In Search of the Carbonic Truth:

Carbon Accounting

Prepared by:

Mark Anielski
Senior Fellow
Redefining Progress
San Francisco/Washington D.C.

&

President, Anielski Management Inc.

AMI

….accounting for a sustainable future…
Edmonton, Alberta, Canada

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In Search of the Carbonic Truth — Carbon Accounting

"*We admit there is a problem, but we argue that the Kyoto accord is unachievable and would have very serious impacts on Alberta*." (Premier Ralph Klein, Edmonton Journal)

Introduction

Premier Klein's statement that the Kyoto protocol is both "unachievable" and "would have serious impacts on Alberta" remains largely unchallenged by concrete evidence or full account of Alberta's carbon balance sheet and income statement. In the absence of such an accounting, political rhetoric tends to precede strategic analysis and physically practical and economically pragmatic action. There is little doubt that the liability of Kyoto challenge, if born mostly by Alberta's energy sector, would be both onerous and indeed one could argue, unfair. Without a provincial and national carbon account or inventory, both physical and monetary, it will be impossible to know how onerous or unfair that expectation might be.

Both the pre-Kyoto preparations and the current response to the Kyoto Protocol lacks a strategic assessment and full accounting of the current stock, flow and monetary value of carbon as an environmental service in our natural environment and economy. Every enterprise, whether business or government, requires a plan and a budget that articulates a desired performance outcome, based in part on a retrospective accounting of the past and a sobering reflection on current knowledge and on what is considerable pragmatically achievable. I would argue that such a practical approach to the greenhouse gas emission reduction challenge is still missing in the post-Kyoto dialogue.

To date, no practical set of carbon accounts have been established for either Alberta or Canada, although carbon budgets have been under development for several years. Undoubtedly, accounting for carbon stocks and fluxes is a complex issue as it relates to forest ecosystems that requires careful scientific analysis. Despite efforts by the Canadian Forest Service since at least 1991 in development of a national carbon budget for forests, "the results are not yet complete."[1] Apps and Kurz (1997) have studied carbon stocks and fluxes in the Boreal-Cordellian forest of Alberta with some important preliminary findings, upon which we will reflect. However, we still lack a plain-language account of the current stock and annual sequestration rates of Alberta's forests that are so vital to the Kyoto challenge. In the absence of national and provincial carbon account of stocks, flows, and economic values, all discussions and strategies for carbon management, carbon credits, carbon sinks, voluntary reductions and other policy responses to the Kyoto Protocol are being made in an information and knowledge

[1] Canadian Council of Forest Ministers. 1998. Criteria and Indicators of Sustainable Forest Management in Canada : Technical Report 1997. P. 58.

vacuum. Such accounting is fundamental to establishing a realistic and economically feasible plan of action

The carbon accounts would provide a reality check on the physical and economic opportunities for carbon management. How large is Alberta's net carbon deficit? What role do forests and peatlands currently play in the carbon cycle and in sequestering anthropogenic emissions? Are they net sources or sinks of carbon? What are the economic value of the services of forests and peatlands in sequestering carbon? What are the economics of carbon management options, including planting of hybrid poplar, aforestation and reforestation and how do these compare with others? How important is fire and forest management to managing carbon? These are just some of the questions to which a full carbon capital account could provide answers.

These accounts would enlighten Premier Klein's lament that the "Kyoto accord is unachievable and would have serious impacts on Alberta."

We are then empowered to devise a realistic game plan, one which is economically and physically achievable. We would be better prepared to manage our carbon deficit and net carbon debt, if we had a "carbon business plan and budget."

My concern is that we may be naively optimistic about both the physical and economic carbon benefits from some carbon management strategies, particularly in intensive management of our forests and agricultural soils. I have openly hypothesized whether or not attempts to increase the sequestration capacity of forests through ecosystem management would make a measurable dent in Alberta's carbon deficit. Undoubtedly, some of these options buy us time while searching for technological solutions that reduce absolute carbon emissions in combination with a shift to renewable energy resources.

More importantly, is that many of the carbon management investment options, which may already exceed the current market value of carbon, face the ongoing risk from random catastrophic natural disturbances, such as the 1998 fire season (the second largest area burned on record). These "acts of God" pose enormous threats in our efforts to manage our ecosystems for maximum carbon storage. Indeed, I wonder whether we can actually improve upon a carbon cycle that, governed by the laws of thermodynamics, tends towards a steady state.

In the end, if our consumption of low-entropy non-renewable energy resources is out of balance with the natural carrying capacity and indeed the laws of physics, it is the absolute throughput of carbon from anthropogenic sources that we must ultimately reduce. Agreement that the second law of thermodynamics and the principles of the entropy hourglass of Goergescu-Roegen (1971) actually rules and bounds our economic existence (our oikos or household) is itself a theological "Everest", as environmental economist Dr. Herman Daly discovered while at the World Bank. As Daly (1994; 13)) in *For the Common Good* the ideology of our post-industrial age remains one which "rely heavily on non-renewable resources and tend to exploit renewable resources and waste absorption capacities at nonsustainable rates." It is the rate at which the absorptive capacity of our renewable natural capital base which is of interest to me since if we are to achieve Goergescu-Roegen's vision of ensuring the conversion of low-entropy matter-energy is reduced to a level that does not tip the entropy balance and that we ultimately move to a society that lives sustainably off renewable natural capital income flows, ultimately off solar income. Of course the economic implications that such a physics constraint would imply are simply anathema to most who view the economic system as capable of infinite exponential growth defying even the laws of physics.

