

The Economic Sleuth: Tracking Carbon in British Columbia's Forests

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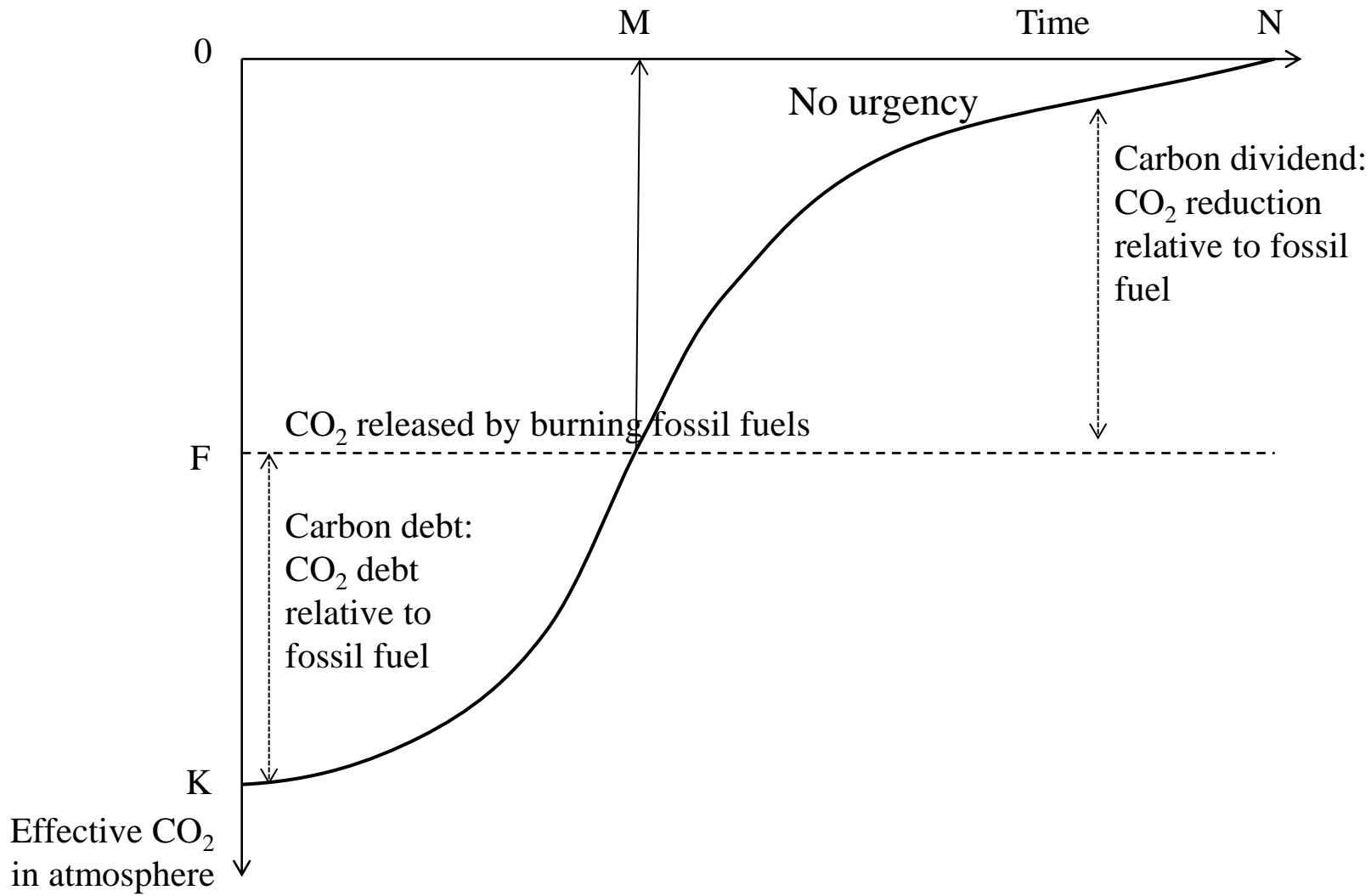
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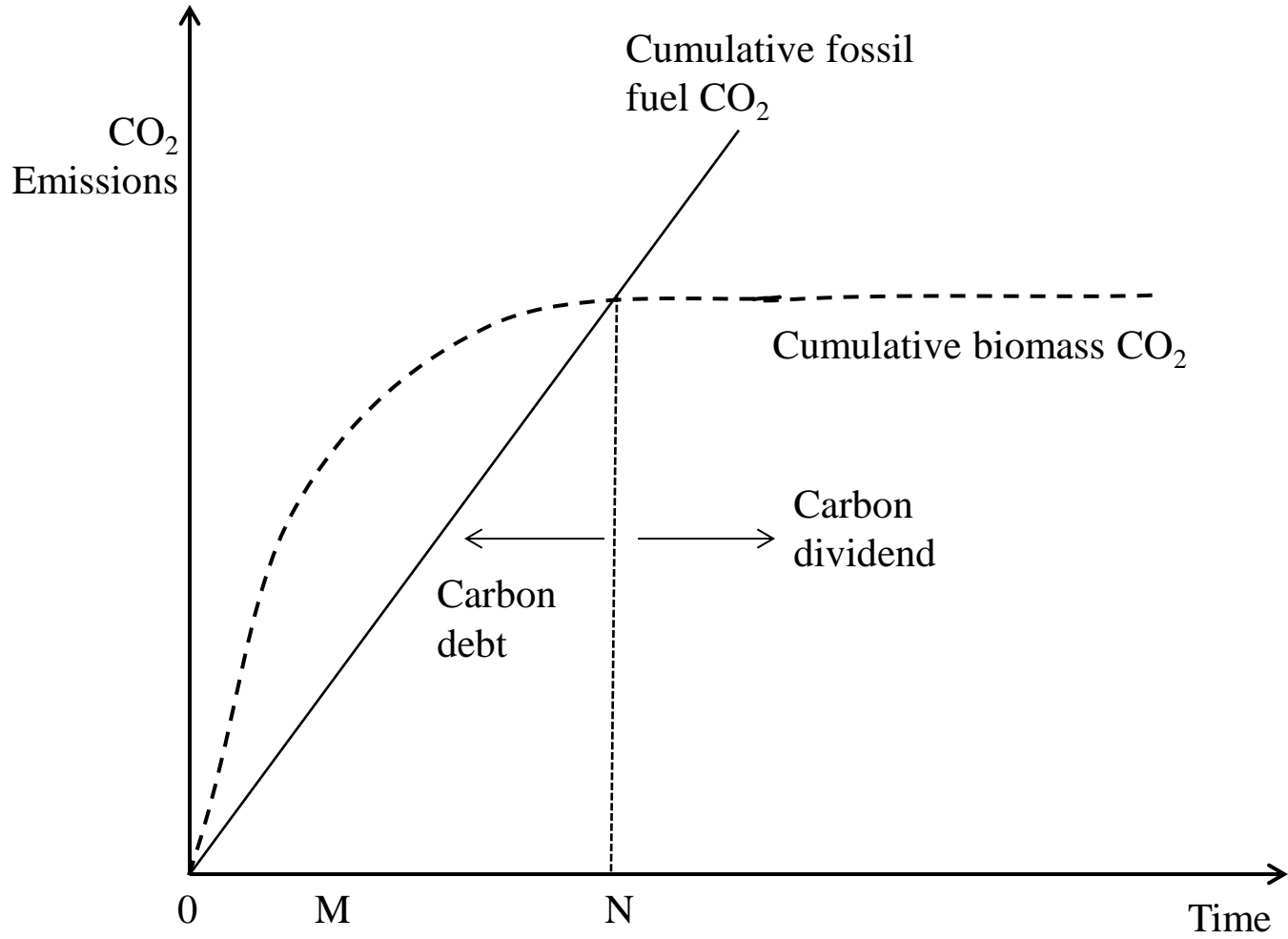
Introduction

