FORESTRY AND CARBON IN BC

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Seven Forest Carbon Myths, Misconceptions, or Oversimplifications

MYTH #1
Forestry is carbon neutral.

It could be but usually isn't.

At the scale of a forest stand, the conversion by logging of mature and old forests to young forests results in an increased release of carbon immediately, and for several years thereafter. This is because a) clearcutting generally leaves minimal carbon sinks (living trees and other plants) on the cutblock; b) a large pulse of carbon is lost immediately after logging due to the removal of trees and to the associated fossil fuel emissions; and c) disturbance to the soil and the original vegetation, and sometimes warming of the site, results in an increased rate of decomposition of coarse woody debris, litter, and soil organic matter, whereby losses of CO_2 due to respiration exceed the amount fixed through photosynthesis by the regenerating forest—for at least a decade. Moreover, in managed forests, the overall carbon store is reduced if the secondary forests are managed on typical commercial rotations. The oldest stands typically have the largest stores of carbon.

At the scale of a large landscape (say 300,000–500,000 ha) or of the entire province **and** if forest management is performed sustainably, it is possible that forestry-related emissions could be offset by uptake of carbon dioxide by the unharvested forests. It should be emphasized that the underlying carbon budget calculations are complex and depend on assumptions about a future with much uncertainty around carbon dynamics in a rapidly changing environment.

Logging primary, mature and old forests and converting them to secondary, managed forests can reduce total carbon storage by 40–50% or more, even when off-site storage of carbon in wood products in buildings is factored in. The carbon dynamics are sensitive to rotation length, proportion of felled wood that becomes wood products in long-term storage (reportedly 25–40% for BC wood used domestically), and longevity of storage. Construction materials such as lumber, plywood, and laminated beams can last for many decades but wood products include paper and pulp materials (office paper, toilet tissue, paper towels, cardboard packaging, disposable diapers) as well as pallets and pellets, all of which have much shorter lifespans. Conventional short rotations and relatively short 'life cycle' even of long-lasting wood products (often reckoned to be 50–70 years in both cases, although some storage persists beyond 100 years) probably result in a significant one-time net loss of about 100–300 tonnes C/ha.

A managed secondary forest could — in principle — recapture the lost forest carbon if allowed to regrow long enough to fully recover its carbon stock, which could be achieved more quickly and easily in most interior forests than in coastal or interior wetbelt forests.

"Oversimplification, and the second part is mostly false."

MYTH #2

Young forests take up more carbon than they emit and are 'carbon sinks'; mature and old forests take up less carbon than they emit, are 'carbon sources', and contribute to climate warming.

That is an oversimplification and the second part of it is mostly false.

Forests both absorb and release carbon throughout their life, from regeneration after disturbance through youth and maturity to old age. This results in a dynamic balance that changes over time, depending on stand age and on type and intensity of disturbance. The relative balance between uptake and emission determines whether a particular forest ecosystem is a net carbon sink or a source.

After a stand-initiating disturbance, young forests are net carbon sources for several years until the amount of carbon they take up exceeds the carbon they emit through respiration and decomposition. Some old forests (sources) emit more carbon than they fix but most (sinks) fix more than they emit, depending on levels of within-stand mortality, decay, and growth. Net carbon uptake in old forests does level off or decrease, but total storage increases. Old forests usually store much more carbon on site than do young post-logging forests. Depending on how they naturally function, how they are disturbed, and how they are managed, forests can therefore either mitigate or contribute to greenhouse gas emissions and climate change.

MYTH #3

Mature and old forests are not permanent carbon banks because inevitably the trees die; the forests will succumb to wildfire, insects, disease, drought, and logging.

Death is inevitable but in this matter beside the point, which is about the time value of carbon currently stored in forests.

Indeed some existing forests will succumb or are already on the way out but BC forests will not disappear overnight. And some of these forests grow very old—ancient even—and carry on functionally intact for a long time, for several centuries or even millenia. If stand-replacing disturbances are rare or infrequent, as they are in wet coastal forests and many wet subalpine forests and interior wetbelt forests, the majority of the landscape will be occupied by old forests and most of them will just keep ticking along, taking up and storing carbon.

Trees can get very old but they don't live forever. If a forest does not experience a stand-replacing disturbance (like wildfire, beetle attack, blowdown, clearcutting), as it ages individual or small groups of trees continually die and are replaced in what is called gap dynamics. The forest carries on with new recruits. Moreover, although all BC forests will eventually be replaced—suddenly, episodically, or gradually—currently they are carbon banks and their stored carbon has much greater **time value** now and in the crucial next three decades than anticipated, post-logging carbon storage recouped over the ensuing seven or more decades. Regardless of whether BC forests are a net source or a sink at any given moment, they continue to store megatonnes of carbon as long as they still have trees on site—even if the trees are dead.

MYTH #4

Trees will grow faster and forest productivity will be enhanced as climate continues to become warmer and wetter and as CO_2 levels rise. The growth and yield models show a wall of wood coming our way.

That is unlikely to be a widespread response in BC.

Some trees and some forests will grow faster, in some parts of the province, especially in the north and at high elevations. But as climate warms, drought stress is increasing in warmer drier areas. Even in wetter areas, moisture stress can increase because higher temperatures result in greater water loss through evapotranspiration. Moreover, the effects of CO_2 fertilization have generally been shown to be short-lived for trees, which eventually end up respiring away most of the carbon that they photosynthesize.

Wildfires are becoming more frequent and intense, forest insect pests and diseases are causing more problems. Many of BC's intensively managed forests have simplified stand structure and low tree species diversity, further reducing their resilience to climate change and to forest pests and diseases. Given the amount of climate change since 1960, some of our older (40–50+ years) secondary forests could already consist of genetically maladapted trees.

MYTH #5

Production forestry can help slow global warming. When forests are logged, the carbon that they store is transferred to long-lasting forest products, and the young replacement forests rapidly absorb more carbon.

This argument is flawed on several counts:

- ➔ It assumes that most if not all of the carbon from the logged forest is transferred to wood products. But most forest carbon is lost as residues from harvesting (40–60% of tree carbon to waste and breakage in cutblocks) or processing (pulp chips, hogfuel, sawdust, shavings). Some carbon goes into short-lived products such as paper and pallets. Only a small fraction is processed into 'longer-lived' products such as dimensional lumber, panels, plywood, house logs—especially if the logged forests were old with lots of decay and cull wood.

- ➔ Wood products in practice often don't last very long. Product half-lives are about 2–3 years for paper and shipping materials, and between 30 and 90 years for sawn wood, usually not several hundred years as some claim. Wood products often end up in landfills, where their carbon can be 'stored' if the wood isn't incinerated. Reportedly 44% of carbon in paper and 77% of carbon in wood can be stored for decades or centuries in landfills, where however there is potential for increased emissions of methane. Capturing and burning methane and waste wood from landfills can substitute for fossil fuel use, but these are not regular practices.

- ➔ The considerable surface area of logging roads and landings (in BC allowed to occupy up to 7% of cutblock area) represents a significant loss of carbon storage potential. However, most unsurfaced winter logging roads (more than half of cutblock roads in the interior) rather quickly become revegetated, and eventually a forest usually grows back even on 'permanent' roads unless they are maintained.

- ➔ The machinery of industrial forestry—logging, transporting, processing, shipping machinery—burns a lot of fossil fuel. The resultant emissions are not consistently factored into the carbon accounting.

- Forests generally are carbon sinks that remove carbon from the atmosphere and store it as above- and below-ground organic matter (living and dead). Producing lumber or moving wood products to landfills involves removing wood from the forest pool and processing and relocating that wood. This processing and transfer do not sequester carbon, rather they shift some of the stored carbon elsewhere and release to the atmosphere other carbon, from the forest pool and from burning fossil fuels. The net result is an increase in atmospheric carbon; more emissions than if the wood was left in the forest pool—even if carbon uptake by the regenerating forest is factored in.

MYTH #6

Intensive, short-rotation 'agroforestry' can maximize carbon storage. Thrifty young forest plantations fix lots of carbon, and over time long-lasting wood products could substitute for fossil-fuel-intensive products like concrete and steel.

In terms of carbon stewardship, the agroindustrial approach to forest management is a losing proposition.

The agroforestry + wood products strategy stresses the importance of carbon **uptake** (a rate or flux, which usually is greater in juvenile forests) over that of carbon **storage** (a state or pool, which is cumulative and greater in older forests). The strategy also assumes that old forests exhibit little or no increase in carbon storage, which is a false assumption. The C uptake rate and the C storage pool are both important in carbon stewardship, but both cannot be optimized on the same piece of land.

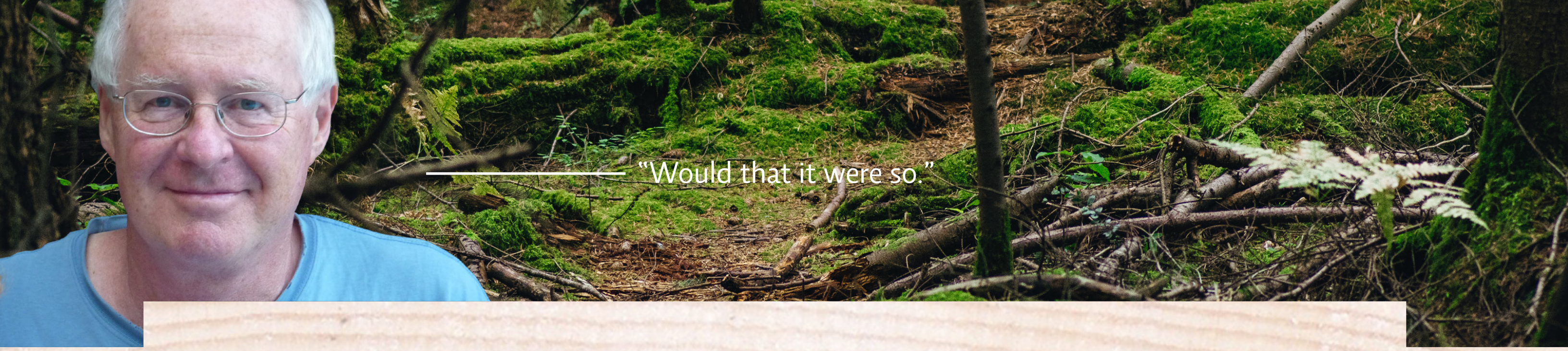
Intensive forest management typically draws down the carbon pool by increasing the frequency and intensity of disturbance, thereby reducing amounts of coarse woody debris and of forest floor and soil organic matter, resulting in lower levels of dead carbon storage—to say nothing of negative impacts on forest biodiversity. Logging primary, mature and old forests for wood products and converting them into intensively managed plantations releases large and essentially unrecoverable amounts of carbon to the atmosphere. These emissions cannot be simply offset overnight or on paper by planting more trees because it takes a **long time** for trees and forests to establish, grow, and mature. The intensively managed, short-rotation stand will not attain the original levels of carbon storage, thus incurring a permanent 'carbon debt'. Landscapes dominated by mature and old forests can store several times as much carbon as intensively managed, industrial forest landscapes.

The benefits of carbon storage by intact natural forests are **immediate** and greater than anticipated storage (more accurately, avoided emissions) in wood products in the future. If the wood products substitute for concrete and steel in construction, the presumed benefits would be cumulative and would exceed the carbon storage of an unlogged forest only after several to many decades, if ever.

In terms of carbon management, afforestation (establishing new forests) makes sense, as does converting some pasture land or marginal cropland to wood plantations. Replacing persistent, old, carbon-rich forests with plantations does not make sense in the present dire circumstances.

Even though carbon storage in wood products will always be less than in an undisturbed forest (because of inherent inefficiencies in converting trees to wood products), this strategy **could** be carbon-friendly in the long run if indeed wood substitutes in a huge way for other construction materials—especially concrete.

But substitution is problematic as a long-term solution to excessive GHG emissions. It is very sensitive to assumptions about technology used over a product life cycle and to the time frame considered. Substitution also requires a favourable policy and regulatory environment, and to determine its benefits you need a way to document and quantify it.



MYTH #7

Generating energy by burning woody biomass is both renewable and carbon neutral. Wood pellets help fight climate change. They reduce the amount of carbon dioxide released into the atmosphere when they replace a non-renewable source of energy such as coal or oil.

Would that it were so, but it isn't.

Yes, logged forests can be renewed but carbon neutrality for forest biomass means that emissions from the harvesting, transport, processing, and burning of trees and wood products are offset by future carbon stores. That is unlikely and would take many years—in BC perhaps 70 to 400+ years.

Wood typically has one-third to one-quarter the specific energy (MJ/kg; aka energy density) of hydrocarbons. This means that, to get a unit of energy, you need to burn more wood relative to fossil fuels and more CO_2 will be put into the atmosphere with wood than with fossil fuels. Thus, wood burning is associated with **greater initial** CO_2 emissions. Pellets have greater specific energy than unprocessed wood but still less than fossil fuels. Burning wood or wood products from mature and old-growth forests **will not** help reduce anthropogenic emissions of CO_2 to the atmosphere by 2040 or 2050.

Yes, wood is renewable in the long term; wood bioenergy uses carbon that is already within the biosphere; and wood biofuel can substitute for fossil fuel. However, the CO_2 from the combustion of biofuel is released almost instantly, whereas the growth and regrowth of wood takes several decades at least (mostly more than 75 years in BC). It takes time to regain the carbon storage on the landscape – i.e., to pay off the 'carbon debt'. Moreover, if the imperative is to avoid carbon emissions now and reduce emissions 80% or achieve net zero emissions by 2050, it's the amount not the origin of the atmospheric CO_2 that really matters for the next few decades. The atmosphere can't discriminate among molecules of carbon dioxide.

It makes economic sense for forest product companies to utilize their mill residues in secondary processing for pulp and bioenergy. Environmentally, it's a silver lining in that the residues are used instead of being incinerated in beehive burners as in the past. But if forest management is unsustainable, any environmental upside to utilizing residues can mask, or divert attention from, the overall negative impacts of the timber juggernaut on forest carbon and biodiversity.

Domestic use of pellets for heating would reduce air pollution in many rural communities if pellet stoves replaced inefficient, traditional wood stoves and fireplaces.