There is little doubt that the challenge of climate change is one of the most important and complex challenges in human history. Most would agree that "climate change is emerging as one of the central policy concerns of our time" (Decanio, 1997). Indeed 2,500 economists, including eight Nobel Laureates in economics, from the United States recently signed a public statement stating unequivocally that "as economists, we believe that global climate change carries with it significant environmental, social, and geopolitical risks, and that preventive steps are justified" to deal with the risks (economic) of global climate change. Indeed the high degree of consensus amongst economists is remarkable for an issue that is largely a non-market and intangible issue that resides outside the traditional scope of economic and national income accounting, such as GDP.

The signing of the Kyoto Protocol and Canada's own commitment to reduce carbon emissions was a endorsement that climate change is perceived to be real, at least the economic consequences of a change in climate, regardless of whether there is a definitive scientific link between the consumption of non-renewable high-carbon energy and changes in climate. Indeed, one of the most tangible pieces of market evidence of the costs of climate change are the soaring insurance payouts and economic losses to property and persons as a result of environmental calamities, some of which might yet be linked to our unsustainable use of non-renewable energy.[2]

The Need for Natural Capital Accounts

In my view it is imperative that provinces and the federal government develop policy on the basis of the best historical performance evidence. In the case of management of natural capital resources, prudent management necessitates a full set of integrated natural capital accounts, including a full stock, flow and monetary account for carbon. While such accounts cannot, in themselves, provide answers to the policy challenges we face, they at least form the basis for a more enlightened discussion of what is realistically possible in the stewardship of our natural capital wealth we inherited.

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[2] One aspect that is not accounted for is the increasing rate of depletion of our natural resource capital (both renewable (timber) and non-renewable (fossil fuels) to rebuilt and refurbish property and produced assets that have been destroyed or damaged due to environmental calamities and climate change.

Preliminary natural capital accounts were attempted in 1992 for Alberta's forests (Anielski, 1992), carbon (Anielski, 1992), oil and gas (Smith, 1992), and agricultural soils (Lerohl, 1992). The carbon account I presented in 1992 at the second meeting of the International Society for Ecological Economics in Stockholm, Sweden, along with the first Canadian timber capital account. This first back-of-the envelope carbon account, while crude, provided a plain language assessment of Alberta's carbon balance sheet and income statement with respect to forests and peatlands. It was my hope that such natural capital accounts would provide a tool for more prudent natural resource management for Alberta's vitally important natural capital stocks: oil, gas, coal, forests, and productive agricultural soils. This work was based on the resource accounting work of Robert Repetto of World Resources Institute, Washington, D.C. in 1991 in the case of natural resource accounts for Indonesia. The United Nations Statistical Office and the World Bank have since made considerable progress in advancing the framework and tools for natural capital accounting as part of the existing System of National Accounts used by virtually every nation in accounting for GDP and national income.

Unfortunately, while resource accounting has made important inroads it has not yet been fully adopted in Canada, the U.S. or other OECD nations, as part of an integrated set of ecological and economic national accounts. In the U.S. attempts at constructing natural capital accounts by the Department of Commerce met with resounding opposition from the Kentucky coal industry which successfully lobbied for a "stop work" order on the development of mineral resource accounts. The basis for the coal industry's anxiety remains a mystery to those of us who advocate environmental accounting.

Despite these apparent setbacks, I am continually surprised by the positive feedback I receive when presenting the forest (timber), carbon, and energy accounts for Alberta, regardless of the audience. The accounts are apparently relevant to a plain-language discussion of how to account for sustainable resource development. I believe in the need for natural capital accounts at the national and provincial level simply because it makes good policy sense. The accounts provide an important inventory and account of the sustainable development and sustainable income stream from Alberta's natural capital.

Complex Carbon Budgets Emerge at Glacial Speed

Kurz and Apps (1992) and Price et.al. 1997) have been developing complex carbon budgets for Canada that estimate the exchange of carbon in forest ecosystems. They attempt to track the flow of carbon both amongst and between forest biomass, forest soils, forest products, and peatlands. These are complex carbon input-output models of the flows of carbon between trees, atmosphere, soils and timber products as well as the flow of carbon released from fires and other natural disturbances to the atmosphere and forest soils. These models are under continuous refinement as scientist learn more about the complexity of where these molecules of carbon end up. Our particular carbon accounting focus is on the potential carbon sequestering capacity of the growing forest biomass and peatlands in terms of net carbon income from the net growth of the forests and peatlands.

These complex carbon budgets are still under development and are subject to the normal caveats of incomplete knowledge and data. The bottom line is that we simply do not have complete knowledge of the carbon budget for Alberta or Canada at this stage.ue nature of stocks and flows in the case of Canada's forest. Much scientific evidence needs to be gathered and discerned before a more definitive full carbon account emerges.

On a global scale, the Canadian Forest Service carbon budget for 1985-1989 (Canadian Council of Forest Ministers (CCME), 1998) estimates that roughly 100,000 million tonnes of carbon per year (roughly half of the total annual carbon dioxide exchange) is attributed to global forest ecosystems which represent vast carbon pools of some 1,500,000 million tonnes of carbon in soils and 650,000 tonnes in forest biomass.

These same studies estimate that in Canada, roughly 221,000 million tonnes of carbon are stored in our forest ecosystems. Apps and Kurz (1992) estimated that for 1986 Canada's entire forest ecosystem served as a net sink sequestering an estimated 76.858 million tonnes of carbon. In the most recent estimates covering 1985-1989 the Canadian Forest Service (CCME, 1998) estimates the following net flows of carbon:

• Forest biomass pool	- 79 million tonnes
• Forest products pool	+ 23 million tonnes
• Forest soils pool	+ 19 million tonnes
• Peatlands pool	+ 26 million tonnes
Total Net Sink/Surplus (Source/Deficit)	- 11 million tonnes
Including	
• Fossil fuel used by forest industry	– 4.8 million tonnes
Total Net Surplus/Sink (Deficit/Source)	-15.8 million tonnes

Thus the most recent evidence suggests that Canada's forest have actually been a net source or in net deficit of some 11 million tonnes of carbon (or a 15.8 million tonne deficit when including fossil fuel used by the forest industry). This represents a significant departure from estimates for 1920-1975 which estimated that the forest biomass and soil pools were massive net sinks. In fact the amount of carbon stored in the total forest ecosystem biomass declined by 18% from 1970 to 1989 (CCME, 1998) with a loss not so much to the atmosphere but rather to the soil pool. However since 1985 the soil pool and the standing forest biomass pool have lost carbon as the figures indicate. This apparently due to the increase in fire and insect disturbances that have increased in the 1980s and 1990s.

