pr\{v_1(m+\Delta m, s)+\varepsilon_1 \geq v_0(m, s)+\varepsilon_0\}=\Pr\{(\varepsilon_1-\varepsilon_0) \geq -[v_1(m+\Delta m, s)-v_0(m, s)]\}$.

Replacing $[v_1(m+\Delta m, s)-v_0(m, s)]/\sigma$ with Δv and $(\varepsilon_0-\varepsilon_1)/\sigma$ with ε, where $\varepsilon \sim N(0,1)$ yields the probit model

(5) $\Pr(a=1)=\Pr\{\varepsilon \geq -\Delta v\}=F_\varepsilon(\Delta v)$,

where F_ε is the normal cumulative distribution function (c.d.f.). Researchers like to assume a well-behaved distribution function with desired properties, such as the logistic or normal distribution functions, which result in logit or probit, respectively. In some cases the choice of c.d.f. is based on practical considerations, though theoretically there is no justification for choosing one over the other (Greene, 1997). Many researchers choose a logistic distribution for their error terms since "this assumption leads to convenient closed-form integrals for the cumulative probability density functions that must be evaluated" (Cameron & Quiggin, 1994, p.220). This thesis requires joint modeling of two discrete responses using a bivariate probability density function. The most familiar and well-understood function appears to be the bivariate normal probability density function that, compared to the logistic distribution, allows for non-zero correlation (Cameron & Quiggin, 1994). Prior to proceeding with the bivariate model, the basic probit model is explained.

Regardless of the choice of c.d.f., its argument represents the difference in utilities of yes and no responses. In order to quantify this difference, the utility function needs to be specified. One simplification is made by not including timber benefits in the Δm measure even though the contingent valuation scenario stipulates that trees become farmer's property when contract matures. It is assumed that annualized timber benefits will not significantly impact the decision to accept the tree-planting bid since the reversed conversion costs offset, at least to some extent, the timber returns. Stump removal and root raking put land out of production for one to two years and require, therefore, compensation for the production lost. Timber returns also occur relatively far in the future, thus creating a considerable risk premium further offsetting any timber benefits. The alternative to converting the land back to agriculture is keeping it in forestry, which requires farmer's long-term commitment to growing trees and learning about forestry practices, timber marketing or forestry as a whole. As Plantinga (1997) points out, other studies of large-scale tree planting programs also ignore timber benefits even though, "in theory, forestry rents will be capitalized into the value of the land and may therefore decrease the level of required compensation" (p. S270-S271).

Further, it is assumed that a farmer will base his or her decision to accept the proposed compensation on returns from the least economically marginal acre of land, by comparing $v_1(m+B-OC,s)$ and $v_0(m,s)$, where B is the bid and OC is the opportunity cost or current agricultural returns from the acre.[25] If a farmer agrees to provide more than one acre for tree planting, then he or she carries out the same analysis on a per acre basis, always considering the least productive acre first. McConnel (1990) warns against including any endogenous variables in the utility regression. In this case, the number of hectares supplied is determined based on the

[25] For convenience, the error terms associated with each of the utilities have been dropped.

bid value and their current agricultural returns. For this reason, the number of acres made available by a farmer is kept out of the regression.

Following Hanemann's (1984) example, when the least marginal acre of land is considered (i.e., the first acre to be made available for tree planting), the deterministic parts of the two utility functions can be written as[26]:

$$\text{(6)} \qquad \begin{aligned} v_1(m+B-OC,s) &= \alpha_1 + \beta'(m+B-OC) + \delta_1 s \\ v_0(m,s) &= \alpha_0 + \beta' m + \delta_0 s \end{aligned} .$$

Subtracting v_1 from v_0 and dividing by σ results in

$$\text{(7)} \qquad \Delta v(B-OC,s) = (\alpha_1 - \alpha_0)/\sigma + \beta'/\sigma(B-OC) + (\delta_1 - \delta_0)/\sigma(s),$$

which can be rewritten as

$$\text{(8)} \qquad \Delta v(B-OC,s) = \alpha + \beta(B-OC) + \delta s,$$

where $\alpha = (\alpha_1 - \alpha_0)/\sigma$, $\beta = \beta'/\sigma$ and $\delta = (\delta_1 - \delta_0)/\sigma$. This provides an empirical estimate of $\Pr(a=1)$ that is also the conditional mean probability of a. The $E[a/X]$ is then equal to:

$$\text{(9)} \qquad E[a/X] = \Pr(a=1) = F_{\varepsilon'}(\Delta v) = \int_{-\infty}^{+\infty} \phi(\Delta v) = \int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi}} e^{\frac{-\Delta v}{2}} \, d\Delta v,$$

where X is a vector of exogenous variables, F_ε is the standard normal cumulative distribution function and ϕ is the corresponding density function (see Greene, 1997). Expression (9) shows the probability of a farmer agreeing to a 10-year contract. Researchers are often interested in the marginal effects of exogenous variables on this probability. As Greene (1997) shows, the marginal effect of given X variables can, in general, be obtained from

[26] Following usual convention, Greek letters stand for coefficients and Latin letters for variables.

$$(10) \qquad \frac{\partial E[a/X]}{\partial X} = \left\{\frac{\partial F(X\beta)}{\partial (X\beta)}\right\}\beta = \phi(X\beta)\beta_X ,$$

where β_X is the coefficient associated with the given X, β is the vector of all parameters to be estimated, and F and ϕ are defined in (9).

The length of the contract may play an important role in the farmer's decision to plant trees, *ceteris paribus*. A longer contract provides the incentive to plant indigenous species as opposed to fast-growing hybrid poplar varieties that can prove undesirable to some farmers due to their susceptibility to diseases and esthetic preferences. The possibility of accounting for environmental attributes when considering long-term tree planting contracts can result in long-term benefits and more long-term financial security. To find out if the farmer has a time preference for contracts, a 40-year contract is proposed as a follow up to the question proposing a 10-year contract. The compensation offered in the first question is randomly assigned among the individual surveys and therefore uncorrelated, *ex ante*, with the error term, ε_1. The assignment of compensation in the second question is, however, always lower to accommodate the longer period and therefore endogenous to the compensation offered in the first question.[27] In addition, since both questions are based on similar criteria and identical farmer characteristics and attitudes, as well as environmental conditions of a farm, some degree of correlation between the responses to the first and second questions is expected. In order to account explicitly for the correlation between the equations in the estimation process, a bivariate probit framework is chosen for simultaneous estimation of both WTA distributions.

3.4 Bivariate Probit Model

Poe, Welsh and Champ (1997) show that, when a respondent is faced in a single questionnaire with two values to the same dichotomous choice contingent valuation question, his or her answers are to some degree correlated. In this case, the use of the standard, double-bounded approach is likely to result in biased estimates of the significance of the difference in the mean values. The two questions in this survey are not precisely the same, so one could assume that a farmer bases

[27] This endogeneity can give rise to negative correlation between the compensation amount in the first (10-year contract) question, B_1, and the error term in the second (40-year contract) question, ε_2.

his or her answer on two distinct, unobserved resource values. If this is true, then the correlation coefficient between the two values will equal zero and the bivariate probit reduces to the estimation of two independent probits. However, there is no *a priori* reason to assume independence of the two resource valuations since they can be related. A farmer could be considering the programs as alternatives, in which case the error terms are likely to be correlated. The bivariate probit allows for estimation of the two valuation functions in case correlation exists.

Probabilistic models explicitly account for random disturbances (errors) that include systematic components, unmeasurable or omitted factors specific to individuals (Poe et al., 1997). When these factors are common across the responses to the two questions, correlation across the error terms arises. Poe et al. (1997) also bring attention to several other causes of correlation, such as "yea saying", "symbolic" effects and "starting point" bias. Given that the two goods to be valued – short-term versus long-term tree planting contracts – are closely related, the correlation is likely to be positive. As Cameron and Quiggin (1994) point out, failure to account for the correlation of the two random errors will bias all of the coefficients of the second valuation equation.

By assumption, the theoretical specification of the probability to accept the 40-year contract is the same as that of accepting the 10-year contract, with separate parameters and correlation between the two WTA functions explicitly estimated. More specifically,

$$(11) \qquad \Pr(I_b = 1) = F_\varepsilon^b(\Delta v_b^*),$$

where $b = 11{,}22$ (for 10-year and 40-year contracts, respectively), and F_ε^b is the standard normal cumulative distribution function (c.d.f.), since $\varepsilon_b \sim N(0,1)$.[28] Such modeling allows for a statistical test of the difference between the two implied valuation distributions (Cameron & Quiggin, 1994).

In order to proceed with estimation, the dependent variable has to be specified. A farmer answers 'yes' to the first question if $\Delta u_{11} \geq 0$ (denoted by $I_{11} = 1$), and 'no' otherwise (denoted by $I_{11} = 0$). Similar to the first question, the discrete response indicator for the second question, I_{22}, equals 1 (a 'yes' response) when $\Delta u_{22} \geq 0$ and zero otherwise (a 'no' response). The discrete response

[28] The subscript i is suppressed.

indicators, I_{11} and I_{22}, represent the dependent variables in the bivariate probit analysis. Four distinct possibilities arise depending on the responses to both questions. A farmer can say (1) 'yes' to both questions, (2) 'yes' to the first one and 'no' to the second one, (3) 'no' to the first one and 'yes' to the second one, or (4) 'no' to both.

For ease of exposition, rewrite $\Delta v_b = \alpha_b + \beta_b(B_b - OC_b) + \delta_b s_b$ in a matrix form separately for both equations as

(12) $\Delta v_{11} = X_{11}\omega_{11}$ and $\Delta v_{22} = X_{22}\omega_{22}$,

where X_{11} and X_{22} are (i × k) matrices, with i being the total number of farmers and k the number of regressors, and ω_{11} and ω_{22} are column (k × 1) vectors of coefficients to be estimated.[29] Following Cameron and Quiggin's (1994) approach, the bivariate probit model is developed in the context of the bivariate normal distribution, BVN $(X_{11}\omega_{11}, X_{22}\omega_{22}, \sigma_{11}^2, \sigma_{22}^2, \rho)$, for the two implicit valuations. In this context, the correlation between the differences in errors of the two alternative responses is explicitly accounted for by ρ.

For I_{11} = 1, recall that $\Delta u_{11} \geq 0$. Applying $\Delta u_{11} = X_{11}\omega_{11} + \varepsilon_{11}$, where ε_{11} now indicates the difference in error terms between the two alternatives in the first equation (i.e., $\varepsilon_{11} = \varepsilon_1 - \varepsilon_0$) implies

(13) $(\varepsilon_{11} / \sigma_{11}) \geq [(-X_{11}\omega_{11}) / \sigma_{11}]$,

where $\varepsilon_{11} / \sigma_{11}$ is a standard normal random variable. The probability function for I_{22} can be analogously transformed using $\Delta u_{22} = X_{22}\omega_{22} + \varepsilon_{22} \geq 0$. Define z_1 as the standard normal error $\varepsilon_{11} / \sigma_{11}$ and z_2 as the standard normal error $\varepsilon_{22} / \sigma_{22}$. The two standard normal variables z_1 and z_2 are, therefore, jointly distributed following the standard bivariate normal distribution, SBVN $(0,0,1,1,\rho)$. Cameron and Quiggin (1994) adopt notation $g(z_1, z_2)$, which indicates the bivariate

[29] In this thesis, Δv_{11} and Δv_{22} are not the same, but, in general, X_{11} and X_{22} may or may not be identical (Cameron & Quiggin, 1994).

standard normal density function, in order to simplify the writing of the log-likelihood function. This density is defined as

$$(14) \qquad g(z_1,z_2) = \frac{1}{\sqrt{2\pi(1-\rho^2)}} e^{\frac{-(z_1^2 - 2\rho z_1 z_2 + z_2^2)}{(2-2\rho^2)}} .$$

Applying (13) and the definition of z_i results in $z_1 = (-X_{11}\omega_{11})/\sigma_{11}$ and $z_2 = (-X_{22}\omega_{22})/\sigma_{22}$ in (14). The analysis can now proceed with formulation of the log-likelihood function,[30]

$$(15) \qquad \log_e L(\omega_{11},\omega_{22},\sigma_{11},\sigma_{22},\rho) = \sum_{i=1}^{n} \left\{ \begin{array}{l} (I_{11}I_{22}) \log_e\left[\int_{(-X_{11}\omega_{11})/\sigma_{11}}^{\infty} \int_{(-X_{22}\omega_{22})/\sigma_{22}}^{\infty} g(z_1 z_2) dz_2 dz_1 \right] \\ + (I_{11})(1-I_{22}) \log_e\left[\int_{(-X_{11}\omega_{11})/\sigma_{11}}^{\infty} \int_{-\infty}^{(-X_{22}\omega_{22})/\sigma_{22}} g(z_1 z_2) dz_2 dz_1 \right] \\ + (1-I_{11})(I_{22}) \log_e\left[\int_{-\infty}^{(-X_{11}\omega_{11})/\sigma_{11}} \int_{(-X_{22}\omega_{22})/\sigma_{22}}^{\infty} g(z_1 z_2) dz_2 dz_1 \right] \\ + (1-I_{11})(1-I_{22}) \log_e\left[\int_{-\infty}^{(-X_{11}\omega_{11})/\sigma_{11}} \int_{-\infty}^{(-X_{22}\omega_{22})/\sigma_{22}} g(z_1 z_2) dz_2 dz_1 \right] \end{array} \right\} .$$

Log-likelihood function (15) has a convenient form that can be estimated using the maximum likelihood method. Maximum likelihood estimates (MLE) of any of the unknown parameters $\omega_{11},\omega_{22},\sigma_{11},\sigma_{22},\rho$ are obtained by maximizing $\log_e L(\omega_{11},\omega_{22},\sigma_{11},\sigma_{22},\rho)$ over the respective parameters. The results are $\hat{\omega}_{11},\hat{\omega}_{22},\hat{\sigma}_{11},\hat{\sigma}_{22},\hat{\rho}$ that maximize the probability of obtaining observed values for I_{11} and I_{22} for a given set of X_{11} and X_{11}. This maximization will yield a value for the $\log_e L$ function that can be compared across alternative specifications for the deterministic part of the utility function. A higher value of $\log_e L$ generally implies a better fit of the model to the given set of data. The employment of various covariates and exploration of alternative functional forms for the deterministic part of the valuation functions are found in Chapter 5.

[30] Probability density function of any ordering of outcomes for I_{11} and I_{22} is the product of the joint probabilities of I_{11} and I_{22} for each farmer (see Greene, 1997).

3.5 Supply Curve

The ultimate objective of this research is to determine a supply curve for marginal agricultural land available for tree planting. The estimated parameters discussed in the previous section determine the probabilities of accepting bids for 10-year and 40-year contracts. From the estimated probability functions, shadow prices for provision of marginal agricultural land can be calculated.