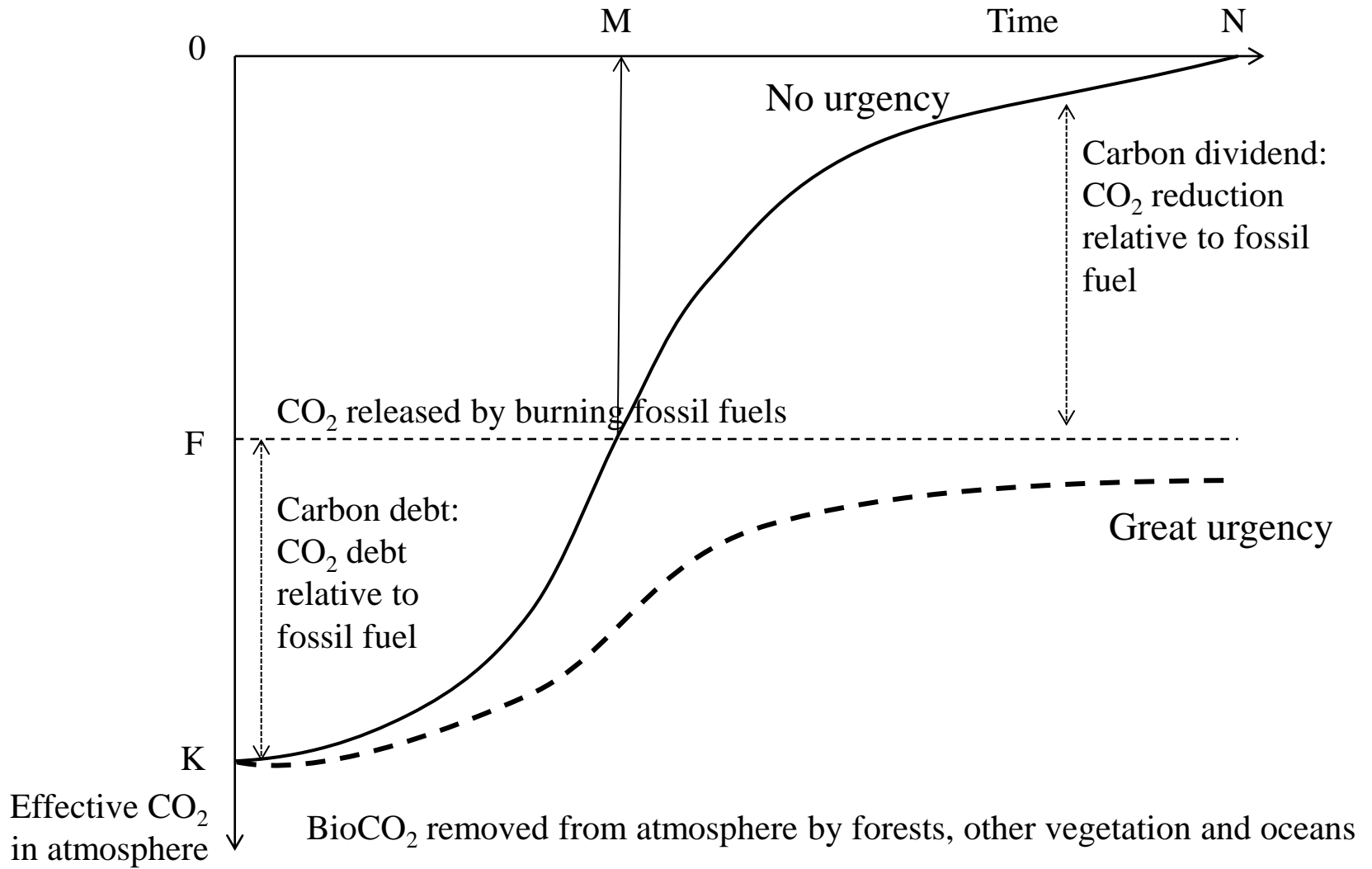
- During 1970-2010, total anthropogenic GHG emissions have been continuously rising, with emissions of CO₂ from fossil fuel combustion and industrial processes contributing about 78% of the total GHG emissions
- Half of increase in global surface temperature from 1951 to 2010 is attributed to anthropogenic forcings
- To mitigate the effects of climate change, carbon reducing strategies are becoming increasingly important.
- Forests can play an important role in mitigating global warming