The Kurz and Apps (1992) carbon budget for Canada estimated Canada's total Boreal West ecoregion carbon balance as a net sink of 14.189 million tonnes of carbon in 1986 (based on estimates of carbon fluxes from net forest growth, natural disturbance releases to the atmosphere, sequestration by soils and transfers to forest products). For the Cordellian forest ecoregion (which constitutes much of the Eastern Slopes forests of

Alberta) Kurz and Apps (1992) estimated a net sink of 7.0 million tonnes of carbon. These balances will change dramatically due to the influence of forest fires on the carbon budget.

In addition, they have recently develop a comprehensive assessment of carbon stocks and fluxes in the Boreal-Cordellian ecoregions, namely the Foothills forest region of Weldwood of Canada's FMA. These accounts provide more precise estimates of the complex input and output flows of carbon from forest growth, fires, insect, harvesting, soils, peatlands, forest products, and the atmosphere. Their initial 1986 carbon budget suggested that the Boreal-Cordellian forests of Alberta were net sinks of carbon. However, there is considerable debate as to whether forests are net sinks or sources of carbon, particularly given the importance of catastrophic forest fires which can release massive tonnes of carbon to the atmosphere and which then destroy carbon sequestering trees, in the short term. Indeed, the Canadian Forest Service notes that Canada's' forests may have become net sources of carbon beginning in 1985 due to fires (Canadian Forest Service, 1998).

Exactly how and where anthroprogenic emissions find a sink sustains a scientific debate. Indeed, the methodologies and science for quantifying carbon dioxide removal from the atmosphere are still poorly developed (Hormug, 1998). This may be one of the reasons that scientist studying the carbon budget model have been reluctant to present a definitive carbon budget model, to date. However, under the circumstances, even crude estimates become relevant to framing our policies and strategies.

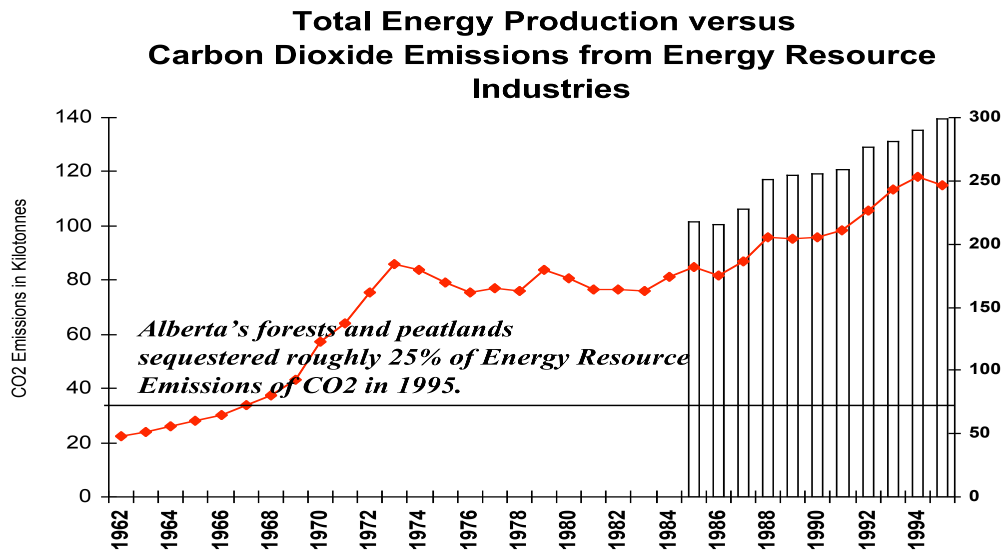
These question are fundamental however to our inquiry and determining whether the investments we are now considering in terms of biophysical carbon management make economic or financial sense, let alone carbonic sense. It may be that in the end our solution to carbon management must come from the absolute reduction of emissions from their anthropogenic source while ensuring maximum natural system sequestration capacity.

Alberta's Contribution to the Greenhouse Problem

The main greenhouse gases include CO_2, methane, nitrous oxides, and chlorofluorocarbons (CFCs). Of these gases CO_2 is the most important greenhouse gas. Total Alberta CO_2 in 1995 were estimated at 152 million tonnes of carbon dioxide or 41.523 million tonnes of carbon C equivalent. Compared to global CO_2 emissions of 5,650 million tonnes of C equivalent per annum, Canada contributed roughly 2.7 percent to the total global emissions in 1988 (Jaques 1990, p.4). Alberta's CO_2 emissions in 1988 were roughly 124 million tonnes or 33.9 million tonnes[3] of C equivalent; 23.3 percent of the national total emission.

[3] Carbon, by weight, constitutes 27.3% of a carbon dioxide molecule.

Chart 52



Source: Canadian Association of Petroleum Producers..
AUEB: Energy Conservation Board (1994). Energy Requirements for Alberta: Supplemental Report 1994-2008.
Environment Canada, Canadian Emissions Inventory of Common Air Contaminants
Note: IncludesC02 emissions from coal electric generation which made up 30% of total emissions in 1995.

