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British Columbia's Forests and the Carbon Cycle

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Forests have been proposed as sinks for the carbon released through the burning as fossil fuels. Concerns have been expressed that harvesting forests will result in large net releases of carbon into the atmosphere. Discussion on these issues requires consideration of the cyclic nature of carbon movement between the Earth's forested ecosystems and the atmosphere. This paper summarizes the carbon cycle in forested ecosystems, describes the situation for British Columbia (B.C.), and reviews options for using forest as a sink for the fossil fuel carbon.

Carbon Cycle in Forested Ecosystems

Forested ecosystems contain large amounts of carbon in live and dead trees, and in the soil. The amount of carbon present and whether the ecosystem is accumulating or releasing carbon depends on the time since the last disturbance. Disturbances are either natural, e.g., disease, fire and windthrow, or anthropogenic, e.g., harvesting, land clearing. The type of disturbance affects the amount and rate of carbon loss from the site.

There is a large release of carbon at the time of a disturbance that removes or rapidly kills most of the live vegetation. After disturbance, the ecosystem continues to release carbon to the atmosphere as small pieces of wood and material in the forest floor decay rapidly. Large pieces of wood decay slowly. As new trees grow their photosynthesis takes in more carbon than the ecosystem releases through respiration, and they store carbon in trunks, branches and roots. The rate of accumulation of carbon increases over time, offsetting the release of carbon by decay of the dead wood, and then surpassing it so that the forest becomes a sink for carbon. The net rate of accumulation varies greatly with ecosystem type. For example, coastal Douglas-fir forests accumulate carbon about 5 times more rapidly than interior lodgepole pine ecosystems, but at less than half the rate of radiata pine forests in more southerly latitudes.

As the forest ages, the rate of accumulation of live material decreases. At the same time the amount of dead wood available for decay and the amount of carbon released by decay increase. Eventually, in old-growth forested ecosystems, the accumulation of carbon by photosynthesis more-or-less equals the loss of

carbon through tree respiration and decay of dead wood. Thus over the long term forests should be considered to be carbon stores not sinks.

The land base is made up of ecosystems in different stages of the carbon cycle. This results from the variation of natural disturbance rates in time and space, and variability in the success of forest regeneration after disturbance. Anthropogenic disturbances, forest harvesting, and protection against forest fire alter the spatial and temporal patterns of disturbance.

Forest harvesting alters carbon cycling in terms of changes in the decay rate, and the location of the decaying wood. In this situation, disturbance rapidly removes a substantial portion of the carbon from the site through transfer to mills for processing and preparation of the site for replanting. Wood processing and decay of some of the products by burning or in landfills rapidly releases carbon to the atmosphere. Other products, e.g. lumber used in buildings, have a longer life before decaying. The new forest follows much the same pattern of accumulation of carbon as outlined above, while the pattern of decay is somewhat different. Forest products continue to decay as the forest matures and increases on-site carbon storage. After many years on-site carbon equals that on the site prior to harvest. Whether this occurs depends on the time to the next harvest. Forests with natural disturbance rates of 100's of years may not recover all their carbon in the space of an 80-year rotation, even allowing for storage in forest products (Harmon et al. 1990; Kurz and Apps 1992; Kershaw et al. 1993).

It is usually assumed that harvesting of second growth forests results in no long-term net loss of carbon to the atmosphere. This is because there is much less dead material on the forest floor and unuseable material in standing trees than in an old-growth forest. Thus decay losses in the second growth forests are a much smaller fraction of the carbon cycle than in the old growth case.

Land clearing for agriculture, power line rights of way, forest roads and urban development breaks the carbon cycle. Some of the carbon goes into long-term storage as wood products, and some is released rapidly through decay. However, there is no regrowing forest to return carbon to the site and offset the release of carbon.

