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## Climate Change and Forestry: What Policy for Canada?

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# **Climate Change and Forestry: What Policy for Canada?**

by

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## **ABSTRACT**

On the basis of projected global climate change, Canada is expected to experience large land-use impacts. As indicated in this paper, forestry and agriculture are likely to be net gainers from climate change, with Canada as a whole possibly gaining from global warming. Adaptation to climate change will require shifting land out of forestry and into agricultural activities. Nonetheless, cost-effective mitigation strategies will likely involve the opposite—planting trees on agricultural land. The quandary for decision makers is whether to pursue mitigation strategies that could be the detriment of future adaptation.

## INTRODUCTION

Climate change is considered by some to be the world's most important environmental policy issue (Clinton and Gore 1993). Average global temperatures are projected to increase by 1.0–4.5°C under an anthropogenic doubling of atmospheric carbon dioxide (CO<sub>2</sub>) (Kattenberg et al. 1996). Globally, air surface temperatures have already risen by 0.3 to 0.6°C since 1854 (Trenbreth et al. 1996), but the temperature rise has not been consistent. The majority of the 0.3 to 0.6°C increase in global temperature happened in the years prior to 1940, with the remainder occurring after 1975 (see Balling 1995; Weber 1996).<sup>2</sup> A link between human activities and climatic change has not yet been definitively established, with some scientists even arguing that increases in atmospheric CO<sub>2</sub> are the result of rising temperatures rather than the other way around (see Trenbreth et al. 1996; Corbyn 1996).<sup>3</sup> Our purpose here is not to question the scientific evidence, but, rather, to alert readers to the lack of scientific consensus that can have important implications for policy.

The climate record does point to fluctuations in weather cycles, and this makes it difficult to predict and assess future climatic conditions. A major concern among scientists is that, regardless of the direction of causality, increases in atmospheric CO<sub>2</sub> may increase weather variability, and this may be just as important as projected changes in average temperatures and precipitation for Canada's forest regions. Increased weather variability could cause considerable disequilibrium in ecosystems, leading to more frequent forest fire and pest episodes (Binkley and van Kooten 1994). On the other hand, there is mounting evidence that a CO<sub>2</sub>-fertilization effect (as well as technical progress) could increase commercial timber yields (Froud-Williams et al. 1996), while the direct impact of elevated atmospheric CO<sub>2</sub> (but not higher temperatures) on biodiversity and other ecosystem functions is likely negligible.

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<sup>2</sup>“Nearly 70 percent of the warming of the entire time period [1854–1993] occurred in the first half of the record; the bulk of the greenhouse gas buildup occurred in the second half of the record” (Balling 1995, p.91). In an analysis of data from European weather stations going back as far as 1706, Weber (1996) concludes that “... the warming since c.1880 can almost entirely be accounted for by a warming between c.1900 and 1940, which cannot be ascribed to an enhanced greenhouse effect” (pp.133–34).

<sup>3</sup>Controversy surrounds the length of time that CO<sub>2</sub> remains resident in the atmosphere, with the IPCC (Trenbreth, Houghton and Meira Filho 1996) favouring a CO<sub>2</sub> lifetime of 50 to 200 years while others defend one of only five years (see Segalstad 1996).

Economics also provides a contribution to the discussion on climate change. Economics is both the guardian of rationality and the defender of the poor. This is certainly true in the context of climate change. As an example of the former, engineers have urged greater adoption of energy-conserving technical advances as a cost-saving means of slowing CO<sub>2</sub> emissions, but economists have pointed out the unanticipated consequences of doing so. Energy conservation may not achieve the emission reductions claimed because the realised income savings will be spent (either by consumers who experience the savings or by governments that tax it away) in ways that increase economic activity and emissions, something unanticipated by the proponents of conservation (Musters 1995).<sup>4</sup> Economists have identified a further dilemma in CO<sub>2</sub>-abatement policy—substantial reductions in anthropogenic emissions on a global scale are only possible if developing countries also take action. In order to provide basic necessities, to alleviate mass poverty and to stabilise populations, substantial economic development in these countries will be required, but that increases energy use and CO<sub>2</sub> emissions (Folmer 1993).