Introduction

- Great deal of literature on wood biomass as a fuel source for generating electricity in lieu of coal, or co-firing wood pellets with coal in power plants
- Assumption: Carbon neutrality
 - Discussed by economists: Walker et al. (2010, 3013); papers by Sedjo, Sedjo & Tian, Johnston & Kooten
- Life-cycle of carbon when biomass is burned instead of fossil fuels: Distinction between bioCO₂ and CO₂: Cherubini et al., Helin et al.
- Lemprière et al. and Smyth et al. show that, if forest activities are managed for commercial and climate change benefits, burning wood biomass is a bad outcome (although some burning is good). Better to store carbon in post-harvest products.







This paper

- Maximize commercial plus carbon benefits using integrated model a la Lemprière et al. & Smyth et al.
- Two questions:
 - Should we allow conservation of forests since no emissions are involved? Benefit: not charged for emitting CO₂
 - If we allow wood biomass to substitute for fossil fuels in power generation, thereby counting the saved fossil fuel emissions, should we not also count the saved emissions from steel/cement production when wood substitutes for non-wood materials in construction? This could change everything!

Post-harvest Carbon Dynamics

r_c = rate used to weight physical carbon

d = rate at which C in a carbon pool decays

k = proportion of C going into wood product sink at harvest time

$$PV_{C_{stored}} = \left(1 - \frac{d}{r_c + d}\right)kC = \left(\frac{r_c}{r_c + d}\right)kC$$

Objective Function

$$\sum_{t=1}^T \beta^t \left[\begin{aligned} & (p_{lum} \varepsilon_1 + p_{chip} \varepsilon_2 + p_{fuel} \varepsilon_3) H_t - C_t \\ & - p_C (E_t + \gamma CO2_t + A_t - \Delta Eco CO2_t) \end{aligned} \right]$$

p_j is price of j^{th} forest product;

ε_j is proportion of logs going to various commodities;

H refers to harvest;

C to costs;

E to emissions of CO_2 from logging, transport, processing, etc;

$CO2$ is release of CO_2 from post-harvest sinks;

γ is the duration factor;

A refers to emissions avoided in making steel/cement or burning fossil fuels;

$\Delta Eco CO2$ is the carbon sequestered in the ecosystem plus in growing trees, etc.

Harvest and Other Costs, Quesnel TSA

Item	Value	Cost Item	Value
General parameters		Transportation	
Monetary discount rate	4%	Roads & infrastructure (\$/ha)	944.0
Discount rate for carbon	2%	Road maintenance (\$/ha)	295.0
Min volume to harvest (m ³ /ha)	150.0	Yarding (\$/ha)	1,844.0
Price of lumber (\$/m ³)	160.0	Tree to truck (\$/m ³)	19.90
Price of chips (\$/m ³)	140.0	Hauling (\$/m ³ per cycle hour)	6.67
Price of fuel (\$/m ³)	120.0	Hauling distance (km)	100
Silviculture		Manufacturing costs	
Regen survey & prescr (\$/ha)	20.0	Milling per log (\$/m ³) ^a	72.00
Site preparation (\$/ha)	472.0	Conversion factors	
Basic (\$/ha)	730.0	m ³ per bone dry tonne residue	2.6525
Intensive (\$/ha)	1,820.0	Average lumber recovery (bf/m ³)	215

Source: Author calculation

Rates of CO₂ emissions and decay rates for various forest carbon pools

Carbon emissions	Value ^a	Item	Value
Activity		Decay rate of:	
Harvesting	0.016	Dead organic matter	0.00841
Trucking	0.00007	Softwood lumber	0.002
Production of:		Chips and pulp wood	0.003
Sawlogs	0.04	Fuel ^b	1.0
Veneer	0.06	Biofuel ^b	0.7
Panels	0.12	Substitution	
Mechanical pulp	0.48	Biofuel for fossil fuels in burning	0.9
Chemical pulp	0.13	Wood for non-wood in constr (tC/m ³)	0.75-2.0

^a Tonnes of carbon (tC) released per tC in logs as raw material

^b The decay rates for fuel and biofuel indicate that, respectively, 100% and 70% of the CO₂ is emitted in the first year after harvest.

