Impact of carbon market on Timber and Non-timber Values under Sustainable Forest Management

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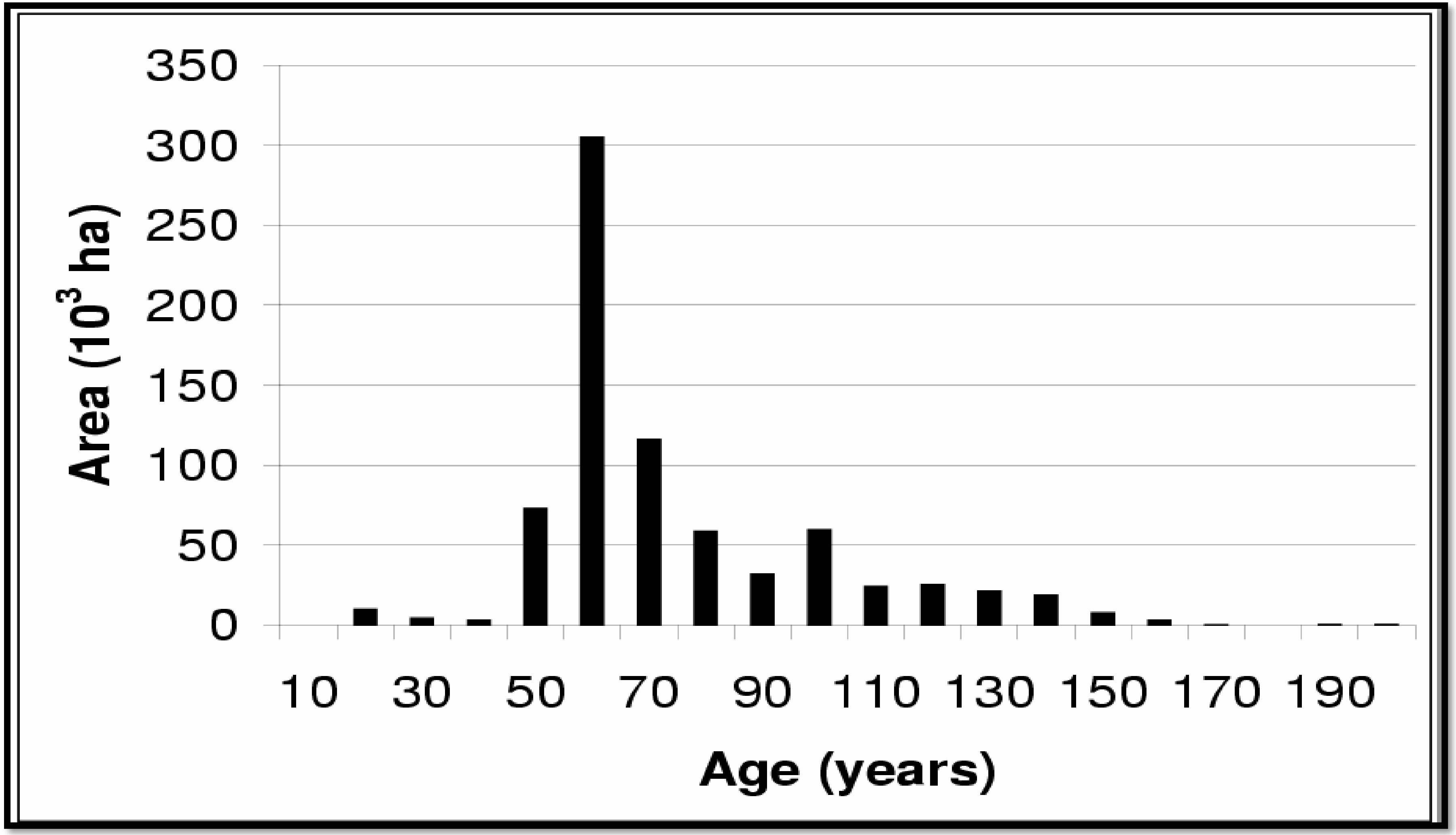
Take home message

- With the current decline in harvest levels in BC, **Forest Carbon Credit Trading** can be used to keep the forest industry viable.
- Forestry firm reaches a contract with a carbon-seeking firm. This contract "**guarantees**" that a specific amount of carbon stock will be maintained over a defined period.