The purpose of this paper, however, is to examine economic and policy aspects of climate change as these relate to forestry, with particular focus on Canada. We begin in the next section by considering the contribution of forests to atmospheric CO<sub>2</sub>. Then, in section 3, we consider adaptation as a policy response, addressing in particular the issue of whether Canada is likely to gain or lose from climate change. In section 4, we consider the potential for carbon uptake in forest biomass, because terrestrial carbon sequestration might offer an intermediate-term solution for governments attempting to meet CO<sub>2</sub> emission targets agreed to in international negotiations. The conclusions ensue.

## **FORESTS AS A CONTRIBUTING FACTOR TO CO<sub>2</sub> EMISSIONS**

Deforestation is considered a major contributing factor both to loss of biodiversity and emissions of CO<sub>2</sub>. Tropical deforestation alone is thought to contribute about 25% of total anthropogenic emissions of CO<sub>2</sub>, as indicated by rates of deforestation and accompanying release of carbon (C) for selected countries shown in Table 1.

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<sup>4</sup>An exception occurs if the savings are spent on further emission-reducing activities.

Table 1. Rates of Tropical Deforestation and Release of Carbon

Country	Deforestation in 1989 (millions of hectares)	Release of carbon (millions of tonnes)	C release (tonnes C per ha)
Bolivia	0.15	14	93.3
Brazil	5.00	454	90.8
Guyanas	0.05	4	80.0
Indonesia	1.20	124	103.3
Vietnam	0.35	36	102.9
34 countries	13.86	1,398	100.9

Source: Pearce and Warford (1993, p.129)

A major cause of deforestation, at least in tropical regions, is conversion of forestland to shifting and permanent agriculture, or pasture. Table 2 provides some indication of the impact of land use conversion on atmospheric CO<sub>2</sub>. The carbon storage function of various land uses is summarised in the first row and the first column of the table. The remaining entries in the table provide an indication of the carbon flux when natural forest types are converted to one of three agricultural uses. The data are gross estimates of the averages for tropical forests and provide an indication of direction only; regional effects of shifting land uses can vary substantially.

Table 2. Changes in Carbon due to Land-Use Conversion (tonnes of C per hectare)

	Original Carbon	Shifting Agriculture	Permanent Agriculture	Pasture
Original Carbon		79	63	63
Closed primary forest	283	-204	-220	-220
Closed secondary forest	194	-115	-131	-131
Open forest	115	-36	-52	-52

Source: Adapted from Pearce (1995)

In boreal forest ecosystems, the concerns of deforestation are not as important as those related to fire and the loss of peat wetlands. The area burned each year by fire is substantial compared to the area that is harvested, and it may be increasing despite (and partly because of) high expenditures on suppression. Peat lands are a large sink of carbon and important for their annual carbon uptake. Although the inventory of Canadian peat lands is not well documented, they are estimated to be an annual net sink of 26.2 Mt of carbon, which represents approximately 34% of the overall carbon uptake of Canadian forests (Kurz et al. 1992). These peat lands may be lost, both as a result of non-

forest related human activities (in Alberta, through exploitation of tar sands) and climate warming itself. Little is known about the actual amounts of C stored in peat lands in northern Canada.

### **IMPACT OF CLIMATE CHANGE ON FORESTRY: ADAPTATION**

Economic research concerning the effects of climate change on agriculture and forestry, or land use in general, has focused on both mitigation and adaptation. Mitigation is considered below. Adaptation research has focused on the economic well being or efficiency (i.e., costs and benefits) effects of climate change and on their income distributional impacts.

Global warming is expected to have a greater impact on northern latitudes, so Canada and Russia should experience the greatest changes. Given lack of good economic and crop production data for Russia, early studies focused on western Canada. Canada's grain belt is projected to migrate northwards, but constrained by the Canadian Shield. With the southern extent of the boreal forest zone likely to shift some 150–200 km to the north, a 50–100 km belt of grazing land (for domestic livestock and wildlife herbivores) might emerge in the short term (< 100 years). Darwin et al. (1995) provide some indication of the extent to which land use in Canada is likely to be affected by climate change. The model employed by these researchers—the Future Agricultural Resources Model (FARM)—consists of a geographic information system and a computable general equilibrium economic model of the global economy. Climate projections from four global circulation models (GCMs) are used to determine land use potentials. Land use potential in the FARM model is based primarily on climate factors (moisture and temperature) since these also affect soil formation.