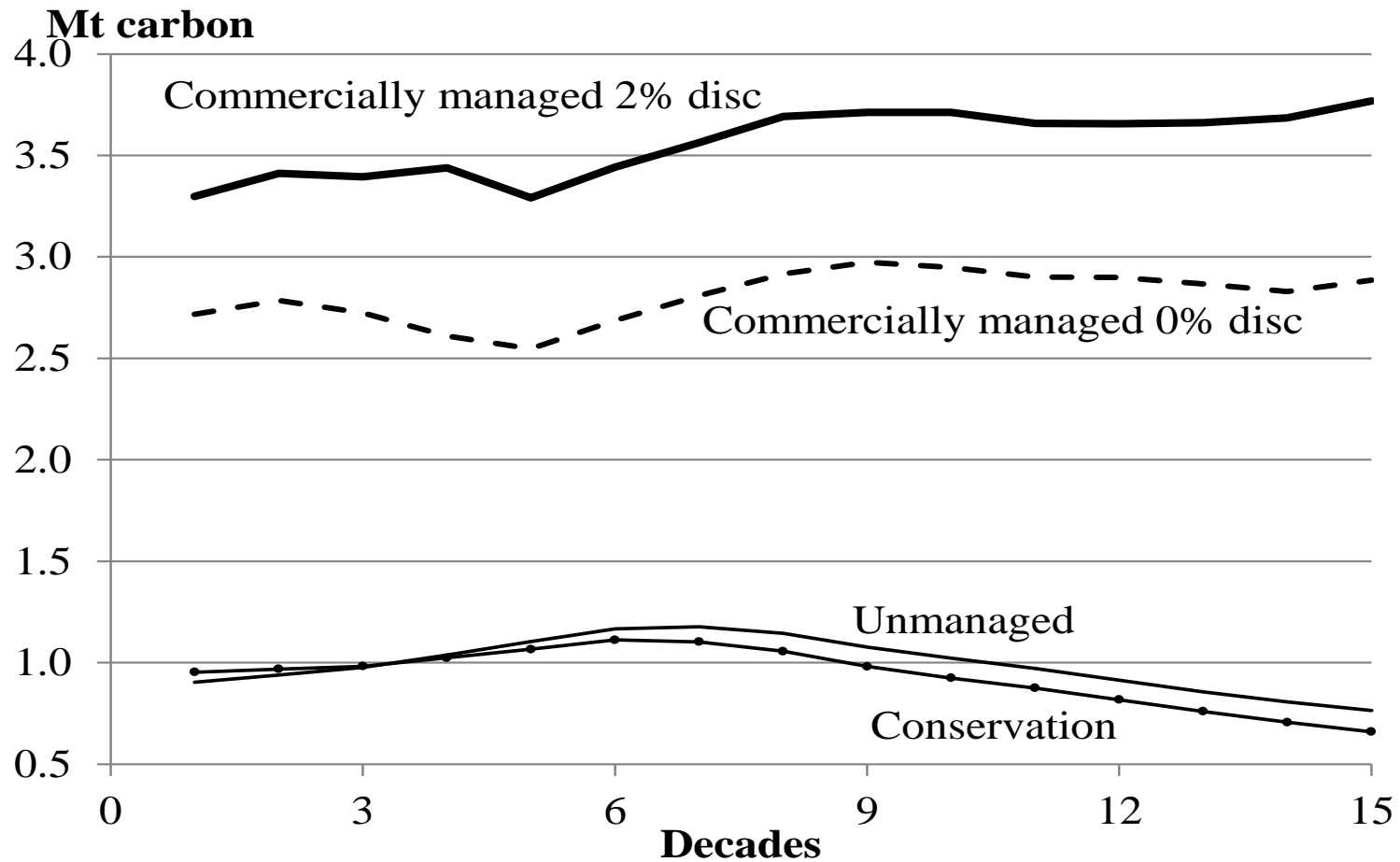
Source: Author calculation

Annualized Carbon Sequestered in BC Forest under Different Management Regimes, '000s tCO₂

Forest Management Method	Emission offset credit, ^b (tCO ₂ /m ³)	Discount rate on carbon					
		0%		2%		4%	
		Price of carbon \$/tCO ₂					
		\$0	\$10	\$0	\$10	\$0	\$10
Unmanaged		91.7	91.7	100.2	100.2	99.1	99.1
Conservation	0.25	-25.5	-23.0	-14.0	-12.5	-8.8	-8.3
	0.75	-7.2	-4.7	4.2	5.7	9.7	10.3
Commercial Management	0.25	8.1	22.4	57.1	60.3	77.3	80.2
	0.75	186.3	193.3	238.1	243.9	265.8	271.4

^b Credit for emissions avoided producing concrete/steel when wood substitutes for non-wood in construction.

Source: van Kooten et al. (2015)



Annualized Discounted Carbon Uptake per Decade for Unmanaged, Conservation Managed and Commercially Managed Forest, 0% and 2% Carbon Discount Rates, 4% Monetary Discount Rate, Carbon Price = \$10/tCO₂, and Credit of 0.75 tCO₂/m³ for Reduced Emissions when Wood Substitutes for Non-wood in Construction (Source: van Kooten et al. 2015)

Determining Optimal Rotation Age

- What if we add emission savings from not burning fossil fuels or not making cement/steel?
- We employ the same approach used in van Kooten et al. (1995)

Optimal Forest Rotation Ages when only Carbon Taxes and Subsidies are taken into Account (Commercial Value of Timber is Zero): Various Forest Types, Pickling Factors & Discount Rates (Years)

