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Viability of Carbon Offset Generating Projects in Boreal Ontario

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Abstract

Carbon offsets generated under the Kyoto Protocol should be included in the management options that resource managers are considering. This paper investigates investments in afforestation for the generation of KP compliant carbon offsets in the Timmins Management Unit, concentrating on the availability of quality carbon budget models, domestic carbon market concerns and the presence of an enabling environment. A modelling exercise is undertaken using GORCAM-WC1, with ownership, leading species, investment horizon, site productivity and carbon price as variables. Under current institutional frameworks, afforestation projects with the purpose of generating carbon offsets in the TMU are not viable investments for the first commitment period, though such projects will be profitable under certain conditions if constraints are removed and investment is long term.

Key Words: Afforestation, Kyoto Protocol, Boreal Ontario, Carbon Sequestration

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Introduction

The Kyoto Protocol (KP) arose out of the recognition by the United Nations Framework Convention on Climate Change (UNFCCC) that traditional legislative means of protecting environmental services are inadequate, and it was hoped that the KP would provide enforceable goals for reducing the concentration of atmospheric greenhouse gases (GHGs). Countries with GHG abatement targets for the first commitment period (CP1: 2008-2012) have several options to meet their objectives: increased energy efficiency, conversion to renewable energy forms, forestry, agriculture and afforestation, and can do so using fiscal incentives, taxes and caps on GHG producing industries.

In order to harmonize marginal abatement costs spatially, and thereby minimize total cost, mechanisms have been created to produce tradable carbon offsets that represent sequestered CO_2. These offsets allow sequestration and emission abatement to occur in regions where it is most cost effective, and they also provide an incentive for landowners and resource managers to promote carbon sequestration as an economically viable activity (Bahn *et al.* 2001).

The forestry related options to generate offsets are afforestation (Article 3.3) and forest management (Article 3.4). Despite a difference in definition[1], both reforestation and afforestation are governed by the same rules for offset production, and are hereafter referred to as 'afforestation' to distinguish them from planting as a silvicultural treatment after harvest, commonly referred to in the forest industry as reforestation. Regeneration after harvest does not count towards creation of a carbon sink, but neither does harvesting

[1] Under the KP, reforestation is the act of establishing tree cover on land that has been historically forested, but not since 1990, while afforestation occurs when the same activities establish forests on land that has been without trees for significantly longer.

count as deforestation, as long as the land can be expected to regenerate to forest. There is no cap on the amount of domestic afforestation that Canada can apply towards its KP commitment, unlike forest management.

Carbon sinks have the potential to play a significant role in meeting KP targets. The federal government of Canada committed to decrease national emissions to 6% below 1990 levels by the end of CP1, representing ~650 Mt-CO_{2eq} (Gunter *et al.* 1998). Various actors have claimed that its large land base and developed forest industry means that Canada can not only meet significant amounts of its KP commitments through afforestation, but that it will be a seller on the international offset market (Bernoux *et al.* 2002). The Canadian government has made it clear that it expects a significant proportion of Canada's commitment to come from afforestation.[2] Though several papers have discussed national and provincial opportunities for such activity (e.g. Cherry 2001) none have examined the requirements necessary for the generation of KP compliant carbon offsets through afforestation for individual management units, outlining the specific steps necessary for an individual forest manager. This paper fills that gap, examining the unique characteristics of the Timmins Management Unit (TMU) in Northeastern Ontario and identifying the circumstances within which an investment in afforestation for carbon offset production would be reasonable, the profit that such a project could expect and the amount of carbon that would likely be sequestered. The paper is organized as follows. First, the practical requirements for the generation of carbon offsets through afforestation are discussed, with particular emphasis on modelling tools, markets and the institutional environment. Second, the unique characteristics of the TMU are considered and modeling

[2] It has yet to say exactly how much. Figures range from 15 – 40% (Cherry 2001, Griss 2002).

assumptions are presented. Finally, scenarios are developed and executed, and the results are discussed.