B.C. Situation

Repeated cycles of accumulation and disturbance-induced loss of carbon have occurred in B.C.'s forests since the end of glaciation about 12,000 years ago. There has been a slow accumulation of carbon in the soil of these ecosystems with the amount varying with climate and the frequency of disturbance. The greatest accumulations are in the cooler, wetter ecosystems

where the decay and 'natural' disturbance rates are the lowest. However, this does not continue indefinitely and net storage of carbon in old-growth ecosystems tends to level off. Natural disturbance rates vary in time and space, with recurrence intervals of 100's of years in coastal ecosystems to less than 50 years in dry interior ecosystems. The success of regeneration at a site after disturbance varies depending on climate and site conditions after the disturbance. Consequently, there may be delays in returning to large on-site carbon stores during some cycles.

Coastal forests of Douglas-fir, hemlock and western redcedar average 400 to 600 tonnes of carbon per hectare (TC/ha) with a large amount in dead wood and forest floor. In contrast, interior lodgepole pine may have up to 200 TC/ha with a smaller percentage as dead wood and in the forest floor (P. Comeau, unpublished data). Interior spruce stands are intermediate between the coastal forests and the pine.

In coastal forest the natural disturbance rates average about 0.02% of the area per year. The annual disturbance rate by harvesting in the last decade was about 0.44% (Kurz and Apps 1992; MOF 1993). In contrast the respective rates for the northern interior are 0.26% and 0.2%, with the latter offsetting some of the natural disturbance by harvesting mature stands.

Carbon Balance of B.C.'s Forests

The computer model of Kurz et al. (1995) is being used to quantify carbon cycling in B.C.'s forests. This model considers all of the forest estate (unharvestable as well as harvestable land) in determining the annual growth and death of trees, decay of wood, type of disturbance, the release of carbon during processing, and decay and storage of wood products. The balance is calculated on the land where the wood was harvested. The model will be used to assess the effects of different disturbance rates and forest management practices on the carbon balance. This information will allow comparison with fossil fuel emissions and assessment of options for using forest growth for carbon offsets.

Model simulations for B.C. are not yet available. However, results for Canada as a whole and from Washington and Oregon can be used as guidelines. The coastal and interior ecosystems are expected to respond differently, mainly due to differences in the carbon content resulting from different disturbance rates. The coastal ecosystems contain a large amount of carbon in wood that will decay rather than be used for forest products. Thus rotation ages of 80 to 100 years may result in a net loss of up to 20% of the carbon to the air in coastal forests (Harmon et al. 1990; Kurz and Apps 1992; Kershaw et al. 1993).

The smaller biomass and shorter disturbance cycles in the interior mean that harvesting is less likely to have a significant long-term effect on the carbon balance. Comeau (unpublished data) suggests that there is likely little net loss for pine stands because of they contain relatively small amounts of carbon in dead trees and the forest floor. The spruce and hemlock stands contain a greater fraction of their carbon in this material. Consequently, these stands will probably have a small net loss of carbon by the second rotation.

Growth on unharvested areas must be considered in the provincial balance. The distribution of age classes in B.C.'s forests has changed over the last 70 years. There is now less young forest than in the early part of this century. This is similar to the situation in the rest of Canada. Protection from forest fires is one reason for this change, and it has resulted in an increase the carbon storage on the land (Kurz and Apps 1994; Kurz et al. 1995). The aging of B.C.'s forest means that they are presently a sink for carbon, though the rate at which this is occurring is being reduced by forest harvesting (Kurz and Apps 1995, unpublished data). It may become negative in the future depending on harvest rates, growth rates and wood utilization.

Using forests as sinks to offset carbon released by burning fossil fuels

Gains through forestry can be made in one of three ways:

- Maintaining or increasing the crop (dead and live material) of carbon.
- Increasing the use and life of wood products.
- Using wood (recyclable carbon) as a substitute for more energy intensive (non-recyclable carbon) materials.