Discount rate	Pickling Factor (β)			
	0	0.5	1.0	2.0
	Coastal Rainforest			
2.5%	**	68	64	62
5.0%	**	**	104	62
	Interior/Boreal Forest			
2.5%	150	82	77	74
5.0%	**	190	150	73
	Genetically-Enhanced Interior/Boreal Forest			
2.5%	**	43	40	39
5.0%	**	**	51	38

** indicates no harvest takes place

Source: Author calculation. See REPA working paper 2015-04

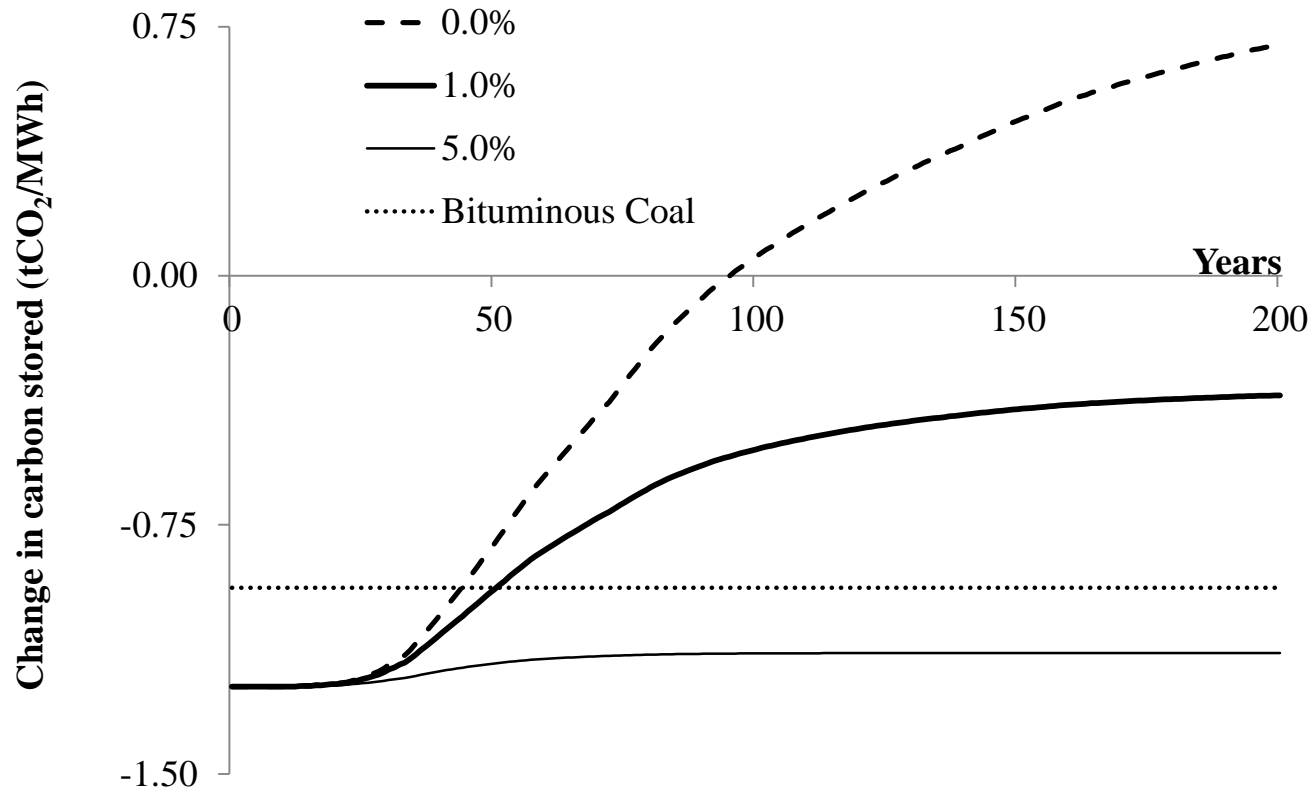
CO₂ Offsets Created, Carbon Storage in Forest Products and Biomass used to Produce Electricity in lieu of Coal, 2% Discount Factor (Source: REPA WP 2015-04)

	Spruce		Hybrid Poplar	
Pickling factor	Cumulative	Annual	Cumulative	Annual
β	(tCO ₂ per hectare)			
No account of harvest-related emissions				
0.0	31.3	0.6	66.1	1.3
0.5	78.4	1.6	268.7	5.4
0.8	107.3	2.1	392.8	7.9
Including harvest-related emissions				
0.0	30.8	0.6	62.3	1.2
0.5	77.9	1.6	264.8	5.3
0.8	106.7	2.1	389.0	7.8
Biomass energy, including harvest-related emissions (no pickling)				
No fuel offset	30.8	0.6	62.3	1.2
Fuel offset	30.9	0.6	62.4	1.2