Results from FARM indicate that, "... across scenarios, world wheat production increases, while production of nongrains falls. Output of other grains increases or decreases depending on the scenario. Production of livestock and forest products generally increases" (Darwin et al. 1995, p.23). Output of other food products increases in all scenarios, so that "... climate change's overall impact on world food production is likely to be beneficial" (p.26). Real global GDP is projected to increase slightly. However, this is true only if landowners are free to shift into other activities, by taking advantage of new agricultural lands or changing crop mixes.<sup>5</sup>

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<sup>5</sup>Droughts are projected to increase under climate change, but most studies ignore this because only general trends can be discerned. Nonetheless, by relying more on irrigation and better management techniques, the effects of drought can be mitigated against.



Of all the regions in FARM, Canada stands to gain the most from climate change. Canadian GDP is projected to increase by an average of 2.2% across the four GCM scenarios, which is the largest increase in GDP of any region, although the absolute increase in GDP is relatively small (\$0.13 billion). Changes in production and land use (assuming full adjustment) are reported for Canada in Table 3. Production of wheat, other grains, non-grains and livestock are all projected to rise with climate change. Forestry output also increases, although the forestland base is reduced. The relative magnitude of these increases in output is a result of significant expansions of cropland and pasture (Table 3), and that land itself is more productive due to improved growing conditions. Much of the increase in arable crop production in Canada comes from a northward shift in the western grain belt at the expense of boreal forest, and a shifting of the highly productive corn belt in the U.S. into the eastern portion of the grain belt (Arthur and Abizadeh 1988).

Table 3. Projected Changes in Land Use and Primary Activity in Canada as a Result of Double CO<sub>2</sub> Climate Change

Land Use	Base Output	With climate change Output	With climate change % change
Cropland (mil. ha)	46.0	103.4	+124.9
• Wheat (mil.tonnes)	32.1	74.0	+130.4
• Other Grains (mil. tonnes)	25.0	93.4	+273.7
• Non-grains (mil. tonnes)	13.0	72.2	+455.5
Pasture (mil. ha)	28.2	39.7	+40.6
• Livestock (mil. head)	23.8	84.6	+255.6
Forestry (mil ha.)	358.0	332.5	-7.1
• output (mil. m <sup>3</sup> )	155.5	207.1	+33.2
Other (mil. ha.)	489.9	446.6	-8.8

Source: Adapted from Darwin et al. (1995)

Adaptation of forest management to a changing climate will ensure that forest sector returns are maximized. Examples of management adaptation include salvaging dying trees, vegetation control to help offset drought, replanting with more suitable species, and shifting processing capacity to areas where timber is relatively plentiful (Binkley and van Kooten, 1994). In addition, as the frequency of pest outbreaks and forest fires increases, investment in the management of pests and fire is also expected to rise. As the northern fringe of the boreal forest shifts northward, tree planting will help to maintain forested area as land is lost to agriculture on the southern border.

The conclusion from economic research is that climate change is unlikely to bring about noticeable reductions in the supply of primary commodities (including wood products) (Schimmelpfenning et al. 1996). Rather, if economic markets and institutions are sufficiently flexible, landowners will make decisions to take advantage of changes, whether these be production of different crops or new crop/tree varieties, adoption of new management regimes (e.g., greater use of irrigation, enhanced silviculture), or expansion of activities to new areas. However, market failure and policy failure can be obstacles to attainment of enhanced well being in the face of climate change.

Public ownership of forestlands may also be an impediment to adaptation. Policy failure occurs, for example, if the public authority requires forest companies to reforest cut over lands on the boreal-grassland interface, thereby preventing their conversion to a better use (pasture or cropland) (van Kooten 1995). An example of market failure occurs if no account is taken of climate change impacts on recreation and other non-timber benefits of forests, particularly biodiversity. If this is done, the optimal policy might still be to attempt to mitigate climate change rather than adapt to it.