Hanemann (1984) proposes a conceptual approach for deriving farmer's minimum WTA compensation, denoted by B^*. In effect, this can be accomplished by determining the amount of money needed to keep the farmer just indifferent between accepting the bid and retaining his or her marginal land in agriculture. Analogously, one can express this indifference by setting the probability of accepting a bid to 0.5 and solving for B^*,

$$(16) \qquad \Pr(a=1) = \Pr\{v_1(m + B^* - OC, s) + \varepsilon_1 \geq v_0(m,s) + \varepsilon_0\} = 0.5 \,.$$

In (16), the probability of accepting the bid, B*, is the same as the probability of rejecting it and is therefore equivalent to

$$(17) \qquad \Pr(a=1) = \Pr\{\varepsilon \geq -\Delta v\} = F_\varepsilon(\Delta v) = 0.5 \,,$$

where F_ε is the standard normal c.d.f. of the probit model. Given the symmetric properties of the standard normal c.d.f., $F_\varepsilon(0) = 0.5$, expression (17) can be solved using (8) and (9) for B^*,

$$(18) \qquad \Delta v = \frac{\alpha}{\sigma} + \frac{\beta}{\sigma}\left(B^* - OC\right) + \frac{\delta}{\sigma}s = 0 \Rightarrow B^* = OC - \left(\frac{\alpha}{\beta} + \frac{\delta}{\beta}s\right).$$

This result facilitates the interpretation of two basic welfare measures, the median and the mean willingness to accept. The median is the value of B that corresponds to a value of $\Pr(a=1) = 0.5$ and is equivalent to B^*. Hanemann (1984) shows that specifying utility as in (6) results in the mean being equal to the median and ensures that no 'income effects' occur since probabilities are independent of the individual's income. Hanemann (1984) ascertains that only the median and mean "are fully compatible with the notion of cardinal utility" (p. 336). In the case that they differ, the choice of measure is left to the researcher's discretion.[31]

The median WTA measure can be used for estimating a supply of marginal agricultural land for tree planting. So far, the analysis has focused on predicting the probability of accepting a bid for the least marginal acre. However, a farmer may decide to supply more acres for the same bid. The survey design accommodates this possibility by enabling each farmer to say 'yes' to as many acres as desired. Equation (18) provides the estimate of the minimum amount of compensation that has to be offered to a farmer in order to make him or her just as well off with planting trees as without. Collecting this data for each farmer and regressing the number of acres that each farmer makes available for tree planting on the difference between the bid and the minimum willingness to accept results in a supply curve type of relationship for marginal agricultural land.

3.6 Conclusion

This chapter provides a theoretical background for the analysis of some of the survey data. In particular, it shows how the probability of accepting the proposed afforestation contract can be estimated. Knowing this probability for each farmer assists in formulating a minimum willingness to accept for a given farmer. Chapter 5 applies the survey data to the theory developed in this chapter and concludes with estimating a supply schedule for marginal agricultural land available for tree planting. This schedule is obtained by regressing the number of acres a respondent makes available at a given bid on the computed difference between the bid and the minimum willingness to accept. The next chapter provides a short overview of some general results about the farmers analyzed in this research as well as about the way these data are obtained.

[31] See Hanemann (1984) for more detailed discussion of the merits of each measure.

Chapter 4: Survey of Landowners in Canada's Grain Belt

4.1 Introduction

A mail-out survey instrument is used to estimate the capacity of Canadian farmers to adapt to warmer climate and their willingness to change current agronomic practices to help mitigate climate change. This chapter begins with a brief description of how the survey was conducted and structured. Then, detailed results of the mail-out are provided and the response rate is discussed. Finally, basic summary statistics are presented.

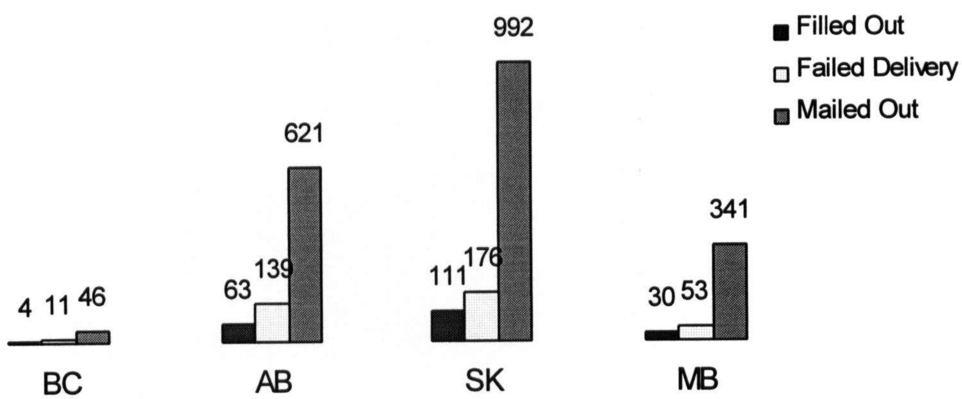
4.2 Use of Survey Instruments

Conducting surveys by mail is one way of soliciting contingent valuation data. Mitchell and Carson (1989) advocate phone interviews over mail surveys in spite of their higher costs and limits on the information that can be obtained. Scarce financial resources ruled out the use of phone interviews in this study. On the other hand, a mail survey is less stressful for respondents making contingent valuation decisions that, in this case, require extensive consideration of various issues. Therefore, a mail survey was chosen which, for practical purposes and budget constraints, identified 2000 farmers from the grain belt region of Canada, which includes northeastern British Columbia, Alberta, Saskatchewan and Manitoba.

Mailing addresses were obtained from the "Canadian Farmers" database of Watts List Brokerage (WLB), a firm managing various address lists related to agribusiness. Ideally, an 'unbiased' list of addresses from Statistics Canada ought to be used, but Statistics Canada policy prevents disclosure of personal information to the public. According to WLB, the 'Canadian Farmers' database is updated quarterly exclusively from survey and research sources, so the most current and accurate information can be assured. WLB considers this list to be the largest and most comprehensive farm database in Canada.

After omitting dairy farmers and farmers with less than 160 acres of land, the database contains information on 34,618 farmers in Western Canada, out of which a random sample of 5000 names was provided by WLB. Saskatchewan farmers are the most numerous group in this sample, followed by farmers from Alberta, Manitoba and British Columbia. Dairy farmers were excluded from the sample because they likely have high opportunity costs of tree planting. The survey's contingent contracts considered explicitly block forest plantings for which small landowners were unlikely to contribute relatively significant portions of their land.[32] A random sub-sample of 2000 names was prepared for mail-out (see Figure 1).

Figure 1. Number of Responses by Province.



The mail-out was preceded by a pilot study within the Faculty of Agricultural Sciences at the University of British Columbia (UBC) in order to determine the validity and clarity of questions contained within the survey. Mitchell and Carson (1989) recommend carrying out both focus groups and pilot tests with potential respondents prior to sending out a survey.

A researcher has to be prepared to commit a significant amount of time and money to focus groups. The cost of establishing and implementing a focus group study in each of the four provinces alone could easily amount to $3,000. Further, a survey of farmers is akin to a survey of small business firms. In business surveys, focus groups are rarely used (Ilan Vertinsky, personal

[32] Bell et al. (1994) consider landowners with 100 or more acres in their study of participation in Tennessee's Forest Stewardship Program.

communication, October 21, 2000). For this reason and due to a lack of funding, no focus group study was carried out. Pilot tests usually consist of sending out surveys to small samples of randomly chosen subjects. The results from pilot tests provide the researcher with feedback on clarity, relevance and validity of the survey and give the researcher an opportunity to make changes before the final mail-out. Ignoring the costs of such pilot tests, time restrictions precluded the implementation of extensive pilot tests.

Time became a constraint after a lengthy review process by the Behavioural Research Ethics Board at UBC, which must approve all surveys conducted by UBC students and/or faculty. The review required submission of the entire survey, including the cover letter, and took two months to complete. With the approaching harvest season on the prairies (a time during which farmers are unlikely to pay attention to a survey), there was pressure to mail out the survey within a limited time frame. The survey was sent out on the 17th of July with postcard-type reminders following after approximately three weeks.

4.3 Survey Content and Structure

The survey includes a brief, personalized cover letter explaining the purpose of the questionnaire and a definition of carbon credits. The letter also identifies the project leader who would utilize data supplied by the survey. The actual 12-page (8"-11") survey was printed, folded and stapled to form a booklet by a professional printing company. The survey was designed according to Fink and Kosecoff's (1998) guide to proper survey design. It is split into six sections beginning with a short explanatory page that attempts to motivate farmers into responding, while pointing out the climate-change mitigation benefits of tree planting. Due to the broad extent of the survey, only sections and questions relevant to this study are discussed in greater detail in this chapter. The survey and cover letter are found in Appendix A.

Section one of the survey comprises opinion questions and a history of former contracts a farmer may have been involved in. In section two, farmers are asked to describe their farming enterprise by identifying their least productive fields. This information is helpful in determining the ability of marginal land to support growing trees. The remainder of section two asks farmers to identify the livestock they own. The questions are meant to obtain insights into economies of scale associated with raising livestock. Section three is a one-page sub-survey of adaptation strategies that farmers might employ in order to avert losses from agriculture or take advantage of new opportunities brought about by warmer climate.

The section most relevant for this study is section four. In the introduction to this section, soil requirements for tree species are briefly described for the four western provinces. One question recognizes the potential impact previous participation in tree-planting projects might have. Another focuses on farmers' willingness to plant trees conditioned upon no impact on current agricultural subsidies. Recipients are then asked whether they would 'in principle' accept a particular level of compensation given that all tree-planting costs were covered. This question separates those farmers unwilling to take part in a tree-planting project from those willing to participate, regardless of whether the latter are willing to accept offered compensation or not. Due to the efficient design of the survey, only farmers who indicate a willingness to accept (WTA) compensation "in principle" are asked to answer the WTA questions.[33] A dichotomous choice (DC) format is selected, as it best resembles a market decision. Key data for the bivariate probit analysis come from answers to the following DC questions, which assume that all tree-planting costs are covered (i.e., a contractor does the planting, monitoring and management):

> Suppose a block tree-planting program (planting of entire fields) is available, and at least one of your fields is identified as a potential site for tree plantations. Would you be willing to accept annual compensation of $xx per acre for a 10-year contract?
>
> Again, suppose a block tree-planting program is available and your land is eligible for tree plantations. Would you be willing to accept an annual compensation of $yy per acre for a 40-year contract?

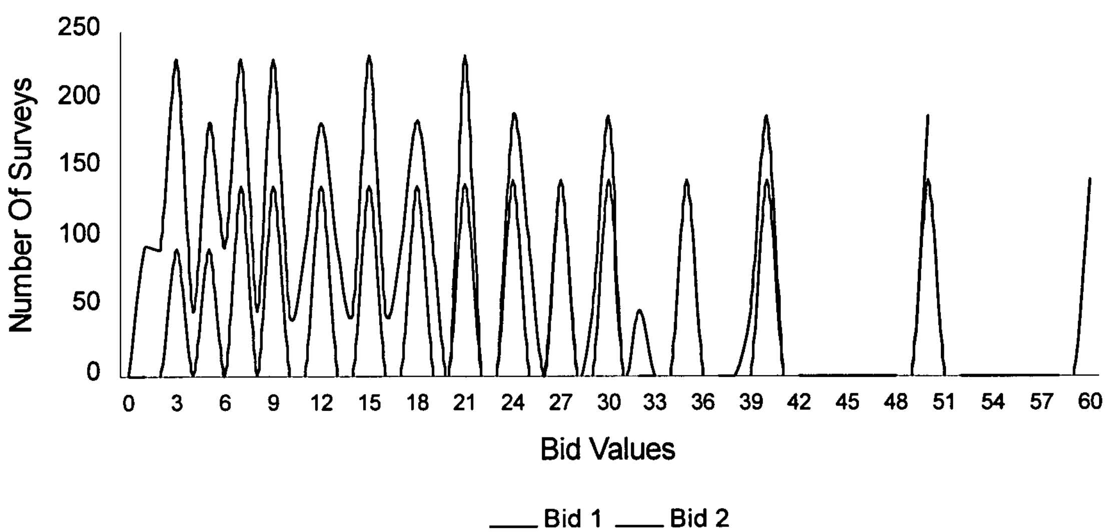
In these two DC questions, farmers are offered a certain randomly chosen pair of annual per acre levels of compensation ($xx and $yy) for their acceptance of block tree-planting programs on their marginal land (the land identified by farmers in section two) for 10 and 40 year contracts, respectively.[34] The 'yy' bid is always smaller. It is assumed that the longer contract would

[33] There are 46 to 47 copies of each pair of bids in the mail-out of the survey in order to account for the 2000 surveys sent.

[34] Direct compensation from an unidentified source is used as the payment vehicle in this survey since the varying credibility of different compensation schemes could be a source of bias.

provide more financial security and enable farmers to grow commercially more valuable species of trees. In the absence of *a priori* valuation information, the compensation levels are selected based on the results of the pilot study and range from $1 to $60 per acre annually. As Figure 2 demonstrates, the distribution of these bids is skewed towards the lower bound of the range in order to provide more efficient estimates of WTA, as recommended by Cooper (1993). Farmers are further asked how many acres they would contribute at the accepted "bid" level. Other questions in this section involve the type and length of program preferred, desired tree species and action likely to be taken at the end of the contract, as well as reasons for not considering a tree-planting program. The contingent contract indicates that farmers have no right to harvest the trees before the contract expires, but trees become their property at the end of the contract. No compensation is provided for the reversed conversion back to agriculture if the farmer decides to do so. It is assumed that the farmer incurs the cost of returning the land back to agricultural production.

Figure 2. Mail-out Bid Distributions.



Since the Kyoto Protocol recognizes that some countries, and, for that matter, even certain industries within a country, can reduce emissions of greenhouse gases and/or sequester carbon more efficiently than others, economists have been involved in designing a carbon credit trading scheme. As a result, farmers are given an opportunity in section five to identify their willingness to engage in contracting with various parties for carbon credits. The survey concludes with section six that provides demographic information of respondents. The last page of the survey is set aside for any comments and concerns regarding the survey and/or the research undertaken. These are summarized in Appendix B.

4.4 Response Rate

In many recent contingent valuation studies, potential respondents are contacted by phone prior to the interview or survey mail-out in order to establish the respondents' willingness to participate in the research. This is an efficient way of sorting out those who do not wish to participate while keeping a sample of sympathizing subjects. Although making initial contact with respondents can contribute significantly to higher response rates, it requires substantial financial resources, which were not available.

A total of 2000 survey packages was bulk-mailed to landowners in the grain belt region of Canada. Perhaps, only one half of these reached the targeted farmers. The uncertainty of actual delivery stems from the fact that 379 initial surveys were returned undelivered. Canada Post identifies eight basic reasons for delivery failure. Table 2 lists the eight reasons and shows the number of surveys in each category. The majority of undelivered surveys was received prior to sending out of reminder cards. However, six reminder cards were also returned as undeliverable. This suggests that not all initial surveys sent to wrong addresses or people were returned. An inaccurate and perhaps outdated address list meant that the survey was sent to many retired farmers. Some farmers (18 in total) no longer actively farming their land decided not to fill out the survey and simply returned the survey (see Table 2). One can only speculate on the number of retired farmers who did not return the survey. To illustrate the aging farmer population, Figure 3 depicts the age distribution of the actual respondents. Using a cumulative distribution for farmers' age reveals that only 17 percent of farmers are less than 45 years old, but 40 percent of them are over 60 and 30 percent over 65 years of age.

Given the low reliability of the mailing list from Watts List Brokerage, the number of undelivered surveys could be significant. Despite claims to the contrary, Watts List Brokerage data are considerably out-of-date, since some of the farmers on their list have been deceased since as far back as the 1960s. Watts List Brokerage pointed to the inherent difficulties of Canada Post with delivering mail in rural areas, but recognized the unacceptability of the large number of undelivered surveys and offered partial financial compensation.

Table 2. Survey Responses and Effectiveness of Delivery.