Requirements for offset generating afforestation projects

A resource manager considering investing in afforestation for the generation of KP compliant carbon offsets will base the decision on the presence, form and quality of three things: 1. credible monitoring and modelling tools, 2. the nature of the domestic carbon market, and 3. an enabling environment. Credible monitoring is necessary in order to quantify the number of carbon offsets generated by a project, whereas the domestic carbon market controls the value of those offsets and the rules under which they are exchanged. An enabling environment affects the confidence of a project manager that the return on an investment can be estimated in advance. Without these elements a manager does not have the information necessary to assess the viability of an afforestation investment. This section examines these elements with specific reference to the TMU.

Credible Models

Models that estimate the change in carbon sinks over time rather than actually monitoring them are necessary because current technology does not allow for accurate landscape measurement carbon flux at practical timescales. Development and improvement of such models would alleviate the problems associated with monitoring ecosystem carbon for KP compliance if enough experience can be gained before CP1 that model shortcomings can be addressed. For a carbon budget model (CBM) to be compliant with both the KP and the best available carbon science, it should be able to predict carbon flux for at least 11 ecological carbon sinks (ArborVitae 1999). In addition, the CBM must be spatially explicit to the stand level, transparent with verifiable algorithms, adaptable to changing definitions and procedures, cost and time efficient, and able to interpret the past and project the future (Kurz 1999). Perhaps most importantly, CBMs must be available and easy to use so that a manager can predict the effects of proposed management plans on carbon balances accurately and with a minor investment in resources.

With respect to the TMU, a number of CBMs approach these requirements, though none meet them exactly. GORCAM is available, easy to execute and has been used to predict management unit scale carbon budgets in Canada. It models nine of the required sinks, but lumps three soil sinks into a single value making it compliant to the minimum KP standard if not reflecting the most up-to-date science (Bird 2003). It uses the Chapman-Richards formula to convert merchantible volume to biomass, but the user supplies expansion factors, growth curves and average yearly temperature.[3] This requires a not insignificant amount of research by the user. Furthermore, existing management plans in electronic format (e.g. Woodstock) cannot be input directly into the model, requiring a duplication of data input effort. Given the likelihood of high international scrutiny for projects claiming removal units, it is uncertain that GORCAM and similar models will meet global standards.

The weaknesses of GORCAM and other CBMs have been recognized for several years, and as a result the Canadian Forestry Service (CFS) has been developing a new CBM (the CBM-CFS3) whose release is predicted for late 2004. It will not only include

[3] Interested readers may refer to Schlamadinger & Marland (1996) for a thorough examination of GORCAM and its equations.

all 11 ecological sinks, but provides Kyoto specific outputs, includes growth curves and biomass expansions for all tree species found in Canada for all climatic zones and site classes and allows users to import management plans from both the Strategic Forest Management Model and Woodstock. Furthermore, it has been developed by a team that participates in the development of KP reporting requirements, ensuring its compliance. As a result, it requires significantly less time to produce results than other models and the results are likely to have more credibility.

Though the CBM-CFS3 will be superior to currently available models, a forest manager wishing to consider an investment in KP compliant afforestation before 2005 will have to rely on other models. As a result, there is added uncertainty, and improvements in this area are necessary before CP1 if full KP benefits are to be realized.

Domestic Carbon Market

Much like the carbon budget models, the domestic carbon market is under development, and has yet to be brought on-line. From a more theoretical standpoint, Sandor *et al.* (2002) argue that a carbon credit market already exists, for there is a demand for capital to address a specific objective and that some norms for trade and participation have been developed. However, the exact form of the market mechanisms have yet to be determined, though a significant effort internationally is currently underway involving the creation of pilot markets. Pilot markets allow assumptions to be tested, verification strategies to be honed, participation to be gauged and mechanisms to be evaluated before final markets are in place, which is critical given the sums of money likely to be invested (Bernard & Vielle 2003).

