Forest carbon management in the boreal forest of Eastern Canada: opportunities and issues

Jean-François Boucher[1], Boris Dufour[1], Pascal Tremblay[1], Xavier Cavard[1,2], Daniel Mailly[3], Claude Villeneuve[1], Daniel Lord[1]

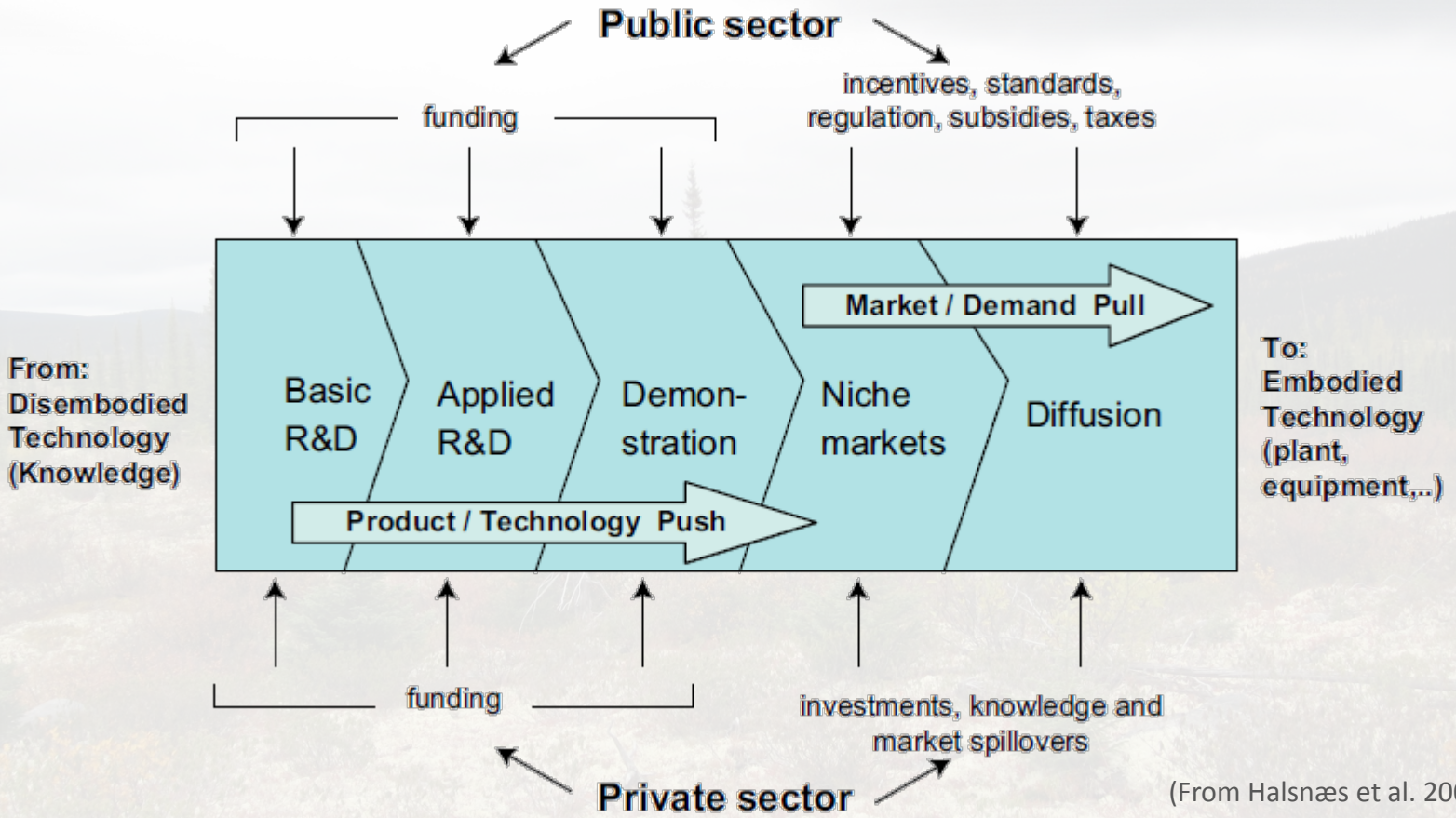
[1] Université du Québec à Chicoutimi, Chair on eco-advising, Qc, Canada
[2] Université du Québec en Abitibi-Témiscamingue, Qc, Canada
[3] Ministère des Ressources naturelles et de la Faune, Qc, Canada

4th North American Carbon Program All-investigators Meeting

Albuquerque, NM
February 6th 2013

NSERC CRSNG
RioTinto Alcan
Fonds de recherche sur la nature et les technologies Québec
eco conseil
UQAC Chaire en éco-conseil Université du Québec à Chicoutimi
carbone boréal

A praise for small scale (detailed) study!