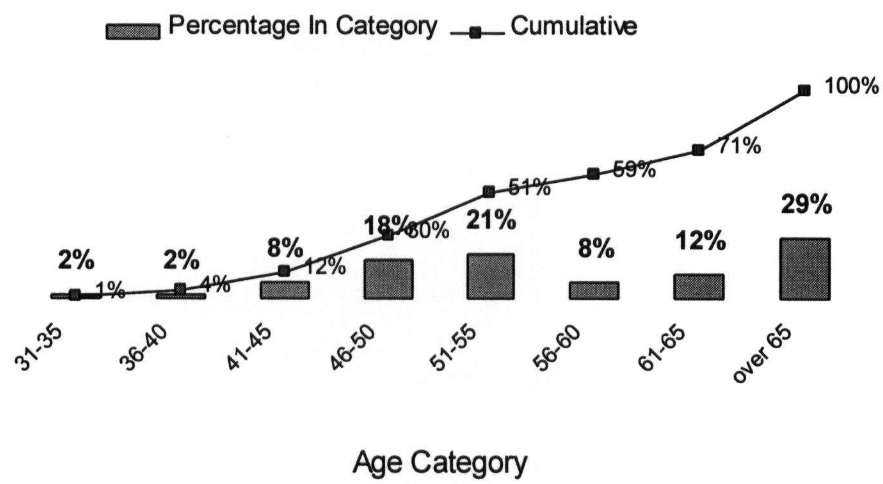
Survey Status			**Number**
Undelivered	1. Unclaimed		5
	2. Not such address		31
	3. Address incomplete		4
	4. Moved or address unknown		190
	5. No such post office		1
	6. Refused by addressee		2
	7. Deceased		93
	8. Name unknown		53
Total (undelivered)			**379**
	Before reminders		(373)
Returned	9. Retired and/or no longer farming (blank responses)		18
	10. Filled out, but unusable	Nearly blank response	1
		No longer farming	4
		Insufficient acreage	2
		Retired	1
	Subtotal (unusable)		**26**
	11. Filled out (including those with missing values)		182
Total (returned)			**208**
	Before reminders		(140)
Total Mailed			**2000**

Another factor possibly affecting the response rate and data reliability is perception and interpretation on the part of the farmer. A number of farmers indicated in their comments at the end of the survey that they found some questions difficult to answer, or even to understand (see

Appendix B).[35] Still others pointed out the lack of sufficient information in the survey to provide meaningful responses. This problem serves as a caveat on the analysis and conclusions.

The response rate is calculated by subtracting the number of undelivered surveys from the total number of surveys sent out. In total, 140 surveys were returned prior to sending out reminders, yielding a nine percent effective response rate; reminders increased the effective response rate to 13 percent.[36] This response rate is just slightly higher than the 12 percent response rates reported by the Environics Research Group (2000) and Bell et al. (1994). The actual response rate is significantly higher than 13 percent, but remains unknown due to unreliable address list and unreliability of the postal service. Figure 1 displays the distribution of mailed and returned surveys by province.

Figure 3. Age Distribution of Respondents.



[35] Comprehensibility resulting from a difficult survey wording is also a problem of the Environics Research Group (2000) survey (discussed below), which uses a sample of farmers and landowners from all of Canada.

[36] Effective response rate = returned / (sent - undelivered) * 100%.

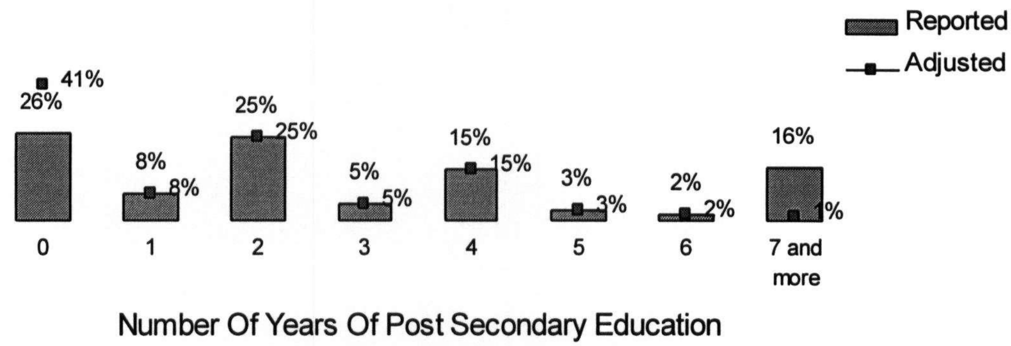
4.5 Summary Descriptive Statistics

In total, 182 completed surveys were received plus 26 that were incomplete. Wherever appropriate, the survey results are compared with those reported by the Environics Research Group (2000) in its recent study of attitudes and behaviours of farmers and landowners in the entire Canada. That study is based on a survey that the Environics Research Group declares to be "the most comprehensive survey of its kind ever undertaken in Canada and, [they] believe, should be considered a benchmark study of rural landowners on the topic of land use and land stewardship" (p. 8).[37]

The respondents to the UBC survey seem fairly well educated since 122 out of 165 (or 74 percent) reported at least one year of post-secondary education. Environics Research Group (2000) found that perhaps only 50 percent of farmers had some level of post-secondary education and only 10 percent obtained a post-graduate or university degree. In contrast, the current study suggests that 36 percent of farmers have four or more years of post-secondary education (see Figure 4). This is highly improbable considering the poor English grammar of those who reported having seven and more years of post-secondary education, as well as their age and the number of years working in agriculture. It is assumed that the majority of these farmers simply misunderstood this question and provided the total number of years of education as such. Even though they may still have some level of post-secondary education, they are assigned to the lowest education category. When this adjustment is made, the number of farmers with at least a year of post-secondary education drops down to 59 percent and only 20 percent have four or more years of post secondary education. The results of this adjustment agree more closely with the findings of the Environics Research Group.

[37] The Environics Research Group surveyed farmers and rural landowners across Canada who derive at least $2,500 per annum from their land and their primary farming activity is one of the following six commodity groups: grain/oil seed, cattle, dairy, forage, hog/other meat or horticulture. In addition, there is no limitation on farm size.

Figure 4. Post Secondary Education of Respondents.

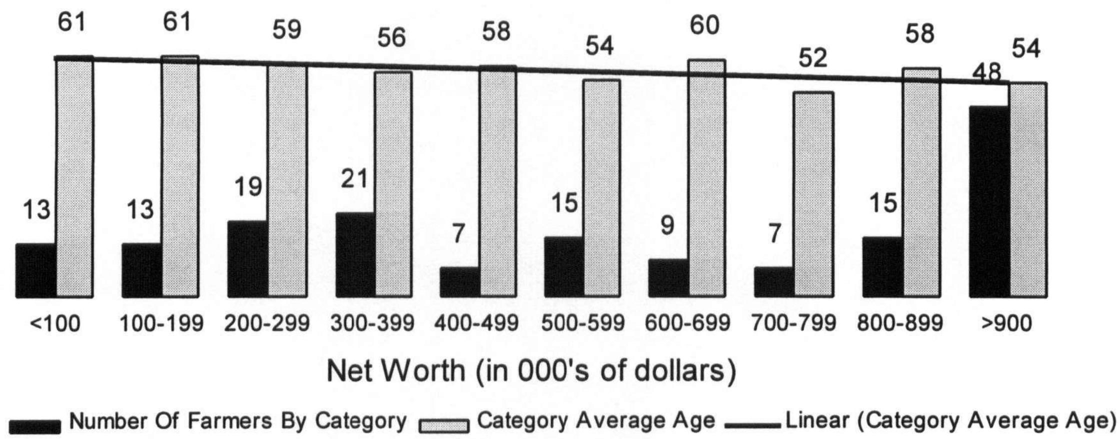


The average farm size for my sample is 1,873 acres, ranging from a minimum of 160 acres to a maximum of 10,000 acres. In total, all the land combined accounts for 327,838 acres. Almost all farmers (i.e., 98 percent) own at least some of the land they farm. The average size of land owned by the respondent is 1,246 acres. On the other hand, 61 percent of farmers rent on average 1036 acres of land.

When asked about land that is not used, not even for grazing cattle or as summerfallow, 20 percent of respondents indicate zero acres. However, some of these farmers then provide a positive number for the follow-up question that asks for the number of acres of this unused land currently covered by trees. As a result, an adjustment is made so that the answer to the former question indicates at least as many acres of land as the answer to the latter question for all observations. This reduces the ratio of farmers with zero unused land to 15 percent. The remaining 85 percent of farmers have on average 111 acres of idle land. Of these farmers, 87 percent reported at least some tree cover on the idle land, with an average of 49 acres. In addition to trees on the unused land, 44 percent of all farmers have on average 77 acres of tree cover elsewhere on their farms.

That Canada's farm population is aging is supported by Figure 5, which depicts the distribution of farm net worth. Farmers have owned their operations for an average of 33 years, providing them with enough time to accumulate wealth of over $900,000. As Figure 5 shows, the "over $900,000" category describes the largest number of respondents and represents close to 29 percent of all farmers. This matches the 29 percent of farmers of age 65 and older. However, a close inspection of Figure 5 reveals that wealth decreases with age. One explanation is that 71 percent of respondents operate on land that has been passed down within their families – much net worth has been inherited. Average farm net worth is $586,527 and farming is the primary source of income for more than 60 percent of farmers. Only 39 percent of respondents supplement their farm income through off-farm employment.

Figure 5. Net Worth Distribution of Farmers.



Prior to discussing the specific issue of willingness to participate in tree planting on marginal agricultural land, it is meaningful to dissect the attitudes of farmers to climate change and tree planting in general. Farmers are well acquainted with the topic of climate change, considering that 98 percent of them are aware of the potential for climate change or global warming. Moreover, as Figure 6 demonstrates, farmers tend to agree that Canada needs to invest in reducing emissions of greenhouse gases. The possibilities for addressing climate change through minimum tillage, reduced summerfallow, and other changes in agronomic practices are known to 85 percent of farmers. Finally, 66 percent have read or heard about the possibility for planting trees on marginal agricultural land to mitigate climate change. The Environics Research Group (2000) finds 87 percent of its respondents agreeing that forests can reduce the effect of climate change.

Planting trees on marginal agricultural land can impact farmers and landowners in various ways. In general, farmers are sensitive to the esthetic attributes of their local landscape. Only three out of 179 express no opinion or knowledge on this topic. The majority, however, feel that increased tree cover in their region would not detract from the visual appeal of their surroundings (see Figure 7).

Figure 6. Farmers' Attitude towards Climate Change.

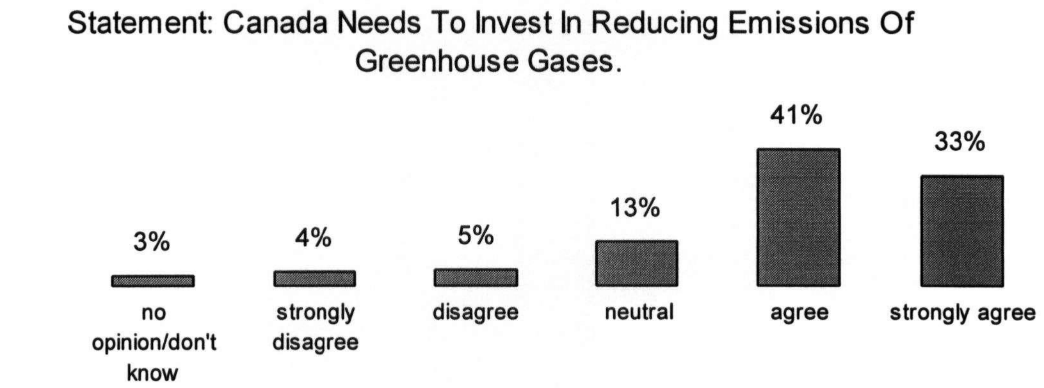


Figure 7. Esthetic Perception of Increased Tree Cover in Local Area.

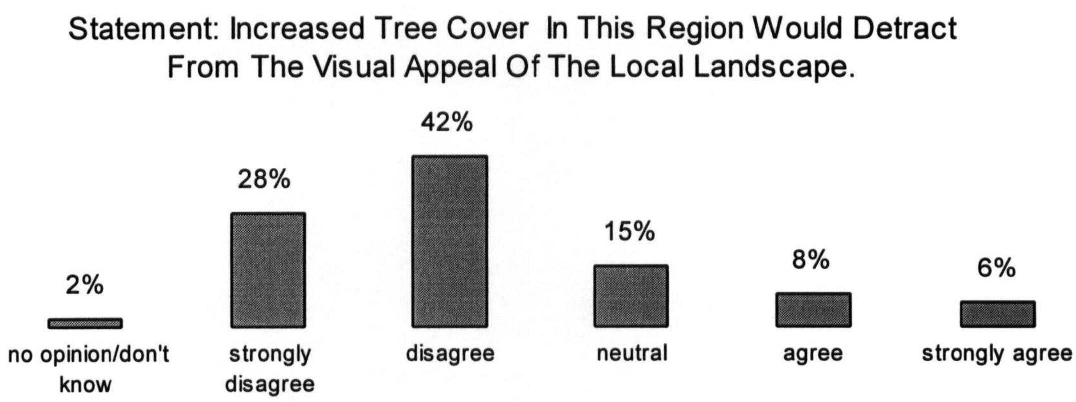
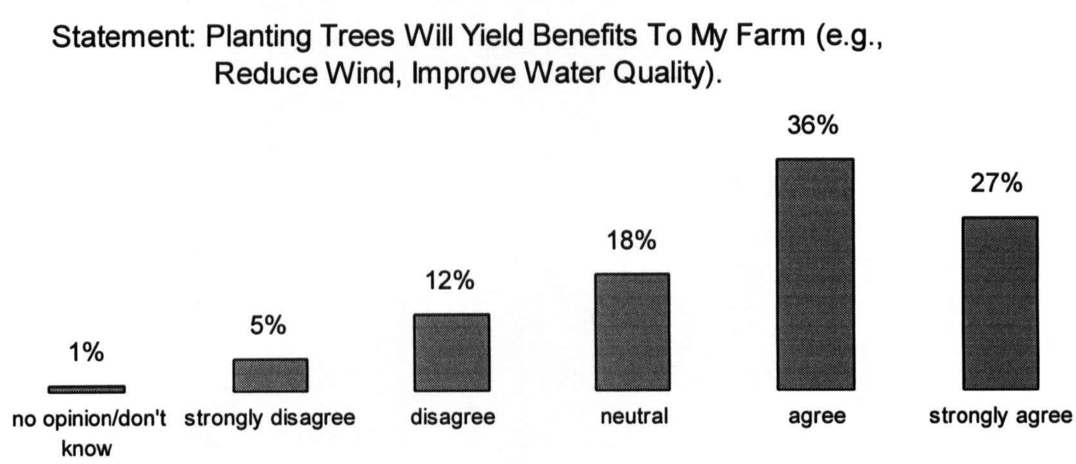
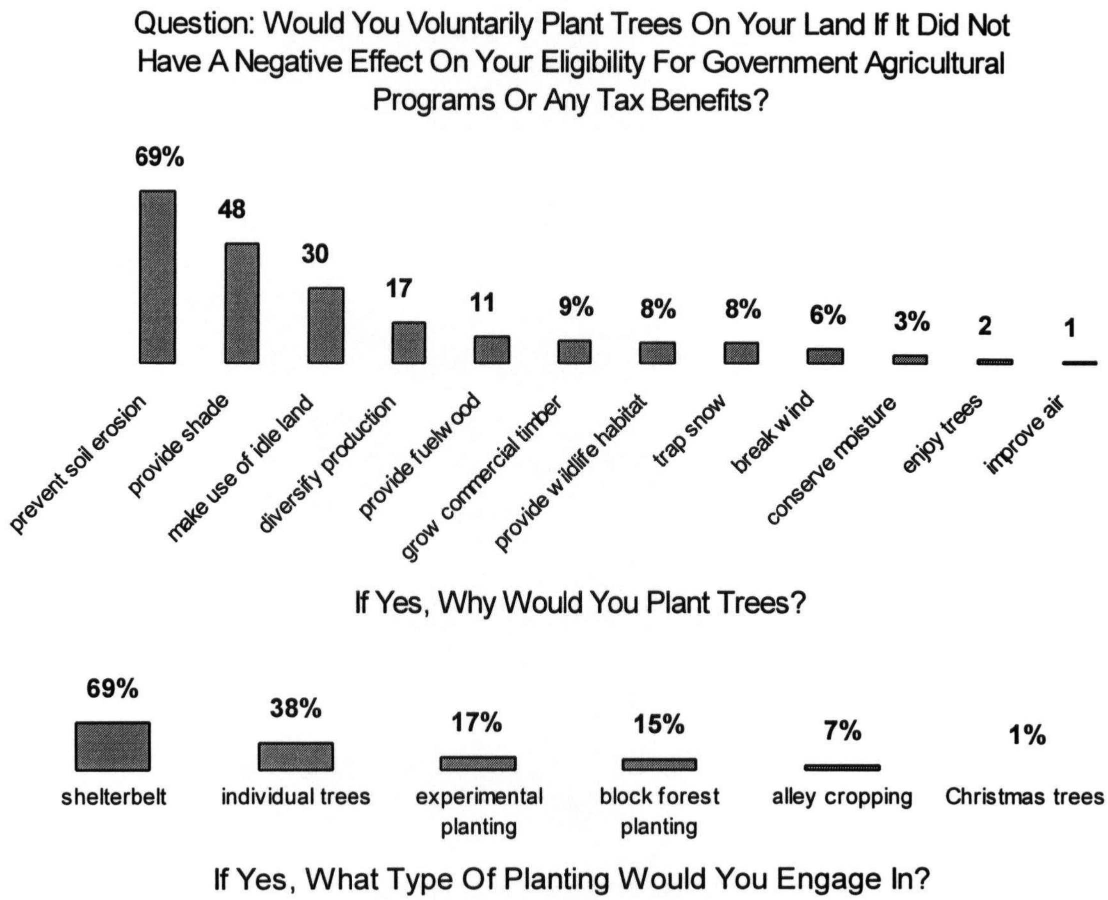


Figure 8. Benefits of Planting Trees on Agricultural Land.