Analysis of pilot market mechanisms, especially the European Trading Scheme (ETS), the UK Climate Change Levy (CCL) and the Chicago Climate Exchange (CCX) reveal the likely shape of the market (Christiansen & Wettestad 2003 and Varma 2003). The extremely successful US Clean Air Act Amendment to restrict emissions of SO_x has also been widely used as a template and will continue to be influential (Bonnie *et al.* 2002). That is, domestic markets will have mandatory participation of all major emitters with sectoral caps and trade. In initial stages, credits will be grandfathered on the basis of historical emissions, though auction based allocation is more economically efficient. Perhaps most importantly, these new markets will not be based solely on government environmental policy, but will be worked out in dialogue with a variety of public, private and transnational partners. As a result of these characteristics, demand for domestic carbon offsets is virtually guaranteed and the Canadian government will likely encourage new projects rather than endorsing old ones, in order to ensure a high price (Bernoux *et al.* 2002, White & Kurz 2003). However, there is currently no functioning domestic market in Canada, and none in the TMU. Since the exact characteristics of this market are unknown, benefits are not guaranteed and uncertainty will remain high.

From a cost perspective, trees have been tended and planted in Northeastern Ontario for a significant length of time, and therefore, the costs of afforestation in the TMU are well understood. When site preparation, seedling purchase, planting and tending costs are included, DeMarsh (1999) identified an average cost around 1 500 \$/ha,[4] in accordance with similar values provided by van Kooten *et al.* (1999) and Griss (2002). However, since carbon offsets have never been traded before, the benefits accruing to sellers are much less certain. Significant debate has occurred in economic

[4] All monetary figures in this paper are reported in Canadian dollars.

literature as to the price of credits, but international price of offset credits will likely range from 2 to 7.5 $/t-$CO_{2eq}$ (e.g., Sager 2003).

Enabling Environment

An enabling environment consists of the physical and institutional structures that facilitate projects generating KP compliant carbon offsets through afforestation. They include support from various levels of government, afforestation expertise, willingness among resource managers and a suitable land base for afforestation activities.

Although the government of Canada was a major proponent of securing recognition from the international community that the benefits of carbon sinks should be included in the KP, it has taken little action to date to promote them domestically (Griss 2002). At least part of this delay can be attributed to conflict with provincial governments who see environmental considerations and resource management as a uniquely provincial concern. Apart from its conflict with the Canadian government over jurisdiction, the government of Ontario has stymied afforestation of both private and public lands through canceling provincially operated afforestation programs (Cherry 2001). Despite repeated calls for a comprehensive government sponsored afforestation program accompanied by tax breaks and incentives to be developed in partnership with landowners and resource managers, little has been done aside from introducing the Managed Forest Tax Incentive Program (MFTIP) (Cherry 2001, Williams & Griss 1999). Municipal governments have also hindered afforestation by refusing to direct municipal tax assessors to reassess privately held land under MFTIP guidelines, resulting in tax burdens for those wishing to convert their land to forest (Miller & Balsillie 2003).

This lack of government support at all levels is one of the most significant barriers to afforestation projects in the TMU. Though the Model Forest Network has attempted to bridge this gap through a collaborative research agreement with the Canadian Forest Service, supporting the Feasability Assessment of Afforestation for Carbon Sequestration and promoting afforestation among its partners, it cannot fill governments' role. Insufficient government support together with the uncertainty relating to the carbon market make it difficult to pursue afforestation for the generation of KP compliant carbon offsets in management units such as Timmins, leading some researchers to conclude that afforestation under the KP may be very small (Duinker *et al.* 1999).

In general, polls conducted throughout Ontario in 2000-2001 indicate that landowners are willing to participate in afforestation programs, with interest increasing as the size of the area owned decreases (Cherry 2001). The characteristics of such a program are important, with partnerships between landowners, government agencies and forest companies and significant subsidies (90% of costs) required for program success (DeMarsh 1999). Under this sort of arrangement, where a government subsidy pays 90% of costs, one would assume that revenues from carbon sequestration would also accrue to the government, but if the overall benefits were well established beforehand, it is likely that managers would be less adamant about subsidies. If the effectiveness of MFTIP could be increased or further tax incentives given, willingness among managers would likely increase further (Griss 2002). This willingness is dependent on increased government support, however, and unless this exists resource managers in the TMU will have low incentive to afforest. The interest in afforestation might be higher in the TMU, however, since there is a significant amount of experience with planting trees to maximize biomass accumulation[5] due to the size of the managing forestry company, its proximity to the Iroquois Falls Forest Management Unit (IFFMU) and the Lake Abitibi Model Forest, and the involvement of local agencies with the Model Forest Network.