The above chart shows the increase in carbon dioxide emissions (bar chart) in Alberta 1988-1995 compared with the long term production of non-renewable energy resources (oil, gas, and natural gas by-products, the line chart). Generally, CO_2 emissions have tracked total energy production. Between 1990 and 1995 Canada's emissions of total greenhouse gases (GHG) grew by 9.5 percent (Environment Canada, 1998). Canada's carbon dioxide emissions from fossil fuel use increased 9% from 1990 to 1995 while Alberta's emissions of carbon dioxide grew by 8.2% between 1990 and 1995 (Environment Canada, 1998, www2.ec.gc.ca/climate/fact and Alberta Environmental Protection, 1996, personal communication).

Where is the excess carbon going?

According to Environment Canada (1998) and scientists, global atmospheric carbon dioxide concentrations have increased by 4% in the decade between 1987 and 1996 and are believed to be the highest concentrations (360 ppm) in the last 220,000 years, based on glacial ice core analysis. As these scientists note, the growth in global atmospheric carbon dioxide emissions follows the trend in global emissions of carbon dioxide.

It is this increased concentration of carbon dioxide in the atmosphere which is being attributed to global warming and climate change.

If much of the increase in carbon dioxide output is finding itself in increasing concentrations in the atmosphere, including water and ice (as many such as Mike Apps and others suspect might be the missing sink), then what role at all might forests and peatlands play in the sequestration of anthropogenic emissions? Common sense would suggest that based on the global carbon account that our forests and peatlands of Alberta may already be in a steady state and thus play little role in sequestering increasing amounts of anthropogenic sources of carbon. Ironically, as noted earlier, Canada's forests and peatlands might already be in a net deficit as a net source of carbon as evidenced by estimates of increased net carbon flux to the atmosphere as per the Canadian carbon budget 1985-1989 (Kurz and Apps), even before we consider the anthropogenic emissions issue. This would imply that our net carbon deficit for Alberta might actually be significantly higher when considering the net source of carbon from Boreal-Cordellian ecoregions and the tonnes of carbon released through fossil fuel production and use in the province.

If so why are we spending time and money tinkering with what may amount to be rather insignificant adjustments at the margin of a giant net deficit elephant? What are the relative economic and physical economies of scale that can be achieved by investing in the intensive management of our forests and agricultural soils for increased sequestration capacity?

First and foremost, our efforts should be focused on a) reducing absolute emissions from anthropogenic sources, b) dealing with the net carbon deficit of our forests by dealing with the tremendous influence of fires on our carbon deficit and c) investing in land management options that make economic and carbon sense in terms of maximum carbon sequestration benefits.

A carbon accounting framework would allow us to assess both the current stock and low of carbon in Alberta but also help to measure and track the impact of carbon management on our existing carbon deficit.

A Back-of-the-Envelope Carbon Capital Account

My preliminary account for carbon was intended to satisfy a curiosity as to exactly how much carbon Alberta's vast forests and peatlands sequester per annum and how does this capacity compares to annual anthropogenic emissions from fossil fuel use, industrial production and households.

This preliminary inquiry into the development of a carbon account for Alberta was motivated by the work of Dr. Casey Van Kooten of UBC who in 1991 estimated the economic values of carbon fixation by B.C's forests. Based on these preliminary estimates and early carbon budget work by Gorham (1991) and Kurz and Apps (1992). I was able to construct back-of-the envelope accounts of Alberta's carbon account related to forests and peatlands. The 1992 carbon account revealed some startling results.

My original estimates for forest biomass and peatlands showed an annual carbon sequestration capacity equivalent to only 24.2 percent of Alberta's total anthropogenic (industrial and household) carbon dioxide emissions in 1990. These were based on conservative assumptions of the annual growth rates of the forest biomass (trees) and the annual net carbon uptake by peatlands. The 1992 estimates were based on the work of Gorham (1991).

Since those first estimates, other studies have been produced notably by Kurz and Apps (1992, 1997) that revealed higher peatland sequestration levels. [4] In addition, new and higher average forest growth rate estimates for Alberta's forests were revealed (from an MAI (mean annual increment) of 1.70 cubic meters/hectare/year in 1990 to 2.00 m3/ha/yr in 1995, according to a Alberta Land and Forest Service timber supply study). These changes inflated my original sequestration capacity figures considerably. The 1990 estimates changed to roughly 33.8% of total anthropogenic emissions. By 1995, however, that had declined to 30.9% of 1995 emissions.

My estimates consider the annual tonnes of carbon absorbed by growing trees on productive forest land and carbon sequestered by the existing inventory of peatland annual carbon absorbed by the existing is the annual growth of trees and the annual absorption by peatlands of carbon in the atmosphere. Thus the estimates only provide estimates of the potential absorptive capacity of the forests and peatlands of Alberta and not actual.

Carbon Fixation on Forestlands

The Boreal forests of Canada play a critical role in C fixation or sequestering. Boreal forests in general dominate the dynamics of the terrestrial carbon cycle (Sedjo, 1993) and account for roughly 50% of the natural exchange of carbon dioxide (Maini, 1994). They act as massive, net carbon sinks or storage reservoirs (MacKenzie, 1994). Earlier estimates by van Kooten et. al. (1992) indicate that 97.7 Mt of C is sequestered per annum, or roughly 62 percent of the total C sequestered by all Canadian forests.

Of Alberta's total 66.1 million hectare land base, roughly 57% or 37.75 million hectares is forest land, primarily Boreal and some Cordellian forest. Of the total forest land area, 25.4 million hectares is productive forest land[5] or suitable for commercial timber harvestingally owned.

It is possible to estimate the amount of C sequestered by Alberta's forests by using data on C sequestered in a cubic meter of growing timber (green wood), the total area of productive forest land, and the productivity (growth per unit area per annum) of forests.