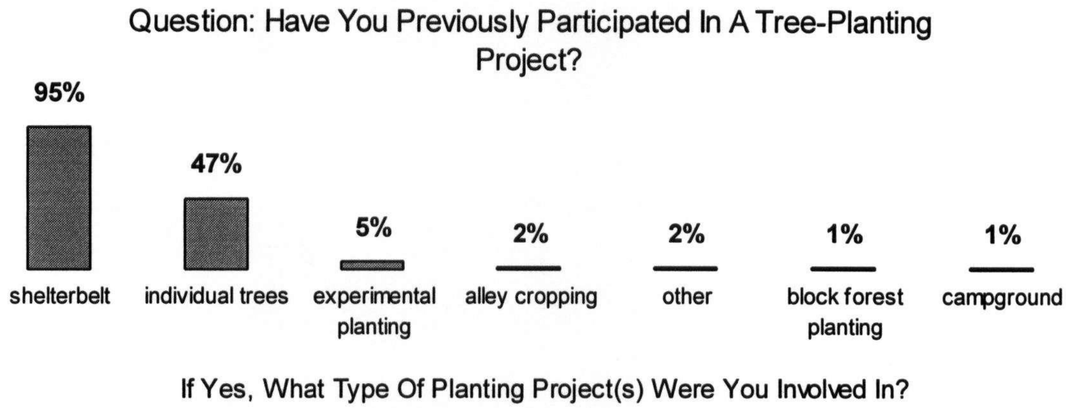
More trees on or around farms can benefit farmers esthetically and provide them with other benefits, such as reduced wind and improved water quality (see Figure 8). Two thirds of farmers would voluntarily plant trees on their land primarily for the purpose of preventing soil erosion and providing shade, but only if they remain eligible for government agricultural programs or any tax benefits (see Figure 9).[38] To date, 62 percent of farmers have already participated in some tree-planting projects, mainly planting shelterbelts and individual trees, for which 91 percent received no monetary remuneration (see Figure 10). These basic results provide evidence to support the hypothesis that farmers are interested in planting trees. The Environics Research Group (2000) also implies that farmers take significant interest in environmental issues and appreciate the value of forests, wetlands and wildlife.

Figure 9. Reasons for Voluntary Engagements in Tree Planting.



[38] A similar finding is reported by Wilson, Whitham, Bhati, Horvath & Tran (1995) for Australian farmers who retain trees primarily for the provision of shelter and shade, rehabilitation of degraded land and/or protection of land from degradation, and conservation of native vegetation and wildlife.

Figure 10. Previous Tree Planting Initiatives.



Giving farmers' positive attitudes towards tree planting and its perceptible environmental benefits, why do they not engage in more tree planting? The Environics Research Group (2000) survey acknowledges that "the greatest obstacle keeping landowners from doing more to conserve wetlands or forests are needing the land for other uses and the money that it cost" (p. 6). The survey suggests that farmers would respond to monetary incentives. Adequate compensation for the loss of agricultural production and tree-planting establishment costs is capable of overcoming this obstacle. The current survey adopts the premise of direct financial compensation in order to encourage tree planting. Farmers operating on land that is not suitable for growing trees (mainly due to lack of water) would not plant trees.[39]

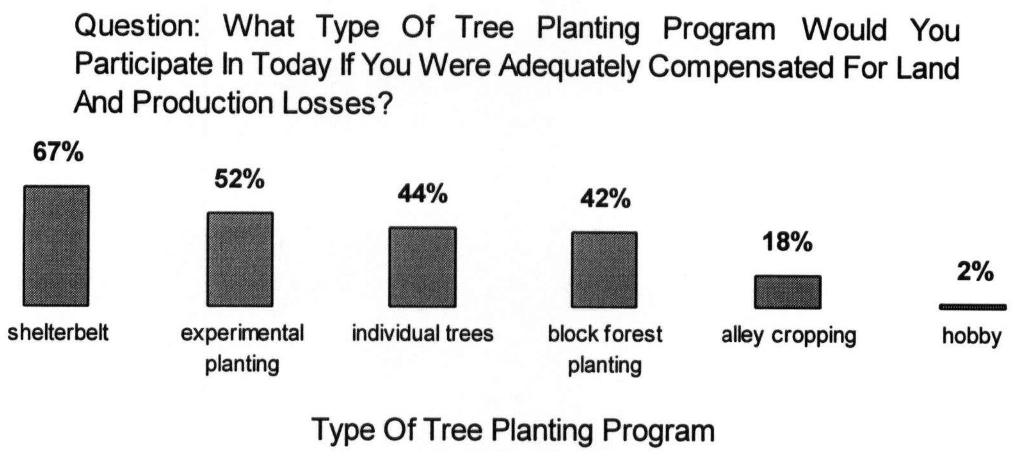
Three quarters of farmers would consider a tree-planting contract that covered all tree-planting and tree-growing related costs if they were adequately compensated for their land and production losses. Shelterbelts and, to some extent, individual trees remain the most desired types of tree-planting programs among farmers, whether on historical, voluntary or compensatory basis.[40] However, with the provision of incentives (e.g., financial compensation or no change in government support), farmers express significant interest in experimental and/or block forest plantings (see Figure 9 and 11). With regards to the choice of tree species, mix of species is preferred by 61 percent of respondents. Hybrid poplar, spruce and pine are approved by 37, 33

[39] This assumption is based on two survey results: first, most farmers have at least some tree cover on their land and, second, 62 percent of farmers have participated in tree-planting projects in the past.

[40] Wilson et al. (1995) summarize the nature and extent of planted trees on Australian farms. In 1994, 35 percent of Australian farmers had tree belts and corridors and 14 percent had tree blocks, while alley belts and widely spaced trees were each reported by 6 percent of farmers.

and 23 percent of farmers, respectively; some also show a slight interest in orchards (5 percent). Other species of trees such as elm, larch, green ash and willow each represent the preferences of only two percent of farmers willing to plant trees. Contrariwise, respondents to the Environics Research Group (2000) survey indicate a strong preference for native species of trees.

Figure 11. Willingness to Participate for Adequate Compensation.



The remaining 25 percent of farmers are not interested in planting trees for various reasons displayed in Figure 12. The most prominent reason is that they are content with status quo, and are unwilling to change current practices or indicate having an adequate number of trees already.[41] Bell et al. (1994) conclude that landowners might not participate in a stewardship program regardless of the program's compensation and benefits when their attitudes oppose the goals of the program. The nature of growing forests may not appeal to landowners whose primary occupation is farming. These farmers may only be willing to provide their unused pasture for tree planting, but are unable to convert their cropland to trees (Bell et al., 1994). Tree planting can also be perceived as a waste of productive farmland or an activity unsuitable to the local soil and climate conditions. Other factors, such as loss of visual appeal of the landscape and lack of knowledge of issues involved, can also play a role in the decision not to consider tree planting (see Figure 13).

[41] In addition to having enough trees, most Australian farmers who did not engage in tree planting during the three-year period prior to the Wilson et al. (1995) study pointed to the high costs of establishing trees as a most common reason for not planting.

Figure 12. Main Reason(s) for not Considering Tree Planting Program.

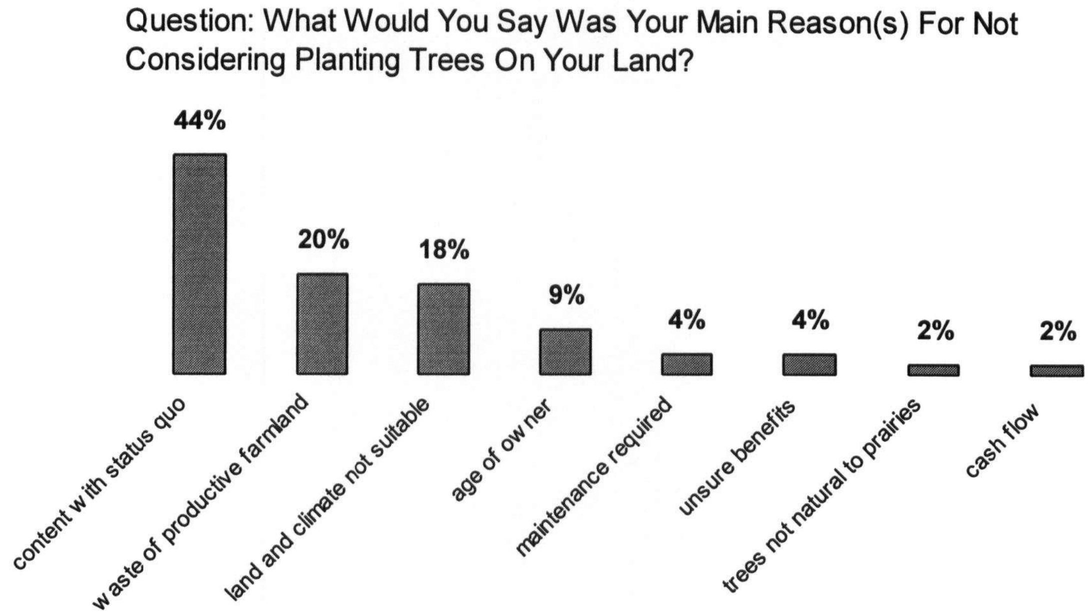
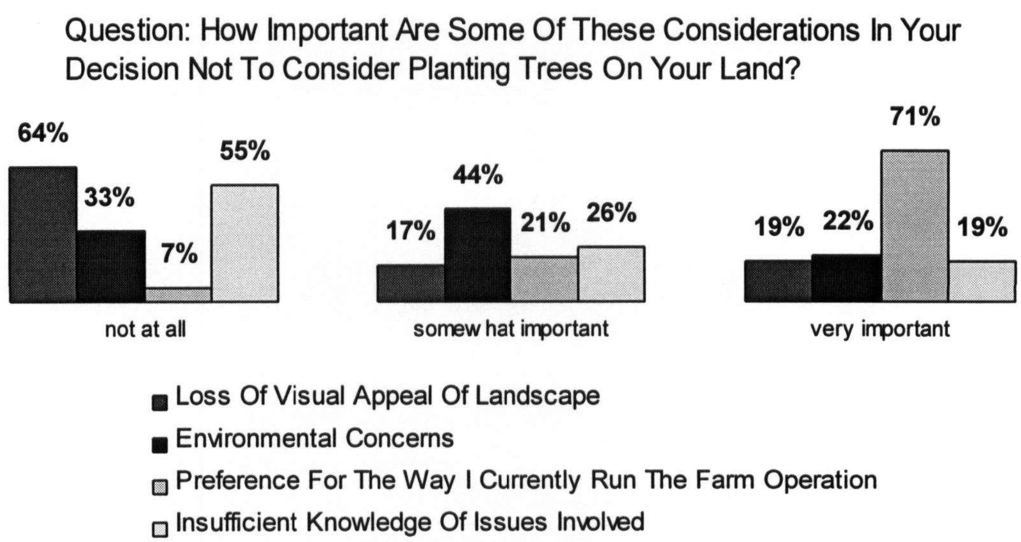


Figure 13. Factors Possibly Preventing Tree Planting.



For reasons already discussed, this study offers various levels of bids for a block tree-planting program. The average bid values for the three quarters of respondents willing to consider a tree-planting program are literally identical to those who rejected it. As intended, this indicates that the level of offered compensation has no impact on willingness to plant trees for adequate compensation.

When farmers are willing to accept adequate compensation for enrolling in a tree-planting program, they prefer a short-term to a long-term contract, which does not necessarily reflect their preference for longer-growing, native species (see Figure 14). The Environics Research Group (2000) provides one possible explanation for this kind of behaviour by pointing out that farmers, for their independent character, are not particularly fond of regulations. At the end of the contract, farmers will likely harvest the trees, but not immediately after the contract matures. As the above discussion reveals, farmers can be enticed to plant trees, but money is not the only reason for doing it. Farmers also appreciate trees for a variety of other reasons and, therefore, will likely delay harvesting trees until they reach maturity (see Figure 15).[42] Higher commodity prices, on the other hand, may result in a greater timber harvest since the opportunity cost of delaying harvests increases.

Figure 14. Preferred Contract Length.