See Working Paper 2015-04 at

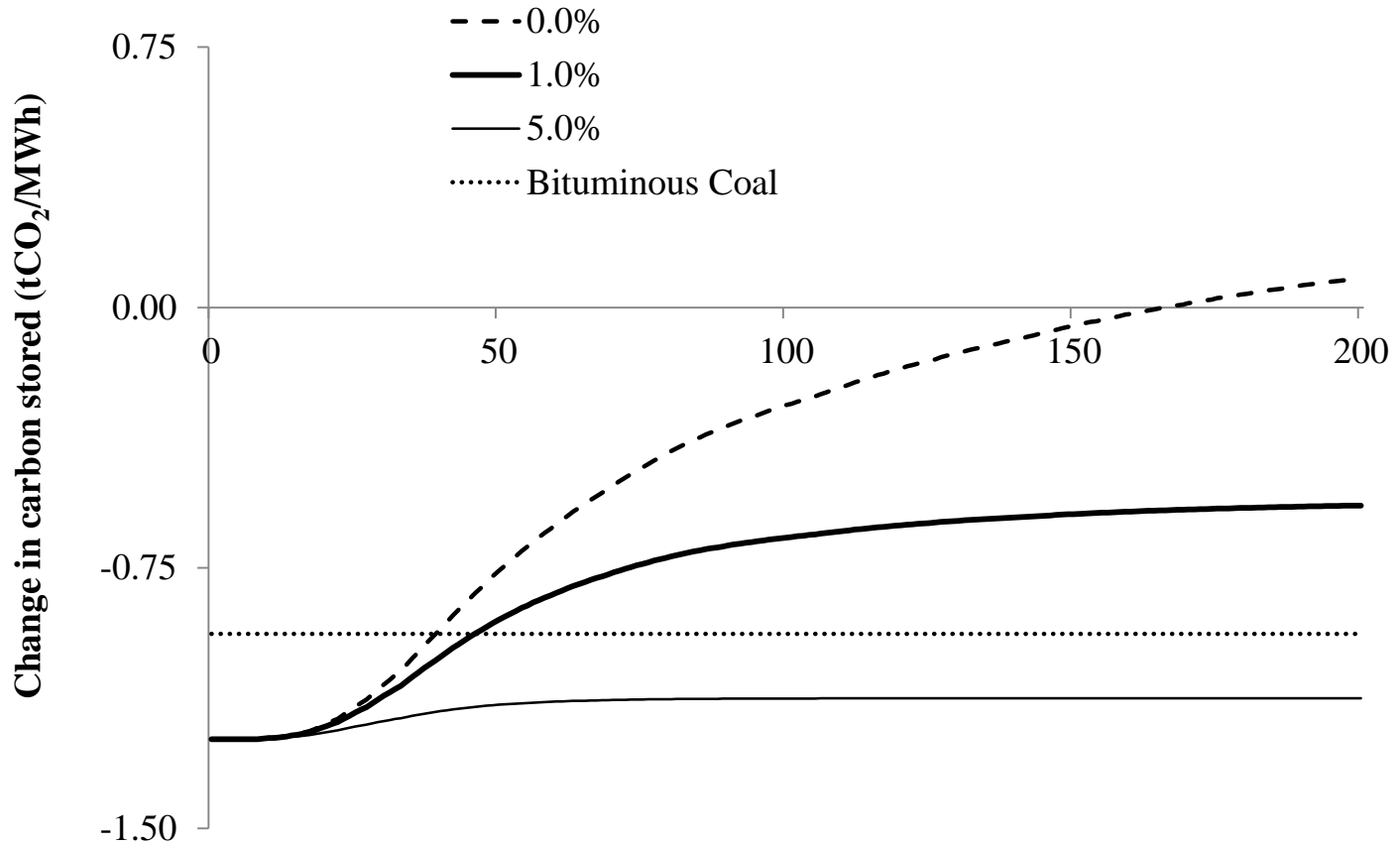
<http://web.uvic.ca/~repa/publications.htm>

White spruce (*picea engelmannii*)