(From Halsnæs et al. 2007)

- "We need to expand our research agenda to include human systems (economics, land-use, etc.)" - *Kenneth Davis*, Monday morning

… and to develop new niches that tackle global warming!

Urgent need to hurry (and worry!)

COMMENTARY:

The challenge to keep global warming below 2 °C

Glen P. Peters, Robbie M. Andrew, Tom Boden, Josep G. Canadell,
Philippe Ciais, Corinne Le Quéré, Gregg Marland, Michael R. Raupach and Charlie Wilson

NATURE CLIMATE CHANGE | ADVANCE ONLINE PUBLICATION | www.nature.com/natureclimatechange

© 2012 Macmillan Publishers Limited. All rights reserved

- Chances to curb global warming to 2 °C are extremely thin, but **massive mitigation measures must be rapidly implemented** to limit severe and global disturbances

Mitigation options in the LULUCF sector

	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)*	↓		

(From Nabuurs et al. 2007)

- Activities with rapid impact = maintaining forest areas, site-level C density, and landscape-scale C stocks → **REDD+ activities in the tropics…**

Cumulative mitigation potential of low cost options

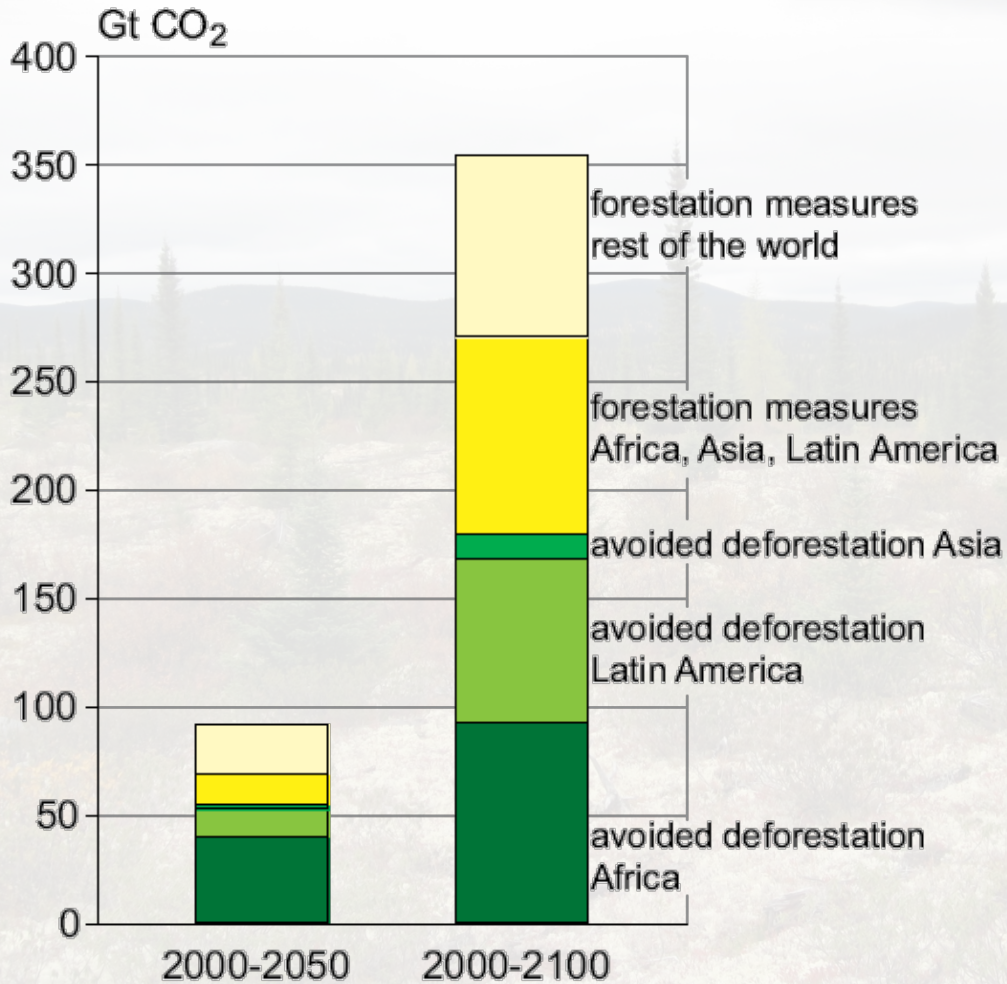


Figure 9.6: *Cumulative mitigation potential (2000-2050 and 2000-2100) according to mitigation options under the 2.7 US$/tCO2 +5%/yr annual carbon price increment*

Source: Sathaye et al., 2007.

- Most of cheap and short term (as well as longer term) mitigation gains are with reduced deforestation options in the tropics (Nabuurs et al. 2007)