Some argue that greater production of biofibre (pellets) should be promoted because it could help reduce slashburning. For that to work the slash would have to be retrieved and brought to a pellet plant or somehow processed on site. Both propositions are dodgy economically and both dodge the fundamental issue of poor harvest utilization and excessive logging debris. Such schemes—especially if subsidized by government, as is likely—could also provide a perverse incentive to continue wasteful logging practices.

As a primary industry with a continual demand for fibre, additional pressure likely would fall on natural forests to supply fibre during shortages of cheap and abundant mill residues. If there isn't a reasonable and reliable source of mill residues, presumably the wood would come from existing forests. Grinding up healthy, young and mature forests for pellets is an ill-advised use of wood. Logging old forests (including irreplaceable old growth) solely to produce pellets makes no sense economically, ecologically, or in terms of carbon stewardship. High-grading old decay-rich forests to retrieve only the 10-25% best sawlogs for milling or whole log export, while producing pellets from the mountains of bush residue, is also a bankrupt approach.

Salvage logging strictly to produce pellets from beetle-killed or fire-killed forest often isn't justified either, and compromises the recovery of already stressed forests. Stands partially affected by beetles or fire often still have lots of residual live trees and/or advanced understory regeneration. They will continue to sequester and store carbon and provide wildlife habitat, and could contribute to mid-term timber supply, thus could be managed for continued provision of multiple values instead of mere salvage. Whereas it makes sense to log affected stands that are poorly stocked with residual live trees and prone to fire. Shifting harvest (for sawlogs or pulp, with pellets as a byproduct) to residual forests that have experienced stand-replacing disturbances could also be justified on a timber harvesting landbase that has more naturally disturbed, young forests than mature and old forests.

Some Recommendations and Potential Solutions

1. **Develop and implement a strategy for forest carbon stewardship.**

   - ➔ The strategy should focus on specific, carbon-rich, less disturbance-prone ecosystem types, in particular humid forests and associated peatlands.

   - ➔ Protect more of such ecosystems, especially old carbon-rich forests that have a good chance of being with us for decades and centuries to come. For example, establish 'carbon buffer forests' or 'carbon protection forests' in selected areas of wet coastal (coastal temperate rainforest), wet subalpine, and interior wetbelt (inland temperate rainforest) forest land. Include in the 'carbon buffer' area adjacent secondary forests that have been logged or that have experienced stand-replacing natural disturbances. Replant them if necessary and allow them to regrow, become old, and realise their carbon bank potential.

   - ➔ A start has already been made in a report that identifies, estimates, and maps where and how much biological carbon occurs in BC today, in vegetation and as soil organic carbon.[1]

2. **Broaden core protected areas into a climate conservation network.**

Establish new conservation areas designated primarily for biodiversity and ecosystem services, especially carbon storage and sequestration. Increase the area and effectiveness of the protected area network and provide incentives for beyond-reserve conservation to maximise carbon stocks and biodiversity, and hence the resilience of ecosystems.

3. **Prevent catastrophic wildfire—if we can.**

   - ➔ Yes of course but it won't be easy. Requires the right mix of legislation, policy, licensee incentives, some prescribed fire, and most importantly, building a network of landscape level discontinuity that is sensitive to both fire management objectives and ecological function. We should resist preoccupation with the stand level and embrace forest complexity at the landscape level.

   - ➔ This is a much needed but complicated initiative that must be an integral part of higher level planning and embedded in Ministry of Forests, Lands and Natural Resource Operations (FLNRO) policy.

4. **Reduce energy consumption and increase its efficiency, conserve existing natural forests, emphasize restoration of disturbed or degraded forests.**

5. **Reduce the allowable annual cut (AAC) to sustainable levels.**

   - ➔ In an orderly but accelerated fashion, starting with the Timber Supply Areas where timber supply

1 Holt, RF and Kehm G. 2014. Conservation and adaptation in British Columbia: Strategic opportunities in a climate changing world. 43 p. https://veridianecological.files.wordpress.com/2010/11/report_final_april2014.pdf

reviews and AAC determinations are already due or overdue.

- Use **realistic** estimates of a) the limited opportunities that marginal and remote stands could provide for harvesting, and b) projected losses due to insect pests, disease, fire, windthrow, frost damage, susceptible growing stock—all interacting in a rapidly changing climate.

- Include a more balanced consideration of the full range of forest resource values; in 2019 it's not just about maintaining timber supply.

- Permanently reserve more old forest stands and remove them from the timber harvesting land base (THLB). BC's dwindling intact forests play an indispensable role mitigating climate change (especially through carbon uptake and storage), regulating local climate and hydrology, conserving biodiversity, providing key ecosystem services, strengthening indigenous cultures, and helping maintain human health and well-being.

6. Do more partial cutting and less clearcutting, especially in primary forests.

- Instead of cutting down all the trees in a cutblock and in the process removing the most desirable logs and leaving the rest on the ground, retain some standing trees, in groups or patches and as individuals. This would reduce the amounts of logging debris and of tree carbon lost to logging.

- Do the partial cutting in ways that mitigate wildfire (e.g., promote stand structure that helps prevent running crown fire and reduces rate of spread on the ground) and still maintain ecosystem function and some timber supply.

- But don't do the same thing everywhere.

7. Manage more commercial forests on extended rotations.

Longer rotations result in more carbon stored per hectare. The carbon benefit of longer rotations is not due to the rate of uptake, which slows after 80-100 years, but rather to increasing storage in biomass and in dead wood and soil carbon.

8. Reduce drastically the amount of slash burning.

- Reduce logging debris (slash) in cutblocks. We need better utilization but the trend over the past decade appears—in west central BC anyway—to have been towards greater waste, more high-grading, more 'cut-to-length' at the roadside (leaving tree bole sections behind if they don't fit the logging truck bunk or meet the quality or species expectations of the sawmill).

- Perhaps make biochar (charcoal produced by the incomplete combustion of organic materials) from the slash and use it to amend the soil and store carbon for centuries or millenia. Biochar is great stuff but its production requires money and energy and gives off its own cocktail of emissions.

- Pile but don't burn the slash. Stopping the burning of slash piles can substantially reduce GHG emissions. Although the increased area occupied by unburnt slash reduces the area available for growing trees, and slash piles are said to increase the risk of wildfire.

- "Combine methods: use the largest and soundest pieces for manufacturing, convert as much of what remains as economically feasible to biochar, tipi some non-commercial poles for slow decay, spread some large woody debris for biological reasons, and bury the rest."[2]

- Apply the BC Carbon Tax to the burning of slash.

9. Continue planting trees to remove CO_2 from the atmosphere in the future.

- Concurrently do more work on tree species/stock selection for adaptive reforestation, and on assisted migration of tree species that might more effectively mitigate climate change while producing wood.

- In some clearcuts, establish plantations with higher densities so as to sequester more carbon, buffer some forest health impacts, and create a stand condition that, at 20 to 40 years of age, is (reportedly) relatively fire resistant. This is somewhat counter-intuitive and would sometimes conflict with biodiversity objectives, but foresters report examples of where this type of stand has been effective.

10. Husband the forests that we still have and avoid converting them to alternative uses.

- To avoid additional emissions of CO_2 to the atmosphere over the next 2-3 decades, protection of existing carbon-rich forests is a more effective and environmentally acceptable approach (with immediate net carbon benefits) than is the strategy of increased logging combined with intensive forest management and carbon storage in wood products.

- Notwithstanding the "fierce urgency" of the next 2-3 decades, BC will probably need to pursue all feasible options to mitigate climate change, whether they provide short- or long-term GHG reduction benefits.

2 Voices for Good Air (a network affiliate of Clean Air Now). 2017. Position paper on smoke and carbon emissions from forestry slash burning. 32 p. https://drive.google.com/file/d/0B20WJyYNc-9UbkhNRFp3UnhGX0E1YV9wb2tyUE5TeTE1QWhV/view?usp=sharing

Introduction

Global climate change is well underway. Humanity has only about two to three decades to avoid the 1.5° – 2° Celsius threshold and forestall runaway climate warming.[1] We have been urged to reduce greenhouse gas emissions 80% below 1990 levels by 2050 or (more recently) 45% by 2030, and to achieve net zero emissions by 2040[2] or 2050.[3] **The imperative is to avoid carbon emissions now**, rather than to rely on increased rates of carbon sequestration and recovery of storage 30 to 80+ years from now.

Canada and British Columbia have established targets for greenhouse gas (GHG) emissions.

- Federal targets: emissions down to 30% of 2005 levels by 2030; carbon neutral by 2050[4].
- Provincial targets (Fig. 1): 40% reduction by 2030 compared to 2007 levels; 80% by 2050.[5] Put another way: reduce provincial emissions from the 65 million tonnes of 2007 to 38 million tonnes by 2030 and 13 tonnes by 2050. Note that direct and upstream CO_2 emissions from the Pacific Northwest LNG proposal for Lelu Island would have been around 12 million tonnes annually,[6] and the recently approved LNG Canada proposal for Kitimat could emit 9-10 million tonnes annually.

Forest management plays a nearly unique role in climate change mitigation because forestry (along with agriculture) both generates emissions and removes carbon from the atmosphere (Fig. 2); the carbon taken up by forests is stored in vegetation, soil, and harvested wood products.[7,8]

The management challenges posed by climate change to British Columbia's forests were starkly manifested in the early 2000s in a series of environmental shocks that included the massive mountain pine beetle outbreak and the damaging wildfires of 2003.[9] The challenges and shocks have continued to the present. The Province responded with a flurry of reports and arm-waving, but to date has developed "few effective policies targeting forest carbon management"[10] and few substantial on-the-ground management interventions[11] to reduce GHG emissions and improve forest carbon stewardship.

1 IPCC 2014, 2018; Paris Climate Agreement 2016.

2 Figueres C, Schellnhuber HJ, Whiteman G, Rockström J, Hobley A, Rahmstorf S. 2017. Three years to safeguard our climate. *Nature* 546: 593–595. doi:10.1038/546593a

3 IPCC 2018.

4 Paris Climate Agreement. 2016.

5 https://engage.gov.bc.ca/app/uploads/sites/391/2018/07/MoE-IntentionsPaper-Introduction.pdf

6 Zickfield, K. 2017. Affidavit in support of submission by SkeenaWild Conservation Trust to the judicial review of the PNW LNG proposal for Lelu Island.

7 Ryan MG, Harmon ME, Birdsey RA, Giardina CP, Heath LS, Houghton RA, Jackson RB, McKinley DC, Morrison JF, Murray BC, Pataki DE, Skog KE. 2010. A synthesis of the science on forests and carbon for U.S forests. *Issues in Ecology* 13:1–16.

8 Ter-Mikaelian MT, Colombo SJ, Chen J. 2016. Greenhouse gas emission effect of suspending slash pile burning in Ontario's managed forests. *The Forestry Chronicle* 92: 345-356. doi: 10.5558/tfc2016-061.

9 Haeussler S, Hamilton EH. 2012. Informing Adaptation of British Columbia's Forest and Range Management Framework to Anticipated Effects of Climate Change: A Synthesis of Research and Policy Recommendations. Report prepared for BC Future Forest Ecosystem Scientific Council (FFESC). 44 p.

10 St-Laurent GP, Hoberg G, Sheppard SRJ. 2018. A participatory approach to evaluating strategies for forest carbon mitigation in British Columbia. *Forests* 9: 225. doi:10.3390/f9040225

11 The Province in April 2018 awarded, through the Forest Enhancement Society of BC (FESBC), $134 million to 71 projects, many of them about wildfire management generally and some of them more directly about climate change mitigation. But it's too early to assess what these projects have accomplished.

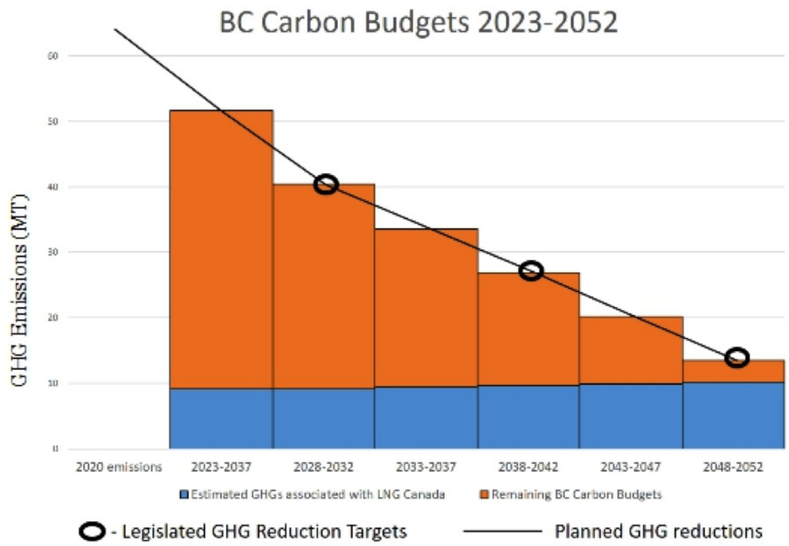


Figure 1. Expected emissions from LNG Canada's plant against a declining carbon budget.[12]

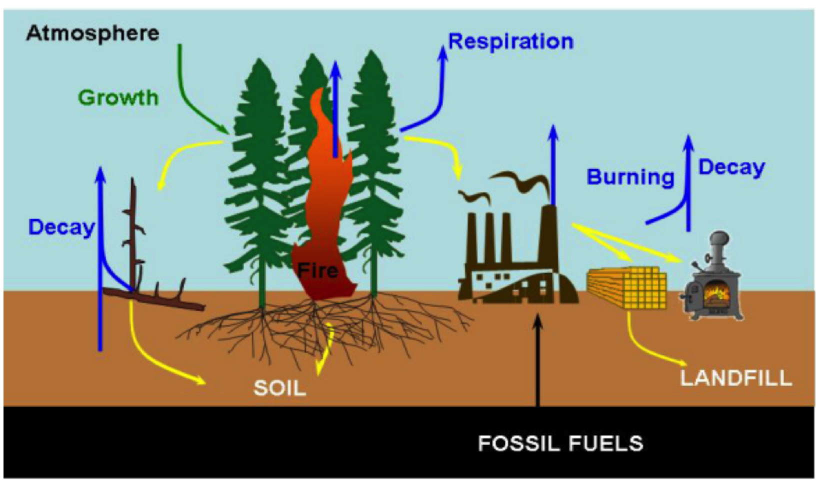


Figure 2. Forest sector carbon flows. As trees grow they take up carbon from the atmosphere (green arrow). The blue arrows indicate where carbon is released back to the atmosphere. The yellow arrows indicate transfer of carbon within the forest ecosystem or to the forest products industry. Plant respiration, forest fires, and natural decay cause releases of carbon to the atmosphere. Harvesting results in releases of carbon due to decay and burning of logging residues. Storage of carbon occurs in the trees themselves, in forest soils, in forest products, and in landfills.[13] Image: C. Dymond & M. Apps

The provincial government's position in 2013 was circumspect: "Overall, the province supports the use of forest carbon management options that satisfy the diverse values British Columbians seek from forests. This includes carbon storage and sinks, socio-economic values provided by forestry and timber production as well as other ecological values such as biodiversity, water, fish and wildlife."[14] The 2013 report outlines six management options:

12 Gage A. 2018. We're told LNG is good for the budget – but what about our carbon budget? West Coast Environmental Law. https://www.wcel.org/blog/were-told-lng-good-budget-what-about-our-carbon-budget?utm_source=LEB

13 Dymond C, Spittlehouse, D. 2009. Forests in a carbon-constrained world. Extension Note 92. Ministry of Forests & Range, Research Branch, Victoria, BC.