Introduction

- There is substantial debate over how to properly credit carbon sequestered in forests.
- This study looks at a carbon market where a forestry firm is assumed to reach a contract with a carbon-seeking firm.
- Can a forestry firm manage for timber, carbon and non-timber forest products (Wildlife Habitat) on a sustainable basis and remain viable?

Initial Age Class Distribution



Habitat Quality Model

- The forest is described in terms of area of **cover type** by **habitat stage** combinations.
- The recognized cover types: **pine, white spruce, aspen, mixed, and black spruce.**
- Six **habitat stages** were recognized:
  1. Establishment,
  2. Maximum Stem Density,
  3. Maximum Crown Closure,
  4. Maximum Basal Area,
  5. Mature Stage, and
  6. Overmature Stage.

Habitat stage definition by cover type and age

Habitat Stage		Age Range (Years)	
ID	Description	Aspen Cover Type	Other Cover Types
1	Establishment	0 – 5	0 – 5
2	To Maximum Stem Density	6 – 15	6 – 25
3	To Maximum Crown Closure	16 – 30	26 - 60
4	To Maximum Basal Area	31 – 60	61 – 100
5	Maturity	61 – 80	101 – 150
6	Overmaturity	81+	151+

Vertebrate Species

American Marten

Meadow Vole

Broad-winged Hawk

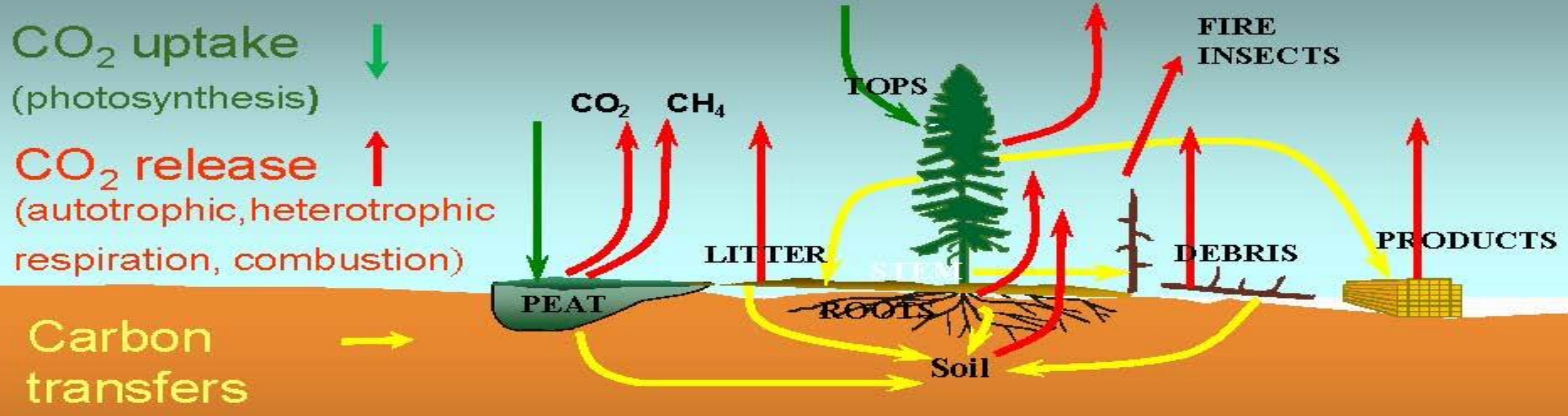
Three-toed Woodpecker

Black-throated Green Warbler

Habitat quality index by vertebrate species, cover type and habitat stage

Species	Cover type	Habitat stage 1	2	3	4	5	6
American marten	Pine			2	2	2	2
	White spruce			2	3	4	6
	Mixed				2	3	4
Meadow vole	Pine	3	2				
	White spruce	6	3				
	Aspen	6	3				
	Mixed	6	3				
	Black spruce	3	2				
Broad-winged hawk	Aspen					4	6
	Mixed				4	5	4
Three-toed woodpecker	Pine	4			2	4	5
	White spruce				3	4	6
	Mixed				2	3	4
	Black spruce	3			2	4	6
Black-throated green warbler	White spruce			2	4	5	4
	Mixed			2	4	6	6