Based on previous estimates (Anielski, 1992) we estimate that the average carbon content of Alberta's timber growing stock at roughly 189 kg/m3 of wood. (a weighted average for all species using the 1991 Alberta Land and Forest Service inventory). Using an average

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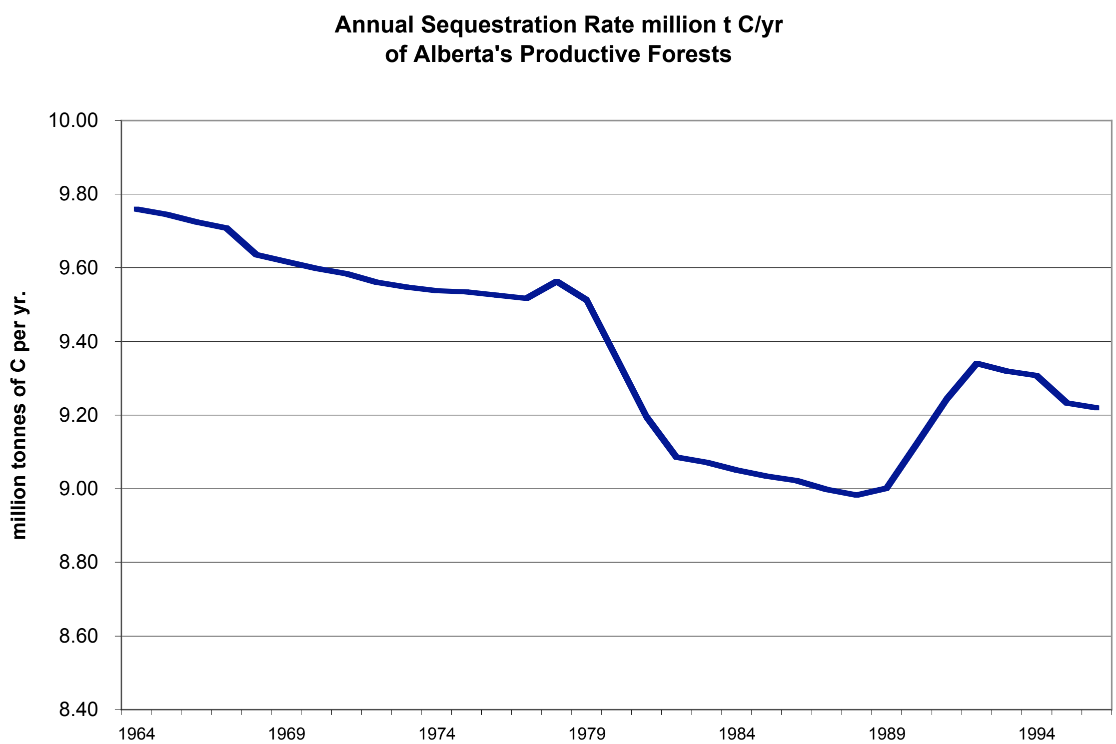
[4] The difference is due to the estimates of methane released from Alberta's peatlands which were significantly lower in the case of Kurz and Apps (1992; 59-60) 0.074 million tonnes of C equivalent per annum compared to my estimates based on Gorham (1991) which came to 1.77 million tonnes per annum.

[5] Includes both provincial, federal and private productive forest land.

provincial growth rate of 2.00 m3/ha/yr, average carbon content, and the area of productive forest land, it is possible to make crude estimates of the annual carbon sequestration rates of Alberta's productive forest land base. The average sequestration rate equates to an average 0.378 t C/ha/yr for Alberta's timber growing stock inventory in 1991. This is roughly 6% greater than the 0.355 t C/ha/yr carbon sequestration from net growth of the Boreal West-Cordellian forest ecoregions estimated for 1986 by Kurz and Apps (1992).

The total C equivalent sequestered by Alberta's productive forest land base (which contains the carbon sequestering growing stock of timber) is estimated to be 9.58 million tonnes (Mt) of carbon in 1988 and has declined to roughly 9.55 million tonnes of C in 1995.[6]

Using the estimated changes in productive forest land area from the 1995 timber capital account (Anielski, 1996) and the assumed sequestration rates it is possible to construct a rough estimate of historical carbon sequestration capacity of Alberta's forests. The graph shows a steady decline in the sequestration capacity of Alberta's forests due mainly to the impacts of assumed permanent removals from oil and gas development activities (e.g. seismic lines). Overall, the forest is likely in a relatively steady state.



[6] The original 1992 estimates estimated annual sequestration rates of 8.17 million tonnes per annum based on a lower growth rate (MAI – mean annual increment) of 1.70 m3/ha/yr. Based on the recent Timber Supply Status Report prepared by Alberta Environmental Protection, the average provincial MAI has been revised upwards to 2.00 m3/ha/yr.

Peatlands – The Silent Better Half

One of the silent and least profiled partners in the carbon budget of Alberta is peatland. Peatlands contain not only massive tonnage of carbon, they also contribute to the annual net accumulation of carbon, rivaling the accumulation through the net growth of trees. For example, Kurz and Apps (1992) estimates that for the Boreal West (which includes Alberta) ecoclimatic zone, carbon sequestered by peatlands (11.18 million tonnes) net is roughly 56% of the carbon sequestered by the net growth of forest biomass (trees) (19.84 million tonnes).

Given this account, peatlands take on significant strategic importance both as a store and annual carbon storage sink. Given their strategic importance and the economic value of their carbon budget services, may challenge the prudence of converting peatlands to marginal agricultural land or as a fuel source.

Alberta's peatlands cover roughly 12.67 million hectares or 20 percent of the total provincial land area (Alberta Forestry, Lands and Wildlife, 1990). This amounts to an estimated 36.1 billion tonnes (oven dry) of peat (Tarnocai, 1984). Alberta contains roughly 11 percent of the total Canadian peat resource.