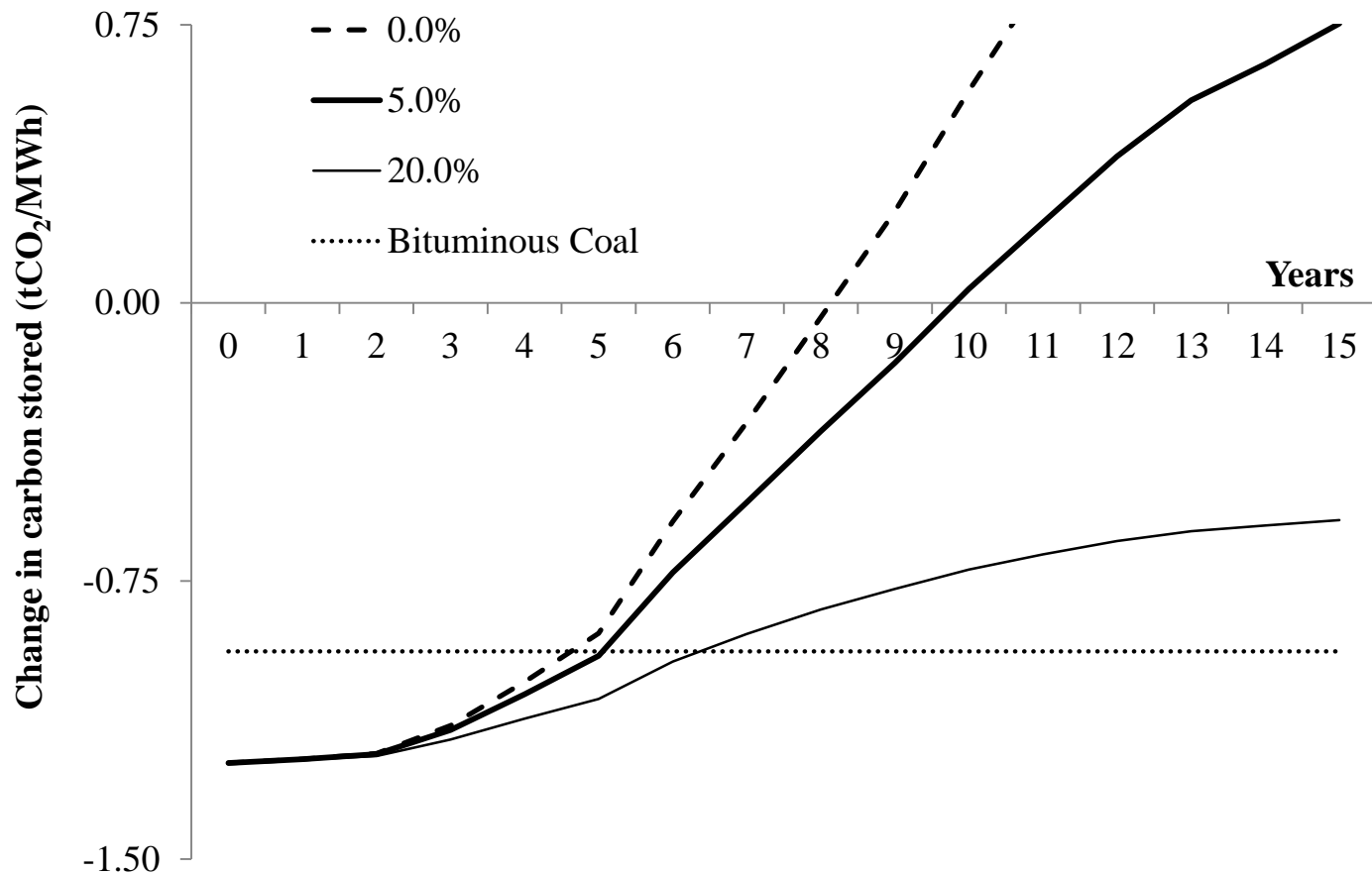
Projected volume ($m^3 ha^{-1}$) in Dawson Creek forest of Prince George district with average slope of 10% & initial density of 1,600 trees ha^{-1}

Lodgepole pine (*pinus contorta*)



Projected volume ($m^3 ha^{-1}$) in Dawson Creek forest of Prince George district with average slope of 10% & initial density of 1,600 trees ha^{-1}

Hybrid poplar (Northwest: *P. balsamifera* x *P. deltoides* or Walker: *P. deltoides* X *P. petrowskyana*)



Projected cumulative carbon flux associated with fossil fuel and biomass energy production for select climate change urgencies for hybrid poplar