Ecosystem science perspectives on boreal forests and climate change mitigation

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Differing “visions” of the role of forests on C sequestration and climate mitigation





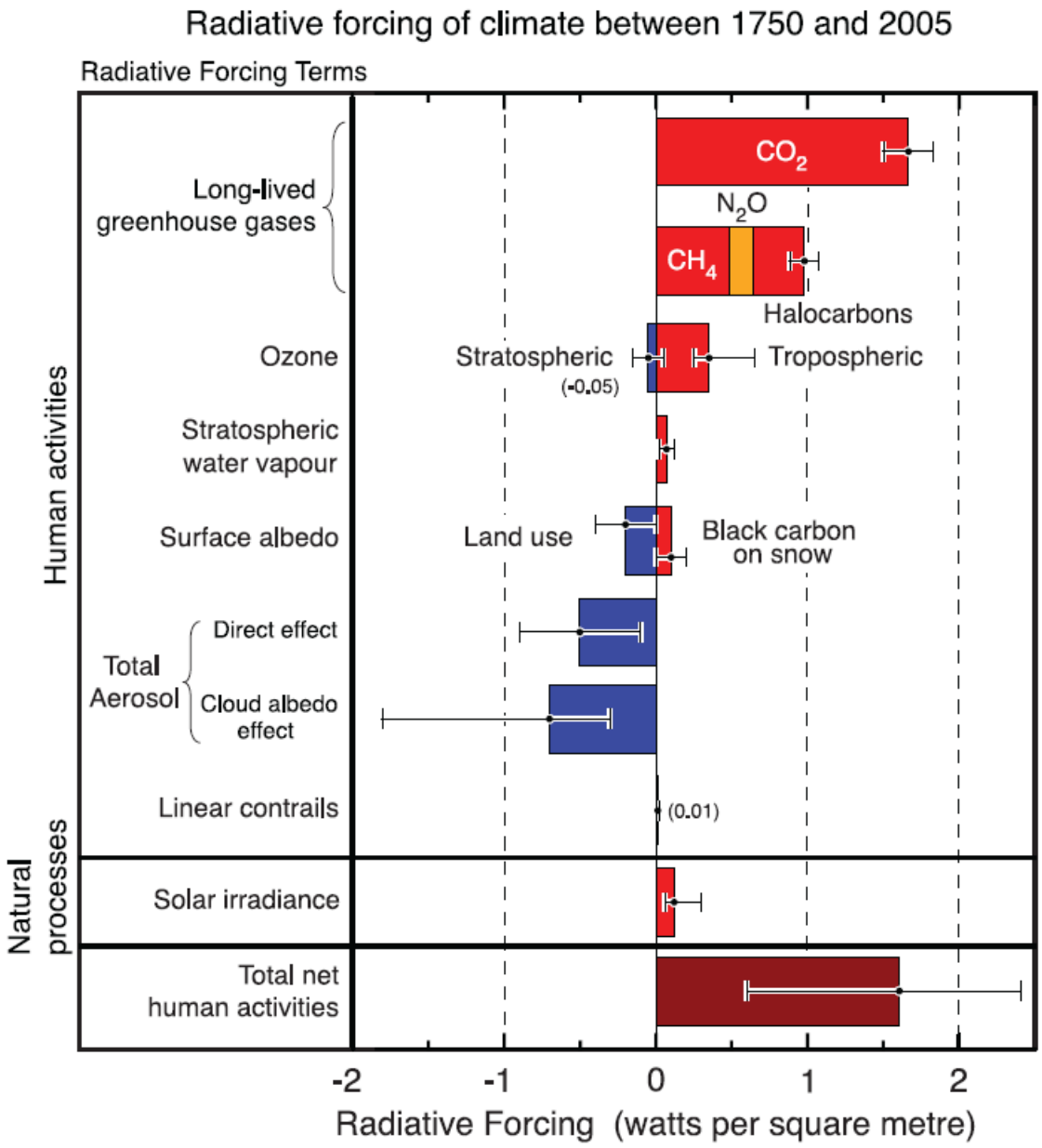
Do boreal forests warm the climate?