14 BC Ministry of Forests, Lands, and Natural Resource Operations. 2013. Climate mitigation potential of British Columbian forests: Growing carbon sinks. Victoria, BC. 29 p.

Forest management strategies

1. Carbon smart harvest – take a greater proportion of the trees off the cutblock, leaving less to be burned as waste or decay, and increase the proportion of wood derived from salvage harvesting.

2. Harvest less – increase the amount of conservation areas and reduce the amount of timber harvested.

Harvested wood product strategies

3. Bio-energy harvest – increase the amount of timber harvested, and use that additional harvest for bio-energy.

4. Wood substitution – increase proportion of harvest used for long-term wood products (e.g., lumber, panels) that could substitute for more emissions-intensive non-wood products; reduce proportion used for short-term products (e.g., pulp, paper).

5. Bio-energy – increase the recovery rate of the sawdust and shavings from sawmills and use for bio-energy that could substitute for fossil fuels.

Combined forest management and harvested wood products strategy

6. Carbon smart harvest and wood substitution – a combination of the assumptions used for Carbon smart harvest and Wood substitution."

The report concludes that in terms of carbon management, "the best strategy over the long-term is a combination of carbon smart harvest and wood substitution." The report also favours increased storage in harvested wood products. In contrast, a particpatory workshop approach in BC found that citizen "stakeholders and Indigenous Peoples" ranked eight mitigation strategies in the following order of descending preference: rehabilitation, old growth conservation, increased growth rate, harvest efficiency, bioenergy, reduced harvest, longer-lived wood products, increased harvest.[15] In general the study found more support for a rehabilitation strategy (reforestation) and for conservation strategies (old growth conservation, reduced harvest) than for enhanced forest management strategies.[16] Note that participants did not necessarily consider slowing climate change as the highest priority but as one of many objectives (such as biodiversity conservation, improved water quality, poverty reduction) that should be considered when using forests to mitigate climate change.[17]

15 St-Laurent GP, Hagerman S, Kozak R, Hoberg G. 2018. Public perceptions about climate change mitigation in British Columbia's forest sector. *PLoS ONE* 13(4): e0195999. https://doi.org/10.1371/journal.pone.0195999

16 *Ibid.*

17 St-Laurent GP, Hoberg G, Sheppard SRJ. 2018. *Op. cit.*

BC's Climate Leadership Plan of 2016 is a rather desultory document. It doesn't have much to say about forestry and mitigation, aside from the standard invocation of "intensive forest management practices and storing carbon in long-lived wood products", and a call for rehabilitating under-productive forests, recovering more wood fibre, and avoiding emissions from slash-burning.[18]

The BC Climate Change Strategy of 2018 (aka CleanBC)[19] is ambitious and includes many specific actions to reduce GHG emissions, especially in the transportation, buildings + housing ('built environment'), and energy sectors. But this new strategy too skates around forestry and the forest sector. It offers a bioenergy plan that includes "working with the forest sector, Indigenous and non-Indigenous communities, and the technology sector to advance the use of forest residuals for advanced building materials, commercial products and renewable fuels"and some examples of domestic heating with wood chips and residues. It also notes that "the Province and Ottawa are partners in a Forest Carbon Initiative, which invests in projects that sequester forest carbon and reduce carbon emissions – promoting the improved use of forest fibre for biofuels and longer-lived wood products." That sounds like more logging and greater production of lumber and wood pellets. Despite the alarming increase in forestry-related emissions since 2003, the strategy doesn't even include the forest sector in a table entitled Changes in Emissions by Sector 2007– 2016. This is surprising, given that forests fix and store huge amounts of carbon, and forestry is by far the biggest source of carbon emissions in BC.

So why isn't forestry considered part of the picture? "Because of the risk of natural disturbance impacts and the accounting rules" that require reporting of emissions resulting from both human activities and natural events, Canada in 2006 "decided not to elect forest management for its Kyoto Protocol accounting."[20] Afforestation and deforestation **are** factored into Canadian GHG totals and included within BC's Provincial Inventory totals. Emissions and uptake associated with forest management "are important sources and sinks but are more volatile and subject to natural factors outside of direct human control and so are not reported as part of BC GHG emissions totals in accordance with international practice."[21] Forestland GHG emissions are calculated as the sum of forest growth minus decay, slash pile burning, wildfires, and decomposition of harvested wood products. These emissions "are published as 'Memo Items' in the Provincial Inventory for transparency purposes."[22] What should also be transparent is that logging, slash burning, reforestation, and harvested wood products **are** under direct human control and gross GHG emissions from these sources exceed all other BC sources, even if wildfire is not included. The voodoo accounting used to assess compliance with emissions limits and in climate legislation is seriously flawed[23,24] and has been since the Kyoto Protocol. It erroneously treats forestry and forest-related subsectors such as bioenergy as carbon neutral, not counting their emissions as GHGs because in theory the trees eventually will grow back—even if it takes until 2100 and beyond for logged forests to recover their carbon stocks, as it would in BC.

The 2016 Paris Climate Change Agreement calls for "achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century."[25] Perhaps the Province, in a disingenuous interpretation of the Paris Agreement, is aiming for net zero emissions **by** 2100. A scenario to achieve this could involve logging as much/as quickly as possible, pumping out a glut

18 https://www2.gov.bc.ca/assets/gov/environment/climate-change/action/clp/clp_booklet_web.pdf

19 https://cleanbc.gov.bc.ca/app/uploads/sites/436/2018/12/CleanBC_Full_Report.pdf Accessed 8Dec2018.

20 Kurz WA, Stinson G, Rampley GJ, Dymond CC, Neilson ET. 2008. Risk of natural disturbances makes future contribution of Canada's forests to the global carbon cycle highly uncertain. *PNAS* 105: 1551–1555. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2234182/pdf/zpq1551.pdf Accessed 8Dec2018.

21 https://www2.gov.bc.ca/assets/gov/environment/climate-change/data/provincial-inventory/2016/bc-methodology-book_ghg-provincial-inventory.pdf Accessed 8Dec2018.

22 *Ibid.*

23 Searchinger TD and many others. 2009. Fixing a critical climate accounting error. *Science* 326: 527-528. DOI: 10.1126/science.1178797

24 Ellison D, Lundblad M, Petersson H. 2011. Carbon accounting and the climate politics of forestry. *Environmental Science & Policy* 14: 1062-1078. https://doi.org/10.1016/j.envsci.2011.07.001

25 https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf Accessed 9Dec2018.

of long-lasting wood products, stuffing wood waste into landfills, and reforesting the cutover and fire/insect-killed backlog areas as quickly as possible. This would probably appeal to the forest industry, which could maximize net present value of its timber stocks and then, when the juvenile forests on public land reach 'free-growing' status, be relieved of the responsibility to look after the trees, which once again would become the responsibility of the Province.[26]

Presumably the provincial government is now contemplating various schemes for carbon stewardship (real and illusory) and emissions reductions in forestry. We currently have a BC Forest Carbon Strategy (2016-2020),[27] and a Forest Carbon Initiative (2017-2022), both of which are mainly aspirational. No doubt the BC Forest Enhancement Society and the Office of the Chief Forester's Climate Change & Integrated Planning Branch are developing more concrete strategies with objectives, performance measures, and timelines. We don't yet know what the elements[28] of these strategies will be, but they will have manifold consequences for BC's forests and communities. Not only are forests the linchpin of carbon dynamics in BC, they are also the primary storehouse for the province's biodiversity, providing multiple ecosystem functions and services that underpin forest resilience and are essential for sustaining human well-being.[29,30,31] These days critical thinking about how we manage our forests is at a premium.

26 https://www.bcfpb.ca/wp-content/uploads/2016/04/SR16-Reforesting-BC-Public-Land.pdf Accessed 9Dec2018.

27 https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change/bc_forest_carbon_strategy_09092016_sept_21.pdf

28 Currently the Forest Carbon Initiative is concentrating on four activities: rehabilitation, fertilization, increased planting density, less slash pile burning. [Paradine, D. Forest Carbon Initiative: Science and Research Agenda. Presentation 12Dec2018 at UNBC, Prince George]

29 Austin MA, Buffett DA, Nicholson DJ, Scudder GGE, Stevens V (eds.). 2008. Taking Nature's Pulse: The Status of Biodiversity in British Columbia. Biodiversity BC, Victoria, B.C. 268 p.

30 Mori AS, Lertzman KP, Gustafsson L. 2017. Biodiversity and ecosystem services in forest ecosystems: a research agenda for applied forest ecology. *Journal of Applied Ecology* 54: 12–27. doi: 10.1111/1365-2664.12669

31 Watson JEM and many others. 2018. The exceptional value of intact forest ecosystems. *Nature Ecology & Evolution* 2: 599-610. doi:10.1038/s41559-018-0490-x

Intact Ecosystems Sequester and Store Large Amounts of Carbon

Natural terrestrial ecosystems play two major roles in the carbon cycle. Nature removes carbon from the atmosphere and stores it as organic carbon. BC ecosystems store huge amounts of 'living' and 'dead' carbon[32], especially in our coastal old-growth forests (Fig. 3), which along with the world's other temperate rainforests, store the largest amounts of carbon per hectare on the planet.[33,34]

Figure 3. Coastal old-growth forest, Big Falls River near Prince Rupert. A. Inselberg

Through photosynthesis the primary producers (mostly plants) remove (fix) CO_2 from the atmosphere. After accounting for releases to the atmosphere, the net amount of carbon fixed annually is termed carbon sequestration, which is synonymous with net ecosystem production.[35]

$6CO_2 + 6H_2O + \text{Sunlight} <\text{---}> C_6H_{12}O_6 + 6O_2$ [photosynthesis>> << respiration, burn, decay]

32 Carbon exists in three terrestrial forms: living carbon (in ecosystems that sustain life), dead carbon (organic matter, for example, in snags and downed logs and in soils within forests, in peat), and ancient carbon (held as fossil fuels or hydrocarbons—coal, oil, gas). [Hebda RJ. 2008. Climate change, forests, and the forest nursery industry. Pp. 81–87 in Dumroese & Riley (tech. coordinators). National Proceedings: Forest & Conservation Nursery Associations. 2007. Fort Collins, CO. USDA Forest Service, Proc RMRS-P-57].

33 Black TA, Jassal RS, Fredeen AL. 2008. Carbon Sequestration in British Columbia's Forests and Management Options. Pacific Institute for Climate Solutions, Victoria, BC. 19 p.

34 Keith H, Mackey BG, Lindenmayer DB. 2009. Reevaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests. *PNAS* 106: 28 11635–11640.

35 Chapin FS and others. 2006. Reconciling carbon-cycle concepts, terminology, and methods. *Ecosystems* 9: 1041–1050.

Terrestrial ecosystems store the carbon primarily as:

- stem wood along with other biomass (living organic matter) above-ground (branches, leaves, bryophytes and lichens);
- below-ground wood and other biomass (roots, fungi, soil microbiota);
- necromass (litter, woody debris); and
- organic carbon in the soil.

Ecosystems release CO_2 back into the atmosphere when trees, other vegetation, and other organisms living in ecosystems respire, burn or decay.

Forested Ecosystems of British Columbia

Forests play a dominant role in the carbon budget of BC. Well over half of the province is forested. The carbon stored in the trees, roots and soils of these forests averages 311 tonnes per ha. In total 18 billion tonnes of carbon were estimated (in 2008) to be stored by BC's forest ecosystems, nearly 1000 times the province's annual emissions of greenhouse gases.[36] There is a strong link between ecosystem conservation and carbon stewardship.

Sources of Greenhouse Gas Emissions

A decade ago, a BC Greenhouse Gas Inventory Report[37] indicated that timber harvesting (72.7 million carbon dioxide equivalent tonnes [MtCO_2 e]) and slash-burning (8.2 MtCO_2 e) were responsible for a combined 80.9 MtCO_2 e GHG emissions in 2007 alone, exceeding the gross carbon emissions (64.7 MtCO_2 e) from all other sectors in the province (Fig. 4). BC's gross greenhouse gas emissions for 2016 were reported as 62.3 Mt CO_2 e,[38] but that figure does not include 'forest management' (logging + slashburning) gross emissions of 47 Mt CO_2 e. Similarly in Oregon, where logging has been "by far the number one source of greenhouse gas emissions"[39] since 2000, and in the western US generally between 2006 and 2010,[40,41] carbon losses to harvesting were much greater than those due to wildfire & insect damage combined.

BC does not include forestry emissions in its official GHG emission inventory, in accordance with Canada's

36 Wilson SJ, Hebda RJ. 2008. Mitigating and Adapting to Climate Change Through the Conservation of Nature. The Land Trust Alliance of British Columbia, Saltspring Island, BC. 58 p.

37 Ministry of Environment. 2009. B.C. Provincial Greenhouse Gas Inventory Report 2007. http://www.env.gov.bc.ca/epd/climate/ghg-inventory/index.htm. Accessed 9Dec2018.

