Foreword

The Government of Canada and the provincial and territorial governments are working with the agriculture and agri-food industry and interested Canadians to develop an architecture for agricultural policy for the 21st century. The objective of the Agricultural Policy Framework (APF) is for Canada to become the world leader in food safety and food quality, innovation and environmentally-responsible production. To contribute to these goals, Agriculture and Agri-Food Canada (AAFC) has an ongoing research program to provide information on the effects of agricultural policy and technology scenarios on the environment and on the economic performance of the agriculture sector.

Included in this work program is the economic evaluation of various scenarios for the mitigation of greenhouse gas (GHG) emissions in the agriculture sector. Carbon sequestration practises in primary agriculture comprise one such mitigation scenario. This report analyses and models the potential decision-making process of farmers when they are presented with the opportunity to enter into carbon sequestration contracts. The focus of the report is on the complex factors and uncertainties involved in deciding whether and when to enter into such contracts. The report uses dynamic optimization methods to simulate potential solutions to the decision-making problem, and provides an analytical framework for further empirical analysis. Its major contribution is in the development of a methodology to estimate farmers' potential response to carbon credit incentives in a domestic emissions trading system.

Any policy views, whether explicitly stated, inferred or interpreted from the contents of this report do not necessarily reflect the views or policies of AAFC.

Executive Summary

Soil carbon sequestration is a strategy for dealing with greenhouse gas emissions. This report provides models and analyses of the decision-making process of a farmer who has the opportunity to sign a carbon sequestration contract. In signing the contract, the farmer agrees to adopt a technology or farm management practice that will eventually result in a higher level of soil carbon. Common examples of carbon-conserving technologies include continuous cropping, zero tillage, inclusion of a legume in the crop rotation and converting cropland to permanent grassland.

The farmer's decision is complex because carbon sequestration is inherently dynamic, there are several sources of uncertainty and the decision to sequester carbon is costly to reverse. In addition, the decision to sequester carbon is a once-in-a-lifetime opportunity because once the soil carbon reaches a new equilibrium level, the benefits from the soil contract disappear.

To simplify the analysis, three distinct types of models are used to analyze the problem:

- In the first model, all uncertainty is assumed away and the focus is on the type of technology the farmer should choose. This model draws heavily on the general principles of renewable resource management.
- In the second model, three sources of uncertainty are introduced: the market price of sequestered carbon, the rate of soil carbon accumulation and the opportunity cost of operating with a carbon-sequestration technology rather than the status quo technology. The focus here is on when to adopt a particular technology rather than what type of technology to adopt. This model draws heavily on the general principles of option pricing from the finance literature on investment under uncertainty.
- The third model consists of a conceptual framework rather than a set of mathematical relationships. Key to this framework is the link between carbon sequestration and variability in farm profits and the extent that a change in farm profit variability affects the adoption decision because of risk aversion and prudence.

The first model is a theoretical analysis. The farmer has a range of technologies to consider. At one end, the technology conserves comparatively high levels of carbon and will eventually result in maximum sustainable annual profits. At the other end, the technology conserves comparatively low levels of carbon and results in maximum short-run profits. In the absence of a carbon contract, the size of the farmer's discount rate determines where the optimal technology lies (a lower discount rate shifts the technology toward carbon conservation). A carbon contract offsets the incentive to choose the short-run carbon depleting technology. If the price of sequestered carbon is sufficiently high, then it is possible that the optimal technology conserves more carbon than that which maximizes sustainable annual profits. Given the simple structure of the model, it is always optimal for the farmer to sequester carbon as quickly as possible from the day the contract is signed until the long-run equilibrium is reached.

In the second model of option pricing, the combination of uncertainty and a contracting decision that is assumed irreversible implies that the option to defer the signing decision has value. Because of this option value, the expected net present value (NPV) of the carbon sequestration scheme must be sufficiently positive (i.e. at least as large as the value of the option) before it is optimal for the farmer to sign the contract. For relatively high parameter values of the market price of carbon and for relatively low parameter values for the level of foregone profits from adopting the carbon sequestration technology, immediate investment is optimal. For more intermediate parameter values, the NPV is positive but not sufficiently positive to warrant immediate investment. In this case, the value of the option to delay is about 15 percent.

In the third model, the decision to sequester carbon results in higher risk for three reasons:

- Activities such as summerfallow and conventional tillage tend to reduce risk; eliminating these activities will generally raise risk.
- Investment in any new technology generally involves a period of learning and thus a period of higher risk.
- Investment in a particular carbon sequestration technology such as a zero till drill will generally increase financial leverage and thus financial risk.

If the decision to sequester carbon raises risk, then the more risk averse and prudent the farmer, the higher the needed expected rate of return from the carbon sequestration scheme before the farmer will sign the contract. This risk premium must be added to the option value to get a true sense of the likelihood that a farmer will participate in a carbon sequestration scheme.

There are many strong assumptions that underlie the analysis. These assumptions should be relaxed in future analysis to assess the overall robustness of the results. Similarly, there are many features of the decision to sequester carbon that the current models do not capture. More general forms of analysis are needed to obtain a more robust set of results. The Summary and Limitations section contains a detailed discussion of possible extensions.