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The economics of carbon sequestration through pest management: application to forested landbases in New Brunswick and Saskatchewan, Canada

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ABSTRACT

This analysis employs a spruce budworm (*Choristoneura fumiferana* Clem.) decision support system to examine costs and benefits of sequestering (protecting) carbon in forests through pest management. We analyzed 24 alternative spruce budworm protection scenarios for outbreaks on Prince Albert Forest Management Area (PAFMA) in Saskatchewan and Crown License 1 in New Brunswick. Scenarios included two outbreak severities (moderate and severe), three protection frequencies (very aggressive—protecting every year of the outbreak; aggressive—protecting the peak 3 years of outbreak; and semi-aggressive—protecting every second year of outbreak), and four protection program sizes (10,000 ha, 25,000 ha, 100,000 ha, or 150,000 ha). Under a severe outbreak, the largest (150,000 ha), very aggressive protection scenario provided the highest net CO_2 protected at 24.95 million metric tons (Mt) in PAFMA and 29.19 Mt in License 1. This protection scenario also provided the highest net present value at $64.23 M and $91.36 M in PAFMA and License 1, respectively. On the other hand, benefit/cost ratios were maximized under the smallest (10,000 ha) protection size at 11.90 and 15.37 using the aggressive and semi-aggressive protection frequencies in PAFMA and License 1, respectively. Finally, the discounted cost per ton of CO_2 protected was minimized at $0.48 and $0.37 using the smallest aggressive and semi-aggressive protection frequencies in PAFMA and License 1, respectively. The comparable costs and benefits from the moderate outbreak scenarios were similar, but generally less than, the severe outbreak scenarios. These results provide forest managers with important information needed to justify such carbon sequestration programs on economic grounds.

1. Introduction

Scientists believe that global climate change is occurring as a result of increasing atmospheric concentrations of greenhouse gases (GHGs). The most dominant GHG from human activities is carbon dioxide (CO_2), both in terms of emissions and potential to affect climate (Krcmar et al., 2001). Over the past century, about three quarters of the greenhouse gas emissions to the global atmosphere originated from fossil fuel burning and the remainder from land use, land-use change, or forestry (Kurz et al., 2003).

In 2002, Canada ratified the Kyoto Protocol, which embodies an international agreement to reduce net GHG emissions in order to slow their rate of increase in the global atmosphere. According to the Protocol, Canada has committed to reduce GHG emissions by 6% from 1990 levels (Environment Canada, 2007a). Canada can achieve its objectives through a variety of means ranging from emission reductions to carbon sequestration. While the Canadian Federal government has indicated that it will not meet its Kyoto commitments in the 2008–12 commitment period, it has developed a plan to reduce carbon emissions through the establishment of an emissions trading program and targeted industrial emissions intensity reductions (Environment Canada, 2007b). Additionally, organizations such as the Western Climate Initiative (Western Climate Initiative, 2008), the Regional Greenhouse Gas Initiative (Regional Greenhouse Gas Initiative, 2008), and various provincial governments are helping to develop regional climate change strategies. These and other such developments have encouraged Canadian companies to investigate opportunities for buying and selling emissions reduction credits in several voluntary exchanges including the Montreal Climate Exchange (MCeX) and the Chicago Climate Exchange (CCX). While trading on the MCeX has just recently begun in May of 2008, other exchanges such as the CCX and the European Union Emissions Trading Scheme (EU-ETS) have been in place for a number of years and have grown into the billions of dollars.