### **FOREST POLICIES THAT MITIGATE CLIMATE CHANGE**

Mitigation research in forestry has focused on estimating the costs of carbon uptake in plant biomass and wood products and on economic incentives (carbon taxes and subsidies) (van Kooten, et al. 1993, 1995). There has been less analysis of possibilities for substituting wood for non-wood products or biomass for fossil fuels in generating electricity, although Sweden is increasing its use of biomass energy relative to fossil fuels.<sup>6</sup> Intersectoral market interactions and impacts on carbon uptake have been analysed for U.S. forest and agricultural sectors (Alig et al. 1997). However, since forests provide a range of non-market and non-carbon benefits, forest policies should be oriented to mitigation of climate change taking into account such values as biodiversity, wildlife, recreation, soil stability, water yield and visual aesthetics (Englin and Callaway 1995).

Land can be used in four different ways: crop production, livestock production (range and pastureland), forestry, and other uses (e.g., settlement). Changes in land use, particularly from forestry to cultivation, have a major impact on the amount of CO<sub>2</sub> that enters the atmosphere (Table 2). Hence, one objective of economic policy should be to prevent deforestation while, at the same time, encourage

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<sup>6</sup>Fossil fuels release CO<sub>2</sub>, while hydro and nuclear sources are environmentally unacceptable to Swedes.

C uptake in new plant growth, primarily forests. Such policies mitigate climate change by (1) increasing the standing inventory of biomass and, thus, the size of the C sink; (2) increasing storage of C in wood products; (3) reducing C emissions by substituting wood for non-wood products, such as cement, which release large quantities of CO<sub>2</sub>; and (4) substituting fuel from wood biomass for fossil fuels (Sedjo et al. 1995). For the U.S., it has been suggested that the forest policies discussed above could reduce costs of mitigation by as much as 80 percent compared to emissions reductions (Rosenthal et al. 1993).

One line of economic research has focused on estimating the costs of sequestering C in forest biomass. However, the economic feasibility of tree planting and other forest management strategies is highly dependent on assumptions about the timing of C uptake benefits and discounting.

Discounting is a source of controversy in many environmental debates, with some advocating the use of a social rate of time preference or, at the extreme, a zero rate of discount (see Lind 1982 for a review). In a review of carbon sequestration studies, Richards and Stokes (1995) found that both approaches—discounting and no discounting—were used to estimate the costs of carbon uptake on a per tonne basis; the alternative approaches lead to large differences in cost estimates and subsequent confusion for policy makers. For example, van Kooten, Arthur and Wilson (1992) estimated the costs of C uptake from planting trees in Canada. When the time at which carbon uptake occurs is unimportant (no discounting), costs range from \$6.40 to \$23.08 per tonne of C stored. However, if carbon is discounted (timing of C uptake matters), costs increase to \$38.59–\$184.71/tonne. For plantation forests in the Netherlands, costs of C uptake are estimated to be US\$300–400 per tonne when physical C is discounted, compared to US\$100–150 per tonne when it is not (van Kooten and Slangen 1997). Higher land values explain why sequestration costs in Europe are so much higher than in Canada.

Should carbon benefits be discounted? The Global Environmental Facility (GEF) is part of a collective arrangement to finance investments, technical assistance and institutional changes to mitigate global climate change, protect biodiversity and the ozone, and improve water resources. GEF is managed by the United Nations Development Programme, the UN Environment Programme and the World Bank. It will disburse some \$US1.5 billion during the early 1990s, with its main function to serve as a temporary means for learning how to transfer money from richer to poorer nations as

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compensation for restrictions on development. In judging among projects to reduce CO<sub>2</sub> emissions, GEF requires that costs of providing C uptake services be discounted at an appropriate rate, although the rate is often left unspecified, but that the timing of carbon uptake is unimportant (i.e., no discounting of future C uptake). Richards (1997) demonstrates that the use of a zero discount rate for timing of C uptake benefits (i.e., the value of the damages averted) can be justified when damages from atmospheric carbon increase at a rate that is equal to the discount rate. However, if the causality between temperatures and atmospheric CO<sub>2</sub> remains unclear, it is not surprising that little if anything is known about the relationship between damages and atmospheric CO<sub>2</sub> concentrations.

We feel that the market rate of discount (i.e., the rate at which a country can invest capital for growth) is the appropriate one to use in thinking about climate change. Suppose that climate change results in \$1.05 of expected damages in the next period. This damage can be avoided by investing \$1 today as a mitigation strategy. Suppose, however, that the market rate of return over this period is 10%. Then, by investing \$1 today in a market instrument, one can have \$1.10 in hand in the next period. Since climate change was not avoided, \$1.05 is needed to cover the damage caused by climate change, leaving \$0.05 in the second period. Had the \$1 available in the first period been spent on mitigation, nothing would have been left, but there would also have been no damage. The strategy that yields the greatest benefit (\$0.05) is to suffer the consequences of (or adapt to) climate change.