Peatlands are vital to the carbon cycle, particularly as a carbon sink. Forestry Canada (1991) estimates that peatlands contain roughly 60 percent (135 billion tonnes) of the total carbon of forested lands in Canada, significantly more than the forests and forest soils combined. Using the formulas for estimating carbon storage by Gorham (1991), it is estimated that Alberta's peatlands contain roughly 16.88 billion tonnes of carbon (= 12.673 million ha (area of peatland) x 10,000 m^2/ha(conversion factor) x 2.3 m (depth of peat) x $112x10^3$ g/m^3 (mean bulk density of peat) x 0.517 (carbon content of dry mass)).

We then estimate the annual net accumulation of carbon based on the work of Kurz and Apps (1992) who estimated annual absorption rates of 3.466 million tonnes of C equivalent per annum for Alberta's peatlands. This works out to a per hectare annual sequestration rate of 0.273 t C/ha/yr or roughly 72% the per hectare absorption rate of Alberta's Boreal-Cordellian forest net growth.

Drainage of peatland and harvesting as a fuel source has been rather insignificant, to date. Roughly 1,700 ha have been drained for forestry and agricultural purposes (Anielski, 1992). More recent data is not available though more peat is being consumed as a "renewable" fuel source as a byproduct of pealtand conversion to agriculture by companies such as Drayton Valley Power.

Alberta's Increasing Carbon Deficit

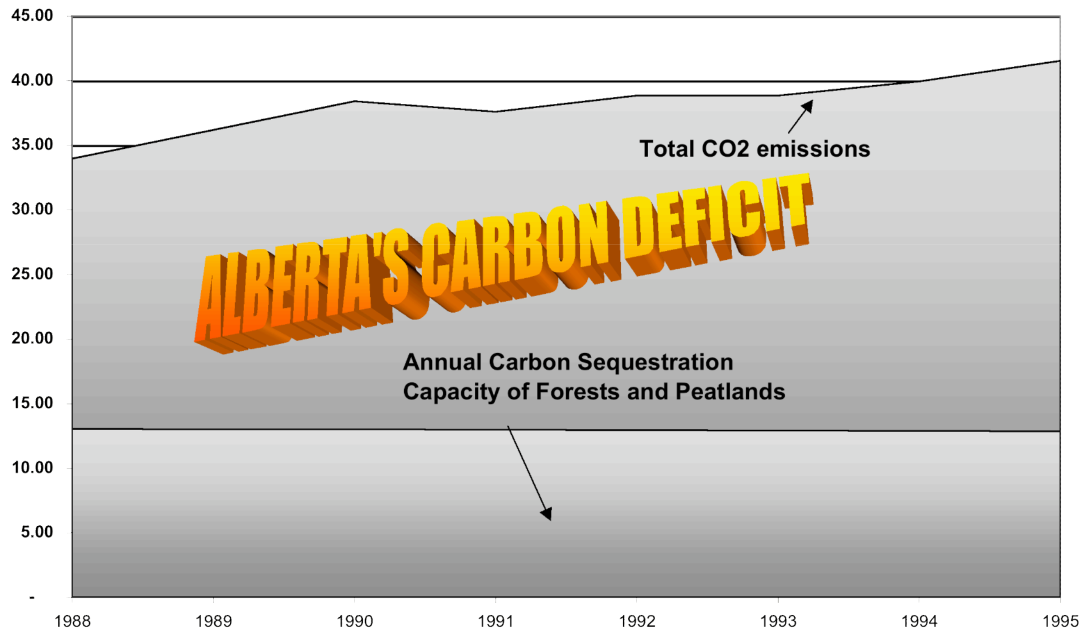
If the Canadian carbon budget for 1985-1989 is correct, that the forests and peatlands are already in a carbon net deficit position, what does this suggest for Alberta given we are already faced with increased anthropogenic emissions since 1990, with the prospect of increasing emissions from billions in new oilsands production development, and given the rather steady state of Alberta's existing forest and peatland land base? Can we make a reasonable dint in the carbon deficit?

While our account focuses on the capacity of forests and peatlands to sequester carbon annually, we may be fighting a losing battle as fires and other impacts on the carbon budget leave us in a net deficit position before we begin to deal with the impact on our carbon deficit of anthropogenic emissions, which will continue to rise in absolute terms as Alberta's economy expands.

When the deficit is viewed only in terms of the balance between net sequestration capacity of growing trees and sequestering peatlands and anthropogenic emissions the net carbon deficit has been increasing as emissions have risen from 1990 levels. In 1995 total anthropogenic carbon dioxide emissions were estimated at 152.1 million tonnes (up 8.2% from 140.6 million tonnes in 1990) or the equivalent of 38.38 million tonnes of carbon. Carbon sequestration capacity of forests and peatlands declined from 34.0% in 1990 to 31.3% in 1995 due to both an increase in absolute emissions and a reduction in fully-stocked forest land and peatland due to industrial development. Forests and peatlands are estimated to have sequestered roughly 13.0 million tonnes of carbon in 1995.

The following graph shows Alberta's estimated carbon deficit with respect to forests and peatlands – the difference between the theoretical absorptive capacity of forest biomass (trees) and peatlands and total anthropogenic emissions from industrial and household sources.