One activity that has received much attention for its potential role in reducing net carbon emissions is forest management. An extensive literature exists on the costs of carbon sequestration projects both within Canada (Jaccard, 2002, van Kooten et al., 1992, 2000; McKenney et al., 2004; Krcmar et al., 2005a,b; Yemshanov et al., 2007) and globally (Wangwachabakul and Bowonwiwat, 1995; De Jong et al., 2000; Huang and Kronrad, 2001; Sathaye et al., 2001; Pohjola et al., 2003; Baral and Guha, 2004; van Kooten et al., 2004; Nijnik and Bizikova, 2008). In one of the many studies, van Kooten et al. (2004) used a meta-analysis approach to estimate carbon sequestration costs

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for forest conservation in the range of \$13–\$71 per ton of CO_2. Similarly, studies reviewed in Baral and Guha (2004) estimate carbon sequestration costs for afforestation/reforestation in the southern United States to range from \$0.70 to \$150 per ton of CO_2. These studies have emphasized that, in some cases, forest management can be a cost-effective way of reducing net carbon emissions. To date, a number of carbon credits have been issued for specific afforestation/reforestation carbon offset projects by the United Nations Framework Convention on Climate Change (UNFCC, 2008) and the CCX (CCX, 2007).

An important factor influencing forest carbon stock changes that has received relatively little attention is the impacts of forest pest outbreaks and management. Projections of Canada's carbon budget for 1980–2032 indicate that assumptions about the rates of future natural disturbance have a large impact on the direction and magnitude of predicted carbon stock changes in the managed forest (Kurz et al., 2003, 2008). Additionally, Kurz and Apps (1999) and Kurz et al. (2008) found that recent changes in the forest pest disturbance regime resulted in a switch of Canadian forests from being a net sink of carbon to a small net source of C to the atmosphere. This is of particular importance as Canada's forests have long been subject to natural disturbances from insects such as the spruce budworm (*Choristoneura fumiferana* Clem.) and mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Between 1975 and 2002, spruce budworm (SBW) defoliated on average 16 million hectares per year, causing significant growth loss and mortality in spruce (*Picea* sp.)—balsam fir (*Abies balsamea* (L.) Mill.) forests, as well as extensive wood supply, non-timber, and economic impacts (MacLean, 1980; Health Canada, 2005).

Pest management activities aimed at keeping trees alive and maintaining their 'sink' function in the midst of an insect outbreak could potentially play a significant role in helping to reduce a region's net carbon emissions. Such reductions could provide carbon credits either within the United Nations Framework Convention on Climate Change or through voluntary carbon credit exchanges.[1]

The purpose of this research was to analyze the potential costs and benefits of sequestering (protecting) carbon in forests through pest management activities. Our analysis builds on previous work by the Canadian Forest Service who developed a SBW decision support system (SBW DSS) to help implement pest management strategies (MacLean et al., 2001). The SBW DSS is based on simulation software that quantifies the marginal timber supply (m^3/ha) benefits of protecting forest stands against SBW defoliation using aerial application of the biological insecticide *Bacillus thuringiensis* (*Bt*).[2] The software has been used to simulate SBW outbreaks and prioritize *Bt* applications to forest stands that would protect the largest quantity of timber volume from specific outbreaks on landbases across Canada (MacLean et al., 2002; Hennigar et al., 2007).

We extended the SBW DSS to account for carbon sequestration, protection costs, and potential carbon credit benefits (revenues). The extension allows pest managers to evaluate the degree to which the traditional SBW DSS objective of 'maximizing timber volume protected' from a protection program corresponds to four carbon/economic objectives, namely: maximizing net CO_2 protected; maximizing the benefit/cost ratio (BCR) of CO_2 protected; maximizing the net present value (NPV) of CO_2 protected; and minimizing the discounted cost per ton of CO_2 (cost/t C) protected. We tested 24 alternative protection program scenarios, comprised of two outbreak severities (moderate and severe), three protection frequencies (very aggressive—protecting in every year of the outbreak; aggressive—protecting the peak 3 years of outbreak; and semi aggressive—protecting every second year of outbreak), and four protection program extents (10,000 ha, 25,000 ha, 100,000 ha, and 150,000 ha). The scenario analyses were conducted on two case-study landbases in Canada to illustrate the extent of carbon sequestration, cost, and benefit variation across outbreaks, management options, and geographic circumstances. Pest managers can use this framework to help them establish protection programs that will best facilitate the sale of carbon credits when (or if) a carbon credit mechanism for pest management emerges.