Offset generation in the TMU

Timmins management unit

The TMU consists of 200 000 ha of land in Northeastern Ontario and borders the Iroquois Falls Forest Management Unit. The forestry activities on each are managed by Abitibi-Consolidated. The forests are dominated by black spruce on moist lowland sites, jack pine on uplands, and trembling aspen on dry sites. Though most of the TMU is forested, significant areas of muskeg, cities (Timmins) and treeless fields also exist.

The area of suitable land for afforestation in the TMU is actually quite small if land currently under agricultural management is excluded. In this study agricultural land is excluded because the managers of agricultural land in Ontario are willing to consider afforestation only if it is accompanied by significant government subsidies (DeMarsh 1999, van Kooten *et al.* 1999). As this paper concentrates on the decision making process of an individual project manager without government intervention, lands that would require a subsidy for afforestation are not considered in the analysis.

Areas in the TMU suitable for afforestation under these criteria were determined from ArcView 3.2 based landuse files as provided by Abitibi Consolidated and the Lake Abitibi Model Forest. Those which fell under the categories of ‘meadows’ or ‘brush and

[5] This is not precisely the same thing as afforestation for carbon sequestration, but the similarities are broad enough that one can be assured that there is a significant amount of knowledge in the TMU about how to get trees to grow well in boreal Ontario.

alder' were considered suitable and were distinguished according to ownership class. There are 40 ha of privately owned suitable land, and 4000 ha of publicly owned suitable land.[6] Though in general afforestation is considered more cost effective in Northern Ontario than in Southern Ontario because of the heavily fragmented nature of the latter, in the TMU the lands under consideration are no less fragmented than one would find in the south, and in relatively small parcels (Cherry 2001).

The prevailing climate regime has a significant effect on ecosystem productivity and carbon sequestration and typically the complex relationships between ecosystem and climate are simplified to one or two parameters. In this paper, average annual temperature as recorded at Cochrane, Ontario, by Environment Canada for the last 30 years was used.

Climate change has been predicted to increase drought stress, wildfire intensity and wildfire duration in the TMU (Stocks *et al.* 1998). It is difficult to predict the response of ecosystem productivity to these changes, however, with various researchers forecasting either increased sequestration or increased emissions depending on which soil processes they think are most significant. Due to the uncertainty, the best response is to select species for planting that are less susceptible to the likely future conditions of drought stress and increased fire activity. As a result of biodiversity and invasive species concerns, only native species are acceptable (Stiers & Siebert 2002).[7] The most likely native species available for afforestation in Northern Ontario, as identified by Cherry (2001), were therefore considered.

[6]Private land was excluded from the modelling exercise because of its low area relative to public land.
[7] Though the afforestation of hybrid poplar has become popular because of its quick growth, it requires careful tending, moist conditions, is prone to insect outbreak and disease, and has not responded well in experimental plantings in Northern Ontario (Cherry 2001, Perry et al. 2001, Samson *et al.* 1999).

White and red pine show promise in boreal regions, with high productivity at young ages, but some research has shown that their impact on soil organic carbon is less desirable than other species (Vesterdal *et al.* 2002). Black and white spruce have the highest productivity of species found in the TMU, especially considering their high litterfall mass and relatively rapid growth, but are susceptible to the dry conditions potentially faced in the TMU under climate change (Chen *et al.* 2002). Jack pine and trembling aspen are the best suited for afforestation in the TMU given the conditions likely to be created by climate change since they both grow well under dry conditions and can have high short-term sequestration. A mix of 50% jack pine and 50% trembling aspen were therefore chosen for afforestation in these modelling scenarios, which is in line with the recommendations of Cherry (2001) and Duinker (1999). There is no difficulty in getting these species from local seed zones (Cherry 2001).