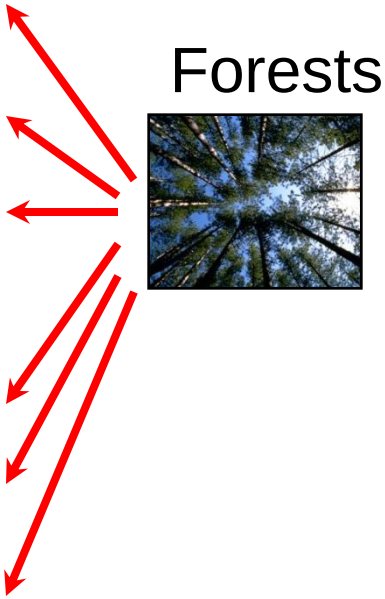
"Afforestation projects in high latitudes would be counterproductive in mitigating global-scale warming" (due to albedo effects). (Bala, G. et al. 2007 *PNAS* 104: 6550)

"For all practical purposes… protected boreal forests are C neutral… Sustainable management, on the other hand, ensures an increase in the combined C stocks in forest and wood products…" (Ter-Mikaelian M. et al., et al. 2008 *For. Chron.* 84: 166-171)

"…if one is truly concerned about the risks to the environment from climate change, then the case can be made that logging… should be encouraged." (Ter-Mikaelian M. et al., et al. 2008 *For. Chron.* 84: 166-171)

Sources of climate forcing





Source:
IPCC 2007

FAQ 2.1, Figure 2. *Summary of the principal components of the radiative forcing of climate change.*

What's the deal with albedo?

Albedo = proportion of total intercepted radiation energy reflected from the earth's surface to space.

Forests generally have lower albedo that other ecosystems, but this varies greatly among ecosystems and species. Largest differences commonly found for conifers with snow cover.

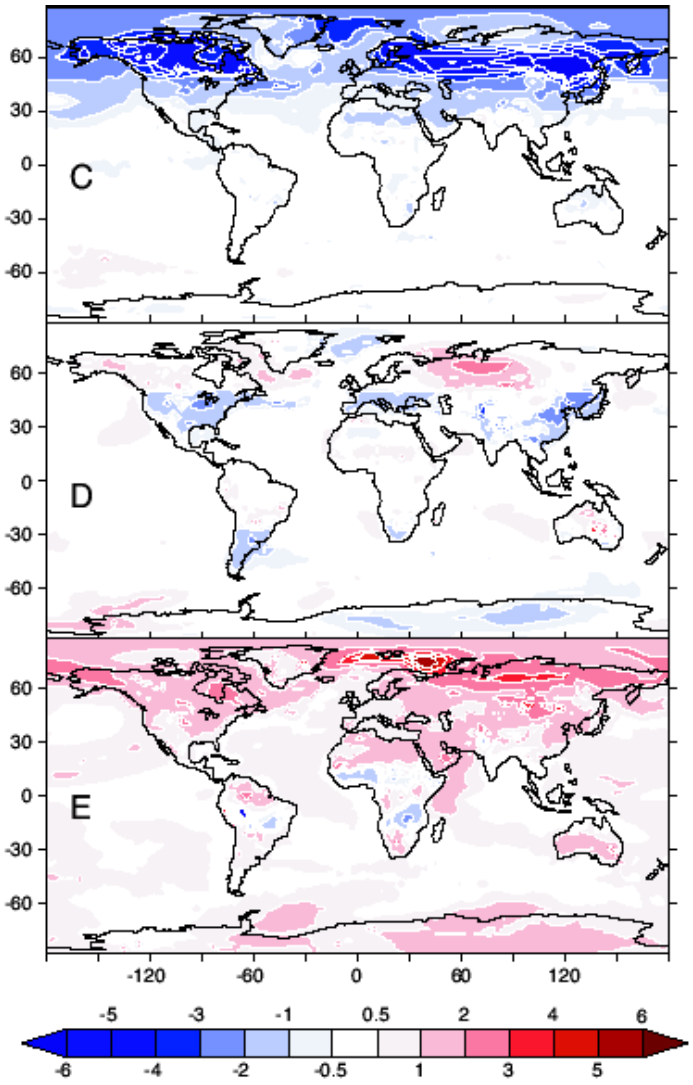
Net radiometers for albedo measurement

Albedo effects: Bala et al. paper(s)