The arguments against this net present value approach are legion. One is that non-market values are not generally taken into account, although the analysis can be extended to include compensatory payments for loss of such attributes (see van Kooten et al. 1997). The magnitude of the payments could be determined from contingent valuation surveys or through *a priori* agreements among the various parties (e.g., governments, NGOs). In establishing compensation levels, it will be necessary to keep in mind global budget constraints and political realities.

Market rates of discount and inclusion of non-market amenities may be one explanation as to why developing countries are less keen on spending monies on mitigation than developed ones. Real discount rates in many developing countries are much higher than in developed countries. While one would expect arbitrage to equate rates across countries via a flow of capital from developed towards developing countries, transactions costs (e.g., cultural differences) appear to prevent this from occurring on a sufficiently large scale. The result of these interest rate differentials is that governments

in developing countries have a predilection for adaptation, while those in developed countries are more prone to favour mitigation.

Further, people in developed countries are better off and, as a result of their higher incomes, demand more public goods, such as clean water and air, biodiversity, scenic amenities and so on. Carbon reduction and uptake strategies, such as investments in non-fossil fuel energy, tree plantations and silviculture, also provide more of these public goods. As income levels in developed countries rise, countries generally release less CO<sub>2</sub> per unit of income (van Kooten et al. 1997; Vincent and Panayotou 1997).

As a policy instrument, carbon taxes and subsidies can be used to encourage private forest companies to take into account the effects of harvesting, tree planting and silvicultural activities (thinning, fertilizing) on CO<sub>2</sub> emissions. Using growth and yield data for BC and Alberta, van Kooten et al. (1995) showed that a subsidy on C uptake (at the time it occurs) or a tax on C released (at time of harvest) affects the optimal harvest decision, generally delaying it. Although they encountered situations where it would not pay to harvest trees at all, this was no longer true if C could be stored for long periods in wood products. However, an obstacle to implementation of such a carbon tax/subsidy scheme is the tenure arrangements that exist on public forests—forest companies do not have rights to harvest trees that they plant or manage today. Further, harvest levels are often set by government decree, and these may be higher or lower than optimal for achieving combined social benefits of commercial harvests and carbon uptake.

## **DISCUSSION**

One of the major conclusions of economic research is that climate change is unlikely to bring about noticeable reductions in the supply of primary commodities; indeed, Canada could experience an increase in production of primary commodities. If markets and other institutions are flexible enough, farmers and landowners will make decisions to take advantage of changes in climate. It follows that, from the perspective of agriculture and forestry alone, the costs of preventing climate change exceed the benefits. However, regional impacts may be large, and this could pose one political obstacle to a policy of adaptation. In addition, there are other political, institutional or even environmental constraints that might prevent a more aggressive policy of adaptation. Mitigation strategies are likely to hold the high ground as a consequence. An additional reason for favouring mitigating policies can be

found in the desire to protect non-market values, which are rarely taken into account in economic models due to the difficulty of so doing.

Both natural and plantation forests are thought to have an important role with respect to CO<sub>2</sub> abatement via carbon sequestration. Although the C uptake role and that of preserving (and enhancing) non-market values are often complementary, tree planting needs to be justified on the basis of its timber and non-market values, not only its C uptake function, as that may be too costly in parts of Canada. Countries that aim to rely on carbon sequestration strategies for meeting their agreed-upon target of reducing CO<sub>2</sub> emissions to 1990 levels by the year 2000 may need to rethink their positions.<sup>7</sup> While forest policies still have an important role to play, it can best be realised by adopting policies that result in greater reliance of wood products (including substitution away from non-wood products) and wood burning in place of fossil fuels. These are the major policy issues of the future.

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<sup>7</sup>This target was agreed upon by 154 countries (including Canada) who signed the Framework Convention on Climate Change in Rio de Janeiro in June 1992. The target is found in article 4 of the Convention. Countries meet in Kyoto, Japan, in December 1997, to consider extending the date to 2010, but then putting in place the possibility of sanctions on non-complying countries.

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