Though under the KP aboveground tree biomass is considered to be 100% emitted to the atmosphere upon harvesting, harvest does not necessarily result in a net emission when the entire landscape and belowground carbon sinks are considered. It is therefore possible to balance the economic returns from harvest against those of carbon sequestration to maximize revenue generation, and to use carbon models to contribute to the determination of optimal rotation ages and silvicultural treatments (Peng *et al.* 2002). The long-term effects can also be identified, for though many carbon pools recover quickly from disturbance, some are sources not only for the year they occur, but for years to come through higher soil temperatures and accelerated decay rates (Chen *et al.* 2002). Despite the obvious value of studying the effect of disturbance on carbon stocks, however, these scenarios do not include it. The purpose of this exercise is to determine whether afforestation for the generation of carbon credits in and of itself is a reasonable investment in the TMU. We do not examine all the potential revenue streams that could accrue to such a project. It should nonetheless be remembered that there are other benefits to afforestation projects than simply KP compliant offsets.

Soil characteristics are critical for landscape scale carbon modelling because globally soils contain approximately three times as much carbon as terrestrial vegetation and have the longest residence time of terrestrial pools, especially in boreal forests (Bhatti *et al.* 2002). In particular, the history of the area to be afforested is important, because soil respiration and decay will continue decades after aboveground biomass has been removed, and will have important effects on the timing and value of the equilibrium soil carbon will reach after an area has been afforested (Bashkin & Binkley 1998). The amount of soil carbon lost when forest is converted to agriculture is between 20 and 40% in Ontario, regardless of initial carbon content or soil texture, with the vast majority lost within the first 20 years (West & Post 2002). In this study, since the only fields under consideration have been cleared for over 25 years and are not currently managed for agriculture, the main effects of deforestation have already occurred, so a current soil carbon value is sufficient.

Another soil value important to this study is productivity, including available soil nutrients, relief, some climatic factors and drainage, all of which are summarized by site class (Marland & Schlamadinger 1997). Based on the recommendation of Duinker (1999), a high site class value for these lands was assumed (Site Class 1, SC1), but a lower class was also modeled for comparison (Site Class 2, SC2). Duinker (1999) recommends a high site class because forests cleared for agriculture or pasture typically represent the most productive lands in an area. Drainage is therefore assumed not to be a constraint, since lands where drainage is a serious problem would be classified as 'muskeg' and therefore not considered. Furthermore, yearly totals are considered rather than continuous tracking of carbon levels, because there are important seasonal differences between whether a landscape is a site or sink.

Regardless of soil characteristics and without minimizing their importance on carbon stocks over the landscape, it is important to remember that soil pools are stable over the long term, and increase slowly even when biomass increases quickly (Seely *et al.* 2002). Studies indicate that in scenarios like those being analyzed here, soil carbon will increase significantly (mainly from inputs of forest litter) but only 100 – 200 years after afforestation (Vesterdal *et al.* 2002). As a result, the contribution of soil is not likely to be significant in the TMU over the short and medium term.

Modelling tools and scenarios

GORCAM-WC1 is used in this study; it is an Excel based stand-level version of GORCAM supplied by Woodrising Consulting Incorporated of Belfountain Ontario. Merchantable volume growth curves were those of Plonski, taken with biomass expansion factors from Alemdag (1983, 1984) and Krcmar *et al.* (2001) based on the methodology of Bird (2003). Though the weaknesses of GORCAM described previously are significant, it has been used in these types of applications before and is representative of the best tools currently available.

In the modelling exercise it is assumed that afforesation in the TMU is immediate (beginning in 2004) on 100% of the available landbase emulating the decision of an individual manager of a tract of land rather than a provincial program. The effect of the project is considered both over CP1 and the following 50 years (2004 – 2054). This will allow a comparison of CP1 and long-term revenues and costs. Table 1 summarizes the characteristics of the modelling scenarios. The entire area is publicly owned, and planted stock is a 50/50 mix of Jack Pine and Trembling Aspen. The species mix remains constant across all scenarios.