Boreal deforestation

Temperate deforestation

Tropical deforestation



Substantial regional cooling

Little overall effect

Global warming

Predicted temperature change in 2100 relative to BAU scenario

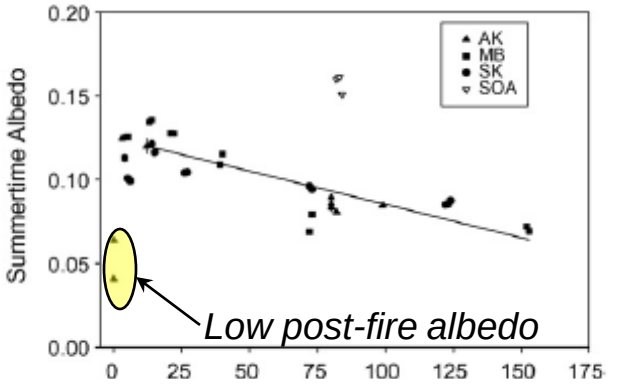
Critiques of Bala

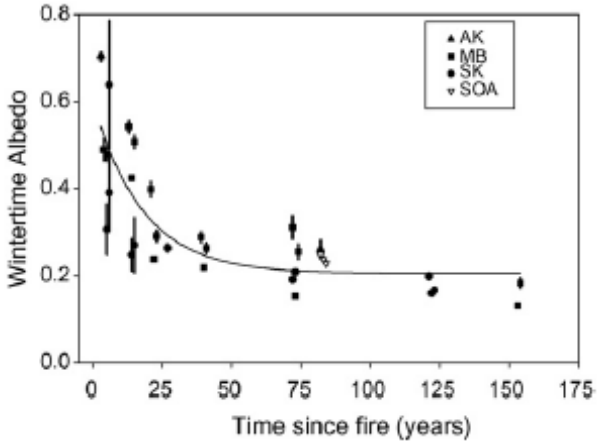
- Forest regrowth results in relatively rapid return to pre-harvest albedo levels (20-30 y).

- Ecosystem substitution is a poor representation of actual deforestation: increased harvesting would rapidly replace old forests with young forests (not tundra).

- Deforested areas are commonly burned, resulting in large initial *decreases* in albedo due to black surfaces. (Amiro et al. 2006, Ag. For. Met. 14:41)

- Stand-level measurements overstate albedo effects (as measured at large scale using remote sensing), since intact boreal forests are patchy. (Lyons et al. 2008, J. Geophy. Res. 113: G02012)





Boreal forest climate feedbacks mediated by aerosols

• Volatile organic compounds (VOCs) - especially terpenes - are emitted by boreal forest trees.

• Boreal VOC emissions impact climate through “direct” and “indirect” aerosol radiative forcing - especially by acting as cloud condensation nuclei and increasing cloud albedo.

• First estimates of boreal VOC effects on climate indicate a cooling effect equal to or greater than warming impacts due to forest albedo. (Spracklen et al. 2008. Phil. Trans. R. Soc. A. 366: 4613-26).

Two counteracting biogeophysical processes:

Albedo warming effect: ~+2.3 Wm^{-2}

VOC cooling effect: -1.8-6.7 Wm^{-2}

Are old-growth forests carbon sinks?

The conventional answer is "no", but recent evidence suggests that many old-growth forests are in fact moderate carbon sinks.

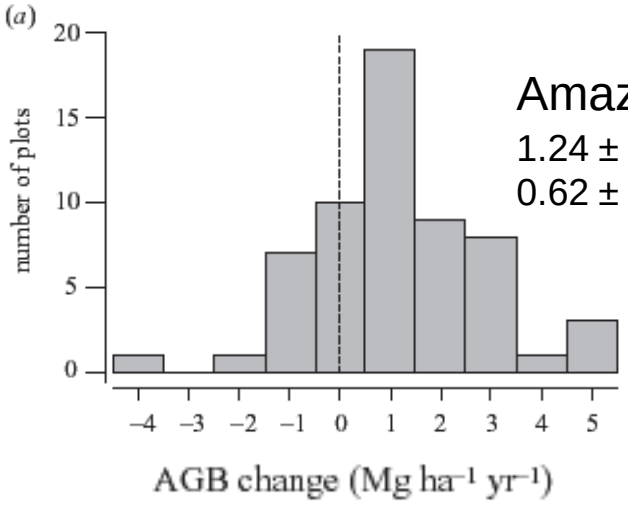
Why it this the case:

• In some systems there is a natural pattern of slow successional dynamics and/or soil accumulation and carbon aggradation.

• "Carbon fertilization" driven by rising CO_2 concentrations.