Carbon Dynamics



Source: Canadian Forest Service

Carbon Dynamics

- Forest carbon stocks can be divided into two major pools; **forest biomass** (both aboveground and belowground) and **dead organic matter** (including detritus and soil organic matter).
- Here, an attempt is made to realistically capture these carbon dynamics. Using the **Carbon Budget Model** of the Canadian Forest Sector (CBM-CFS3)

Constraint Optimization Model

Objective Function:

[1]

$$\underbrace{max}_{x_{ijk}} \sum_{i=1}^{I} \sum_{j=-M_i}^{K-p_i} \sum_{k=1}^{N} e_{ijk}\, x_{ijk}$$

Subject to

Area constraints

[2]

$$\sum_{k=1}^{N} x_{ijk} \; + w_{ij} = A_{ij} \qquad \forall \; i, j$$

[3]

$$\sum_{k=1}^{N} x_{ikl} \; + w_{ik} - \sum_{j-M_i}^{k-1} x_{ijk} \quad = 0 \qquad \forall \; i, k$$

Harvest Flow Constraint

Most forest land in Canada is managed under highly regulated conditions. Here, regulation on timber flow is implemented as a NDY constraint on harvest volumes:

[4] $$F_k = \sum_{i=1}^{I} \sum_{j=-M_i+1}^{k} v_{ijk}\, x_{ijk} \qquad \forall\ k$$

[5] $$G_k = \sum_{i=1}^{I} \sum_{j=-M_i+1}^{k} z_{ijk}\, x_{ijk} \qquad \forall\ k$$

[6] $$F_k - F_{k+1} \le 0 \qquad \forall\ k$$

[7] $$G_k - G_{k+1} \le 0 \qquad \forall\ k$$

Wildlife Habitat Suitability Constraint

For the purposes of the LP model implementation here, habitat area constraints require that the area of "good" habitat in the forest is greater than a minimum level for all 5 vertebrate species. The constraints are specified as:

[8] $$\sum_{i=1}^{I} \sum_{j=-M_i+1}^{k} q_{ijks}\, x_{ijk} + q_{ijks} r_{ijk} \geq \overline{Q_{ks}} \qquad \forall_{k,\, s}$$

Where q_{ijks} is the habitat quality during period k for wildlife species s for forest type i which was regenerated in period j; r_{ijk} is the area (ha) of forest type k that was regenerated in period j not harvested in time period k, and $\overline{Q_{ks}}$ is the minimum level of habitat quality for species s in period k.

Carbon Dynamics Constraint

Constraints, requiring forest carbon stocks to be greater than a minimum level for all periods in the planning horizon, are formulated as follows:

[9] $$\sum_{i=1}^{I} \sum_{j=-M_i+1}^{k} (b_{ijkh} + d_{ijkh})x_{ijkh} + (b_{ijkh} + d_{ijkh})r_{ijkh} \geq \overline{C_k}$$