38 1990-2016 GHG Emission Summary for British Columbia. 2016_provincial_inventory.xlsx https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory. Accessed 9Dec2018.

39 https://sustainable-economy.org/osu-research-confirms-big-timber-leading-source-greenhouse-gas-emissions-oregon/ Accessed 23Nov2018.

40 Harris NL and others. 2016. Attribution of net carbon change by disturbance type across forest lands of the conterminous United States. *Carbon Balance Manage* 11:24 DOI 10.1186/s13021-016-0066-5

41 Woodall, CW and many others. 2015. The U.S. Forest Carbon Accounting Framework: Stocks and Stock Change, 1990-2016. USDA For. Serv. Gen. Tech. Rep. NRS-154. Newtown Square, PA. https://www.fia.fs.fed.us/forestcarbon/docs/CarbonReport_OnlineDraft-opt.pdf Accessed 28Dec2018.

decision under the Kyoto Protocol. Nevertheless, even if one accounts for the fact that some carbon is stored in 'longer-lived' harvested wood products, logging is still a massive source of carbon emissions in the province. These emissions cannot be simply offset overnight or on paper by planting new forests (afforestation) or restoring logged forests (reforestation) because it takes a **long time** for forests to establish, grow, and mature. Conserving BC's carbon-rich and long-lived forests has a pivotal role in carbon storage and in helping meet our **crucial short-term** GHG mitigation objectives.

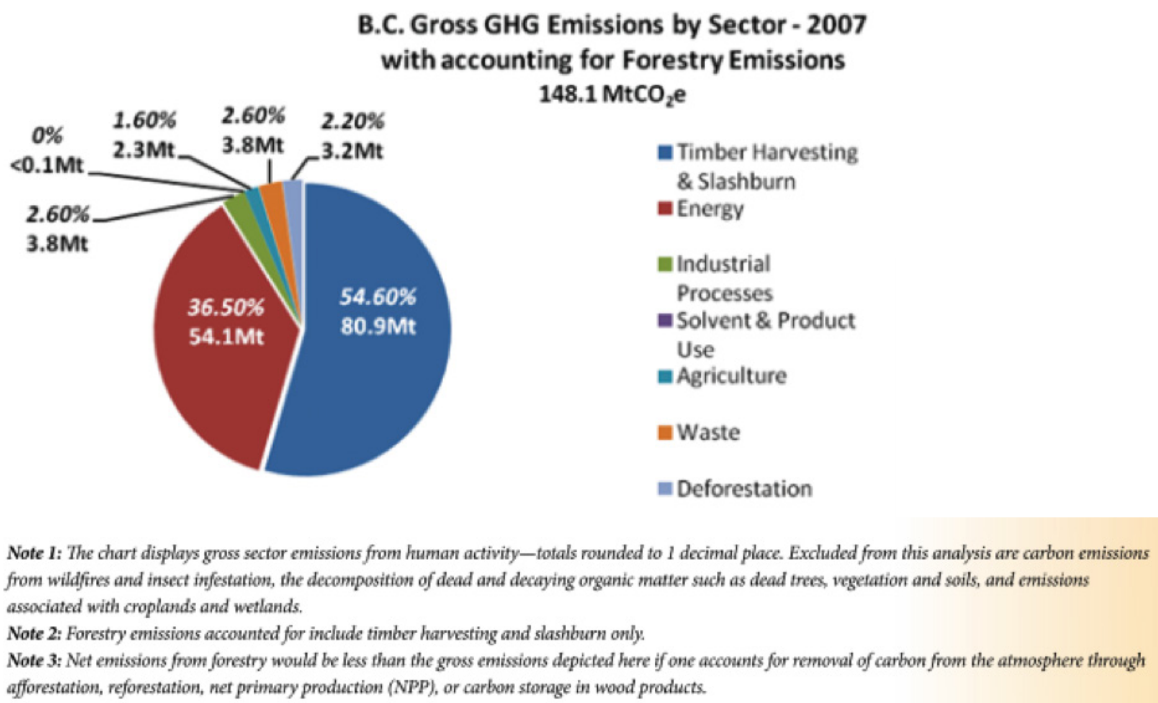


Figure 4. BC gross GHG emissions by sector in 2007, with accounting for forestry emissions. Adapted from BC Greenhouse Gas Inventory Report. 2009.

Source or Sink?

Forests both absorb and release carbon, resulting in a dynamic balance that changes over time, depending on stand age and on type and intensity of disturbance. The relative balance between uptake and emission determines whether a particular ecosystem is a net carbon sink or a source.

The issue of carbon sequestration and carbon storage by young forests and old forests has attracted much attention and study as well as some unclear or conflicting results and interpretations. Net carbon uptake (i.e., the carbon removed from the atmosphere) by forests has a complex relationship with age. After a stand-initiating disturbance, young forests are net carbon sources for several years until the amount of carbon they take up exceeds the carbon they emit through respiration and decomposition. Review papers show that annual net carbon uptake (sequestration) is generally low or negative in forests less than 10–20 years old (because of high rates of decomposition following stand-initiating disturbances), reaches a peak rate in intermediate-aged forests (30–120 years), and declines but remains positive in most forests older than 120–160 years.[42,43,44,45,46,47,48,49,50]

Some old forests (sources) emit more carbon than they fix but most (sinks) fix more than they emit, depending on levels of within-stand mortality, decay, and growth. Net carbon uptake in old forests does level off or decrease, but total storage increases. Old forests usually store much more carbon on site than do young post-logging forests. Depending on how they naturally function, how they are disturbed, and how they are managed, forests can therefore either mitigate or contribute to greenhouse gas emissions and climate change.

Such trends run counter to the traditional forestry view that old forests are at best carbon neutral because old trees grow more slowly than young trees and therefore are not taking up as much carbon on an annual basis, and because tree death and decomposition become dominant processes in old, so-called decadent forests. Although forests become less productive—of wood—beyond a certain age (typically determined as the point at which mean annual increment of diameter growth peaks), temperate and boreal forests can continue to have positive net annual carbon uptake (say about 0.3 to 3 t C/ha/yr) well into old age.[51,52,53,54,55] Net carbon uptake does decrease, but total storage increases –indefinitely as far as we know, unless a stand-replacing disturbance intervenes. These forests can continue to operate as carbon-rich banks because over time they accumulate large amounts of dead carbon as slowly decomposing organic matter in coarse woody debris (snags, down logs), litter, and in the soil.[56,57,58,59,60] Figure 5 depicts the modelled dynamics of carbon storage in a spruce-fir forest after a clearcut. Even though the rate of carbon uptake is faster in younger stands (the slope of the total carbon curve is steepest between 25 and 35 years), older forests continue to increase carbon stores each year (the total carbon line is still rising at 125 years) and total carbon stored in the forest will be greater with extended rotation ages.

42 Suchanek TH, Mooney HA, Franklin JF, Gucinski H, Ustin SL. 2004. Carbon dynamics of an old-growth forest. *Ecosystems* 7: 421-426.

43 Harmon ME, Bible K, Ryan MG, Shaw DC, Chen H, Klopatek J, Li X. 2004. Production, respiration, and overall carbon balance in an old-growth *Pseudotsuga-Tsuga* forest ecosystem. *Ecosystems* 7: 498-512.

44 Pregitzer KS, Euskirchen ES. 2004. Carbon cycling and storage in world forests: biome patterns related to forest age. *Global Change Biology* 10: 2052-2077.

45 Paw U, Falk KT, Suchanek TH, Ustin SL, Chen J, Park Y-S, Winner WE, Thomas SC, Hsiao TC, Shaw RH. 2004. Carbon dioxide exchange between an old-growth forest and the atmosphere. *Ecosystems* 7: 513-24.

46 Fredeen AL, Waughtal JD, Pypker TG. 2007. When do replanted sub-boreal clearcuts become net sinks for CO2? *Forest Ecology & Management* 239: 210-216. https://doi.org/10.1016/j.foreco.2006.12.011

47 Gough CM, Vogel CS, Schmid HP, Curtis PS. 2008. Controls on annual forest carbon storage: Lessons from the past and predictions for the future. *BioScience* 58: 609-622.

48 Luyssaert S, Schulze E-D, Börner A, Knohl A, Hessenmöller D, Law BE, Ciais P, Grace J. 2008. Old-growth forests as global carbon sinks. *Nature* 455: 213-215.

49 Black and others. 2008. *Op cit.*

50 Coursolle C, Margolis HA, Giasson M-A, Bernie P-Y, Amiro BD,Arain MA, Barr AG, Black TA, Goulden ML, McCaughey JH,Chen JM, Dunn AL, Grant RF, Lafleur PM. 2012. Influence of stand age on the magnitude and seasonality of carbon fluxes in Canadian forests. *Agric. For. Meteorol.* 165: 136–148. doi:10.1016/j.agrformet.2012.06.011.

51 Law BE, Sun OJ, Campbell J, Van Tuyl S, Thornton PE. 2003. Changes in carbon storage and fluxes in a chronosequence of ponderosa pine. *Global Change Biology* 9: 510-524.

52 Carey EV, Sala A, Keane R, Callaway RM. 2001. Are old forests underestimated as global forest sinks? *Global Change Biology* 7: 339-344.

53 Griffis TJ, Black TA, Morgenstern K, Barr AG, Nesic Z, Drewitt GB, Gaumont-Guay D, McCaughey JH. 2003. Ecophysiological controls on the carbon balances of three southern boreal forests. *Agricultural and Forest Meteorology* 117: 53-71.

54 Bond-Lamberty B, Wang CK, Gower ST. 2004. Net primary production and net ecosystem production of a boreal black spruce wildfire chronosequence. *Global Change Biology* 10: 473-487.

55 Kurz WA, Shaw CH, Boisvenue C, Stinson G, Metsaranta J, Leckie D, Dyk A, Smyth C, Neilson ET. 2013. Carbon in Canada's boreal forest — A synthesis. *Environ. Rev.* 21: 260–292. dx.doi.org/10.1139/er-2013-0041

56 Trofymow JA, Blackwell BA. 1998. Changes in ecosystem mass and carbon distributions in coastal forest chronosequences. *Northwest Science* 72: 40-42.

57 Suchanek and others. 2004. *Op. cit.*

58 Zhou G, Liu S, Li , Zhang D, Tang X, Zhou C, Yan J, Mo J. 2006. Old-growth forests can accumulate carbon in soils. *Science* 314: 1417.

59 Peng Y, Thomas SC, Tian D. 2008. Forest management and soil respiration: Implications for carbon sequestration. *Environmental Reviews* 16: 93-111.

60 Luyssaert and others. 2008. *Op. cit.*

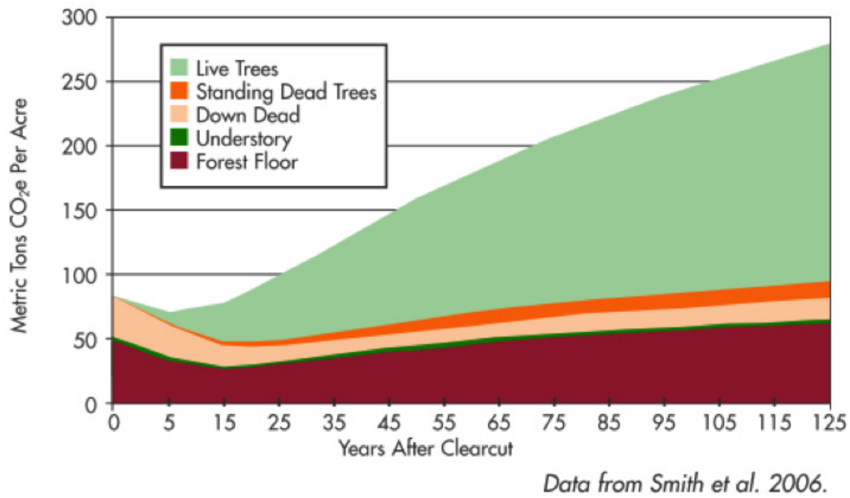


Figure 5. Non-soil forest carbon in a spruce-fir stand, northeastern USA.[61]

Old forests may indeed accumulate relatively small amounts of carbon each year, but they have been at it a long time. They store much more carbon in biomass and necromass (standing and downed wood, litter, roots and organic matter in the soil) than do younger forests (Fig. 6).[62,63] The Carbon Budget for Canada's Forests (1999) estimates that BC's Pacific Maritime (cf. Fig. 7) and Montane Cordillera ecozones store on average about 350 tonnes of carbon per hectare.[64] Individual forest ecosystems in these ecozones can store considerably more than the average, from 600 to 1300 tonnes of carbon per hectare.[65,66] Canadian boreal forests in general, and the Cordilleran Boreal forests that occur in northern BC, store on average 200–250 t C/ha; boreal peatlands store 400–1100 t C/ha.[67,68] In the sub-boreal (southern boreal) forests of central BC, carbon storage in old stands ranges from 120 to 725 t C/ha[69], depending on site quality, and on zonal or average sites is about 300–420 t C/ha.[70,71]

61 Ingerson AL. 2007. *U.S. Forest Carbon and Climate Change.* The Wilderness Society, Washington, D.C. 18p. [Smith JE, Heath LS, Skog KE, Birdsey RA. 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. USDA Forest Service, General Technical Report NE-343. Northeastern Research Station, Newtown Square, PA.]

62 Smithwick EAH, Harmon ME, Remillard SM, Acker SA, Franklin JF. 2002. Potential upper bounds of carbon stores in forests of the Pacific Northwest. *Ecological Applications* 12: 1303-1317.

63 Pregitzer and Euskirchen. 2004. *Op. cit.*

64 Kurz WA, Apps, MJ. 1999. A 70-year retrospective analysis of carbon fluxes in the Canadian forest sector. *Ecological Applications* 9: 526-547.

65 Trofymow and Blackwell. 1998. *Op. cit.*

66 Fredeen AL, Bois CH, Janzen DT, Sanborn PT. 2005. Comparison of coniferous forest carbon stocks between old-growth and young second-growth forests on two soil types in central British Columbia, Canada. *Can. J. For. Res.* 35: 1411-1421.