• Other anthropogenic factors that act to increase tree growth (such as N deposition and increasing temperatures).

Evidence from long-term plot studies in tropical forests



Amazonian data:
1.24 ± 0.43 Mg ha^{-1} y^{-1}
0.62 ± 0.23 Mg C ha^{-1} y^{-1}

African data:
1.24 ± 0.72 Mg ha^{-1} y^{-1}
0.62 ± 0.36 Mg C ha^{-1} y^{-1}

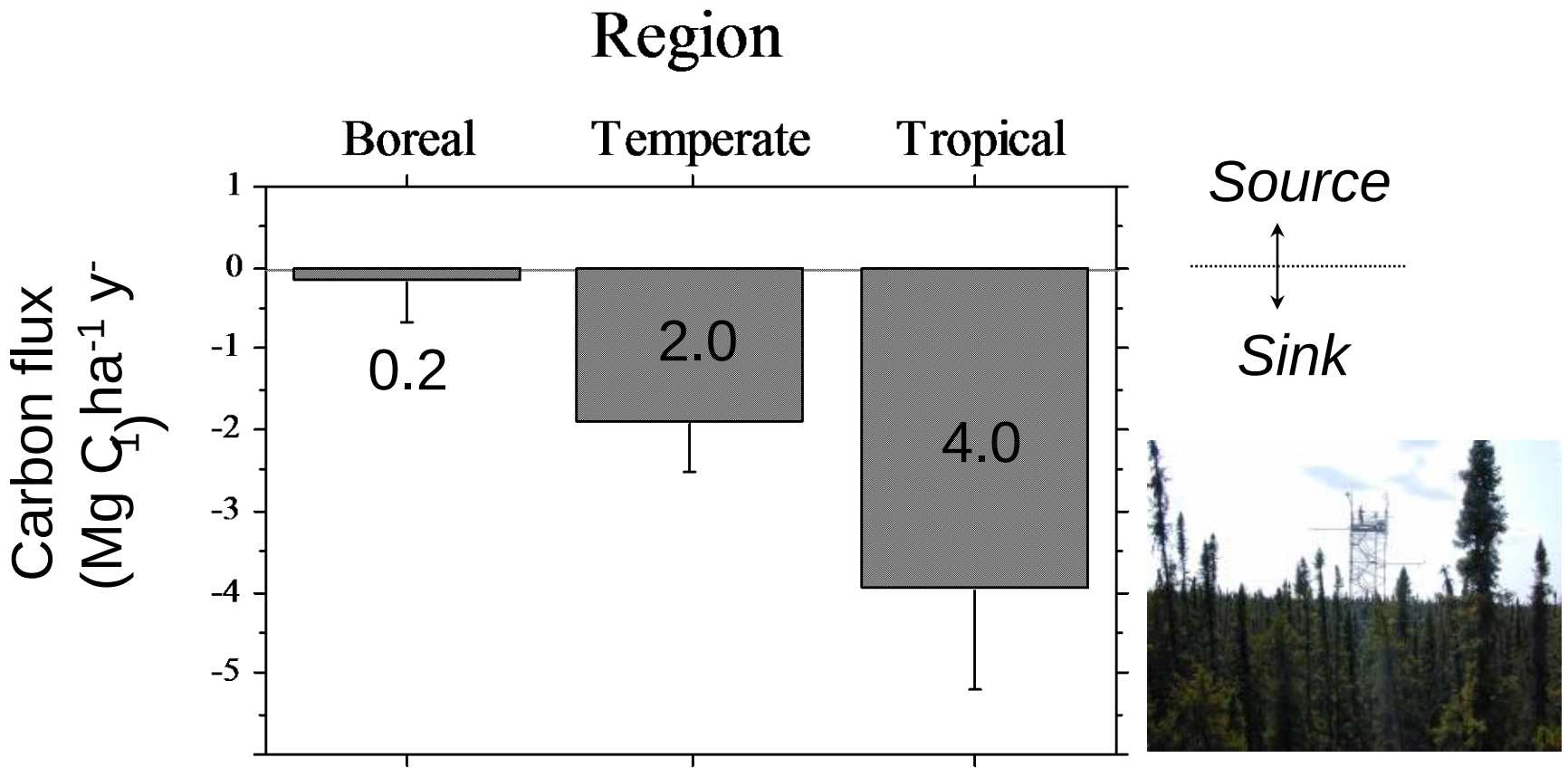
QuickTime™ and a decompressor are needed to see this picture.