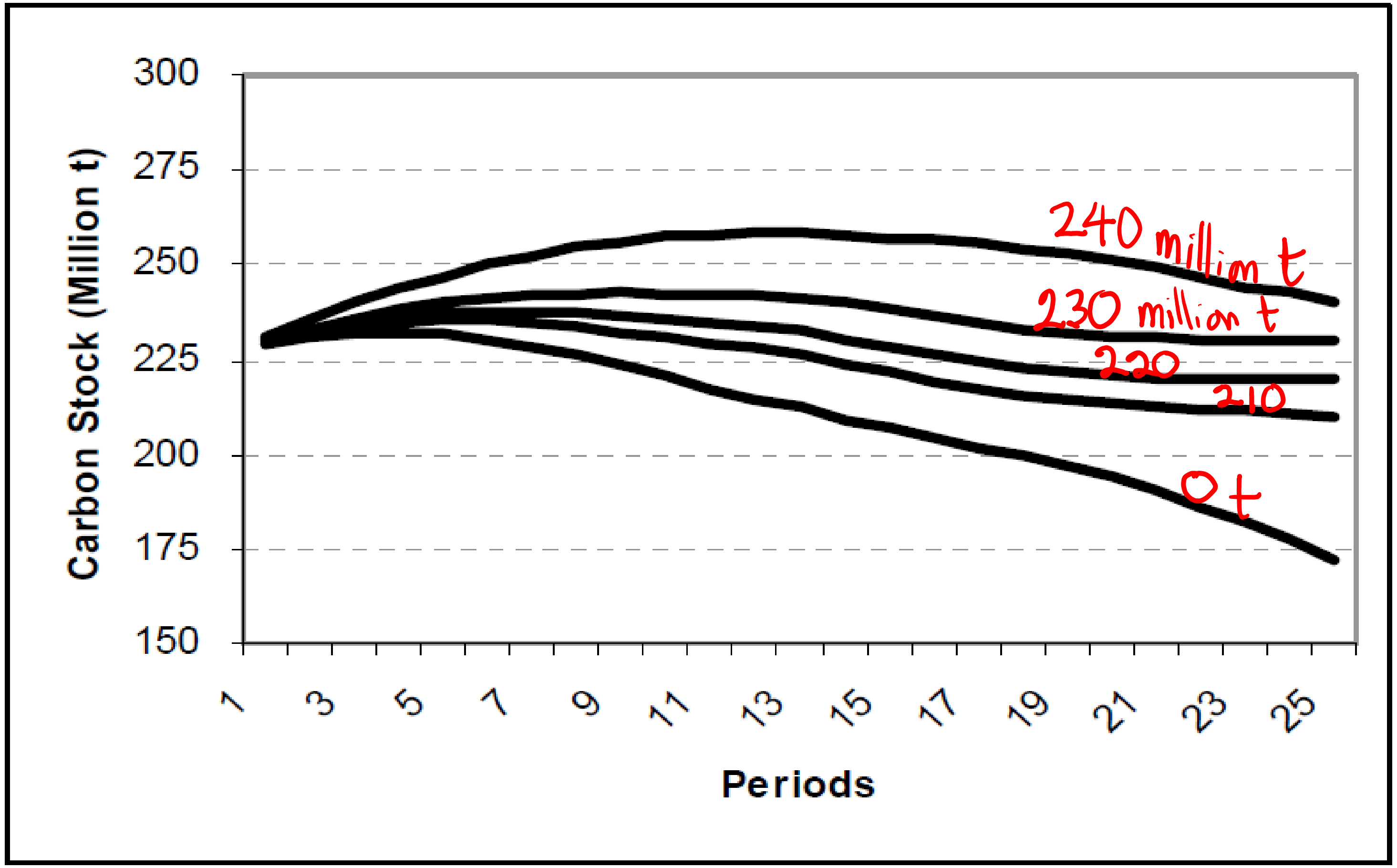
Where b_{ijkh} is the sum of aboveground and belowground biomass carbon stock (t/ha) during period k for forest type i which was regenerated in period j and has followed disturbance history h; d_{ijkh} is the DOM carbon stocks (t/ha) during period k for forest type i which was regenerated in period j and has followed disturbance history h; and $\overline{C_k}$ is the minimum total carbon stocks in period k.

Model Assumptions for the Constraint Optimization Model

- The conversion surplus value is assumed to be $60/m^3 for softwood timber and $50/m^3 for hardwood timber at the mill gate.
- An annual discount rate of 5% is assumed
- Stands are assumed to regenerate to the same cover type after harvest.
- Regeneration costs are assumed to be incorporated into the harvest costs. Timber harvest costs are assumed to be $5 000/ha.