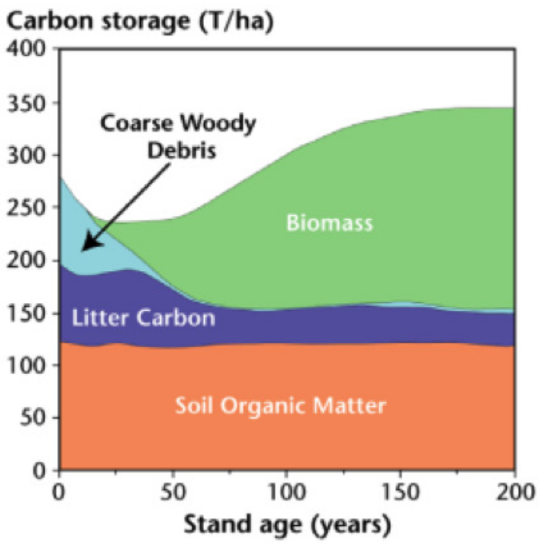
67 Bradshaw CJ, Warkentin IG. 2015. Global estimates of boreal forest carbon stocks and flux. *Global and Planetary Change* 128: 24–30. http://dx.doi.org/10.1016/j.gloplacha.2015.02.004

68 Kurz and others. 2013. *Op. cit.*

69 Kranabetter JM. 2009. Site carbon storage along productivity gradients of a late-seral southern boreal forest. *Can. J. For. Res.* 39: 1053–1060.

70 *Ibid.*

71 Fredeen and others. 2005. *Op. cit.*



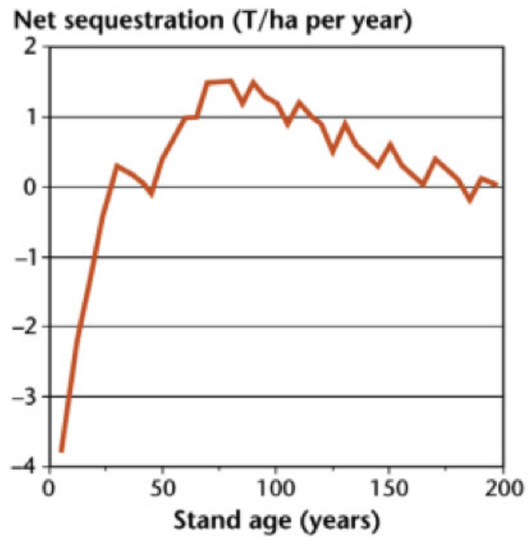


Figure 6 a & b. Carbon storage and sequestration in a boreal forest stand in northeast BC after fire.[72]

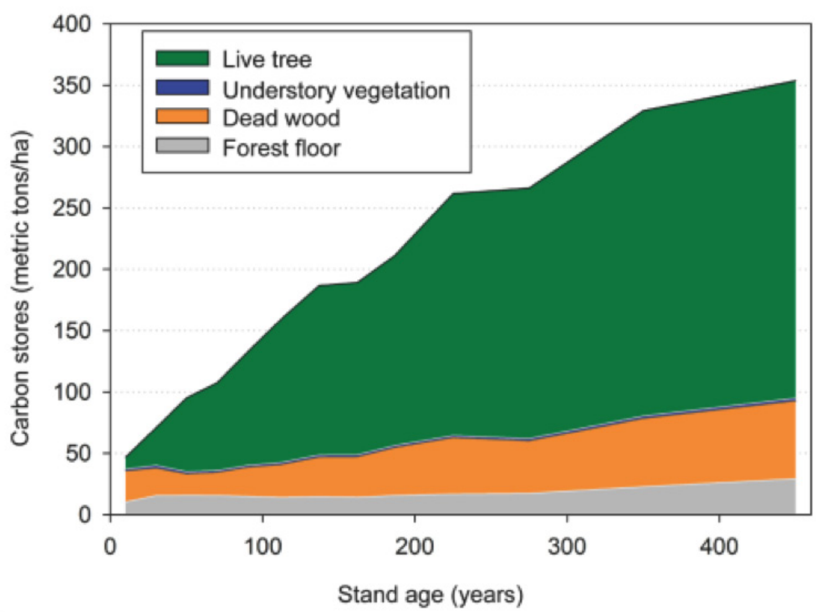


Figure 7. Dynamics of carbon storage over time in forests of Oregon and Washington.[73]

The conversion of mature and old forests to young forests, whether through logging or natural stand-replacing disturbances, results in an increased release of carbon immediately and for several years thereafter. This is because a) clearcutting generally leaves minimal carbon sinks (living trees and other plants) on the cutblock; b) a large pulse of carbon is lost immediately after logging due to the removal of trees and to the associated fossil fuel emissions; and c) disturbance to the soil and the original vegetation,

72 Greig M, Bull G. 2008. Carbon management in British Columbia's forests: Opportunities and challenges. Forrex Forum for Research & Extension in Natural Resources, Kamloops, BC. Forrex Series 24. http://www.forrex.org/publications/forrexseries/fs24.pdf

73 Gray A, Whittier T. 2017. There's carbon in them thar hills: But how much? Could Pacific Northwest forests store more? *Science Findings* 195. USDA, Pacific Northwest Research Station, Portland, OR. https://www.fs.fed.us/pnw/sciencef/scifi195.pdf

and sometimes warming of the site, results in an increased rate of decomposition of coarse woody debris, litter, and soil organic matter, whereby losses of CO_2 due to respiration exceed the amount fixed through photosynthesis by the regenerating forest—for at least a decade.[74,75] Moreover in managed forests the overall carbon store is reduced if the secondary forests are managed on typical commercial rotations.[76,77,78]

For example, logging old-growth spruce forests in central BC and converting them to managed forests reduced total carbon storage (initially 324–423 t C/ha) by 41–54%.[79] In inland temperate rainforest southeast of Prince George, clearcut logging in old-growth stands dominated by western redcedar and western hemlock reduced total carbon storage by 64% (from about 455 to 99 t C/ha).[80] In another example, a Pacific Northwest study[81] found that:

- total carbon storage in a 450-year old Douglas-fir – western hemlock forest was more than twice that in a 60-year old plantation;
- conversion of a typical Pacific Northwest old-growth forest to a young secondary (post-logging) forest reduces carbon storage by 305 t C/ha during one 60-year rotation, even when off-site storage of carbon in wood products in buildings is included.
- harvesting old-growth forests reduced total carbon storage for at least 250 years.

Logging old-growth forests and converting them to managed forests can reduce total carbon storage by 40–50% or more,[82,83] even when off-site storage of carbon in wood products in buildings is factored in.[84] The carbon dynamics are sensitive to rotation length, proportion of felled wood that becomes wood products in long-term storage (reportedly 25–40% for BC wood used domestically), [85] and longevity of storage. Construction materials such as lumber, plywood, house logs, and laminated beams can last for many decades but wood products include paper and pulp materials (office paper, toilet tissue, paper towels, cardboard packaging, disposable diapers) as well as pallets and pellets, all of which have much shorter lifespans. Conventional short rotations and relatively short 'life cycle' even of long-lasting wood products (often reckoned to be 50–70 years in both cases, although some storage persists beyond 100 years[86]) probably result in a significant one-time net loss of ca 100 to 300 t C/ha.

A managed secondary forest could recapture the lost forest carbon if allowed to regrow long enough to fully recover its carbon stock, and that could be achieved more quickly and easily in most interior forests than in coastal or interior wetbelt forests. Over subsequent rotations, such a managed forest could approach carbon neutrality—but never achieves it because of inefficiencies in converting trees to wood

74 Fredeen and others. 2007. *Op cit.*

75 Luyssaert and others. 2008. *Op. cit.*

76 Nelson EA, Sherman GG, Malcolm JR, Thomas SG. 2007. Combating Climate Change Through Boreal Forest Conservation: Resistance, Adaptation, and Mitigation. Unpubl. report for Greenpeace Canada. Faculty of Forestry, University of Toronto, Toronto, ON. 50 p.

77 Mackey B, Keith H, Berry SL, Lindenmayer DB. 2008. Green carbon: the role of natural forests in carbon storage. Part I, A green carbon account of Australia's south-eastern Eucalypt forest, and policy implications. ANU E Press, Canberra, Australia. 47 p.

78 Common Misconceptions about Forest Carbon. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/tree-species-selection/misconceptions_forest_carbon.pdf Accessed 20Nov2018.

79 Fredeen and others. 2005. *Op. cit.*

80 Matsuzaki E, Sanborn P, Fredeen AL, Shaw CH, Hawkins C. 2013. Carbon stocks in managed and unmanaged old-growth western redcedar and western hemlock stands of Canada's inland temperate rainforests. *Forest Ecology & Management* 297: 108–119. http://dx.doi.org/10.1016/j.foreco.2012.11.042

81 Harmon ME, Ferrell WK, Franklin JF. 1990. Effects on carbon storage of conversion of old-growth forests to young forests. *Science* 247: 699–702.

82 Fredeen and others. 2005. *Op. cit.*

83 Matsuzaki and others. 2013. *Op. cit.*

84 Harmon and others. 1990. *Op. cit.*

85 Common Misconceptions about Forest Carbon. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/tree-species-selection/misconceptions_forest_carbon.pdf Accessed 20 Nov 2018.

86 BC Ministry of Forests, Lands, and Natural Resource Operations. 2013. Climate mitigation potential of British Columbian forests: Growing carbon sinks. Victoria, BC. 29 p.

products and the emissions associated with the machinery of logging, wood processing, and product shipping.

> ***"... old-growth forests are usually carbon sinks. Because old-growth forests steadily accumulate carbon for centuries, they contain vast quantities of it. They will lose much of this carbon to the atmosphere if they are disturbed, so carbon-accounting rules for forests should give credit for leaving old-growth forest intact."[87]***

What About Beetles and Wildfires?

How is climate change affecting the carbon balance sheet? There is evidence that global warming is resulting in increased release of forest carbon into the atmosphere, in some cases flipping forests from being carbon sinks to carbon sources. For example, for more than 10 years BC's forests have lost more carbon than they have absorbed. This means that overall the province's forests are now a source of emissions, whereas in previous decades they were a carbon sink.

A 2015 analysis of provincial government data by Sierra Club BC showed net forest emissions of 250 million tonnes of CO_2 between 2003 and 2012 (equivalent to more than four times BC's official annual emissions). This is in contrast to the 441 million net tonnes of CO_2 the forests still absorbed between 1993 and 2002. The increased releases have been attributed primarily to increased wildfire and insect outbreaks,[88,89,90,91,92] but logging also contributes to the problem. Between 2003 and 2012, emissions from logging were 520 million tonnes of CO_2 (after accounting for carbon stored in wood products).[93] Despite the recent shocks of bark beetle epidemics and forest fires in BC, increased insect outbreaks and wildfires could still have less impact than logging on carbon stores.

Beetles

A forest attacked by mountain pine beetles (or by spruce, Douglas-fir, or balsam bark beetles) is still very much alive, even if all the canopy trees are dead. It is not 'devastated'; it still functions as a forest and continues to provide a variety of ecosystem services. Soil is still undisturbed with intact, below-ground carbon stocks. The standing or ultimately fallen dead wood persists for a long time, especially in the relatively cold dry climates of central interior BC, decomposing slowly while a secondary forest grows up.[94,95] Post-beetle forests often still have lots of green trees, especially in the understory. The stands

87 Luyssaert and others. 2008. *Op. cit.*

88 Bond-Lamberty, B, Peckham SD, Ahl DE, Gower ST. 2007. Fire as the dominant driver of central Canadian boreal forest carbon balance. *Nature* 450: 89-93.

89 Goetz SJ, Bunn AG, Fiske GJ, Houghton RA. 2006. Satellite-observed photosynthetic trends across boreal North America associated with climate and fire disturbance. *PNAS* 102: 13521-13525.

90 Kurz WA, Dymond CC, Stinson G, Rampley GJ, Neilson ET, Carroll AL, Ebata T, Safranyik L. 2008. Mountain pine beetle and forest carbon feedback to climate change. *Nature* 452: 987-990.

91 Kurz, Stinson, Rampley, Dymond, Neilson. 2008. *Op. cit.*

92 BC Ministry of Forests, Lands, and Natural Resource Operations. 2013. Climate mitigation potential of British Columbian forests: Growing carbon sinks. Victoria, BC. 29 p.

93 Wieting, J. 2018. B.C.'s climate action must address three elephants in the room. *Narwhal* OPINION. https://thenarwhal.ca/b-c-s-climate-action-must-address-three-elephants-in-the-room/

94 Brown PM, Shepperd WD, Mata SA, McClain DL., 1998. Longevity of windthrown logs in a subalpine forest of central Colorado. *Can. J. For. Res.* 28: 932–936.

95 Brown MG, Black TA, Nesic Z, Fredeen AL, Foord VN, Spittlehouse DL, Bowler R, Burton PJ, Trofymow JA, Grant NJ, Lessard D. 2012. The carbon balance of two lodgepole pine stands recovering from mountain pine beetle attack in British Columbia. *Agricultural & Forest Meteorology* 153: 82–93. doi:10.1016/j.agrformet.2011.07.010

can be complex, with a mix of species and age classes and with lots of vertical and horizontal structure, a variety of layers, patches and coarse woody debris (dead wood standing and on the ground). The surviving understory trees and other vegetation are released from suppression and respond with carbon uptake and biomass growth.

Figure 8a & b. Partial attack by mountain pine beetle, between Topley and Granisle, wc BC.

Figure 9a & b. Advance regeneration and secondary stand structure in beetle-affected forests near Tweedsmuir Park. D. Coates

The carbon dynamics of such stands can be resilient to beetle attack. "The prediction that stands in the central interior of BC would quickly become C sources and remain so for several [decades] (Kurz et al. 2008) has not proven to be true" at two contrasting study sites north of Prince George.[96] Subsequent studies concluded that 1) refraining from salvage-logging stands attacked by mountain pine beetles is a beneficial management strategy from both carbon sequestration and hydrologic perspectives,[97] and 2) carbon fluxes in attacked stands recovered (due to residual live trees and understory) and returned the stands to carbon sinks within a decade,[98] similarly suggesting that a no-salvage strategy can improve the carbon balance of attacked stands.