Table 1 – Modelling scenarios

Variable	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Area (ha)	4000	4000	4000	4000	4000	4000	4000	4000
Productivity	SC1	SC1	SC1	SC1	SC2	SC2	SC2	SC2
Project Length	2004-2012	2004-2012	2004-2054	2004-2054	2004-2012	2004-2012	2004-2054	2004-2054
Costs ($/ha)	1500	1500	1500	1500	1500	1500	1500	1500
Price ($/t-$CO_{2eq}$)	2	7.5	2	7.5	2	7.5	2	7.5

In these scenarios, the only costs considered are the costs of afforestation itself. Though some researchers have noted that opportunity and transaction costs must be considered, and that they are extremely problematic, these were not included in this analysis (van Kooten *et al.* 1999). Opportunity cost is not significant in this case because the lands under consideration have not been under active management for some time. Therefore, there are no alternative uses in competition with afforestation whose potential revenue could be called an opportunity cost.[8] It could be argued that a new project with no opportunity costs could not possibly be executed on a high site class site – as a profitable activity would surely already be in place. This is only a problem if standard rationality assumptions fully reflect reality – which they do not. Many managers have

[8] If a provincial afforestation program were being designed, however, opportunity costs would likely be the single most important factor influencing the participation of resource managers (DeMarsh 1999).

opportunities for profit that they do not pursue simply because they are engaged in other activities or the possibility had not occurred to them. This argument also allows these types of projects to fulfill both the spirit and the letter of the additionality requirements of the KP, in that these projects would not be executed in the absence of a carbon market, even if they would be profitable. Not only does the KP provide a financial incentive to execute a project, it also provides the impetus to overcome institutional inertia and act on viable projects yet to be realized. Transaction cost has not been considered because little is known about the nature of these costs in a KP compliant project, though recent work suggests that they could be low relative to expected returns, and at the very least significantly lower than other costs (Sager 2003). If it is determined by future research that they are important, they could easily be incorporated into similar modelling exercises.

The afforestation costs are held constant across all scenarios. In addition, the effect of a fungibililty constraint requiring the banking of 10% of all offsets against disturbance was applied to S3 to study its effect.

Modelling results

The results of the modelling scenarios are shown in Table 2 and Figure 2. The results clearly indicate that the higher the productivity of the site, the more carbon is sequestered. A comparison of scenarios S4 and S8 that differ only in productivity implies that the difference between SC1 and SC2 is approximately 50% of the value of the latter. A similar significant impact was found by Duinker (1999). This same effect can clearly be seen in Figure 3.

Table 2 – Results of the modelling exercise

Scenario	Carbon Sequestered (t-CO_{2eq})	Profit/Loss ($)
S1	4 030	-5 970 000
S2	4 030	-5 880 000
S3	606 000	-1 150 000
S4	606 000	12 200 000
S5	1 310	-5 990 000
S6	1 310	-5 960 000
S7	474 000	-2 210 000
S8	474 000	8 230 000