REDD+ initiatives in the tropics

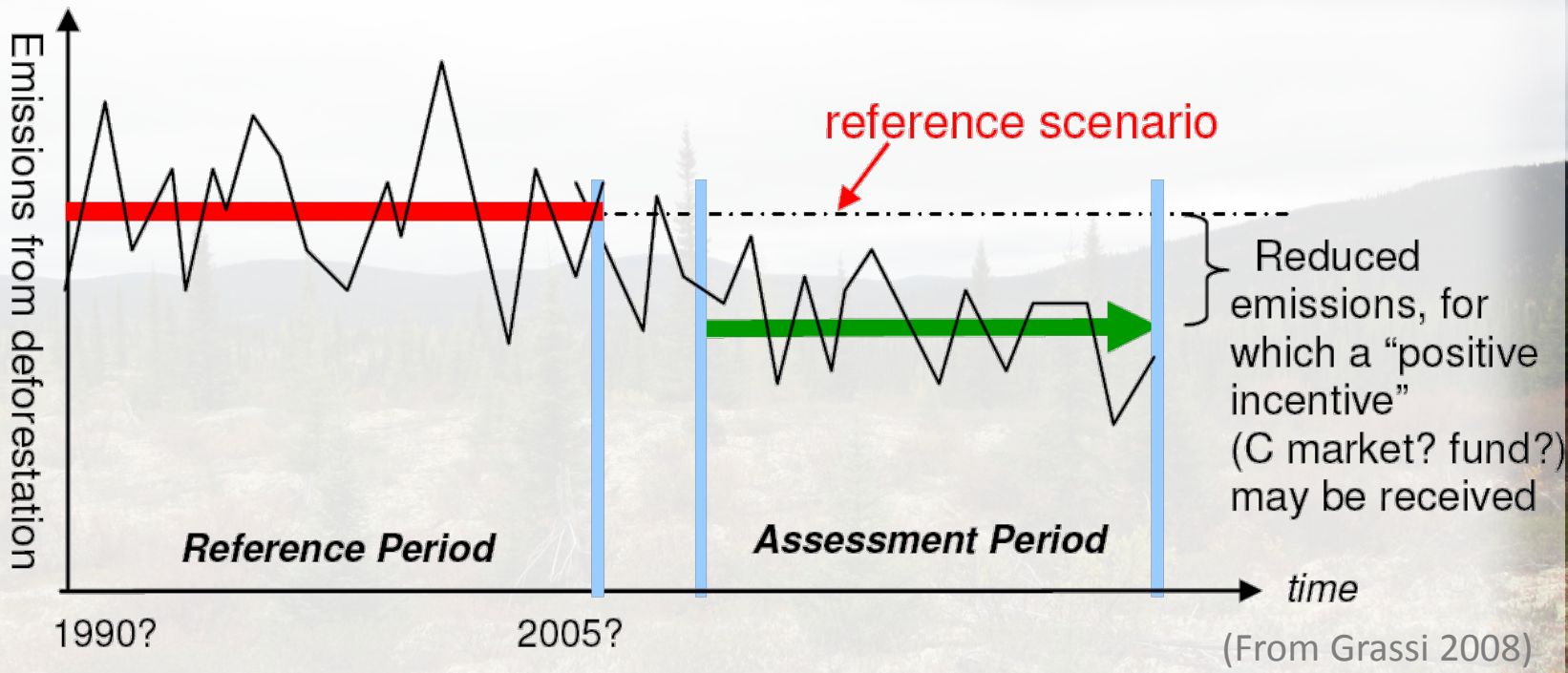
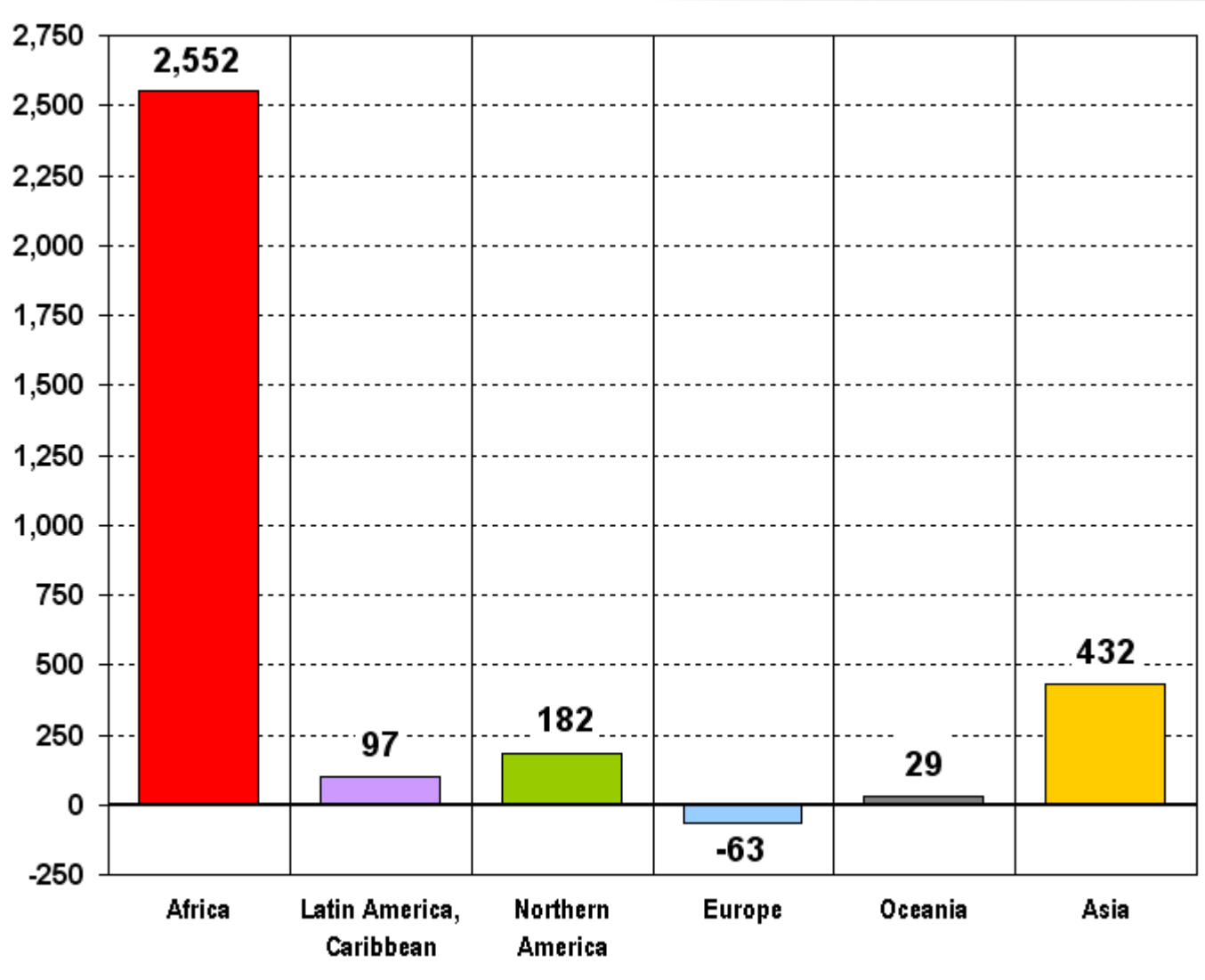


Figure 1: simplified representation of how a REDD mechanism could work.