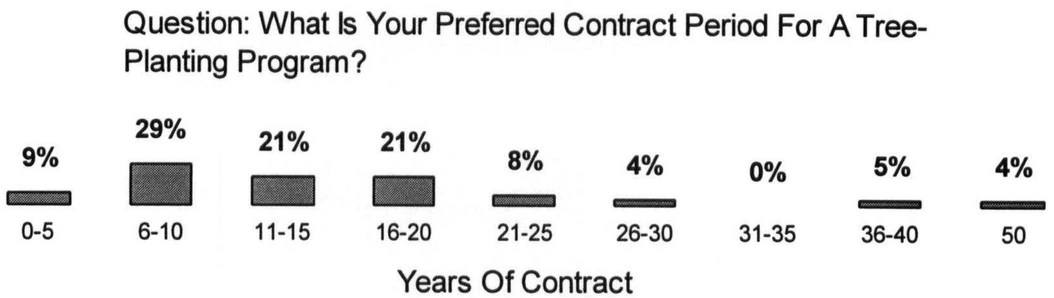
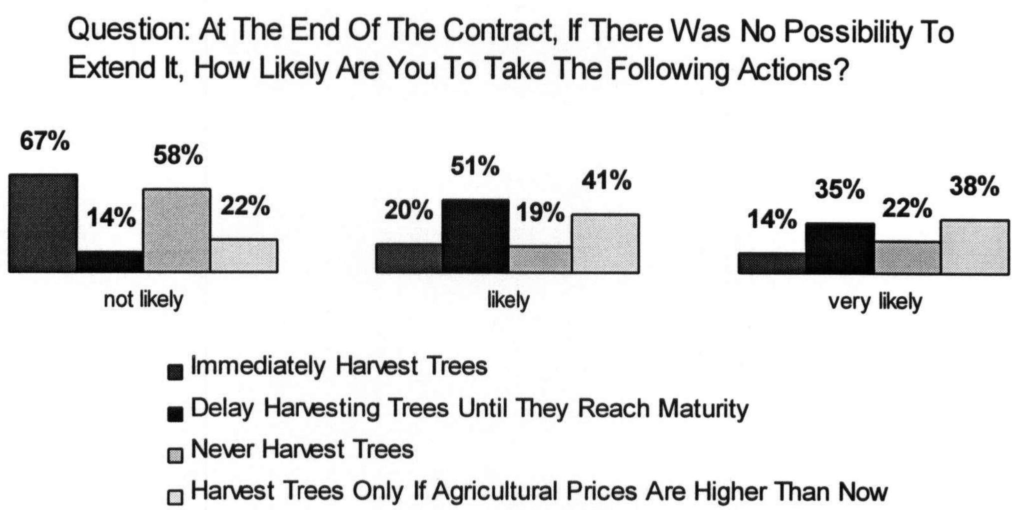


Figure 15. Farmers' Post Contract Responses.



[42] Only six percent of recent tree plantings on Australian farms are intended for harvesting, with only a small proportion for commercial harvest (Wilson et al., 1995).

4.6 Conclusion

Survey results indicate that farmers recognize the environmental values of trees and have historically shown considerable interest in planting trees. Governments can increase areas planted to trees simply by refraining from changing farmers' subsidy levels if they engage in more tree planting. If adequately compensated, farmers would further be willing to plant trees in large blocks and/or experimental settings thereby contributing to the larger social goal of carbon uptake. However, farmers regard trees less as a commodity and more as a landscape attribute with a positive environmental impact on their land. As a result, they prefer planting individual trees and/or shelterbelts with a mix of species and longer-growing trees that would not be harvested until reaching maturity, or perhaps never at all. Farmers' attitudes towards tree planting will acquire a more commercial character with the provision of financial incentives, such as direct annual compensation for a specific time period. Therefore, there is the potential for Canada to offset some of its carbon emissions with sinks from afforestation, but the costs of doing so need further investigation. Chapter 5 provides an estimate of the cost of planting blocks of trees on marginal agricultural land.

Chapter 5: Regression Results

5.1 Introduction

This chapter provides discussion and interpretation of the research results. Once estimated, the bivariate model can be reduced to an estimation of a single probit for which only the first valuation question is used because we can't reject that responses to the two programs were independent. The coefficient estimates obtained from this model are then used to calculate the minimum/expected willingness to accept a tree-planting program for each observation. Finally, this information is applied to the estimation of a supply schedule for marginal agricultural land available for tree planting.

5.2 Model Modification

Prior to proceeding with a discussion of choice of variables, it is necessary to carry out an important adjustment to the bivariate probit model. Careful observation of the raw data file reveals that no respondent indicated a 'no' response to the first valuation question and a 'yes' response to the second one (i.e., the 'no/yes' alternative is not represented in the sample). If no adjustment to the model were made, any computer package would have a problem maximizing the log-likelihood function since the computation method attempts to find optimal non-zero values for some of the coefficients while keeping others equal to zero. Therefore, the bivariate probit model (15) with four response options has to be reduced to three by combining the probabilities of 'no/yes' and 'no/no' alternatives to a single probability of saying 'no' to the first question.[43] The result is,

$$(19) \qquad \log L(\omega_{11}, \omega_{22}, \sigma_{11}, \sigma_{22}, \rho) = \sum_{i=1}^{n} \left\{ \begin{aligned} &(I_{11} I_{22}) \log\left[\int_{-X_{11}\omega_{11})/\sigma_{11}}^{\infty} \int_{-X_{22}\omega_{22})/\sigma_{22}}^{\infty} g(z_1 z_2) dz_2 dz_1 \right] \\ &+ (I_{11})(1 - I_{22}) \log\left[\int_{-X_{11}\omega_{11})/\sigma_{11}}^{\infty} \int_{\infty}^{(-X_{22}\omega_{22})/\sigma_{22}} g(z_1 z_2) dz_2 dz_1 \right] \\ &+ (1 - I_{11}) \log\left[\int_{\infty}^{(-X_{11}\omega_{11})/\sigma_{11}} h(z_1) dz_1 \right] \end{aligned} \right\},$$

[43] See Greene (1998).

where (19) follows the notation of (15) in Chapter 3, except for h(.) that represents the univariate standard normal distribution function. With this modification made, the coefficients of the bivariate probit model are estimated using the Maximum Likelihood Module of the GAUSS computer package.

5.3 Choice of Variables

In theory, many factors can influence farmers' decision to accept or reject participation in a tree-planting program on their farmland. The survey accounts for many such factors although, in reality, it is impossible to conceptualize all the factors in one single survey. The survey is designed to provide for theoretically relevant data that can be used to explain variation in and predict responses to the two contingent valuation questions. Many survey data were applied to model estimation, but only a particular set of variables seemed to fit the model best. The appropriateness of the fit is determined based on improvement in the log-likelihood value while paying attention to the number and combination of variables used due to technical considerations. The variables used in the final regressions are organized and defined in Table 3.

The opportunity cost variable deserves further attention. Farmers have the opportunity to indicate land-use of up to four of their least marginal fields. The land-use types are combined into three categories: pasture, hay and grain.[44] For each of these categories, average contribution margins are calculated using crop revenues and variable costs of production across the commodities, soil zones and provinces that incorporate average prices for the past four to eight years.[45] Each field provided by a farmer is assigned an opportunity cost based on its land-use. The opportunity cost variable is simply the minimum of the four (or less if a farmer provided less than four) least marginal fields. Table 4 illustrates values for the opportunity cost variable used in the regressions.

[44] The category grain includes the following: wheat, canola, barley, rye, oats, flax, lentils, peas and summerfallow.

[45] These numbers are obtained from provincial government websites: Manitoba Agriculture and Food (2000), Saskatchewan Agriculture and Food (2000), Alberta Agriculture, Food and Rural Development (2000).

Table 3. Definitions of Variables.

Name	Variable Description
Opp	Opportunity cost based on the reported land use on the four marginal fields.
BOC1	Compensation offered in the first question minus the opportunity cost.
BOC2	Compensation offered in the second question minus the opportunity cost.
ProvAB	Dummy – takes value one if the respondent farms in Alberta or British Columbia, and zero otherwise.
ProvMB	Dummy – takes value one if a respondent farms in Manitoba, and zero otherwise.
ProvSK	Dummy – takes value one if a respondent farms in Saskatchewan, and zero otherwise.
Soilbr	Dummy – takes value one if a respondent farms in brown soil-type zone, and zero otherwise.
Soildb	Dummy – takes value one if a respondent farms in dark brown soil-type zone, and zero otherwise.
Soilbl	Dummy – takes value one if a respondent farms in black soil-type zone, and zero otherwise.
Visual	A scale variable – takes value from one if a respondent strongly disagrees with the statement that increased tree cover in the region will detract from the visual appeal of the landscape, to five if a respondent strongly agrees. A value of zero corresponds to no opinion/do not know answer.
Trees	Number of acres of farmland covered with trees.
Subsidy	Total amount of subsidy expected to receive in 2000.
Leave	Dummy – takes value of one if a respondent would leave agriculture if climate change scenario described in section 3 became a reality, and zero otherwise.
Previous	Dummy – takes value of one if a respondent previously participated in a tree-planting program, and zero otherwise.
Educ	Number of years of post-secondary education.
Age	Median of an age category checked by a respondent.
Kids	Dummy – takes value of one if a respondent expects their children to continue farming.
Networth	Normalized median of a networth category checked by a respondent.

Table 4. Opportunity Cost Values For A Given Land-Use.

Land-use	Per Acre Opportunity Cost (dollars)
Pasture	42.00
Hay	47.25
Grain	71.85

With the model specified and variables identified, the coefficients of the bivariate probit model can be estimated by maximizing the objective function (19) over the vector of parameters. The next section discusses the results for this model in detail.

5.4 Bivariate Probit Results

This model is estimated using several independent variables for both equations (see Table 5). Its high non-linearity is troublesome for the optimization process, but an adequate choice of starting parameter values, suggested by Maddala (1983), circumvents most of failed inversions of the final Hessian matrix. The best model is selected based on the lowest mean log-likelihood value. In Table 5, matrix X_{11} and X_{22} of independent variables for both valuation equations are not the same. A different set of variables explains responses to the first and second questions better than having X_{11} equal to X_{22}.

Overall, this model is significant on the basis of the log-likelihood ratio test defined by Greene (1997). This test compares log-likelihood values for the unrestricted, lnL (includes the full set of variables as in Table 5), and restricted, $\ln L_r$ (includes only the two constants and the correlation variable), models. The statistic is distributed as chi-squared with a number of degrees of freedom equal to the number of restrictions applied. For the above model, the unrestricted and restricted log-likelihood values are displayed in Table 5 and the likelihood ratio statistic,

(20) $LR = -2[\ln L_r - \ln L]$,

is equal to 52.75. The critical chi-squared value for five-percent significance level with 20 degrees of freedom is 31.41, so the joint hypothesis that the coefficients on all the independent variables, aside from the correlation variable, are equal to zero is rejected.

Table 5. Coefficient Estimates and T-Ratios for Bivariate Probit Model.[46]

Contingent Valuation Question 1			*Contingent Valuation Question 2*		
Variable Name	Coefficient Estimate	T-Ratio	Variable Name	Coefficient Estimate	T-Ratio
Constant	1.4996	1.044	Constant	1.7513	0.918
BOC1	-0.0367	-3.814	BOC2	0.0511	2.482
Soilbr	-0.6156	-1.170	Soilbr	-1.9693	-2.095
Age	-0.0247	-1.460	Age	-0.0050	-0.178
Educ	0.1465	1.527	Visual	0.5991	1.870
Trees	-0.0026	-2.096	Educ	-0.2085	-1.488
Visual	0.1103	0.643	ProvSK	1.1493	1.665
ProvAB	1.0249	1.917	ProvMB	-0.4394	-0.549
ProvSK	0.1985	0.374	Soildb	-1.2181	-1.879
Benefit	-0.1040	-0.614	*Correlation*	-0.4864	-0.742
Soildb	0.3439	0.863			
Leave	-0.5456	-1.892	*Log-likelihood Value (unrestricted)*		-54.1355
Networth	0.1730	1.076	*Log-likelihood Value (restricted)*		-80.5084

However, before adopting the results from the bivariate probit model, it is important to bring attention to the coefficient estimate for rho. In contrast to an initial hypothesis about rho, the coefficient indicates a negative correlation between the two valuation questions. The second question always offers lower compensation than the first and the negative sign suggests that a respondent tends to reverse his or her 'yes' answer to the first question when faced with a lower bid in the second one.[47] However, the t-ratio reveals that the correlation between the two equations is not significantly different from zero at any of the conventional significance levels.[48] Assuming that rho is not significantly different from zero results in breakdown of the bivariate

[46] The effect of these variables should be interpreted with a reversed sign on the coefficient estimates of all variables except for correlation. This is due to the way a probability of 'yes' is modeled.

[47] Note: there are zero observations on 'no/no' response alternative.

[48] The log-likelihood ratio test statistic, when the correlation coefficient is restricted to zero, is equal to 0.37. Therefore, the null hypothesis that rho equals zero cannot be reject since the critical chi-squared value for five-percent significance level with one degree of freedom is 3.84. This test result supports the outcome of the previous t-test on rho.

density to two univariate probability densities (Greene, 1997). This result permits further simplification of the model to two single probits since they can be assumed independent. For the purposes of this thesis, only the first valuation question is chosen for further analysis due to space considerations.

5.5 Single Probit Results

A single probit model is developed for responses to the first question leaving the analysis of the second valuation responses to further research. This model uses many of the same variables as the corresponding part of the bivariate probit model with the exception of two different variables and one that is added to the single but not the bivariate probit. This modification improves the fit of the single probit model that is not possible to attain in the bivariate model due to computation limitations of GAUSS.

The estimation of the single probit is done in the same manner as in the previous section, fitting parameter estimates that maximize the objective function.[49] Once again, the likelihood ratio test is used to evaluate the significance of the model. Greene (1997) provides a convenient formula for computing the restricted log-likelihood value,

$$(21) \qquad \ln L_0 = n[P \ln P + (1-P)\ln(1-P)] .$$

With 86 observations and P (i.e., the sample proportion of observations that answered 'yes' to the tree-planting program offered in the first valuation question) equal to 0.3837, (21) is equal to -57.26. Replacing $\ln L_r$ in (20) with $\ln L_0$ and applying the unrestricted log-likelihood value of -36.20 gives value of 42.12 for the likelihood ratio test under the null hypothesis that all the coefficient estimates are equal to zero. At five- percent significance level and with 13 degrees of freedom, the null hypothesis is rejected.

---

[49] Estimation is done using GAUSS' Maximum Likelihood Module as well as Shazam's probit procedure. Practically the same results are obtained, the slight difference between the two perhaps due to rounding and using different computation procedures, but only the GAUSS estimates are reported.

Analogously to ordinary least squares' R^2, the likelihood ratio index can be used to derive a goodness of fit measure (Greene, 1997). The index is defined as

$$(22) \qquad LRI = 1 - \frac{\ln L}{\ln L_0}$$

and equals to 0.37.[50] It can be argued that the LRI increases as one improves the fit of the model, however, Greene (1997) points out that there is no natural interpretation for values of LRI between 0 and 1. According to Greene (1997), "the important element to bear in mind is that the coefficients of the estimated model are not chosen so as to maximize this (or any other) fit measure, as they are in the linear regression model in which **b** [the vector of coefficients] maximizes R^2" (pp. 892). They are chosen so as to maximize the density of the independent variables and not necessarily to provide the best fit to the binary variable. This suggests that a small change in magnitude of a goodness of fit measure has relatively no implication for the fit of the model in comparison to a large change.

A natural extension of the 'goodness of fit' discussion is to present prediction results for this model. This model accurately predicts roughly 81.5 percent of observed 'yes' and 'no' answers (see Table 6). This prediction is based on a threshold probability of a 'yes' response equal to 0.5. That is, if the computed probability of a 'yes' answer is less than 0.5, a 'no' response is predicted. On the other hand, computed probability of a 'yes' response greater or equal to 0.5 indicates a prediction of a 'yes' response. To put these results into perspective, a naive model is often presented. A naive model always predicts a 'yes' or a 'no' response depending on whose sample proportion is higher. In this sample, the proportion of 'no' responses is 0.62 (i.e., 1.00 minus 0.38), which means that a naive model would accurately predict 62 percent of responses (only the 'no' responses would be predicted successfully). The probit model improves the prediction by almost 20 percent in this case.

---

[50] The Shazam User's Reference Manual (1993) discusses a wide range of other R^2 measures, among them Maddala R-Square: $R^2 = 1\text{-}\exp\{2[\ln L_0 - \ln L]/n\}$. For this sample, this measure is equal to 0.40.

Table 6. Prediction Success Summary.

		Actual Responses	
		0	1
Predicted Responses	0	46 (45)	9 (6)
	1	7 (8)	24 (27)
Number of Actual Responses	86	53	33
Number of Right Predictions	70 (72)		
Percentage of Right Predictions	81.4 (83.7)		
Log-likelihood	-36.2		

Note: Values in brackets apply to threshold of 0.43 as opposed to 0.50.