96 *Ibid.*

97 Meyer G, Black TA, Jassala RS, Nesica Z, Granta NJ, Spittlehouse DL, Fredeen AL, Christen A., Coops NC, Foord VN, Bowler R. 2017. Measurements and simulations using the 3-PG model of the water balance and water use efficiency of a lodgepole pine stand following mountain pine beetle attack. *Forest Ecology & Management* 393: 89-104. https://doi.org/10.1016/j.foreco.2017.03.019

98 Meyer G. and others. 2018. Simulation of net ecosystem productivity of a lodgepole pine forest after mountain pine beetle attack using a modified version of 3-PG. *Forest Ecology & Management* 412: 41-52. https://doi.org/10.1016/j.foreco.2018.01.034

Wildfire

There is some relationship between insect outbreaks and fire risk and hazard,[99] but large catastrophic fire does not automatically follow on the heels of an insect epidemic.[100] Research on impacts of mountain pine beetle outbreaks on fire suggests that post-beetle wildfire is not a given, nor can the location and severity of fires be predicted. [101] Dead needles in the tree crowns result in a higher probability of fire crowning, faster rates of fire spread, and increased fire intensity, as well as more long-range spotting—but only as long as the needles stay on the dead trees. Once the dead needles have fallen, dead stands of pine may be no more likely to burn than live.[102] By the time the dead pines fall down, fire hazard will have decreased, but if fire does break out, surface fire would be more intense and crowning in the remaining live tree canopy would be more probable.

When a forest burns, the majority of its biomass usually remains on site, where it subsequently decays and slowly releases carbon. Carbon persists in the charcoal and charred tree boles (which are highly resistant to decomposition) for a very long time, with residence times of several thousands of years.[103] Logging removes 50-80% of a forest's total above-ground biomass[104] and 40-60% of tree carbon,[105] only some of which ends up in wood products (Fig. 10). Forest fires consume much less, perhaps 5-15% of above-ground woody biomass,[106] and fire rarely entirely burns large landscapes.[107]

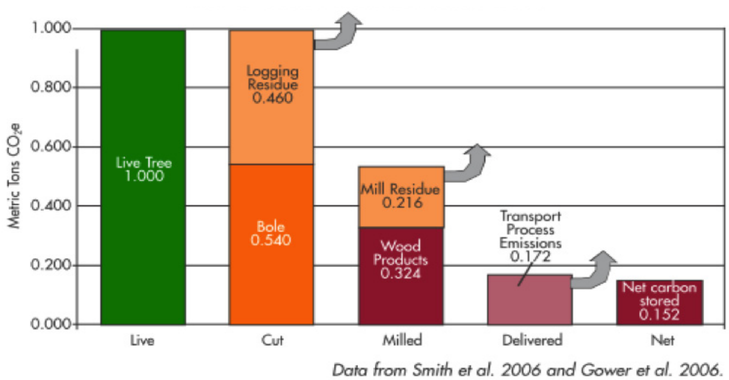


Figure 10. Fate of carbon from harvested wood.[108]

Given the growing evidence that some forest ecosystems are losing their capacity for sequestration of CO_2, due in part to the increasing frequency, severity and scale of natural disturbances,[109] a carbon stewardship strategy should be targeted at specific, less-disturbance-prone forest types.

99 Jenkins MJ, Hebertson E, Page W, Jorgensen CA. 2008. Bark beetles, fuels, fires and implications for forest management in the Intermountain West. *Forest Ecology & Management* 254: 16-34.

100 Parker TJ, Clancy KM, Mathiasen RL. 2006. Interactions among fire, insects and pathogens in coniferous forests of the interior western United States and Canada. *Agricultural & Forest Entomology* 8: 167-189.

101 Hart, SJ, Schoennagel T, Veblen TT, Chapman TB. 2015. Area burned in the western United States is unaffected by recent mountain pine beetle outbreaks. *PNAS* 112: 4375-4380. https://www.pnas.org/content/pnas/112/14/4375.full.pdf

102 Romme WH, Clement J, Hicke J, Kulakowski D, MacDonald LH, Schoennagel TL, Veblen TT. 2009. Recent Forest Insect Outbreaks and Fire Risk in Colorado Forests. Colo. St. U. Dept. For. Rangeland & Watershed Stewardship; Colo. For. Restoration Inst. http://welcome.warnercnr.colostate.edu/images/docs/cfri/cfri_insect.pdf

103 DeLuca TH, Aplet GH. 2008. Charcoal and carbon storage in forest soils of the Rocky Mountain West. *Frontiers Ecol. & Environ.* 6: 18-24. doi:10.1890/070070

104 Gower ST. 2003. Patterns and mechanisms of the forest carbon cycle. *Annual Review of Energy and Environment* 28: 169-204.

105 BC Ministry of Forests, Lands, and Natural Resource Operations. 2013. Climate mitigation potential of British Columbian forests: Growing carbon sinks. Victoria, BC. 29 p.

106 Brown R. 2008. The Implications of Climate Change for Conservation, Restoration, and Management of National Forest Lands. Report for the National Forest Restoration Collaborative, Portland, OR. 32 p.

107 Kashian DM, Romme WH, Tinker DB, Turner MG, Ryan MG. 2006. Carbon storage on landscapes with stand-replacing fires. *BioScience* 56: 598-606.

108 Ingerson. 2007. *Op. cit.* [Smith and others. 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. USDA Forest Service, General Technical Report NE-343. Northeastern Research Station, Newtown Square, PA; Gower ST and others. 2006. Following the Paper Trail: The Impact of Magazine and Dimensional Lumber Production on Greenhouse Gas Emissions. H.J. Heinz III Center for Science, Economics and the Environment, Washington, DC.]

109 Millar CI, Stephenson NL. 2015. Temperate forest health in an era of emerging megadisturbance. *Science* 349: 823-826. DOI: 10.1126/science.aaa9933

Permanence

The case for forests as carbon sinks has been criticized around the issue of permanence. The critics claim that forests are at best only temporary carbon sinks because eventually the trees will die, the forests will succumb to insects, disease, drought, fire, logging. Indeed some forests will succumb or are already on the way out but most BC forests will not just burn up, die off or self-destruct in the next 30 years. The genetic and taxonomic composition of our forests is changing and will continue to change over time, yet natural forests will carry on fixing and storing carbon for as long as there is adequate water and solar radiation for photosynthesis. And some of these forests can get really old—ancient even—and carry on functionally intact for a very long time, for several centuries or even millenia. It depends on the disturbance regime that prevails in the region or ecological zone in which the forest occurs. If stand-replacing disturbances are rare or infrequent, as they are in wet coastal forests[110] and many wet subalpine[111] and interior wetbelt[112,113] forests (Figs. 11, 12, 13), the majority of the landscape will be occupied by old forests and most of them will just keep ticking along, taking up and storing carbon.[114]

Figure 11. Coastal temperate rainforest, VJ Krajina Ecological Reserve, Haida Gwaii. W. MacKenzie

Trees can get very old but they don't live forever. If a forest does not experience a stand-replacing disturbance, as it ages individual or small groups of trees continually die and are replaced in what is called gap dynamics; the forest carries on with new recruits. Moreover, although all BC forests will eventually be replaced—suddenly, episodically, or gradually—they currently are carbon banks and their stored carbon has much greater **time value** now and in the crucial next three decades than anticipated, post-logging carbon storage recouped over the ensuing seven or more decades. Regardless of whether BC forests are a net source or a sink at any given moment, they continue to store megatonnes of carbon as long as they still have trees on site—even if the trees are dead.

110 Parish R, Antos JA. 2006. Slow growth, long-lived trees, and minimal disturbance characterize the dynamics of an ancient, montane forest in coastal British Columbia. *Can. J. Forest Research* 36: 2826–2838.

111 Hallet DJ, Lepofsky DS, Mathewes RW, Lertzman KP. 2003. 11,000 years of fire history and climate in the mountain hemlock rain forest of southwestern British Columbia. *Can. J. Forest Research* 33: 292–312.

112 Sanborn P, Geertsema M, Jull AJT, Hawkes B. 2006. Soil and sedimentary charcoal evidence for Holocene forest fires in an inland temperate rainforest, east-central British Columbia, Canada. *Holocene* 16:415–427.

113 Gavin DG, Hu FS, Walker IR, Westover K. 2009. The northern inland temperate rainforest of British Columbia: old forests with a young history? *Northwest Science* 83: 70–78.

114 Daniels L, Gray W. 2006. Disturbance in coastal British Columbia. *BC Journal Ecosystems & Mgmt.* 7: 44–56.

Figure 12. Wet subalpine forest, Kuldo Lake, Skeena.

Figure 13. Inland temperate rainforest, Kwinageese Lake, Nass Basin.

Forest Management = Carbon Stewardship?

Some forest industry and government agency representatives argue that forest management does not result in substantial emissions of greenhouse gases, that indeed it could actually help slow global warming. The line of reasoning is that when forests are logged, the carbon that they store is transferred to long-lasting forest products, and the young replacement forests rapidly absorb more carbon. This argument is flawed on several counts.

- ➔ It assumes that most if not all of the carbon from the logged forest is transferred to wood products. But most forest carbon is lost as residues from harvesting (40-60% of tree carbon to waste and breakage in cutblocks) or processing (pulp chips, hogfuel, sawdust, shavings). Some carbon goes into short-lived products such as paper and pallets. Only a small fraction (see Fig. 10) is processed into 'longer-lived' products such as dimensional lumber, panels, plywood, house logs—especially if the logged forests were old with lots of decay and cull wood.

In recent years in parts of BC (such as the north coast or middle Nass-Skeena valleys) it has been common practice to clearcut decay-rich old growth, retrieve (high-grade) less than 15% of the volume as saw logs/whole logs, and in the absence of a pulp mill or favourable pulp market, push the rest of the trees into huge piles (Fig. 14) and burn them or let them rot.

- ➔ Wood products in practice often don't last very long. Product half-lives are about 2-3 years for paper and shipping materials, and between 30 and 90 years for sawn wood,[115,116] usually not several hundred years as some claim. Wood products often end up in landfills, where their

115 Nelson and others. 2007. *Op. cit.*

116 BC Ministry of Forests, Lands, and Natural Resource Operations. 2013. Climate mitigation potential of British Columbian forests: Growing carbon sinks. Victoria, BC. 29 p.

carbon can be 'stored' if the wood isn't incinerated. Reportedly 44% of carbon in paper and 77% of carbon in wood can be stored for decades or centuries in landfills,[117] where however there is potential for increased emissions of methane. Capturing and burning methane and waste wood from landfills can substitute for fossil fuel use, but these are not regular practices.

Figure 14 a & b. Slash piles, McCully Creek, Kispiox Valley, 2016.

- ➔ The considerable surface area of logging roads and landings represents a significant loss of carbon storage potential. In BC these 'access structures' are allowed to occupy up to 7% of cutblock area.[118] However, most unsurfaced winter logging roads (more than half of cutblock roads in the interior) rather quickly become revegetated, although their tree-growing productivity has been degraded. Eventually a forest usually grows back even on 'permanent' roads unless they are maintained.

- ➔ The machinery of industrial forestry—logging, transporting, processing, shipping machinery—burns a lot of fossil fuel. The resultant emissions are not consistently factored into the carbon accounting.

- ➔ Forests generally are carbon sinks that remove carbon from the atmosphere and store it as above- and below-ground organic matter (living and dead). Producing lumber or moving wood products to landfills involves removing wood from the forest pool, and processing and relocating that wood. This processing and transfer do not sequester carbon, rather they shift some of the stored carbon elsewhere and release to the atmosphere other carbon, from the forest pool and from the burning of fossil fuels. The net result is an increase in atmospheric carbon; more emissions than if the wood was left in the forest pool—even if carbon uptake by the regenerating forest is factored in. There is some disagreement on that conclusion, depending on the models and their spatial and temporal scales.

117 BC Ministry of Forests, Lands, and Natural Resource Operations. 2013. Climate mitigation potential of British Columbian forests: Growing carbon sinks. Victoria, BC. 29 p.

118 B.C. Forest and Range Practices Act. 2004. Forest Planning and Practices Regulation, Section 36. http://extwprlegs1.fao.org/docs/html/bc77961.htm#section36

Is Intensive Forest Management the Answer?

Some assert that intensive, short-rotation 'agroforestry' could maximize carbon storage. How does that work? Thrifty young forest plantations fix lots of carbon, and over time long-lasting wood products could substitute for fossil-fuel-intensive materials like concrete and steel.

The agroforestry + wood products strategy emphasizes carbon **uptake** (a rate or flux, which usually is greater in juvenile forests) over that of carbon **storage** (a state or pool, which is cumulative and greater in older forests). The C uptake rate and the C storage pool are both important in carbon stewardship, but both cannot be optimized on the same piece of land.

The strategy also assumes that old forests exhibit little or no increase in carbon storage, which is a false assumption. Proponents of this strategy also may assume that initial stores of carbon are zero, which is not the case in BC production forestry because it is practiced on previously forested land.

Intensive forest management typically draws down the carbon pool by increasing the frequency and intensity of disturbance, thereby reducing amounts of coarse woody debris and of forest floor and soil organic matter, resulting in lower levels of dead carbon storage—to say nothing of negative impacts on forest biodiversity. [119,120,121,122,123] The consensus of scientific opinion appears to be that logging primary, mature and old forests for wood products and converting them into intensively managed plantations releases large and essentially unrecoverable amounts of carbon to the atmosphere. The intensively managed, short-rotation stand will not attain the original levels of carbon storage (Fig. 15), thus incurring a permanent 'carbon debt'. Landscapes dominated by mature and older forests can store several times as much carbon as intensively managed, industrial forest landscapes. [124]

119 Harmon ME, Franklin JF, Swanson FJ, Sollins P, Gregory SV, Lattin JD, Anderson NH, Cline SP, Aumen NG, Sedell JR, Lienkaemper GW, Cromack Jr K, Cummins KW. 1986. Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15: 133-302.

120 Krankina ON, Harmon M. 1995. Dynamics of the dead wood carbon pool in northwestern Russian boreal forests. *Water Air & Soil Pollution* 82: 227-238.

121 Dorner B, Wong C. 2003. Natural disturbance dynamics in Coastal BC. FORREX report.

122 Caza C. 1993. Woody debris in the forests of British Columbia: a review of the literature and current research. Land Management Report Number 78, British Columbia Ministry of Forests, Victoria, B.C.