Many countries and power utilities have proposed forest growth as a way to offset fossil fuel emissions (Table 1). These climate change action plans create gains through afforestation, i.e., planting trees on land that was removed from use for forests, or on harvested land would otherwise be neglected. All countries reviewed in Table 1 are doing most of their logging on second growth forests. These options ignore what happened to the forest carbon originally on this site, and are only good for one rotation, though they are where the greatest and least expensive gains can be made through forestry (Maclaren and Wakelin 1991; van Kooten 1991; Dixon et al. 1994; Turner et al. 1995). However, there will be major economic consequences when the wood enters the conventional forest products market (Binkley and van Kooten 1994).

Table 1. Review of selected greenhouse gas management plans claiming forest growth for carbon offsets.

<u>Jurisdiction</u>	<u>Action</u>	<u>Carbon Offset</u>
Australia	Sustainable forest management Replanting of harvested land	No estimate
Denmark	Afforestation Growth of existing forests	No estimate
Ireland	Afforestation Growth of existing forests	2.2 MTC/yr by 2000
Japan	Forest improvement/conservation Encourage afforestation	No estimate
New Zealand	Afforestation Growth of existing plantations	7 MTC/yr by 2000
Norway	Growth of existing forests	4.1 MTC/yr in 1992
Sweden	Growth of existing forests	9.3 MTC/yr in 1992
United States	Reduced old-growth harvest Forest protection, recycling Improved management of private non-industrial land Urban trees for shade	10 MTC/yr by 2000
Illinois	Afforestation Increased rate of reforestation Enhanced productivity	No estimate
Oregon	Stop old-growth harvesting Reforestation of under-productive land that would not be treated	0.2 MTC/yr by 2015
Washington State	Afforestation	No estimate
PacifiCorp power utility in Oregon	Reforestation of private land that would not be regenerated	No estimate
Tenaskin Inc/PacifiCorp power prod/util Washington State	Reforest private land destroyed by fire that would not naturally regenerate	0.25 MTC/yr date not given

Some the action plans claim the growth of the existing second growth stands for offsets. This option also ignores what has happened to the carbon released after the harvest of the original old-growth forest. Enhanced management of existing forests has been proposed as a way to increase carbon storage. This includes speeding the rate of replanting, stand tending, fertilization and reduced impact logging (Kulp 1990; Schroeder 1991; Putz and Pinard 1993; Dixon et al. 1994). Wood can be used as a substitute for more carbon intensive products (Marcea and Lau 1992). Kershaw et al. (1993) consider that the savings in carbon emissions achieved by using wood as a substitute should be included in forest budgets. Small gains may be made through maximizing the amount of wood that goes into products with a long decay time, and increasing the life of these products (Turner et al. 1995).

B.C. situation, are there options for carbon offsets through forestry?

Unlike European and Scandinavian countries, New Zealand, the United States and eastern Canada, the majority of B.C.'s harvestable forest is old-growth forest. These other jurisdictions have already converted most or all of their old growth to second and third growth plantations. Thus B.C. is at a disadvantage in terms of the carbon balance of forestry and for using forest growth to offset fossil fuel carbon emissions. Other biological constraints are the relatively slow growth rates in much of B.C., compared to the southern United States and New Zealand. There are opportunities in that B.C. has a large forested area of land, in a range of age classes, that is accumulating carbon. This at least provides opportunities to offset losses from harvesting.

The following sections review options for B.C. in terms of improving B.C.'s forest carbon balance.

Reduced harvests: The current aging of B.C.s' forest ecosystems results in a net gain of carbon, but this gain is decreasing through harvesting. Would reducing forest harvesting counteract this? In the short term this would reduce the release of carbon; however, harvested forest are usually old-growth, and many of these forest are likely to be disturbed by disease or forest fire in the near future, thus releasing the carbon. Therefore, reduction in harvesting can be expected to make only small contributions to the overall forest carbon balance in B.C.