One way to improve the prediction capability of the probit model is to change the threshold value accordingly. Greene (1997) suggests adjusting the threshold value in samples with disproportionate 'yes' and 'no' responses in the direction of observed proportionality. Only a few observations of one answer type in a sample might not impact the coefficient estimation profoundly enough to make the prediction of that answer type accurate. Reduction in the threshold value to 0.43 improves the accuracy of prediction to 84 percent mainly as a result of a higher score for accurate predicting of 'yes' responses (values in brackets in Table 6). Regardless of the threshold value, wrong predictions remain in proportion as the model erroneously predicts 7 (8) 'yes' responses when a 'no' response is observed and 9 (6) of 'no' responses when a 'yes' answer applies.

Given that the model is highly significant and fits the data reasonably well provides credibility for discussion of parameter estimates that are presented in Table 7. In this table, the marginal effect of a continuous variable x is computed as

$$(23) \qquad \frac{\partial E[y \mid x]}{\partial x} = \left\{ \frac{dF(\beta x)}{d(\beta x)} \right\} \beta = f(\beta \bar{x}) \beta ,$$

where f(.) is the standard normal probability density function (Greene, 1997). As usual, the slope is evaluated at the sample mean of x since the marginal effect is a function of x.[51] A marginal

[51] Another approach is to compute a marginal effect for each observation and calculate a sample average of the individual effects (Greene, 1997).

effect of a binary independent variable requires somewhat different approach although Greene (1997) points out that the use of (21) can result in fairly accurate approximation (values in brackets in Table 7). The appropriate marginal effect of a dummy variable d is equal to

$$(24) \qquad \frac{\partial E[y \mid d]}{\partial d} = \Pr[Y = 1 \mid \overline{X}, d = 1] - \Pr[Y = 1 \mid \overline{X}, d = 0],$$

where the matrix X represents all the other variables in the probit model evaluated at their sample means.

The significance of individual coefficients is evaluated based on the standard t-ratio test. Because the model assumes that the estimators are distributed as standard normal, critical values are chosen from the standard normal probability table for five and ten-percent significance levels that equal to 2.04 and 1.65, respectively. This test's null hypothesis always assumes that a given coefficient estimate is equal to zero. When the absolute value of the t-ratio on the coefficient estimate is greater or equal to the critical value at a given significance level, the null hypothesis is rejected. In the opposite case, the null hypothesis cannot be rejected.

According to Table 7, only two coefficient estimates pass the five-percent significance level test. As hypothesized, the difference between the offered compensation and the forgone agricultural return (on per acre basis) has an effect on the 'yes' probability. A one-dollar increase in the difference between the offered bid and forgone agricultural returns implies an average increase of almost one-percent in the probability of accepting the bid. Similarly, the more trees a farmer has, according to the reported forested area on a given farm, the more likely he or she is to engage in more tree planting. However, the effect of an additional acre of tree cover currently on a farm produces only a 0.1 percent increase in the probability to say 'yes' to future tree planting.

Table 7. Coefficient Estimates and T-Ratios for Single Probit Model.[52]

Variable Name	Coefficient Estimate	Standard Error	T-Ratio (Estimate/standard error)	Marginal Effect
Constant	-1.1548	1.2962	-0.891	-
BOC1^c	0.0338	0.0103	3.288	0.009
Age^c	0.0287	0.0201	1.430	0.003
Trees^c	0.0028	0.0012	2.251	0.001
Soilbr	0.7056	0.6156	1.146	0.271 (0.280)
Visual^c	-0.3573	0.2032	-1.758	-0.142
Leave	0.3792	0.3085	1.229	0.086 (0.109)
Educ^c	-0.1074	0.1014	-1.059	-0.042
Income^c	-0.3066	0.1921	-1.596	-0.122
ProvAB	-0.4247	0.4810	-0.883	-0.149 (-0.167)
ProvMB	0.0418	0.6208	0.067	0.015 (0.017)
Soildb	-0.1266	0.4559	-0.278	-0.045 (-0.050)
Kids	0.2332	0.4179	0.558	0.083 (0.092)
Previous	-0.1735	0.3961	-0.438	-0.063 (-0.069)

Note: Superscript c indicates a continuous variable.

Using ten-percent significance level results in the coefficient on the visual variable becoming significantly different from zero. This means that for a farmer who perceives further increase in local tree cover as visually unappealing, the probability of accepting a tree-planting program is lower than for a farmer fond of trees. The marginal effect on the probability to accept for a one-step increase on the scale of the visual variable is approximately 14 percent. So the difference in probabilities to accept a tree-planting program between a farmer who very much enjoys the esthetics of trees and a farmer who prefers the look of fewer-tree landscape can be as high as 56 percent. Other coefficients are not significantly different from zero even at the ten-percent significance test, but some come close such as age, dummy for brown soil type and networth. Even though a coefficient estimate is not significantly different from zero, its sign may provide information about the possible direction of its effect on the dependent variable.

[52] Following convention, the results reflect modeling a 'yes' response. Since the model is set up to predict a 'no' response, a sign change is applied to these results.

As discussed in Chapter 3, the estimated coefficients can be used to compute thé minimum amount of compensation required to make the respondent just indifferent between accepting and rejecting it. It has been shown that this amount is the mean and median willingness to accept and is, therefore, referred to as the expected willingness to accept. Substituting into

$$(25) \qquad B^{*} = OC - \left(\frac{\alpha}{\beta} + \frac{\delta}{\beta} s\right)$$

provides such compensation level for each observation. This new variable has its own sample distribution whose measures are depicted in Table 8.

Table 8. Distribution of Expected Willingness to Accept Tree-Planting Program ($/acre).

Mean	Standard Deviation	Variance	Minimum	Maximum
$40.52	$29.99	$899.14	$-27.78	$106.50

This table demonstrates that average compensation of about 40 dollars per acre is required in order to encourage farmers to plant blocks of trees. Interestingly, some farmers are willing to pay as much as 28 dollars per acre to have a tree-planting program, such as the one described in Chapter 4, introduced to them. Others, on the other hand, demand over 100 dollars per acre to plant trees. It is important to keep in mind that this discussion pertains to the least marginal acre. Based on the results of this research, a compensation of 40 dollars per acre would entice farmers to plant at least one acre of their farmland (the least marginal) to blocks of trees. This result assumes that farmers overstated rather than understated their willingness to accept and that more acres are potentially available for the same compensation amount offered.

Table 9. Basic Statistics on Number of Acres Made Available for Tree Planting.

Mean	Standard Deviation	Variance	Minimum	Maximum
110.57	334.90	112,158.91	0.00	2160.00

Note: The sample has 86 observations.

The survey allows respondents to state the number of acres they would supply for the tree-planting program (see Table 9). The probit model predicts a 'yes' response in the case when a farmer is faced with compensation greater or equal to his or her expected willingness to accept, and a 'no' response otherwise. Therefore, the greater the difference between the offered compensation and the expected willingness to accept (B-B*), the more acres of farmland a farmer would supply to the tree-planting program. Regressing the number of acres on (B-B*) produces OLS results that are summarized in Table 10.

Table 10. Marginal Effect of Higher Compensation on Number of Acres Supplied.

Variable	Coefficient Estimate	Standard Error	T-ratio	R-squared
Constant	143.67	37.35	3.85	0.071
(B-B*)	2.48	0.98	2.54	

Both the constant and the slope coefficients in the regression are significantly different from zero at any conventional significance level. One can explain the coefficient on the constant as the number of acres that a farmer would supply if offered a compensation amount equal to his or her expected willingness to accept. It can be expected that if a farmer participates, then he or she would provide not just one acre of land but 144 acres. Assuming no change in opportunity cost of land, an additional dollar on top of the expected willingness to accept would entice a farmer to provide roughly 2.5 additional acres of farmland to the tree-planting program. With further acres taken out of agricultural production to forestry, the compensation required for converting a given amount of land would likely increase due to higher opportunity cost while sectoral adjustments could become prominent, applying further pressure on increasing offered compensation.[53] This relationship between the (B-B*) and acreage variables should not be interpreted as a 'true' supply curve for marginal agricultural land available for tree planting because it fails to include some of these factors in. Perhaps, this relationship might only apply for the initial stage of afforestation on marginal agricultural land.

[53] See Chapter 2 for further discussion on the effects of land movements between agriculture and forestry.

5.6 Conclusion

Initially, this research focuses on simultaneous estimation of two valuation questions in the survey. When it becomes apparent that answers to the questions are not correlated, the attention focuses on estimation of only the first question. A probit is developed that models the estimated effects of various independent variables on the probability of accepting proposed per-acre compensation. The parameter estimates are then used for computing a farmer's expected willingness to accept. Having this new variable allows for construction of a simple supply schedule that could help policy makers in formulating a new afforestation program in Canada. Some policy implications and a more general conclusion to the thesis are provided in the next chapter.

Chapter 6: Policy Implication and Direction for Future Research

This thesis attempts to address some issues surrounding climate change mitigation, in particular the possibility for planting trees on the Canadian prairies for environmental, social and carbon sequestration purposes. The physical science of climate change is shown to be uncertain on many fronts. First, evidence of actual global climate warming has not been fully established, yet. Second, if climate change is taking place, some theories suggest phenomena other than accumulation of carbon dioxide as the cause of higher temperatures, not ignoring those that point to natural cycles. Even if human activities, particularly fossil fuel burning, contribute to a warmer climate by emitting annually tonnes of carbon dioxide into the atmosphere, should fossil fuel consumption be reduced or offset by biological sequestration?

Reducing carbon dioxide emissions makes sense for various reasons. Today, the stock of fossil fuels does not appear to be limited in terms of its size, but it might become confined in the future unless new technologies for energy generation replace fossil fuels as energy source. Many developing countries strive for the kind of economic growth developed countries have been experiencing over the last 100 or so years that has been possible primarily by burning fossil fuels. Combustion of fossil fuels will continue inevitably to take place in this modern age given that all, particularly developing, countries will continue generating energy in this way since alternative energy sources are still relatively expensive. Common sense intuition might question whether annual spewing of additional millions of tonnes of pollutants, including carbon dioxide, into the atmosphere would not have some kind of a negative impact on the environment and human health and in turn on the economy.

The uncertainty surrounding the catastrophic impact of climate change on humans and this planet may be resolved with time, but the common sense argument begs ignorance and passive acceptance of continuing and accelerating fossil fuel burning. Reducing carbon dioxide emissions could reduce the alleged risk of damage resulting from climate change and the main argument for reducing current emissions should focus on issues related to risk perception and management. The possibility of a catastrophe with serious consequences for the human species and its environment exists and therefore some action should be taken.

A recent statement by the American president indicating refusal of the United States to comply with the resolutions of the Kyoto Protocol is an indication that an outright reduction in fossil fuel consumption might not be economically feasible. Adhering to the Kyoto protocol would mean a deliberate and significant shriveling in the economy of any developed country that signed the protocol. Some researchers and scientists, however, show that climate change mitigation through planting trees that sequester carbon in their biomass is the cheapest way to offset part of the carbon emissions. In addition to carbon sequestration benefits, planting trees can also provide environmental, economic and social benefits that should provide further incentives for tree planting. In the Canadian context, this thesis sheds light on the price of this mitigation option.

The thesis data are obtained from a survey of farmers in the grain-belt region of Canada. Its general results reveal that farmers value trees for their benefits of wind reduction and improvement in water quality. For these benefits, many farmers have previously participated in planting shelterbelts and individual trees and only very few planted blocks of trees. Farmers can be restrained or prevented from diversifying their productions by current agricultural policies that focus on agricultural activities. The thesis results suggest that significantly more farmers, in comparison to previous tree planting engagements, would voluntarily plant experimental or blocks of trees on their land if it did not have a negative impact on their eligibility for government agricultural programs or any tax benefits. However, the reasons for voluntary plantings with no effect on agricultural programs the farmers are currently involved in are not significantly different from their previous intentions. Prevention of soil erosion and provision of shade prevail as the primary purposes for undertaking tree planting.

Farmers' willingness to participate in a tree-planting program changes when they are faced with the possibility of an adequate compensation for land and production losses. Farmers remain interested in shelterbelts and individual trees, but many more farmers express their desire to plant experimental and forest blocks. Post-contract intentions of farmers with regards to trees support a hypothesis that farmers would engage in block forest plantations for primarily economic reasons. At the end of a contract that had no possibility of extending, a great number of farmers would delay harvesting trees until they reach maturity and/or harvest the trees only if agricultural prices were higher than at the time of signing the contract. Only a small portion of farmers would immediately harvest and/or never harvest the trees.

Farmers are interested in planting woodlots and experimental trees, but they also require adequate compensation for such a business endeavor. Modeling of the survey data in a probit framework provides a convenient way for computation of mean willingness to accept a tree-planting program. On average, farmers would require at least $40 per acre to be more likely to accept than to reject the program. A dollar in additional compensation on top of this mean willingness to accept would solicit further 2.5 acres of land from a farmer. At the $40 per acre compensation level, an individual farmer would provide roughly 143 acres of land. If all non-dairy farmers in the grain-belt region with over 160 acres of land on the Watts List Brokerage list (34,618 in total) were faced with such compensation for undergoing a tree-planting initiative, a total of 4,950,374 acres (or 1,980,150 hectares) would be extracted from agriculture for afforestation purposes.

Van Kooten (2000) shows that following an optimal rate of afforesting marginal agricultural land results at best in converting only less than 2.4 million acres of land if a tree-planting program were implemented in 2000 and lasted until the 2008-2012 period. In this case, afforestation in the study region could only offset some 7 percent of Canadian carbon emissions. According to the results of this study, afforestation of 2.4 million acres of land would cost $96 million in addition to costs of establishing and executing a tree-planting program that would cover all costs of planting, management, maintenance and monitoring. Further research could investigate the costs of establishing and running the program and provide guidance to the kinds of incentives and mechanisms that would make the program implementation as effective as possible. Van Kooten (2000) reports that Canada expects to offset some 25-40 percent of its Kyoto commitment by planting trees. This could easily cost Canada nearly half a billion dollars while ignoring whether such extensive tree planting is logistically feasible.

Mitigation of climate change by planting trees on marginal agricultural land in the grain-belt region of Canada alone could not significantly reduce the country's carbon emissions to meet its Kyoto commitments and proof extremely costly. Biological mitigation in the form of afforestation can only offset a portion of carbon emissions. For larger emission reductions, direct cutbacks are needed that are currently economically and politically not feasible. Therefore, political debate and academic research should begin to focus more on adaptation to climate change than they presently do if climate change remains a global threat. In addition, further financial resources should be applied to investments in new technology that would make industrial mitigation financially attractive enough to be widely adopted and implemented in order to provide significant reductions in emissions of carbon dioxide in the future.

Bibliography

Alberta Agriculture, Food and Rural Development. (2000). *2000 Croping Alternatives of Production Costs and Returns.* Alberta Agriculture, Food and Rural Development [On-line report].
Available: http://www.gov.mb.ca/agriculture/financial/farm/cac40s01.html.

Alig, J.R., Adams, D.M., & McCarl, B.A. (1998). Impacts of Incorporating Land Exchanges Between Forestry and Agriculture in Sectoral Models. *Journal of Agricultural and Applied Economics,* 30(2), 389-401.

Alig, J.R., Adams, D.M., McCarl, B.A., Callaway, J.M., & Winnett, S.M. (1997). Assessing Effects of Mitigation Strategies for Global Climate Change with an International Model of the U.S. Forest and Agriculture Sectors. *Critical Reviews in Environmental Science and Technology,* 27, S97-S111.