Carbon Dioxide Emissions versus Absorptive Capacity of Forests and Peatlands 1988-1995 Alberta



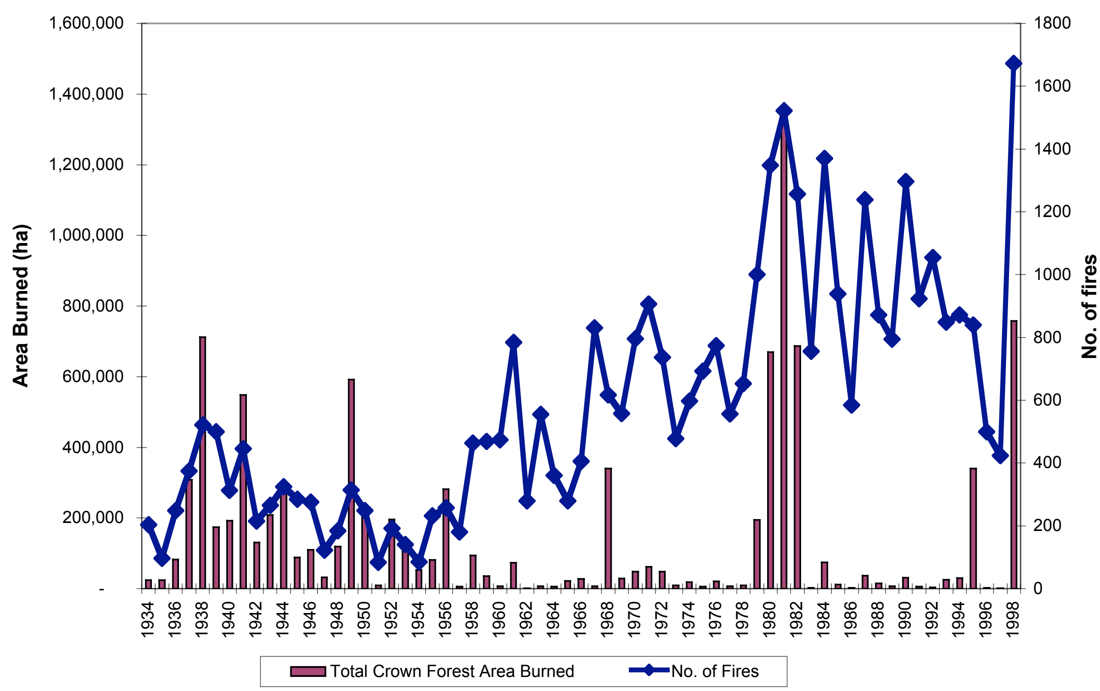
The growing carbon deficit shows that Alberta faces considerable challenges in meeting the Kyoto emissions reduction challenge, certainly in terms of absolute emission reductions. Alberta can ill afford to allow the degradation or depletion of the forest biomass and the vitally important peatlands that play such a significant role in Alberta's carbon budget.

The Unpredictable and Catastrophic Impact of Fire

Fire more than harvesting threatens the carbon budget of Alberta. Some studies have predicted that as a result of global warming the frequency and intensity of fires in the Boreal Forest are likely to increase (Myers, 1997, Kasischke et.al., 1995). Since fires decrease forest biomass and release carbon, this is an important positive feedback that may well exacerbate global warming trends (Alberta Environmental Protection, 1998).

While one year does not make a trend, the catastrophic fires of 1998 are cause for concern. The 1998 fire season has, to date, recorded the most fires since records were kept in 1934 — 1,672 fires. Roughly 758, 200 hectares of forest burned (an area 1.3 times the area of Prince Edward Island), the second largest area burned since 1934. The graph appears to confirm that the incidence of fires is increasing even if there is no evident trend in the intensity or size of fires in the 1980s; possibly a result of better detection.

Alberta Fire History: Area Burned vs. Number of Fires 1934-1998



What is significant about the 1998 fire season is that roughly 60% of the area burned was juvenile stands of high-carbon sequestering trees, much of which had been reforested at great expense to the forest industry. Moreover, mature high carbon stores of merchantable timber are lost thereby reducing the forest biomass and releasing more carbon to the atmosphere. It is highly probable that 1998 will be a net carbon source year.

The incidence of wildfires, more than any other factor, seems to pose the greatest risk to Alberta's efforts at managing carbon as a stock and flow of natural capital and threatens to thwart Canada's attempts to the Kyoto absolute carbon emission reduction targets if we are judged on the basis of a net carbon income basis.

We might presume that suppression of the incidence of fires is a desirable carbon management objective. However, Price et.al (1997) found in their carbon budget models of the Boreal-Cordellian forest of Weldwood of Canada's FMA at Hinton, that managing a forest for wood production may lead to greater C storage than occurs in the natural forest ecosystem, however, only in cases where natural disturbances from fire, insects and disease are more frequent than the sustained yield harvest rotation age. Their models show that estimated long-term increases in C storage from management practices assume that natural disturbances (fires and pathogens) can be completely suppressed and that the fire cycle (frequency of burns), which has historically averaged 50-year cycles. The rate of natural disturbance in Canada's forests is apparently on the increase erasing some of the gains made in the 1960s and 1970s in fire cycles (Canadian Council of Forest

Ministers, 1998). The bottom line is that there is an ongoing threat from wildfires to upsetting the best efforts of forest managers in managing forests and carbon stores.

While the costs of fire suppression in 1998 run in the millions, the economic benefits in terms of carbon from preserving large areas of natural forest from going up in smoke will become increasingly important under a carbon management regime. Indeed sound cost-benefit analysis is required to assess the relative "carbon" returns of investment from fire management in the protection of both merchantable timber but carbon sinks. The opportunity cost of each tonne of carbon sequestration forgone as a result of fire can be assessed within the framework of a carbon capital account expressed in monetary terms in assessing the returns on investment from costly fire suppression expenditures.

A prudent policy response necessitates the ongoing vigilance of protecting forests from burning, at least in the short-term as we make other attempts at reducing absolute greenhouse gas emissions.

The Importance of Energy Development on Alberta's Carbon Deficit

The growth of Alberta's energy sector has come with enormous impacts on the forest land base with the criss-crossed patterns of seismic lines that have effectively resulted in the permanent removal of carbon sequestering forest biomass – trees. Indeed some experts (including Brad Stelfox) are now estimating that the impact of oil and gas activity on the forests of Alberta has been underestimated when examining satellite inventory and adding up the area of forest disturbed from the energy industry's activities.