- Tropics = both an important source and sink of C and harvested wood products (HWP) → need the **enforcement of the REDD+, but with strong consideration to the management of land-use conflicts, loss of arable lands, leak risks and poverty**
- Tropics = important **MRV needs, and for the development or adaptation of accounting approaches and tools** (C accounting models)

Population change between 2010 and 2100 by major region (millions)



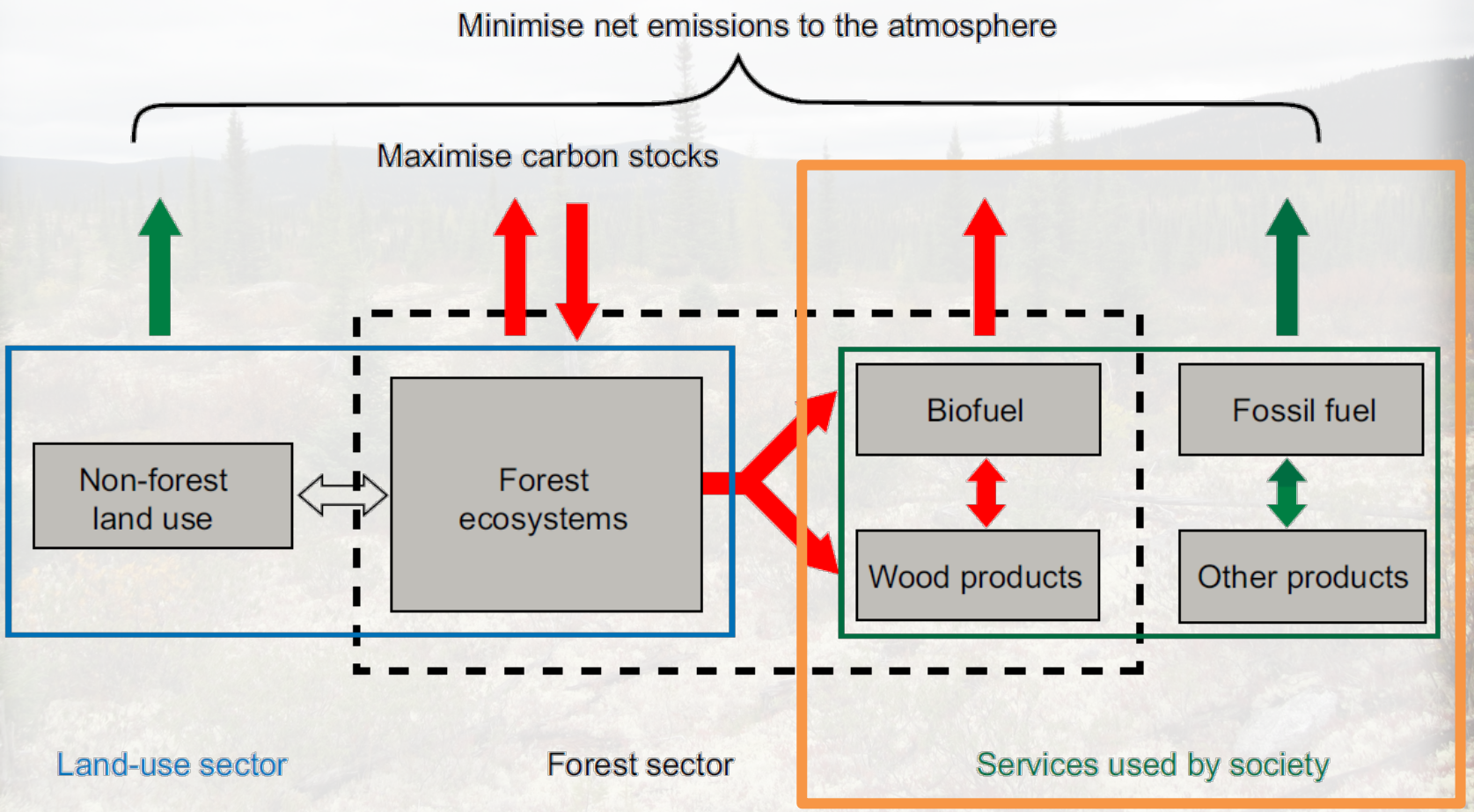
Source: United Nations, Department of Economic and Social Affairs, Population Division (2011): World Population Prospects: The 2010 Revision. New York

Projected high demand for building materials in Africa…

… but where the wood products will come from to face the African demand??