Global average old-growth tropical forest above-ground C sink:

0.49 ± 0.20 Mg C ha^{-1} y^{-1}

(Lewis et al. 2009, *Nature* 457: 1003-1007)

Summary of eddy flux studies conducted in old-growth forests



Unpublished meta-analysis of 21 eddy flux studies (9 boreal, 7 temperate, 5 tropical)

Carbon fertilization in the Canadian northern boreal?

QuickTime™ and a
decompressor
are needed to see this picture.

Factoring out effects of temperature and rainfall, there is an increasing trend ($P<0.001$) of tree ring increment in black spruce in Hudson Bay lowlands (Elizabeth Nelson, unpublished data).

Where does the carbon go?

- Increased above- and below-ground biomass
- Woody debris accumulation
- Soil carbon enrichment and soil accumulation
- Dissolved organic carbon (which may ultimately be deposited in hydrological systems - including oceans - or flux back to the atmosphere)
- Changes in tree community composition (e.g., increasing dominance of dense-wooded species or species with higher root allocation)

Importance of methane fluxes to boreal climate feedbacks

- Methane (CH_4) is 23 times more active as a greenhouse gas than is CO_2 (on 100-y timescale).
- Undisturbed peatlands, while moderately strong C sinks, are sources for methane.
- Peatland disturbance (esp. altered hydrology) generally results in increased flux of methane over several decades.
- Upland forests (boreal included) are generally sinks for methane.

HARP harvesting in Hudson bay lowlands

The landfill carbon sink?

- The argument has been made that decomposition of post-utilization forest products is much slower than forest regrowth. This is the main basis for statements that increased logging will mitigate climate change in Ontario.

- Landfill decomposition is assumed 100% anaerobic and extrapolated from lab incubations. 100% anaerobiosis only occurs in latter phases of decomposition in large landfills (Barlaz 2006).

- Anaerobic decomposition results in methane production - which is 23x more active as a greenhouse gas than CO_2.

Dryden, ON landfill

Does 73.1% of harvested wood product waste remains in landfills "indefinitely"? (Chen et al. 2008, Can. J. For. Res. 38: 1947-58)

If so, then the 26.9% of C released as methane has a climate forcing effect ~6.7x more severe than if the material was incinerated.

Forest sector options for climate mitigation (from IPCC 2007)

	Mitigation Activities	Type of Impact	Timing of Impact	Timing of Cost
1A	Increase forest area *(e.g. new forests)*			
★ 1B	Maintain forest area *(e.g. prevent deforestation, LUC)*			
2A	Increase site-level C density *(e.g. intensive management , fertilize)*			
★ 2B	Maintain site-level C density *(e.g. avoid degradation)*			
3A	Increase landscape-scale C stocks *(e.g. SFM, agriculture, etc.)*			
★ 3B	Maintain landscape-scale C stocks *(e.g. suppress disturbances)*			
4A	Increase off-site C in products *(but must also meet 1B, 2B and 3B)*			
4B	Increase bioenergy and substitution *(but must also meet 1B, 2B and 3B)*			

Important things we know (*scientific consensus*)

- Globally, deforestation and forest degradation are MAJOR contributors to increasing atmospheric CO_2: more carbon has come from deforestation than from the global transportation sector.

- Forest conservation represents one of the few carbon mitigation measures that has high short-term effects on C emissions, and for which there are no technological hurdles.

- Tropical forests are likely to have the greatest potential for carbon sequestration and non-C climate mitigation effects.

- Due to slow growth, high C in soils, and strong biogeophysical climate feedbacks, boreal forests *are* a special case: the strongest “carbon argument” for forest conservation in the boreal is avoided CO_2 and methane emissions from peat soils.

Product substitution

- There has been massive product substitution of wood for more energy-intensive building materials in last 10-20 years (e.g., steel studs for two-by-fours).
- The environmental gains (from reduced C emissions and energy consumption) of reversing this trend are very large, raise no thorny “life-cycle” issues, and have potential to revitalize Canada’s forest industry.