Results

- Carbon stocks would change over time even with carbon constraints imposed.
- The curves represent constraint levels of 0, 210, 220, 230 and 240 million t of carbon, respectively



Results

- Carbon management causes carbon stocks to increase above the actual constraint level for the first few periods.
- Carbon stocks then gradually decline to the constraint level towards the end of the planning horizon.

Results

- As expected, the NPV decreases as the constraints become more binding.
- With no habitat constraints, requiring a 240 million t stock of carbon results in a 52.5% reduction in NPV from the pure timber emphasis run.
- The reduction in NPV is largely due to a decrease in the per period timber volume that can be harvested while still maintaining the required carbon levels and areas of good habitat.

Results: Net Present Value

Net Present Value (10^6 \$) by Carbon and Habitat Constraint Level

Carbon Constraint (10^6 t)	Percentile Habitat Constraint			
	0	**2.5**	**25**	**40**
0	1358.6	1155.9	667.2	439.7
210	1192.4	1126.3	667.2	439.7
220	1100.6	1070.9	667.2	439.7
230	976.1	951.6	667.2	439.7
240	645.4	608.2	520.5	406.1

Results: Per Period Harvest Volume

Per Period Harvest Volume (10^6 m^3/yr) by Carbon and Habitat Constraint Level

Carbon Constraint (10^6 t)	Percentile Habitat Constraint			
	0	**2.5**	**25**	**40**
0	10.34	8.76	6.19	4.39
210	8.87	8.43	6.19	4.39
220	8.16	7.95	6.19	4.39
230	7.10	6.98	6.19	4.39
240	4.27	4.16	3.81	3.35

Average cost of carbon

Average Cost of Carbon Constraint ($/t C) by Carbon and Habitat Constraint Level

Carbon Constraint (10^6 t)	Percentile Habitat Constraint			
	0	2.5	25	40
0	0.00	0.00	0.00	0.00
210	16.65	9.84	0.00	0.00
220	17.97	13.72	0.00	0.00
230	18.36	16.60	0.00	0.00
240	20.77	21.48	9.44	4.32

Average Cost of Carbon Constraint ($/t CO_2) by Carbon and Habitat Constraint Level

Carbon Constraint (10^6 t)	Percentile Habitat Constraint			
	0	2.5	25	40
0	0.00	0.00	0.00	0.00
210	4.54	2.68	0.00	0.00
220	4.90	3.74	0.00	0.00
230	5.01	4.53	0.00	0.00
240	5.67	5.86	2.57	1.18

For conversion: 1 unit of C = 3.6667 or 44/12 units of CO_2 (44/12 is the ratio of the molecular weight of C to CO_2

Results

- The costs of carbon constraints generally decline as the wildlife habitat constraints become more binding.
- For the required change in forest management to be an efficient method of carbon sequestration, the **market value of stored carbon** would have to exceed the **average cost of carbon**.

Shadow Prices of habitat constraints at differing levels of carbon stocks

Carbon Constraint (10^6 t)	Percentile Habitat Constraint		
	2.5	**25**	**40**
0	9,237.39	35,520.01	49,118.20
210	6,342.77	35,520.01	49,118.20
220	2,334.32	35,520.01	49,118.20
230	1,544.71	35,520.01	49,118.20
240	2,827.69	28,323.17	44,476.45

- The marginal cost of an extra unit of good wildlife habitat generally declines as carbon constraints become more binding

Discussion and Conclusion

- The **difference** between the NPV resulting **from a particular combination of carbon and habitat constraints** and the NPV from the constraints a forestry firm currently faces could be viewed as the **minimum contract price required** to entice forest managers to adjust their harvesting practices.

Discussion and Conclusion

- Results demonstrate the potential for co-benefits in non-timber values to arise from forest carbon management.
- Observation from the analysis is that forestry firms' willingness to accept for carbon may be well within the prices at which carbon in currently trading on existing markets.


Thank You!