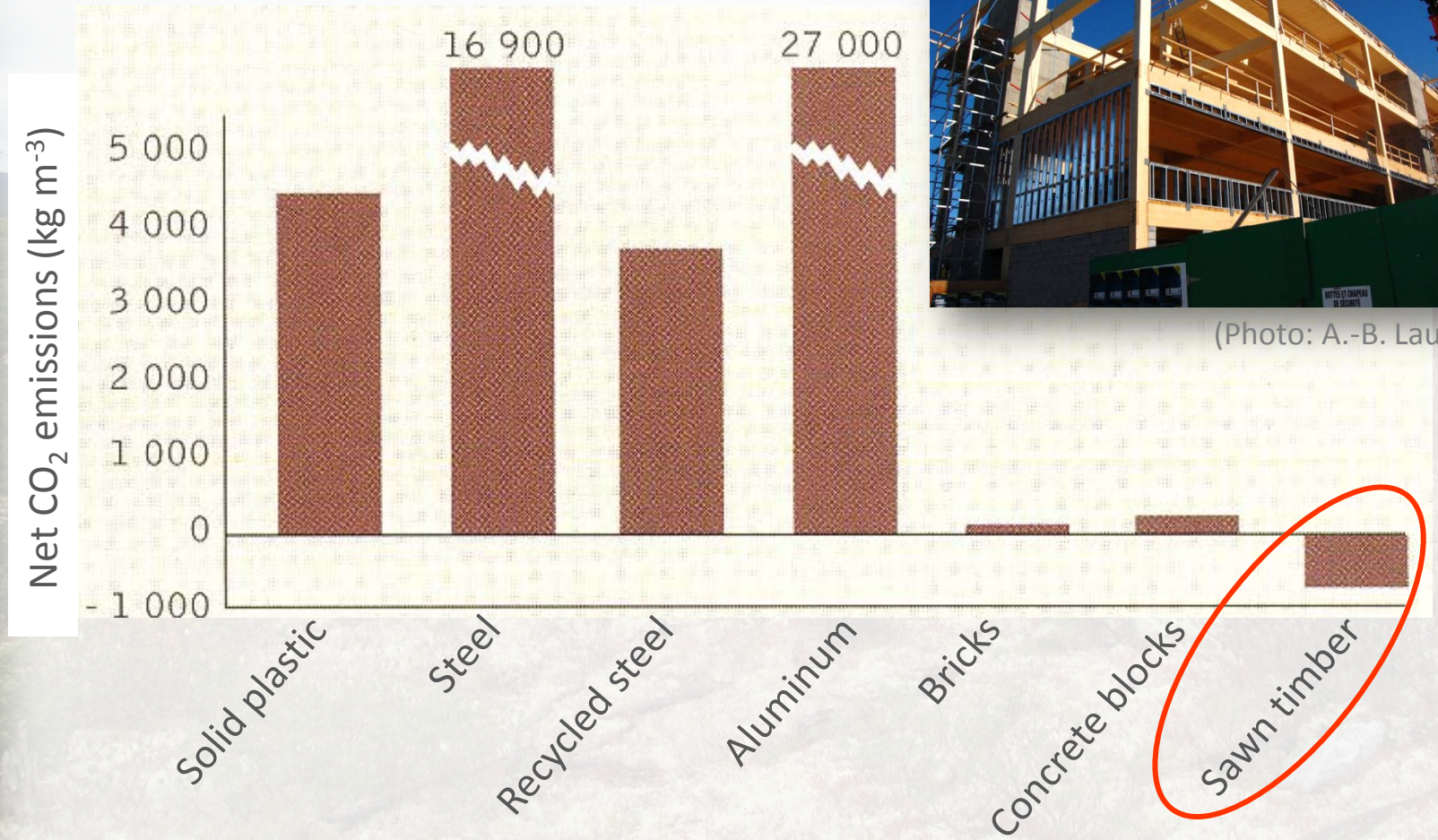
(photo: R. Nsielolo Kitoko)

In the global warming context, wood products is the right choice



(From Nabuurs et al. 2007)

CO_2 emissions of different building materials



(Photo: A.-B. Laurent)

RTS Building Information Foundation', Finlande, Environmental Reporting for Buildings Materials, 1998 – 2001 et Ministère de l'Environnement, Danemark, The Environmental Impact of Packaging Materials, 2001.