123 Erb K-H, Kastner T, Plutzar C, Bais ALS, Carvalhais N, Fetzel T, Gingrich S, Haberl H, Lauk C, Niedertscheider M, Pongratz J, Thurner M, Luyssaert S. 2018. Unexpectedly large impact of forest management and grazing on global vegetation biomass. *Nature* 553(7686): 73–76. doi:10.1038/nature25138.

124 Brown R. 2008. The Implications of Climate Change for Conservation, Restoration, and Management of National Forest Lands. Report for the National Forest Restoration Collaborative, Portland, OR. 32 p.

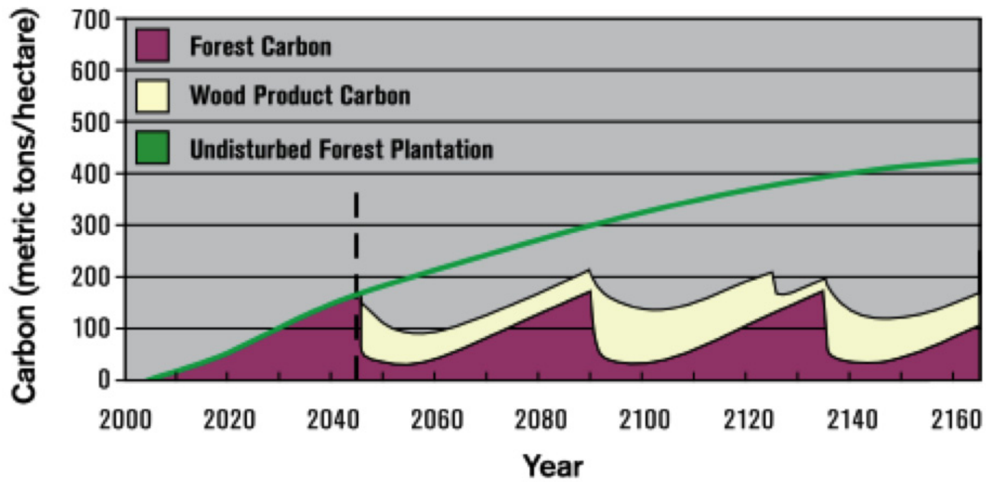


Figure 15. Projected carbon stores in a Pacific Northwest forest clearcut then regenerated in year 2000 under a no-harvest regime (green line) and a 50-year rotation with three clearcuts and a commercial thinning (solid areas).[125]

The benefits of carbon storage by intact natural forests are **immediate** and greater than anticipated storage (more accurately, avoided emissions) in wood products in the future. The net emissions abatement is upfront, immediate, and substantial.[126] If the wood products substitute for concrete and steel in construction, the presumed benefits would be cumulative and would exceed the carbon storage of an unlogged forest only ofter several to many decades, if ever.

Substitution?

Even though carbon storage in wood products will always be less than in an undisturbed forest (because of inherent inefficiencies in converting trees to wood products), the intensive forestry + wood products strategy could in principle be carbon-friendly in the long run, if indeed wood substitutes in a huge way for other construction materials—especially concrete.[127]

But substitution is problematic as a long-term solution to excessive GHG emissions. The substitution effect is likely to be marginal and is very sensitive to assumptions about technology used over a product life cycle and to the time frame considered. Substitution also requires a favourable policy and regulatory environment, and to determine its benefits you need a way to document and quantify it.

The product-substitution scenario would have to satisfy the criteria for any other carbon-offset program—namely, baseline, additionality, leakage, and permanence. Generally to be credited as a carbon offset, an activity must: 1) be additional in that it represents a carbon benefit that would otherwise not occur (the scenario without the activity is the baseline); 2) be permanent, often taken to mean lasting for at least 100 years; and 3) avoid leakage, which would occur if the activity led to carbon emissions elsewhere. [128]

125 Brown. 2008. *Op cit.*

126 Keith H, Lindenmayer D, Macintosh A, Mackey B. 2015. Under what circumstances do wood products from native forests benefit climate change mitigation? *PLoS ONE* 10(10): doi:10.1371/journal.pone.0139640

127 Perez-Garcia, JB and others. 2005. An assessment of carbon pools, storage, and wood products market substitution using life-cycle analysis results. *Wood and Fiber Science* 37: 140-148.

128 Brown R. 2008. *Op. cit.*

Few projects in BC qualify as carbon offsets. Offsetting is a rigorous process that requires a serious commitment (mainly financial) from industry; it can serve as a bottom-up approach in the province's efforts to combat climate change.

Government researchers are also determining the overall baseline for BC's forest product industry and the competing product (cement, steel) and energy process (e.g., natural gas, hydroelectricity, coal) industries. This top-down approach can inform policy makers on the role of BC forests in mitigating climate change, and help assess possible outcomes of new forest carbon legislation and regulations. For example, the province has already established a carbon tax on fossil fuel emissions, but not on undesirable forest emissions (e.g., slash burning).

Both of these approaches to carbon management are limited in scope and are not complementary. Carbon offsets require assurance of sustainable forest management, while the substitution approach requires assurance that forest products actually do offset competing products and processes. These are tall orders given the ambiguity of current forest carbon management in BC.[129]

In terms of carbon stewardship and climate change mitigation, the agroindustrial approach to forest management has been called a "losing proposition".[130] But afforestation makes sense, as does converting some pasture land or marginal cropland to wood plantations. Replacing persistent old carbon-rich forests with juvenile plantations does not make sense in the present dire circumstances.

Will Trees Grow Faster As Climate Warms & Carbon Dioxide Levels Rise?

Yes some of them will, in some parts of the province, especially in the north and at high elevations. But as climate warms, drought stress is increasing in warmer drier areas. Even in wetter areas, moisture stress can increase because higher temperatures result in greater water loss through evapotranspiration. Moreover, the effects of CO_2 fertilization have generally been shown to be short-lived for trees, which eventually end up respiring away most of the carbon that they photosynthesize.[131]

Wildfires are becoming more frequent and intense, forest insect pests and diseases are causing more problems. Many of BC's intensively managed forests have simplified stand structure and low tree species diversity, further reducing their resilience to climate change and to forest pests and diseases. Given the amount of climate change since 1960, some of our older (40–50+ years) secondary forests could already consist of genetically maladapted trees.

129 W. Klopp, pers. com. Dec. 2018.

130 Vitousek PM. 1991. Can planted forests counteract increasing atmospheric carbon dioxide? *Journal of Environmental Quality* 20: 348–354.

131 Körner C, Asshoff R, Bignucolo O, Hättenschwiler S, Keel SG, Peláez-Riedl S, Pepin S, Siegwolf RT, Zotz G. 2005. Carbon flux and growth in mature deciduous forest trees exposed to elevated CO2. *Science* 309(5739): 1360-2. https://doi.org/10.1126/science.1113977

> *"Because plants fix carbon dioxide (CO_2) by photosynthesis and store carbon in their body (close to half of plant dry matter is carbon), faster carbon uptake by plants through faster growth is widely held to increase carbon sequestration. Yet, this assumption is supported by neither theory nor evidence. Faster tree growth stimulated by rising carbon dioxide levels does not translate into more long-term carbon storage in forests. Any gain in carbon storage from faster tree growth will be transitory. Tree longevity rather than growth rate controls the carbon capital of forests."*[132]

What About Bioenergy from Wood?

> *"A push to promote wood as a source of renewable, low-carbon energy has set off a debate among scientists about the implications for the climate and forest ecosystems. Much of the discussion has revolved around forests in the southeastern United States, where a wood pellet industry is booming as the region supplies wood for European power plants, where the fuel has been deemed 'carbon neutral.' Other parts of the world are also starting to tap into wood for electricity. Some scientists say that sustainable logging for energy recycles carbon as new forests grow back. But others caution this process could take decades, whereas carbon emissions from burning the wood are happening now."*[133]

Burning Forests

The use of woody biomass for energy (beyond internal use in the forest sector) has been increasing in BC over the past two decades. This is due to:

- Greater demand for woody fuel because of a) higher costs for traditional energy sources (fossil fuels, hydroelectric) and b) more "awareness of the negative effects of generating energy from these traditional (commercial) sources."[134]
- A glut of 'feedstock'. "On the supply side, woody biomass sources are increasing as a result of insect outbreaks, fires or measures to minimize the risk of such events",[135] **and because** there is a) less broadcast burning of slash than in previous decades and b) much more wood left behind by high-grading and other wasteful logging practices.

Economic opportunities were identified, in particular in BC for producing wood pellets—largely for

132 Körner, C. 2017. Carbon sequestration: A matter of tree longevity. *Science* 355: 130–131. doi: 10.1126/science.aal2449

133 Cornwall W. 2017. The burning question. *Science* 355: 18–21. DOI: 10.1126/science.355.6320.18

134 Stennes B, McBeath A. 2006. Bioenergy options for woody feedstock: are trees killed by mountain pine beetle in British Columbia a viable bioenergy resource? Can. For. Serv. Pacific For. Centre. Info. Rep. BC-X-405. Victoria, BC.

135 *Ibid.*

export—from the sawmill residue of interior forests that were salvage-logged after being attacked by the mountain pine beetle. The emergent opportunities unsurprisingly were accompanied by some extravagant claims and dubious information.

FLIMFLAM AND GREENWASH

"Wood pellets are one way to help fight climate change. They reduce the amount of carbon dioxide released into the atmosphere when they replace a non-renewable source of energy such as coal or oil. Unlike fossil fuels, pellets are carbon-neutral since the wood is part of the current carbon cycle. Wood pellets are also environmentally friendly as they generate heat without contributing particulate to the atmosphere."[136]

"BENEFITS OF USING WOOD PELLET FUEL: Carbon Neutral – Trees absorb carbon dioxide as they grow. This stored carbon dioxide is released when the biomass is burned to generate energy and is absorbed during forest regeneration. No new atmospheric carbon dioxide is produced under a sustainably managed forest system, and for every ton of coal that is replaced by wood pellets, there is a corresponding 1.7-ton reduction in carbon dioxide emissions."[137]

Some proponents of forest bioenergy argue that it is by definition carbon neutral because growing trees once fixed all the carbon that is eventually released by burning; alternatively that it is carbon neutral because the harvested forests eventually grow back, reabsorbing all carbon emitted during wood fuel combustion.

Not so fast. "The critical issue for carbon neutrality … is not past sequestration of carbon embodied in fuels, but whether releases are offset by future carbon stores."[138] "Carbon neutrality is not an appropriate *a priori* assumption for biomass energy."[139] "The immediate impact of substituting wood for coal is an increase in atmospheric CO_2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clearcut, depending on forest type—assuming the land remains forest. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue."[140]

Yes, logged forests can be renewed but carbon neutrality for forest biomass means that all emissions from the harvesting, transport, processing, and burning of trees and wood products are offset by future carbon stores.[141, 142] That is unlikely and would take many years—in BC perhaps 70 to 400+ years, if at all. Some logged, old-growth coastal (Fig. 16) and interior wetbelt (Fig. 17) forests may never recover their original carbon storage capacity.

Yes, wood is renewable in the long term; wood bioenergy uses carbon that is already within the biosphere; and wood biofuel can substitute for fossil fuel. But wood typically has one-third to one-quarter the

136 2010. British Columbia's Wood Pellet Industry. www.bcbioenergy.com accessed 12 Sept 2018.

137 http://www.pacificbioenergy.ca/our-products/ accessed 12Sept2018.

138 Ingerson. 2007. *Op. cit.*

139 Dale VH, Kline KL, Marland G, Miner RA. 2015. Ecological objectives can be achieved with wood-derived bioenergy. *Frontiers in Ecology & Environment* 13: 297-299.

140 Sterman JD, Siegel L, Rooney-Varga JN. 2018. Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy. *Environ. Res. Lett.* 13 015007 https://doi.org/10.1088/1748-9326/aaa512 Accessed 20Dec2018.

141 Schlesinger WH. 2018. Are wood pellets a green fuel? *Science* 359: 1328-1329.

142 Ter-Mikaelian MT, Colombo SJ, Chen JX. 2015. The burning question: does forest bioenergy reduce carbon emissions? A review of common misconceptions about forest carbon accounting. *J Forestry* 113: 57–68. https://doi.org/10.5849/jof.14-016 Accessed 9Dec2018.

specific energy (MJ/kg; aka energy density) of coal or other hydrocarbons. [143,144] This means that, to get a unit of energy, you need to burn more wood relative to fossil fuels and more CO_2 will be put into the atmosphere with wood than with fossil fuels. Thus, wood burning results in **greater initial CO_2 emissions.** Pellets have greater specific energy than some unprocessed wood but still less than fossil fuels.

Figure 16. Old-growth cedar-hemlock forest, northern Vancouver Island. A. Inselberg

Figure 17. Old-growth cedar-hemlock forest, north of Revelstoke.

The carbon debate for and against burning of wood pellets or other forms of bioenergy could be clarified by better data on full-life cycle carbon accounting for different scenarios. A complete cost/benefit analysis would have to factor in carbon emissions from obtaining the wood and disturbing the soil, from processing the wood and transporting the product, and from burning the product, and would require the ability to track substitution calculations from cradle to grave for comparison and to clearly demonstrate that 'leakage' is not occurring.

In principle, wood pellets can be used to displace fossil fuels in the generation of electricity. It happens in Europe,[145] where wood pellets have ill-advisedly[146] been deemed carbon neutral, thereby ignoring the CO_2 emitted during processing and shipping and the losses of carbon stock from forests harvested in North America. This is an example of 'leakage'; the European offsetting results in CO_2 emissions elsewhere, effectively exporting the emissions.[147] Producing wood pellets in BC and shipping them to Europe can account for about 25% of the total carbon emissions from the use of wood pellets in European power plants.[148] Under international rules, these emissions are assigned to BC. Exporting pellets from BC thus results in increased reported emissions in BC. Marine transportation (typically by freighters burning very dirty bunker fuel) is a major contributor to negative environmental impacts.[149]

143 Brown R. 2008. *Op. cit.*

144 Wood is a low grade fuel, with a heat potential 2.5 times lower than that of diesel. In MJ/kg: propane 50; kerosene 46.5; diesel oil 45.6; fuel oil 43; natural Gas 37; coal 29.2; wood pellets 19.8. https://articles.extension.org/pages/69961/energy-basics . Accessed 9Dec2018.

145 Drouin, R. 2015. Wood pellets: Green energy or new source of CO2 emissions? Yale Environment 360 Yale School of Forestry & Environmental Studies https://e360.yale.edu Accessed 28Dec2018.