There is remarkably little government data on the area of forest impacted by the energy sector. Stelfox's inventory work is important to developing a more complete assessment of the interrelationship of the energy industry's activities in the forest and the carbon budget of Alberta. Based on the 1995 timber capital account (Anielski, 1996) we estimate (using Land and Forest Service statistics) that historically roughly 600,000 hectares of productive forest land is lying bare of high-carbon sequestering trees due to the impact of oil and gas activity (seismic lines, pipelines, other dispositions), roads and other disposition.[7] Much of this area remains deforested with low carbon yielding biomass such as alfalfa growing on vast areas of seismic lines. In terms of carbon sequestering capacity this area would be equivalent to a paltry 0.227 million tonnes of additional carbon sequestration capacity per year (based on 0.378 tonnes of carbon/ha/yr sequestered by Alberta's forest inventory in 1991). Even reforesting this entire area of land developed for energy and other industrial uses would hardly put a dent in absorbing part of the 41.5 million tonnes of carbon emitted in 1995.

Part of the carbon management solution must undoubtedly include a strategy to maximize the carbon sequestration capacity of these otherwise bare forest lands resulting from energy exploration and development.

[7] This is likely a highly conservative estimate.

The Economics of Carbon Sequestration by Forests

The economic importance of forests and peatlands in the sequestration of carbon are undoubtedly signficant given their physical importance in Alberta's carbon account. But how should we value these services?

Economic values have been estimated for carbon sequestration by forests by Van Kooten (1998, 1992), Sedjo (1997, 1995) and Anielski (1992). Van Kooten (1998) estimates "reasonable" carbon shadow prices of $20 and $50 per tonne and a high value of $100 per tonne of C equivalent. While such estimates are not precise nor are they based on the market price of carbon (which is currently trading at roughly U.S. $1.00-$3.50 per tonne of C equivalent) they are used to illustrate the potential economic values in the economy.

Based on Van Kooten's estimates, the value of Alberta's forests and peatlands in sequestering carbon in 1995 are estimated from $228 million (@$20/t C) to $572 million (@ $50/t C) to a high value of $1,141 million (@ $100/t C).[8] Compare these figures to the following economic indicators for Alberta's forest industry in 1997 (Natural Resources Canada, 1998):

- Value of exports $2,300 million
- Value of shipments $4,500 million
- Wages and salaries $ 595 million

Since it will be the economics that will ultimately dictate investment decisions in carbon management options, including enhanced carbon sequestration through the planting of hybrid poplar trees, soil management and other forest management options, such economic valuation efforts are necessary in combination with financial analysis of various carbon management options.

Compared with current market value for a tonne of carbon, based on limited international trades, of between U.S. $1.00-$3.50 per tonne of C equivalent, these shadow prices seem inflated. However, the carbon trading market has only begun to heat up.

Another relevant figure is provided by Roger Sedjo of Resources for the Future (Washington, D.C.) who estimates the cost of natural regeneration in per tonne of C to be U.S.$5.00/t C and U.S. $8.00/t C for reforestation ($93/ha (natural regeneration) and $324/ha (reforestation). Neil Bird of Woodrising Consulting estimates that the discounted value of the capital cost of all electricity infrastructure in the U.S. to amount to roughly $9.00/t C. Thus at current market rates, no one would be willing to pay more than $9.00/t C for carbon sequestration or reduction options.

[8] This does not take into account the increasing scarcity value of forests and peatlands which were actually in decline in terms of total area. As more sequestration capacity is lost the more valuable are the services of the existing forests and peatlands.

Conclusions and Policy Issues - Beyond Kyoto

Carbon capital accounts are vital to formulating a prudent strategy for the management of carbon in fulfilling the spirit and letter of the Kyoto Protocol for Canada and Alberta.

While carbon accounting is complex due to incomplete knowledge of the science of carbon stocks and flows, even a preliminary account is necessary to provide a reality check on the physical and economic benefits that can be expected from pursuing various carbon management, post-Kyoto.

Unfortunately, current carbon accounts suggest that we are already significantly behind the eight-ball with a large carbon net deficit. The carbon accounts suggest that forests and peatlands may already be net sources of carbon thus provide little sequestration capacity to absorb increasing anthropogenic emissions. When the net carbon deficit of forests is added to the absolute emissions from anthropogenic sources, Alberta's carbon deficit is signficant. The extent to which carbon management through forest management and soil management options seem insignificant relative to the size of our provincial carbon deficit.

Nevertheless, efforts must be made to attempt to deal with the carbon deficit and oru carbon trade deficit within the eccosystem borders of Alberta, Canada and indeed globally. There are many policy options that should be explored from a carbon sequestration and economic perspective. These include:

- All existing productive forest land, peatlands and arable agricultural lands should be "managed" to ensure maximum carbon sequestration capacity. This requires the identification of all low-yielding lands that could be converted to high-carbon yielding biomass such as reforestation of seismic lines or other low-carbon, yet carbon viable lands that sit idle.
- While carbon sequestration benefits from forest and peatland management may be rather insignificant in relationship to the total carbon deficit, ensuring the maximum sequestration capacity is critical in both the short and long-term, as technical and economical solutions to absolute emission reductions are found and shifts are made to renewable energy sources.
- Management of wildfire will be critical in protecting carbon absorbing timber capital, both young and old, safeguarding both the carbon income of mature trees and the carbon income of young seedlings that have been established under natural or managed conditions. More than any other factor, fires pose the greatest risk to carbon management as has been evidenced by Canada's net carbon deficit in forests since 1985.
- Peatlands play a vital role both as carbon store and as an annual absorber of carbon, thus the need to sustain the existing peatlands land base thereby sustaining the carbon capital and the carbon income contained therein.

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