Anderson hints greenhouse gas goal may be out of reach. (2000, March 13). *The Vancouver Sun,* p.A10.

Bell, D.C., Roberts, K.R., English, C.B., & Park, M.W. (1994). A Logit Analysis of Participation in Tennessee's Forest Stewardship Program. *Journal of Agricultural and Applied Economics,* 26(2), 463-472.

Birdsey, R.A. (1992). Changes in Forest Carbon Storage from Increasing Forest Area and Timber Growth. In N. Sampson & D. Hair (Eds.), *Forest and Global Change: Volume I - Opportunities for Increasing Forest Cover* (p. 23-40). American Forestry Association.

Calder, N. (1999). The Carbon Dioxide Thermometer and the Cause of Global Warming. *Energy and Environment,* 10(1), 1-18.

Cameron, A.T. & Quiggin, J. (1994). Estimation Using Contingent Valuation Data from a 'Dichotomous Choice with Follow-Up' Questionnaire. *Journal of Environmental Economics and Management*, 27, 218-234.

Canadian Forest Service, Science Branch. (1999). *Climate Change and Forests: Context for the Canadian Forest Service's Science Program Canadian Forest Service, Science Branch.* Government Document No. Fo42-289/1999. Ottawa.

Cooper, J. (1993). Optimum Bid Selection for Dichotomous Choice Contingent Valuation Surveys. *Journal of Environmental Economics & Management*, 24, 25-40.

Easterbrook, G. (1999). Warming Up. *The New Republic.* Nov 8, v.221, no.19, p. 42-53.

Environics Research Group. (2000). *Survey of Farmers, Ranchers and Rural Landowners Attitudes and Behaviours Regarding Land Stewardship.* Wildlife Habitat Canada [On-line report].
Available: http://www.whc.org/whc/WHCDocuments.nsf/Documents?OpenFrameSet.

Fink, A., & Kosecoff, J. (1998). *How to Conduct Surveys: A Step-by-Step Guide*. Thousand Oaks, Ca: Sage Publication.

Forest Sector Table. (1999). *Options Report: Options for the Forest Sector to Contribute to Canada's National Implementation Strategy for the Kyoto Protocol.* A Report Prepared by the Forest Sector Table. Ottawa. Canada.

Greene, H.W. (1997). *Econometric Analysis*. 3rd ed., Upper Saddler River, New Jersey: Prentice Hall.

Greene, H.W. (1998). *LIMDEP, Version 7.0: User's Manual*. Econometric Software, Inc.

Hanemann, W.M. (1984). Welfare Evaluation in Contingent Valuation Experiments with Discrete Responses. *American Journal of Agricultural Economics*, 66(3) 332-41.

Hebert, H.J. (2000). *American Panel of Scientist Concludes Global Warming is Accelerating.* The Canadian Press 2000 [On-line report].
Available: http://www.cbc.ca.

Intergovernmental Panel on Climate Change. (1995). *IPCC Second Assessment - Climate Change 1995.* Intergovernmental Panel on Climate Change, Geneva, Switzerland [On-line report].
Available: http://www.ipcc.ch/cc95/wg2.htm.

Lashof, D. & Hare, B. (1999). The Role of Biotic Carbon Stocks in Stabilizing Greenhouse Gas Concentration at Safe Levels. *Environmental Science and Policy,* 2(2).

Ley, E. & Sedjo, R. A. (1997). Optimal Subsidies for Carbon: Cost-Effectiveness and Distributional Considerations. *Critical Reviews in Environmental Science and Technology,* 27, S177-S184.

Lund, G.H. (1999). A 'Forest' by any other Name...,. *Environmental Science and Policy,* 2(2).

Maddala, G. (1983). *Limited Dependent and Qualitative Variables in Econometrics.* New York: Cambridge University Press.

Manitoba Agriculture and Food. (2000). *Guidelines for Estimating 2000 Crop Production Costs.* Manitoba Agriculture and Food [On-line report].
Available: http://www.agric.gov.ab.ca/economic/product/col_index.html.

Marland, G. and B. Schlamadinger. (1999). The Kyoto Protocol Could Make a Difference for the Optimal Forest-Based CO2 Mitigation Strategy: Some Results from GORCAM. *Environmental Science and Policy,* 2(2).

McConnell, E.K. (1990). Models for Referendum Data: The Structure of Discrete Choice Models for Contingent Valuation. *Journal of Environmental Economics and Management,* 18(1), 19-34.

Mitchell, R.C., & Carson, R. T. (1989). *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Resources for the Future. Washington, D.C.

OECD. (1995). *Global Warming. Economic Dimensions and Policy Responses.* Working Paper No. 1.

Parks, J.P. (1995). Explaining "Irrational" Land Use: Risk Aversion and Marginal Agricultural Land. *Journal of Environmental Economics and Management,* 28, 34-47.

Parks, J.P., & Hardie, I.W. (1995). Least-Cost Forest Carbon Reserves: Cost-Effective Subsidies to Convert Marginal Agricultural Land to Forests. *Land Economics,* 71(1), 122-136.

Parks, J.P., Hall, D.O., Kristrom, B., Masera, O.R., Moulton, R.J., Plantinga, A.J., Swisher, J.N., & Winjum, J.K. (1997). An Economic Approach to Planting Trees for Carbon Storage. *Critical Reviews in Environmental Science and Technology,* 27, S9-S21.

Parks, P.J., Brame, S.R., & Mitchell, J.E. (1992). Opportunities to Increase Forest Area and Timber Growth on Marginal Crop and Pasture Land. In N. Sampson & D. Hair (Eds.), *Forest and Global Change: Volume I - Opportunities for Increasing Forest Cover* (p. 97-105). American Forestry Association.

Plantinga, A.J. (1997). The Cost of Carbon Sequestration in Forests: A Positive Analysis. *Critical Reviews in Environmental Science and Technology,* 27, S269-S277.

Poe, L.G., Welsh, P.M., & Champ, P.A. (1997). Measuring the Difference in Mean Willingness to Pay when Dichotomous Choice Contingent Valuation Responses are not Independent. *Land Economics,* 73(2), 255-67.

Sampson, R.N. & Sedjo, R. A. (1997). Economics of Carbon Sequestration in Forestry: An Overview. *Critical Reviews in Environmental Science and Technology,* 27, S1-S8.

Saskatchewan Agriculture and Food. (2000). *Crop Planning Guides.* Saskatchewan Agriculture and Food [On-line report].
Available:
http://www.agr.gov.sk.ca/docs/econ_farm_man/production/cereals/cropplanguide.asp.

Schlamadinger, B. (1999). Preface. *Environmental Science and Policy,* 2(2).

Sedjo, R.A., Wisniewski, J., Sample, A.V., & Kinsman, J.D. (1995). The Economics of Managing Carbon via Forestry: Assessment of Existing Studies. *Environmental and Resource Economics,* 6, 139-165.

SHAZAM User's Reference Manual, Version 7.0. (1993). McGraw-Hill.

Sohngen, B., Mendelsohn, R., & Sedjo, R. (1998). The Effectiveness of Forest Carbon Sequestration Strategies with System-Wide Adjustments. Paper Presented at the 1998 Annual Meetings of the American Agricultural Economics Association Salt Lake City, Utah.

Svensmark, H. & Friis-Christensen, E. (1997). Variation in Cosmic Ray Flux and Global Cloud Coverage: A Missing Link in Solar-Climate Relationship. *Journal of Atmospheric and Solar-Terrestrial Physics,* 59, 1225-1232.

United Nations. (1997). *Report of the Conference of the Parties on its third Session, Held in Kyoto from 1 to 11 December 1997.* United Nations Framework Convention on Climate Change [On-line report].
Available: http://www.unfccc.de/resource/docs/cop3/07a01.pdf.

United Nations. (1992). *Climate Change Information Kit.* United Nations Framework Convention on Climate Change [On-line report].
Available: http://www.unfccc.de/resource/iuckit/index.html.

Van Kooten, G.C. (2000). Economic Dynamics of Tree Planting for Carbon Uptake on Marginal Agricultural Lands. *Canadian Journal of Agricultural Economics*, 48(1), 51-65.

Van Kooten, G.C., & Bulte, E.H. (2000). *The Economics of Nature.* Oxford, UK: Blackwell.

Van Kooten, G. C. & Folmer, H. (1997). Economic Instruments and the Pasture-Crop-Forest Interface. In W.N. Adger, D. Pettenella & M. Whitby (Eds.), *Climate-Change Mitigation and European Land-Use Policies* (p. 134-140). CAB International.

Van Kooten, G.C., Grainger, A., Ley, E., Marland, G., & Solberg, B. (1997). Conceptual Issues Related to Carbon Sequestration: Uncertainty and Time. *Critical Reviews in Environmental Science and Technology,* 27, S65-S82.

Wilson, M.S., Whitham, A.H.J., Bhati, U.N., Horvath, D., & Tran, D.Y. (1995) *Trees on Farms: Survey of Trees on Australian Farms: 1993-94.* ABARE Research Report 95.7.

Appendix A Survey, Survey Cover Letter and Bid Pairs

THE UNIVERSITY OF BRITISH COLUMBIA

FEPA Research Unit
Faculty of Agricultural Sciences
Forest Sciences Centre
2045 - 2424 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Fax: (604) 822-6970

CLIMATE CHANGE — WHERE DO YOU FIT IN?

ADAPTION, MITIGATION AND SALE OF CARBON CREDITS

Recent declines in commodity prices and soaring oil and gas prices have added to farmers' economic stress. Now there is concern about global warming, and it could have a significant impact on Canadian agriculture. There will likely be opportunities to plant new crops as growing seasons expand, but there may also be more pests and less available moisture.

Global warming is primarily caused by the accumulation of carbon dioxide (CO_2) in the atmosphere. Trees play an important role in moderating potential climate change by removing CO_2 from the atmosphere and storing carbon (the C in CO_2) in wood biomass. The federal government has signed an international agreement to reduce Canadian emissions of CO_2, and the government is now looking for ways to fulfil its commitments.

This survey is designed to determine your potential to adapt to warmer climate, and your willingness to change your agronomic practices to help mitigate climate change. Although this is an independent, University-sponsored survey, we intend to make its results known to policy makers. Therefore, the findings of this survey may affect the design of policies that affect you directly as an agricultural producer. **Hence, your responses are important!**

YOUR COOPERATION IS GREATLY APPRECIATED

Please do NOT identify yourself anywhere on the survey. By completing the survey, it will be assumed that consent has been given. While we have numbered surveys for follow-up purposes and to keep track of responses as surveys are returned, the correspondence between respondents and surveys will be destroyed shortly after results have been tabulated. If you have any questions or comments about the questionnaire, please call Pavel Suchanek at (604) 822-5247 or send an e-mail to suchanek@interchange.ubc.ca.

You will be automatically entered in our draw for a **$200 CASH prize** for returning the survey.

ANSWERS PROVIDED WILL BE KEPT IN STRICT CONFIDENCE

This survey should not take more than 20 minutes to complete.

Section 1: Introduction

Please indicate the name of the town/city closest to your farm: ______________________

Prior to receiving this survey had you (**Please ✓**):

	YES	NO
1. Read or heard about the potential for climate change or global warming?	❒	❒
2. Read or heard about possibilities for planting trees on marginal agricultural land to mitigate climate change?	❒	❒
3. Read or heard about possibilities for addressing climate change through minimum tillage, reduced summerfallow, and other changes in agronomic practices?	❒	❒

Instructions: For each of the following statements, please indicate your opinion by **circling the appropriate choice** on the 5-point scale. If you do not know or have no opinion about a statement, please indicate by circling zero (0).

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	No Opinion/ Don't know
4. Increased tree cover in this region would detract from the visual appeal of the local landscape.	1	2	3	4	5	0
5. Canada needs to invest in reducing emissions of greenhouse gases.	1	2	3	4	5	0
6. Forests should contain a variety of tree species, both deciduous and coniferous, rather than only a single type.	1	2	3	4	5	0
7. Planting trees will yield benefits to my farm (e.g., reduce wind, improve water quality).	1	2	3	4	5	0
8. Adapting to a warmer climate will bring opportunities to increase revenues.	1	2	3	4	5	0
9. Contracts among farmers, or between farmers and government, or between farmers and private organisation, must be completely spelled out in their smallest details.	1	2	3	4	5	0

10. Which of the following types of contracts have you ever participated in, and what was their duration?
(Please ✓ and fill in the blanks; more than one is possible)

		Duration (years)
❒	land-use restriction that prevents crop production (e.g. Prairie Pothole Project)	__________
❒	restrictions on crop practices (e.g. on number of field operations or when haying occurs)	__________
❒	cropshare or other lease agreement as ❒ renter and/or as ❒ landowner	__________
❒	other (specify) ______________________________	__________

PLEASE GO TO SECTION 2

Section 2: Describing Your Farm Enterprise

Instructions: Please fill in the blanks.

	# of acres
1. How large is your farm's land base? (include rented/leased area)	________
2. How much land do you rent or lease from others?	________
3. How much of your land is not used (not even for grazing cattle or as summerfallow)?	________
3a. Of this unused land, approximately how much is currently covered by trees?	________
4. Approximately what proportion of the remainder of your farm (i.e., other than the unused land) is covered by trees?	________
5. Approximately what proportion of the remainder of your farm (i.e., other than the unused land) is in intensive crop production (excluding summerfallow and forage crops)?	________

6. How much total subsidy do you expect to receive from government(s) during 2000? $________________

7. Ignoring any of the unused land identified in question 3, how are your LEAST (up to 4) productive fields (to be) used in 2000? If you have less than 4 fields, indicate all of your fields. **Please ✓ the appropriate category** (one for each field).

	Field Identifier #1	#2	#3	#4
Pasture/grazing	❐	❐	❐	❐
Hay/alfalfa	❐	❐	❐	❐
Wheat	❐	❐	❐	❐
Canola	❐	❐	❐	❐
Rye or oats	❐	❐	❐	❐
Flax	❐	❐	❐	❐
Other grain	❐	❐	❐	❐
Other crop (e.g. peas, lentils)	❐	❐	❐	❐
Summerfallow	❐	❐	❐	❐

Please provide the following information for the above fields. **Please fill in the table.**

	Field Identifier #1	#2	#3	#4
Size of field (acres)				
Expected approximate yield				
Please identify units of yield (bu/acre, t/ha, etc.)				

8. Which of the following livestock do you own? **(Please ✓ the appropriate category and fill in the blanks)**

	YES	NO	If YES, what number of animals?
Beef cattle	❑	❑	_______
Dairy cows	❑	❑	_______
Sheep (and/or goats)	❑	❑	_______
Horses	❑	❑	_______
Poultry (chicken, layers, turkey)	❑	❑	
Hogs	❑	❑	
Other (e.g. bison, elk)	❑	❑	_______

__Instructions:__ **ONLY IF** YOU OWN **BEEF CATTLE AND/OR SHEEP/GOATS**, PLEASE ANSWER THE FOLLOWING QUESTIONS. IF YOU DO NOT OWN CATTLE OR SHEEP/GOATS, PLEASE GO TO SECTION 3.