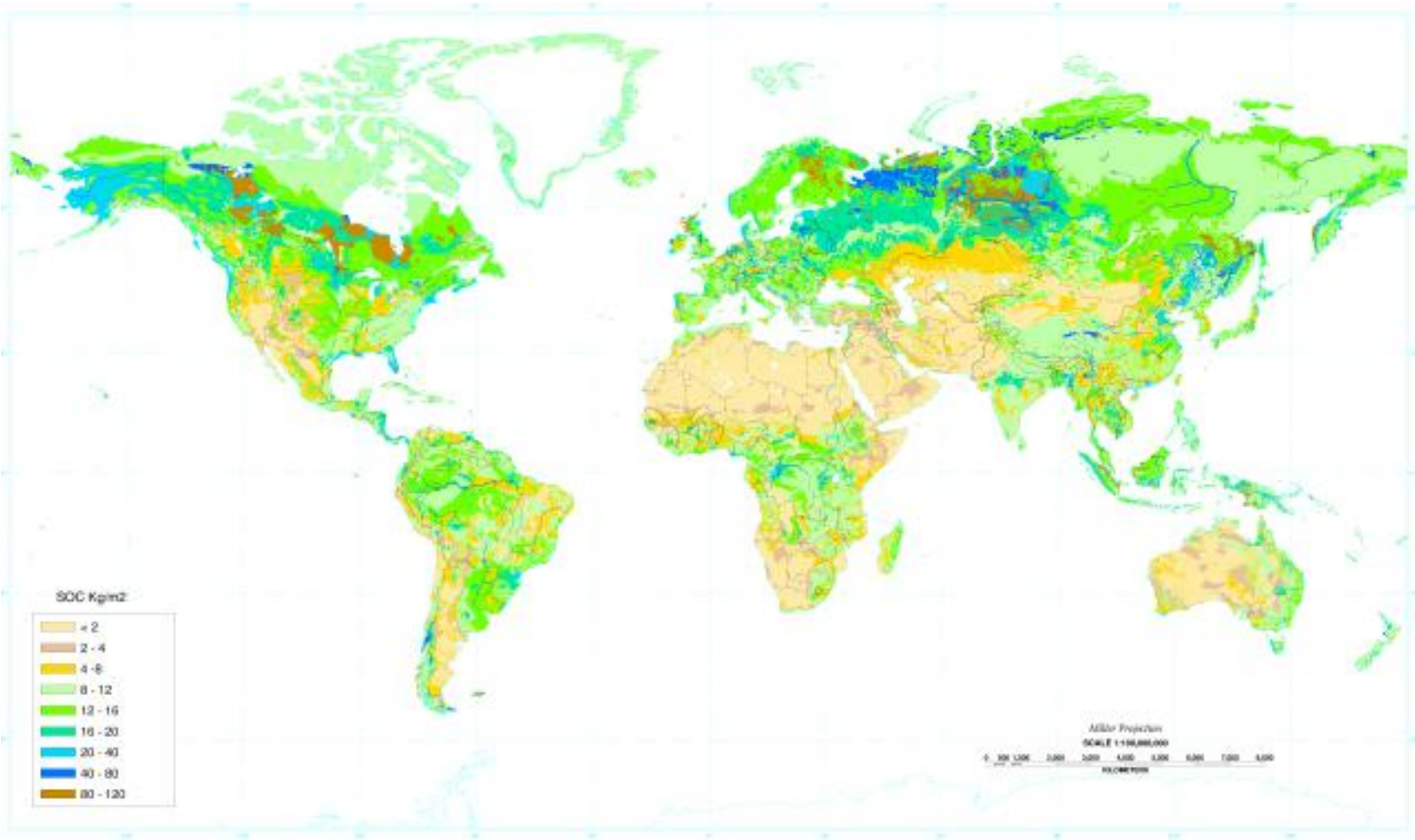
Extremely carbon intensive

± carbon neutral

Some important unknowns

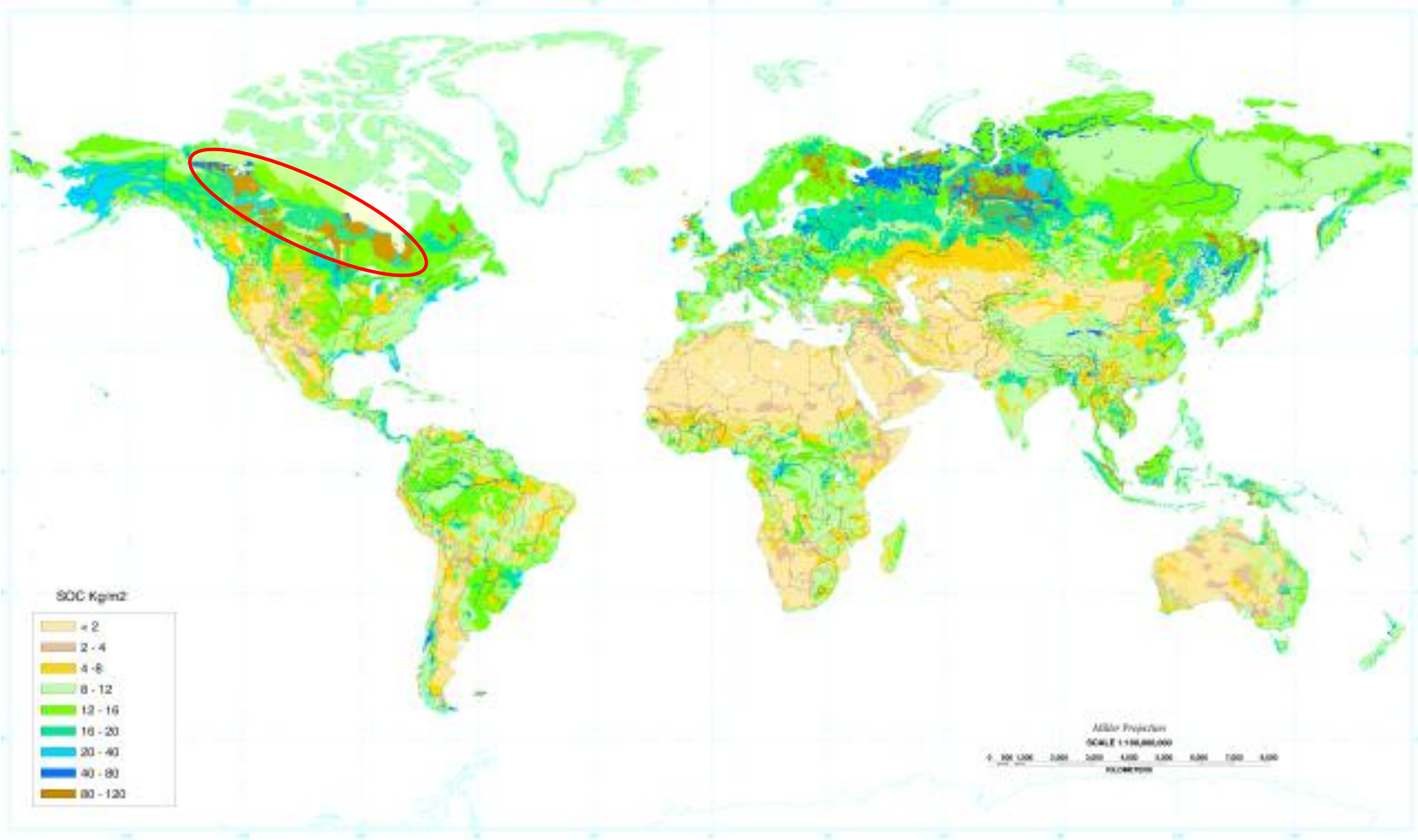
- What accounts for apparent mis-match between eddy flux and inventory estimates of carbon sequestration in old-growth forests?
- Will old-growth forest C sinks saturate, and what processes will drive this pattern?
- How does actual boreal forest harvesting alter biogeophysical processes (albedo and VOC effects)?
- How do the albedo and VOC effects of boreal forests vary with species, stand age, and climate?
- What are the harvesting impacts on soil CO_2 and methane emissions in northern boreal forests on peat?
- What are predisposing factors to initiation of peat fires?

The big picture



Canada is home to highest soil organic carbon levels globally; forest harvesting, road construction, and drainage can release these C stocks.

The big picture



Canada is home to highest soil organic carbon levels globally; forest harvesting, road construction, and drainage can release these C stocks.

Values, visions, and the future

- Climatic effects of boreal forests are NOT just about CO_2: other greenhouse gases and biogeophysical processes are extremely important.
- It's critical to distinguish between currently managed forests and unmanaged forests.
- A mix of conservation and management is likely to be best option to mitigate climate change.
- There are important scientific unknowns, enhancing the importance of a precautionary approach.

Burnt-over peat forest in Borneo