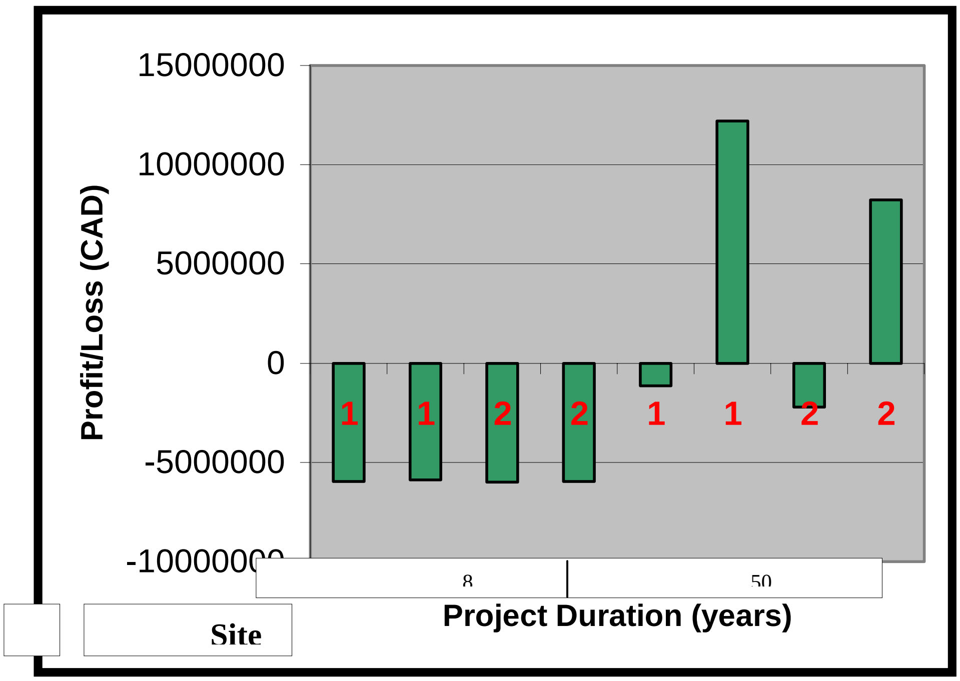

Figure 1 – Profit, loss, project duration and site class

One of the most significant impacts on sequestration is the timescale of the project. Table 2 clearly shows the impact time has on carbon accumulation. A 10-fold increase in project length results in over a 100-fold increase in carbon sequestered in some cases. Figures 1 and 2 also demonstrates this effect clearly. Since the accumulation of aboveground biomass is the major driver of increases in ecosystem carbon in the first century of an afforestation project, it is clear from these results that the slow growth of native trees in the TMU means that afforestation projects will not generate carbon benefits in CP1.

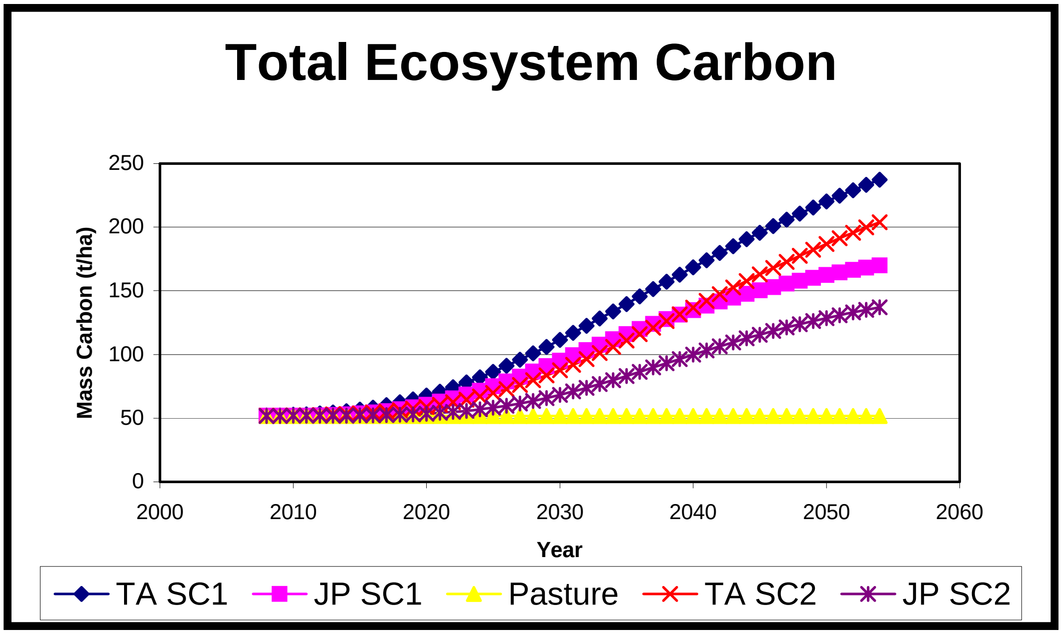

Figure 2– Total ecosystem carbon under various site classes

The results indicate that ecosystem carbon accumulates faster in both trembling aspen and jack pine plantations at SC1 than SC2, which is not surprising. What is more interesting is that in the long term, SC2 trembling aspen sites accumulate more carbon than SC1 jack pine, indicating that, regardless of project length and site class, from a purely carbon oriented perspective, managers should consider trembling aspen superior to jack pine. Given Duinker's (1999) recommendation to assume a high site class, and Betts' (2000) observation that plantations generally have higher sequestration potential than natural forests at mid to high latitudes, assuming high productivity seems reasonable. However, managers should carefully consider whether this assumption is warranted in their particular case, given the effect poor site class could have on their project. Figure 1 demonstrates that site class assumptions are not the primary determinant of profitability, which is clearly the duration of the project.