2. Methods

2.1. Framework of analysis

Five major steps were followed to estimate the costs and benefits of sequestering carbon in forests through pest management activities: (i) defining the CO_2 assessment boundaries (region and program activity); (ii) selecting baseline SBW outbreak scenarios; (iii) estimating baseline CO_2 emissions and CO_2 reductions from the protection program; (iv) estimating costs of the protection program; and (v) estimating carbon credit benefits from the protection program. Steps (i)–(iv) generally follow the 'Land Use, Land-Use Change and Forestry Guidance for GHG Project Accounting' and the 'GHG Protocol for Project Accounting', developed by the World Resources Institute (2005, 2006). The guidelines were adapted for our purposes of evaluating the costs and benefits of SBW management on forest carbon stocks. Additional components outlined in the guidelines such as monitoring and reporting of GHGs were not applicable in this case as the analyses were simulated.

The CO_2 assessment boundaries were defined over two forested landbases, including the Prince Albert Forest Management Area (PAFMA) in Saskatchewan and Crown License 1 in New Brunswick (Fig. 1). The PAFMA landbase, licensed to Weyerhaeuser Canada, is located in central Saskatchewan (53° 50'–55°50' N, 104° 10'– 108° 20'W) (Fig. 1a) and totals 5,038,200 ha, with 2,545,300 ha of timber producing land, 1,761,300 ha of non-productive muskeg and brushlands, 83,100 ha of rock, sand and clearing, and 648,500 ha of water and flooded lands. With regard to SBW vulnerability, the area contains 154,300 ha of highly vulnerable species (fir–spruce, spruce–fir, plantations, and thinnings), 450,700 ha of moderately vulnerable species (mixed spruce–fir/hardwoods, and spruce–fir/other softwoods), 599,500 ha of low vulnerability species (mixed natural and thinned hardwood/spruce–fir and mixed softwood/spruce–fir), and 392,400 ha of non-susceptible species.

Crown License 1, licensed to AbitibiBowater Inc. in northern New Brunswick (47° 25'–48°04' N, 65° 45'–67° 40'W) (Fig. 1b), totals 521,900 ha, including 406,200 ha of productive Crown land, 78,100 ha of productive freehold land, 26,200 ha of non-productive forest land, 7400 ha of roads, and 3600 ha of water. Classified in terms of SBW vulnerability, the License contains 70,770 ha of highly vulnerable species (fir–spruce, spruce–fir, plantations, and thinnings), 157,000 ha of moderately vulnerable species (mixed spruce–fir/hardwoods, and spruce–fir/other softwoods), 171,000 ha of low vulnerability species (mixed natural and thinned hardwood/spruce–fir and mixed softwood/spruce–fir), and 114,700 ha of non-susceptible species.

The general program activity considered for sequestering CO_2 was the implementation of pest management using aerial spraying of *Bt* to keep trees alive and thereby keep carbon sequestered in forests during SBW outbreaks. Specific program activities included several protection scenarios comprised of different protection frequencies and program sizes. Specifically, we considered three protection frequencies: very aggressive—protecting in every year of the outbreak; aggressive—protecting the peak 3 years of outbreak; and semi aggressive—protecting every second year of outbreak. Each frequency was designed to limit defoliation to 40% of current year foliage per year. We also

[1] At present, the United Nations Framework Convention on Climate Change has approved only a limited number of forest management activities (i.e., afforestation and reforestation) that sequester carbon (UNFCC, 2008). While other voluntary carbon credit exchanges such as the CCX have approved a wider range of forest management methodologies for sequestering carbon, none have yet approved methodologies for generating carbon credits from pest management.

[2] *Bt* is the most common control agent used by provincial governments in Canada to protect forests against spruce budworm outbreaks.