9. Of the fields identified in question 7, suppose your <u>very least</u> productive (or least valuable) field were planted entirely with trees. Would this reduce your holdings of cattle and/or sheep? **(Please ✓)**

❑ YES → **a)** If YES, by what proportion would you reduce the number of livestock you own? **(Please fill in the blanks)**

❑ NO

	% reduction	OR	# fewer animals
cattle	__________		__________
sheep/goats	__________		__________

10. Now suppose that, in addition to your least productive field, your <u>second least</u> productive (second least valuable) field were planted entirely with trees. Would this reduce your holdings of cattle and/or sheep? **(Please ✓)**

❑ YES → **a)** If YES, <u>in addition to</u> reductions from question 9, by what proportion would you reduce the number of livestock you own? (If this were to cause you to get out of livestock altogether, please indicate 100%.) **(Please fill in the blanks)**

❑ NO

	% reduction	OR	# fewer animals
cattle	__________		__________
sheep/goats	__________		__________

11. What is the minimum herd size you need to make raising cattle/sheep viable? **(Please fill in the blanks)**

_______ cattle AND/OR # _______ sheep/goats

PLEASE GO TO SECTION 3

Section 3: Adapting to Climate Change

Instructions: Suppose that you are faced with a permanent change in the climate affecting the area in which your farm is located. The new climatic conditions are as follows:

- average daily temperatures during the growing season are 3° C higher
- available soil moisture is on average 10% lower because it is hotter
- the average growing season is 15% (about 7 days) longer
- winters are milder on average with about the same snowfall
- variability around the new average temperature, precipitation and length of growing season is the same as before

1. Would you consider leaving agriculture altogether if the above climate scenario were a sudden reality? **(Please ✓)**

❒ YES

❒ NO

❒ DON'T KNOW

Instructions: Under these conditions and with no help from government, identify the strategies that you would employ to adapt to the changed climate. Please indicate by **circling the appropriate choice,** on the 5-point scale, the likelihood that you would employ the adaptation strategy. If you do not know, please circle zero (0).

Cropping Strategy	Highly unlikely to adopt	Not likely to adopt	Will consider	Some what likely to adopt	Highly likely to adopt	No Opinion / Don't know
2. Rely (more) on irrigation.	1	2	3	4	5	0
3. Plant crops, such as corn, that are currently planted in areas with similar climate in the USA.	1	2	3	4	5	0
4. Plant genetically modified crops that are more drought and pest resistant.	1	2	3	4	5	0
5. Employ more tillage summerfallow as a means to conserve moisture.	1	2	3	4	5	0
6. Employ more chemical fallow as a means to conserve moisture.	1	2	3	4	5	0
7. Consult agricultural experts, or other experts, to help me manage for weather-related risk.	1	2	3	4	5	0
8. Consult agricultural experts to help me identify new crops that are better suited to the changed climate.	1	2	3	4	5	0
9. Rely more on a mix of crops, including livestock, to reduce risks.	1	2	3	4	5	0

PLEASE GO TO SECTION 4

Section 4: Planting Trees to Mitigate Climate Change

Something about tree planting:
This information is useful for answering the following questions and determining the suitability of your land for growing various tree species. Hybrid poplar grows quickly with trees reaching maturity in 10-15 years. To achieve such growth, hybrid poplar requires more water than slower-growing species, such as spruce or pine, that generally require more than 40 years to reach maturity. Similar to hybrid poplar, spruce grows best on moist, well-drained, rich-in-nutrients soils. In contrast to hybrid poplar and spruce, pine tolerates low-nutrient conditions and does well in relatively dry environments.

1. Have you previously participated in a tree-planting project? (**Please ✓**)

❐ YES→
❐ NO

a) If YES, what type of planting project(s) were you involved in? (**Please ✓**)		b) Were you paid any remuneration? (**Please ✓**) NO	YES	If YES, how much PER YEAR?
shelterbelt	❐	❐	❐	$_____per acre over______years
block forest planting	❐	❐	❐	$_____per acre over______years
experimental planting	❐	❐	❐	$_____per acre over______years
alley cropping	❐	❐	❐	$_____per acre over______years
individual trees	❐	❐	❐	$_____per acre over______years
other (please specify)_________	❐	❐	❐	$_____per acre over______years

2. Would you voluntarily plant trees on your land if it did NOT have a negative effect on your eligibility for government agricultural programs or any tax benefits? (**Please ✓**)

❐ YES→
❐ NO

a) If YES, why would you plant trees? (**Please ✓**)		b) What type of planting would you engage in? (**Please ✓ and provide area**)		
❐	to prevent soil erosion	❐	shelterbelt	#_____acres
❐	to provide shade	❐	block forest planting	#_____acres
❐	to provide fuelwood	❐	experimental planting	#_____acres
❐	to grow commercial timber	❐	alley cropping	#_____acres
❐	to diversify production	❐	individual trees (including small clumps of trees)	#_____acres
❐	to make use of idle land			
❐	other (please specify)___________ ______________________	❐	other (please specify) ______________	#_____acres

3. Do you have past experience harvesting and selling trees from your land, even if you relied on a contractor? (**Please ✓**)

❐ YES

❐ NO

4. Suppose you were to enter a contract that permits someone to plant trees on (some proportion of) your land. All direct costs of tree planting (e.g. establishment, monitoring, management, maintenance costs) are covered, AND you are provided annual compensation. You DO NOT have any right to harvest the trees before the contract expires. However, when the contract ends, trees become your property.

Would you consider a tree-planting program if you were adequately compensated? **(Please ✓)**

❒ YES → (answer questions 5 and 6)

❒ NO → (go to Instructions below)

5. What type of tree planting program would you participate in today if you were adequately compensated for land and production losses? **(Please ✓ ; more than one can apply)**

- ❒ shelterbelt
- ❒ block forest planting
- ❒ experimental planting
- ❒ alley cropping
- ❒ individual trees (including small clumps of trees)
- ❒ other (please specify) ____________________

6. What species would you prefer for planting? **(Please ✓)**

- ❒ hybrid poplar
- ❒ pine
- ❒ spruce
- ❒ mix
- ❒ other (please specify)

____

PLEASE CONTINUE ON THE NEXT PAGE

Instructions: Only if you answered NO to question 4, please answer the following:

7. We are interested in how important some of these considerations are in your decision NOT to consider planting trees on your land. **(Please ✓ the appropriate categories).**

	not at all	somewhat important	very important
a) loss of visual appeal of landscape	❒	❒	❒
b) environmental concerns (e.g., trees take too much moisture)	❒	❒	❒
c) preference for the way I currently run the farm operation	❒	❒	❒
d) insufficient knowledge of issues involved	❒	❒	❒
e) other (please specify): ____________________	❒	❒	❒

8. What would you say was your main reason(s) for not considering planting trees on your land? **(Please identify):**

____

____

PLEASE GO TO SECTION 6

9. Suppose a block tree-planting program (planting of entire fields) is available, and at least one of your fields is identified as a potential site for tree plantations. Would you be willing to accept ANNUAL compensation of **$xx** per ACRE for a 10-year contract? **(Please ✓)**

❒ YES

❒ NO

On a scale 1 to 10, how certain are you of your answer to questions 9? **Please circle** the number that best represents your answer if **1= not at all certain** and **10 very certain.**

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
not at all certain				somewhat	certain				very certain

If you agree to a tree-planting contract, how many acres would you make available at the compensation indicated above?

____________________ acres

10. Again, suppose a block tree-planting program is available and your land is eligible for tree plantations. Would you be willing to accept an ANNUAL compensation of **$yy** per ACRE for a 40-year contract? **(Please ✓)**

❒ YES

❒ NO

On a scale 1 to 10, how certain are you of your answer to questions 10? **Please circle** the number that best represents your answer if **1= not at all certain** and **10 very certain.**

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
not at all certain				somewhat	certain				very certain

If you agree to a tree-planting contract, how many acres would you make available at the compensation indicated above?

____________________ acres

11. What is your preferred contract period for a tree-planting program?

❐ 0-5 years	❐ 16-20 years	❐ 31-35 years
❐ 6-10 years	❐ 21-25 years	❐ 36-40 years
❐ 11-15 years	❐ 26-30 years	❐ more than 40 years

12. In EACH of the following situations, on a PER ACRE basis, would you prefer ANNUAL compensation or a ONE-TIME payment for a 10-year contract? (**Please ✓ only one for each of I through IV**)

I.	❐ $10 annual or ❐ $78 lump-sum	II.	❐ $30 annual or ❐ $203 lump-sum
III.	❐ $20 annual or ❐ $170 lump-sum	IV.	❐ $25 annual or ❐ $181 lump-sum

13. At the end of the contract, if there was no possibility to extend it, how likely are you to take the following actions? **(Please ✓)**

Action	Not likely	Likely	Very likely
Immediately harvest trees.	❐	❐	❐
Delay harvesting trees until they reach maturity.	❐	❐	❐
Never harvest trees.	❐	❐	❐
Harvest trees only if agricultural prices are higher than now.	❐	❐	❐

PLEASE GO TO SECTION 5

Section 5: Contracting to Provide Carbon Credits on Agricultural Land

Something about selling carbon credits:
Carbon credits are earned by increasing removal of CO_2 from the air and storage in plant material. Farmers create carbon credits by planting trees on their land, converting cropland to grassland, and/or reducing tillage operations. The size of credits is determined by the increases in tree biomass (i.e. faster growing trees remove more CO_2 from the atmosphere, thereby generating larger carbon credits), crop residues and soil organic matter brought about by the action, with monitoring done by an environmental non-governmental or governmental agency. Farmers could sell carbon credits on carbon markets that are now being developed. Alternatively, farmers could exchange their carbon credits for subsidies (from government, industry, etc.) to engage in the activities that provide the carbon credits – ownership of the carbon credit is effectively transferred to another party.

1. Given this information, would you consider joining other farmers in forming an environmental co-operative to sell carbon credits? **(Please ✓)**

❐ YES

❐ NO

2. Please <u>rank</u> in order from **1 = most preferred** to **4 = least preferred** the following options you might have for being compensated for growing trees on your land.

☐ a) selling carbon credits in markets specifically established to allow trade in carbon emissions and credits (initiating tree planting yourself)

☐ b) entering into tree planting contracts with an environmental non-government organisation (e.g., Greenpeace, World Wildlife Fund)

☐ c) entering into tree planting contracts with the federal or provincial government, or their representative agency

☐ d) entering into tree planting contracts with private companies, such as electricity providers and oil producers (that is, large CO_2 emitters)

3. Suppose a market for selling carbon credits exists. Which of the following strategies would you be likely to pursue in order to produce carbon for sale? *Remember, you pay the cost for implementing any of the strategies you identify, but are compensated from sale of the carbon produced by the strategy.* **(Please ✓; more than one possible)**

❐ reduce the number of tillage operations (i.e. minimum tillage)

❐ reduce amount of tillage summerfallow and use chemical fallow instead

❐ reduce amount of tillage summerfallow by increasing cropping (e.g. continuous cropping)

❐ plant <u>fast-growing</u> trees in large blocks (i.e. entire fields)

❐ plant <u>native</u> trees in large blocks (i.e. entire fields)

❐ plant shelterbelts and/or individual trees (including small clumps of trees)

PLEASE GO TO SECTION 6

Section 6: Personal Information

These last few questions will help us in evaluating the representativeness of our sample.

1. What is your age? **(Please ✓)**

❒ 21-25	❒ 26-30	❒ 31-35	❒ 36-40	❒ 41-45
❒ 46-50	❒ 51-55	❒ 56-60	❒ 61-65	❒ over 65

2. What is your level of education? **(Please circle)**

Post Secondary (Years): 0 1 2 3 4 5 6 7+

3. Including yourself, how many adults (18+ years of age) are in your household? #________ adults

   How many children (under 18 years of age) are in your household? #________ children

4. How long have you owned your farming operation? #________ years

Instructions: Please ✓ the applicable categories.

	YES	NO
5. Are you or have you ever been a member of an environmental group (e.g., Sierra Club)?	❒	❒
6. Are your descendants likely to continue running the same farm operation as you?	❒	❒
7. Are you farming land that has been passed down within your family?	❒	❒
8. Do you supplement your farm income through off-farm employment?	❒	❒

9. What is the approximate net worth of your farm enterprise? **(Please ✓)**

❒ less than $100,000	❒ $100,000 - $199,999	❒ $200,000 - $299,999
❒ $300,000 - $399,999	❒ $400,000 - $499,999	❒ $500,000 - $599,999
❒ $600,000 - $699,999	❒ $700,000 - $799,999	❒ $800,000 - $900,000
	❒ more than $900,000	

THANK YOU FOR YOUR TIME AND COOPERATION

Your comments:

Bid Pairs

Version	$XX	$XX-Y
1	3	1
2	3	2
3	5	1
4	5	3
5	7	2
6	7	4
7	7	6
8	9	3
9	9	5
10	9	7
11	12	3
12	12	6
13	12	9
14	15	5
15	15	8
16	15	11
17	18	7
18	18	10
19	18	13
20	21	9
21	21	12
22	21	15
23	24	11
24	24	14
25	24	17
26	27	13
27	27	16
28	27	19
29	30	15
30	30	18
31	30	21
32	35	17
33	35	21
34	35	25
35	40	19
36	40	24
37	40	29
38	50	25
39	50	32
40	50	39
41	60	30
42	60	40
43	60	50

Appendix B Typical Comments by Respondents

Comments	Number of Respondents
1. The offered compensation is too low (i.e., it will take a lot of money to compensate us). The suggested compensation level should be around $60 per acre per year, possibly adjusted for inflation	11
2. I already have reduced tillage/summerfallow or chemicalfallow	9
3. The offered compensation does not even cover the tax related to that land	8
4. My land is not suitable for planting trees (e.g., because of lack of water, inappropriate soil conditions)	7
5. Planting trees has to be a viable farming enterprise	6
6. I have been applying continuous cropping for a long time (generally over 10 years)	6
7. Tree planting is useful for preventing erosion and protecting wildlife	6
8. I do not trust government because it does not honour contracts (e.g., it can change the terms of the contract as it pleases)	4
9. Grass is an option in carbon sequestration, why focus only on trees?	4
10. I need more information about the contract in order to make a decision.	4
11. Some questions were difficult to answer. More discussion is needed for a meaningful answer.	4
12. I am interested in carbon credits as a result of zero tillage (or minimum tillage)	3
13. Planting trees is a good idea both economically for my farm and environmentally for everyone	3
14. Global warming will be welcome	3
15. I found the survey interesting	3
16. Inflation has to be taken into account.	3
17. I already have trees, am I going to be compensated for the carbon sequestred?	2
18. I am concerned that planting trees will reduce the land base devoted to food production	2
19. We keep our marginal agricultural land in pasture and wildlife habitat, sometimes trees	2
20. Trees are not natural to prairies	2
21. You have sent me the survey at a busy time, during harvest	2
22. I do not believe in global warming.	2
23. Trees are likely to be worthless at the end of the contract period	1
24. Governments should support planting trees for ethanol fuel	1
25. Hemp is a viable alternative to planting trees for carbon sequestration	1
26. The idea of selling carbon credits is appealing	1
27. I am interested in raising bison and/or elk as weed control while trees establish themselves	1
28. Carbon cycle could be managed by lower reliance on fossil fuels and greater use of substitutes for non-renewable resources	1
29. Intensive farming creates huge farms that destroy the look of the landscape by pushing out trees	1
30. Growing population is the problem behind global warming.	1
31. Decreased tillage increases the use of chemicals and pesticides.	1

In addition, one farmer commented as follows:

"I rent my land out on a share agreement that returns me on average $20 per acre net. If I grew trees on the land I would marginally make more money if I was paid $24 per acre, however, one thing that is not being taken into consideration is the cost of removing the stumps etc. after the trees have been harvested to return the field back to agricultural production. At present it would cost well over $100 per acre to remove stumps and root rake the field back to its original condition, also it would put the land out of use for 2 years while this is done. The only alternative is to keep this field in tree production, and replant it with trees when the present trees are harvested. This requires a very long-term commitment from both the landowner and the party paying for the tree planting. There would have to be some guarantee to the landowner that compensation would be paid well into the future. I would be interested in doing this, however, there are lots of wrinkles to iron out yet".