Examining the role of offset price in the exercise reveals several important aspects of TMU afforestation projects. First, for all scenarios describing projects that only run for CP1, that is S1, S2, S5 and S6, both the highest and lowest likely price yield money losing projects. In fact, the break even offset price for a CP1 project is 1 150 \$/t-CO_{2eq}, a ludicrously high price that could not possibly be reached even though prices are expected to rise in future commitment periods (Griss 2002). Clearly, price is insignificant for CP1 and no afforestation based offset generating project in the TMU will yield a profit in the short term. Second, the long-term price is very important, as indicated by the difference between S3 and S4 or S7 and S8. Depending on the price in future CPs, afforestation projects in the TMU could be quite profitable. In the SC1 scenarios, the break even price for long-term investment is only 2.50 \$/t-CO_{2eq} and for SC2 only 3.20 \$/t-CO_{2eq}, both very close to the minimum expected price. Therefore, though in the short term price is insignificant, in the long term it is a critical control on project viability.

An important assumption that has a significant impact on the results is the timing of benefits. Afforestation costs are assumed to occur up-front, in the first year of activities, which is reasonable. However, revenues are also assumed to occur in the first year of the project, which may not reflect reality. Under the KP, offsets generated from sequestration cannot be banked between CPs, but only reissued if the biomass is still standing (Schulze *et al.* 2002). Therefore, only offsets already generated can be sold on the market. While this may leave room for a project manager signing a long-term contract with a buyer to supply them with a certain number of offsets over the next 50 years, it will certainly limit the buyer's use of those offsets to those already extant, which may make them unwilling to purchase credits up-front. If the present value of offsets at a 5 % interest rate sold in future CPs is considered[9], S3 would lose $ 4.9 million rather than $ 1.2 million and S4 would lose $ 2.0 million rather than make $ 12.2 million. The break even price becomes $ 11.30/t-CO_{2eq}. It should be noted that though this price is higher than the maximum price considered likely for CP1, it is projected that in future CPs offset price will rise to at least this much (Williams & Griss 1999).[10] Therefore, prices will have to rise considerably higher than those predicted for CP1 if managers in the TMU are to be willing to invest in afforestation for carbon offset generating projects.

Conclusions

The unique results of this analysis demonstrate that under quite reasonable conditions, that is a high price in future CPs and a few thousand hectares of unused land of high site class afforested using native species, afforestation projects are viable investments in the Timmins Management Unit even when the only revenue generated is from carbon offset sales. These results can be expected to hold in similar circumstances in much of boreal Canada. However, since it takes such a long time in these areas to accumulate significant amounts of carbon, activity should commence immediately for afforestation projects to be profitable.

[9] Assuming nine five-year CPs starting in 2008 and ending in 2052.

[10] Though the costs/benefits of the project are discounted, the volume of carbon sequestered is not. The purpose of discounting is to indicate time preference for the commodity involved, which is obvious in the case of money but less so for carbon. There is no clear social preference for carbon sequestered today over that sequestered 50 years from now (given the uncertainty of the costs of climate change) – time preferences only exist for the costs/revenues of carbon projects, which have been discounted accordingly.

The overriding theme through this analysis has been uncertainty. Current carbon models may be adequate for KP modelling and better models should be coming soon. The nature of the market can be approximated, and the future value of offsets produced can be predicted to a certain extent. That is, the future for such projects may be bright, or it may not. The major cause of this uncertainty is tangible government support – an enabling environment – that has hitherto been absent in Canada. It is up to the various levels of Canadian government to define the nature of the carbon offset market, to give price guarantees, to set banking rules, in short, to provide certainty to Canadians about how the KP will be implemented. Until that happens, this analysis demonstrates that resource managers in the TMU, and potentially elsewhere in Canada, will have no incentive to participate in offset generating afforestation projects not only during CP1, but for future CPs as well. This is not surprising considering the low growth rates found throughout much of Canada, and is in line with previous results.

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