Are there gains from reforesting not sufficiently restocked (NSR) lands: In the context of the carbon cycle of release and accumulation, these are not gains in the sense of something extra. The carbon from these lands has been, or will be, released to the atmosphere. The apparent gains are in reality the accumulation required to bring the balance on these lands back to zero. Furthermore, the values to be returned through

reforesting NSR land is not as large as that presented in early reports (ARA 1992). Those numbers were based on the assumption that the land is 'bare' and neglected. This is not the case. Some of the land is NSR due to failure of anything but brush to grow on it. However, the rest of the land is considered NSR because it does not have the 'right' species of trees, or the 'correct' density of trees growing on the land. Thus there may already be substantial carbon on the site as part of the natural forests. Claiming gains from replanting of harvested land involves admitting that the land would otherwise be neglected, i.e., forest practices were not sustainable. Ensuring reforestation of the land after harvest is the law in B.C. and is part of B.C.'s sustainable use policies.

Afforesting neglected land and marginal agricultural land?:

Again this option assumes that what happened to the original carbon is not relevant, though this seems to be the internationally accepted view. Land that is planted in the next 5 years will not make significant carbon gains until well into the next century. There are some small gains can be made by this action in B.C. (ARA 1992) and is probably the only viable option for claiming offsets.

Can we consider accumulation in existing second growth forests as a gain to offset fossil fuel emissions?: This option also assumes the fate of the original carbon is irrelevant, i.e., time starts now. B.C. could claim substantial gains in this situation. However, when does the time for not ignoring harvest losses start?

Can intensive forest management bring gains?: Gains are likely to be small (Schroeder 1991; ARA 1992).

Who's responsible for the decay of wood products?: Carbon balance modelling charges the producer for the decay of wood products that takes place outside the producer's border. Fossil fuel producers are not charged for the burning of their products outside of their borders. Inventories of greenhouse gas emissions include emissions from landfills, i.e. where forest products decay. Thus, it could be argued that the producers forest balance should be discounted for the decay of exported forest products, if only to avoid double counting of the carbon in global budgets. The computer modelling work will determine whether how this will affect B.C.'s forest carbon balance.

Are we meeting international agreements to protect and enhance carbon sinks?: These agreements have been interpreted to mean that we protect stores, i.e., no clearcut harvesting, or no harvesting at all. However, if forests are to be used to produce products, then protecting sinks can be taken to be synonymous with sustainable forestry and ensuring that forest harvesting and use of the wood products minimizes the net loss of carbon to the atmosphere over the life cycle of the forest ecosystem. Thus we need to ensure rapid reforestation and growth of a healthy,

mature forest after disturbance, that the wood products have as long a life as possible before decay, and that the maxim "recycle, reuse and reduce" is followed. The Forest Practices Code, the Forest Renewal Plan, timber supply reviews, and land use planning initiatives are intended to ensure that B.C.'s forests are managed sustainably.

Conclusions

Harvesting of B.C.'s old-growth forests results in a net loss of carbon to the atmosphere over a 100 year rotation. Options for offsetting this include: balancing losses against gains in the unharvested forest estate; applying decay of forest products to the consumer country rather than the producer; increasing the life time of forest products; balancing against gains in second growth stands harvested prior to some arbitrary date; afforestation of non-forested land or forest land that would otherwise be neglected. The last two options are a major component of the greenhouse gas management plans of other countries who have already liquidated most of their old-growth forests.

The need to balance the net losses from harvesting old-growth forests means that in the near future there is little opportunity on the forested land base to offset fossil fuel carbon emissions. Afforestation of non-forested land is the only option available at present. The carbon balance model being developed for B.C.'s forest will aid in determining if forest management can benefit the carbon balance. B.C. is committed to sustainable use of its forests. Ensuring rapid reforestation and good tree growth are important actions in minimizing net carbon loss from B.C.'s harvested forest ecosystems.

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