146 Isaacs, E. 2018. https://www.policyschool.ca/bioenergy-the-turning-tide-biomass-emissions-are-not-carbon-neutral-we-need-to-change-how-we-account-for-them/ Accessed 9Dec2018.

147 Schlesinger. 2018. *Op. cit.*

148 *Ibid.*

149 Pa A, Craven JS, Bi XT, Melin S, Sokhansanj S. 2012. Environmental footprints of British Columbia wood pellets from a simplified life cycle analysis. *Int J Life Cycle Assess* 17: 220-231. DOI 10.1007/s11367-011-0358-7

Most BC pellets are exported to Europe and Asia but there is a domestic market that could usefully be increased. Switching from traditional firewood and wood-burning appliances (plagued by low efficiency and high emissions) to pellets for residential heating in BC could have positive impacts locally on human health and air quality.[150]

Timing

A key issue for forest bioenergy is the time frame required to reach carbon neutrality. Bioenergy contributes carbon to the atmosphere, which will take several decades to recover as the young replacement forests grow and mature. In addition to the CO_2 emissions from combustion of woody biomass to produce energy, carbon losses start at harvest. For example, beyond the immediate removal of the trees, studies in BC's primary sub-boreal forests reveal that clearcutting decreases carbon stocks by approximately 100 tonnes per hectare, in addition to carbon emissions from soil disturbance.[151] This happens because below-ground respiration exceeds photosynthesis, contributing to an overall net increase in CO_2 emissions of 33 tonnes per hectare over 8 years, despite the 1-1.2 tonnes carbon sequestered per hectare by growing seedlings and saplings.[152]

Remember that, to get a unit of energy, you need to burn more wood relative to fossil fuels and more CO_2 has to be put into the atmosphere with wood than with fossil fuels. Thus, "wood burning is associated with greater initial carbon dioxide (CO_2) emissions. The CO_2 from the combustion of fuel (wood or coal) is released almost instantly, whereas the growth and regrowth of wood takes decades"[153] (mostly >75 years in BC). Burning wood or wood products from mature and old forests won't help reduce anthropogenic emissions of CO_2 to the atmosphere by 2040 or 2050. It takes time to regain the carbon storage on the landscape – i.e., to pay off the 'carbon debt'.[154] Moreover, if the imperative is to avoid carbon emissions now and reduce emissions 80% or achieve net zero emissions by 2050, it's the amount not the origin of the atmospheric CO_2 that really matters for the next few decades. "The atmosphere can't discriminate between molecules of carbon dioxide. CO_2 is CO_2 whether it comes from a tailpipe or a 'carbon neutral' stack."[155]

The Canadian Forest Service in 2010 concluded that on balance: "As long as the forest biomass comes from a sustainably managed forest and is replaced over time through regrowth, the GHG emission from the production of energy can be considered to offset—at least to a large extent—fossil fuel emissions. ... So using forest biomass provides energy and, at the same time, the forest continues to grow and recapture most of the carbon dioxide emitted by this energy production; however, this recapture takes at least as long as it takes the forest to regrow to the size it was when cut. Because forest bioenergy has a lower energy content than fossil fuels, in the short run it can actually generate higher CO_2 emissions than fossil fuels. But over time there is a net benefit to the atmosphere because the forest is renewable; ..."[156] Forests that are sustainably managed for wood products and energy have been shown to be associated with long-

150 Pa A, Bi XT, Sokhansanj S. 2013. Evaluation of wood pellet application for residential heating in British Columbia based on a streamlined life cycle analysis. *Biomass and Energy* 49: 109-122. http://dx.doi.org/10.1016/j.biombioe.2012.11.009

151 Fredeen AL. 2006. How is forest management influencing carbon storage in sub-boreal forests? Natural Resources and Environmental Studies Institute, Research Extension Note #06.01. Univ. Northern British Columbia, Prince George, BC. http://web.unbc.ca/~fredeena/Fredeen%20REN%202006.pdf

152 *Ibid.*

153 Schlesinger WH. 2015. Reply to Dale et al. letter invited by ESA. *Frontiers in Ecology & Environment* 13: 299.

154 *Ibid.*

155 Neads D. 2010. The problem with bioenergy. *The Kingfisher* 21: 22-23.

156 Canadian Forest Service. 2010. Is forest bioenergy good for the environment? Science Policy Note Fo93 1/6-2010E-pdf.

term reductions in atmospheric CO_2 emissions. [157,158]

In contrast, a 2012 editorial claims that "large-scale production of bioenergy from forest biomass is neither sustainable nor GHG neutral."[159] The forest bioenergy strategy "is likely to miss its main objective to reduce GHG emissions because depleted soil fertility requires fertilization that would increase GHG emissions, and because deterioration of current biomass pools requires decades to centuries to be paid back by fossil fuel substitution, if paid back at all. Further, shorter rotations would simplify canopy structure and composition, impacting ecosystem diversity, function and habitat."[160]

Nonetheless the Canadian Forest Service continues to promote the strategy of (purportedly) reducing GHG emissions by burning harvest residues to produce local bioenergy—mainly from combined heat and power facilities—that offsets fossil fuel sources. However, the supporting studies[161,162,163,164,165] apparently assume that the atmospheric benefits materialize because bioenergy displaces fossil fuel energy and emissions. As discussed above, CO_2 emissions will actually increase initially from such displacement and will not decrease in the short term.

Whereas protecting existing forests provides immediate net carbon benefits. Currently stored C has much greater **time value**. When forests are logged and soils are disturbed, they release a lot of C to the atmosphere immediately, and continue to be net carbon sources for a decade at least. Logging also results in lower rates of net C uptake for 3 to 4 decades, until rates in the secondary forest return to pre-harvest levels. So logging + residue management for bioenergy + prompt reforestation today will not help reduce GHG emissions by year 2050—unless the resulting wood products massively displace concrete and perhaps steel in construction.

A Sensible Approach?

It makes economic sense for forest product companies to utilize their mill residues in secondary processing for pulp and bioenergy. Environmentally there is a silver lining in that the residues are used instead of being incinerated in beehive burners as in the past. But if forest management is unsustainable, any environmental upside to utilizing residues can mask, or divert attention from, the overall negative impacts of the timber juggernaut on forest carbon and biodiversity.

It can also make economic sense to replace fossil fuel with biofuel from harvest residues to generate electricity in some remote, off-grid communities. "BC has 86 off-grid communities that rely on diesel for generating electricity."[166] The federal government recently launched a Clean Energy for Rural and Remote Communities program, with "$220 million over the next six years to reduce diesel use and transition to

157 Dale and others. 2015. *Op. cit.*

158 Ter-Mikaelian and others. 2015. *Op. cit.*

159 Schulze E-D, Körner C, Law BE, Haberl H, Luyssaert S. 2012. Large-scale bioenergy from additional harvest of forest biomass is neither sustainable nor greenhouse gas neutral. *Glob Change Biol Bioenergy.* 4: 611–616. doi: 10.1111/j.1757-1707.2012.01169.x

160 *Ibid.*

161 Smyth CE, Stinson G, Neilson E, Lemprière TC, Hafer M, Rampley GJ, Kurz WA. 2014. Quantifying the biophysical climate change mitigation potential of Canada's forest sector. *Biogeosciences* 11: 3515–3529.

162 Kurz WA, Smyth C, Lemprière TC. 2016. Climate change mitigation through forest sector activities: principles, potential and priorities. *Unasylva* 246: 61–67. http://www.fao.org/3/a-i6419e.pdf

163 Smyth C, Kurz WA, Rampley GJ, Lemprière TC, Schwab O. 2017. Climate change mitigation potential of local use of harvest residues for bioenergy in Canada. GCB *Bioenergy* 9: 817–832.

164 Howard C, Smyth C. 2018. Bioenergy Mitigation Potential: Refining Displaced Emissions from British Columbia's Heat and Electricity Production. Information Report BC-X-442. Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. 13 p.

165 Smyth CE, Smiley BP, Magnan M, Birdsey R, Dugan AJ, Olguin M, Mascorro VS, Kurz WA. 2018. Climate change mitigation in Canada's forest sector: a spatially explicit case study for two regions. *Carbon Balance Management* 13: 11. https://doi.org/10.1186/s13021-018-0099-z Accessed 29Dec2018.

166 Pacific Institute for Climate Solutions. 2018. Reducing slash burning emissions in BC: Facts, opportunities and challenges. Background document, Forest Carbon Management Project. Victoria, BC. 6 p.

renewable energy, bioenergy being a feasible option in some cases."[167] The biofuel may be renewable but burning it to generate electricity will not reduce GHG emissions in the short term, although emissions in remote communities are a very small fraction of BC's total emissions.

Some argue that greater production of biofibre (pellets) should be promoted because it could help reduce the air pollution from slashburning and the fire hazard (allegedly) posed by logging debris left in the bush. For that to work the slash would have to be retrieved and brought to a pellet plant or somehow processed on site in the cutblock. Both propositions are dodgy economically and both dodge the fundamental issue of poor harvest utilization and excessive logging debris. Such schemes—especially if subsidized by government, as is likely—could also provide a perverse incentive to continue wasteful logging practices.

In some proposals the sawmill residue would be topped up with logging residue from slash piles that occur within a certain radius (e.g., 40–50 km) around the bioenergy plant. What will happen in ensuing years as logging shifts from nearby salvage to more distant commercial stands and the number of slash piles within 40 km decreases?

As a primary industry with a continual demand for fibre, additional pressure likely would fall on natural forests to supply fibre during shortages of cheap and abundant mill residues. If there isn't a reasonable and reliable source of mill residues, presumably the wood would come from existing forests—perhaps including nearby stands currently considered inoperable or environmentally sensitive. Grinding up healthy, young and mature forests for pellets is an ill-advised use of wood. Logging old forests (including irreplaceable old growth) solely to produce pellets makes no sense economically, ecologically, or in terms of carbon stewardship. High-grading decay-rich old forests to retrieve only the 10–25% best sawlogs for milling or whole log export, while producing pellets from the mountains of bush residue, is also a bankrupt approach.

Salvage logging strictly to produce pellets from beetle-killed or fire-killed forests often isn't justified either, and compromises the recovery of already stressed forests.[168] Stands partially affected by beetles or fire often still have lots of residual live trees and/or advanced understory regeneration. They will continue to sequester and store carbon and provide wildlife habitat, and could contribute to mid-term timber supply, thus could be managed for continued provision of multiple values instead of mere salvage. Whereas it makes sense to salvage-log affected stands that are poorly stocked with residual live trees and prone to fire. Shifting harvest (for sawlogs or pulp, with pellets as a byproduct) to residual forests that have experienced stand-replacing disturbances could also be justified on a timber harvesting landbase that has more naturally disturbed, young forests than mature and old forests.

167 *Ibid.*

168 Burton, PJ. 2010. Striving for sustainability and resilience in the face of unprecedented change: The case of the mountain pine beetle outbreak in British Columbia. *Sustainability* 2: 2403–2423. doi:10.3390/su2082403

Summary

- Forests both absorb and release carbon, resulting in a dynamic balance that changes over time, depending on stand age and on type and intensity of disturbance. The relative balance between absorption and emission determines whether a particular forest ecosystem is a net carbon source or a sink. Depending on how they naturally function, and how they are managed, forests can therefore either contribute to or reduce greenhouse gas emissions and climate change.

- Old-growth forests steadily accumulate carbon for centuries. When old forests are logged, there is a net release of carbon to the atmosphere for decades and sometimes for over a century.

- Logging results not only in losses to above- and below-ground carbon stocks, but also in lower rates of sequestration for one to several decades, until rates of net carbon uptake in the secondary forest return to pre-harvest rates.

- On a landscape scale, industrial strength logging results in less carbon within managed forests than in wild or natural forests. The carbon stock of managed forests will be significantly less on average than that of natural, undisturbed forests.

- Whether BC forests are a net source or a sink, they continue to store megatonnes of carbon as long as they still have trees on site—even if the trees are dead. If we are serious about carbon stewardship we should protect more forest, especially old carbon-rich forests that have a good chance of being with us for decades and centuries to come (in other words, prioritized protection of productive and long-lived coastal, interior wetbelt, and wetter high-elevation forests).

- Although all BC forests will inevitably at some point be replaced, currently they are carbon banks. For the next 2-3 decades, their stored carbon has much greater time value than carbon uptake in contemporary juvenile forests; or than future anticipated carbon storage several decades hence. This is a key point that requires emphasis and repetition. Keeping forests buys us time to develop alternative energy strategies to reduce CO_2 emissions, to change our behaviour, and also to establish a lower GHG base level, thus reducing the ultimate impact from warming on the forests themselves.

- In terms of climate change mitigation, the benefits of carbon storage by intact natural forests are immediate and greater than anticipated storage in wood products in the future. Replacing persistent, old, carbon-rich forests with juvenile plantations does not make sense in the present dire circumstances.

- Bioenergy from wood can make economic sense as a secondary by-product industry, where there is 'waste' from existing processing facilities, such as sawmills. Pellet production from harvest residues could also help reduce the air pollution caused by slashburning, but it won't help reduce anthropogenic emissions of CO_2 to the atmosphere by 2040 or 2050. Large-scale production of bioenergy from forest biomass is not GHG neutral, nor is it sustainable or environmentally friendly.

- If the imperative is to avoid carbon emissions now and reduce emissions 80% or achieve net zero emissions by 2050, it's the amount not the origin of the atmospheric CO_2 that really matters.

In terms of GHG emissions, burning carbon-containing fuel to generate energy is generally undesirable, regardless of where the CO_2 comes from.

- Notwithstanding the "fierce urgency" of the next 2-3 decades, BC will probably need to pursue all feasible options to mitigate climate change, whether they provide short- or long-term GHG reduction benefits.

- It's not just about carbon. Forests are much more than mere carbon factories. Forests are key to sustaining the web of life/biodiversity; conserving natural capital and maintaining ecosystem services; maintaining habitat connectivity; and strengthening our Life Support System. Forests also have deep cultural and spiritual significance for humans. BC's forests have many different values and provide multiple goods and services, including clean water, wood, wildlife, food and medicinal plants, other non-timber forest resources, recreational opportunities, and aesthetic and spiritual experiences.