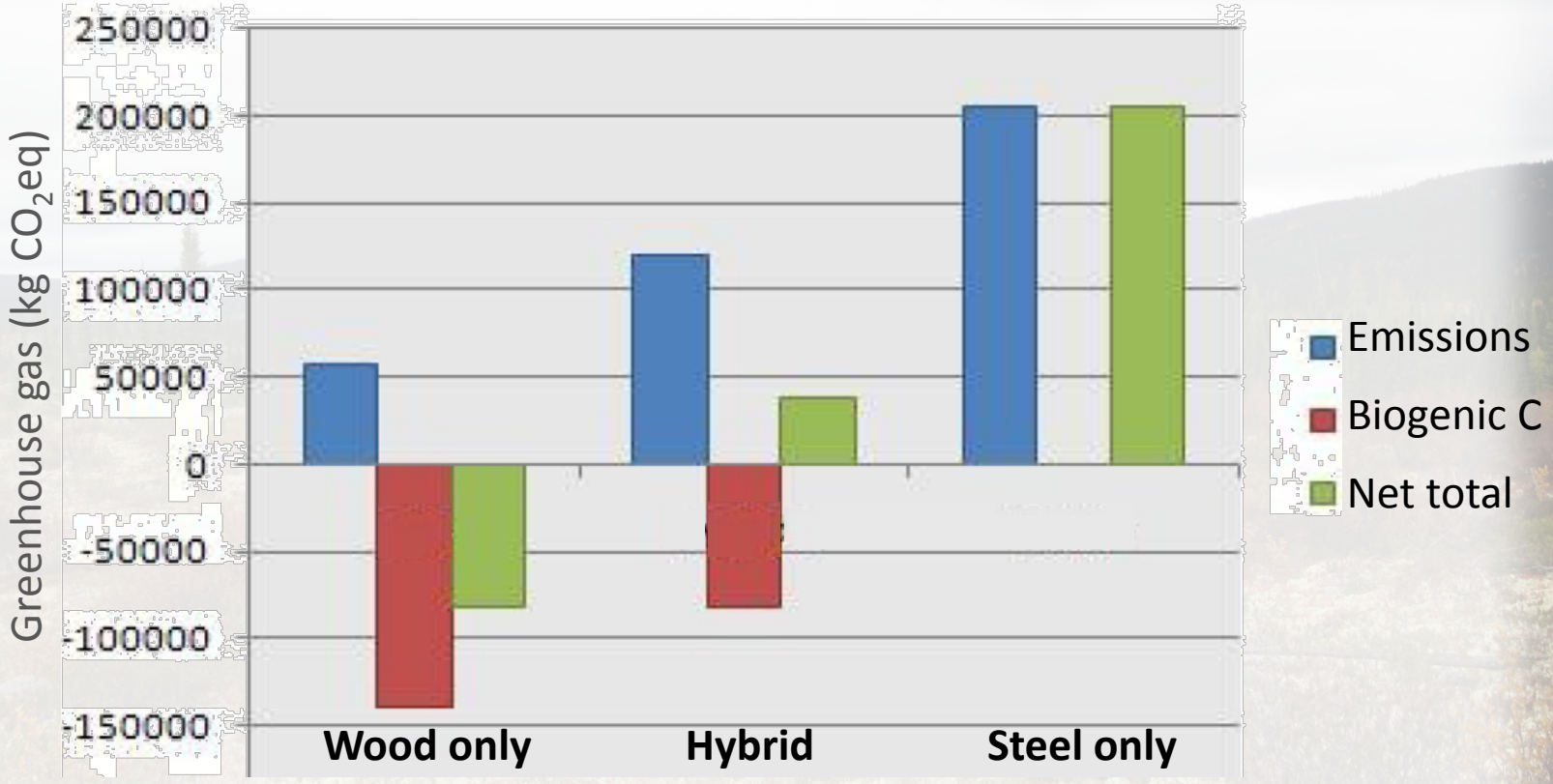
Example of a building life-cycle analysis (LCA)

Glulam beam

- Laurent et al., In prep.

Net C balance of different construction alternatives

(Laurent et al., In prep.)



- Steel production (from Toronto) = 0.91 kg CO_2 kg^{-1}
- Black spruce in glulam = 745 kg CO_2 m^{-3}
- LCA of glulam production = 110 kg CO_2 m^{-3} (Laurent 2012) ➔ **Net biogenic C in 1 m^3 of glulam = 635 kg CO_2 sequestered** (during its life time)

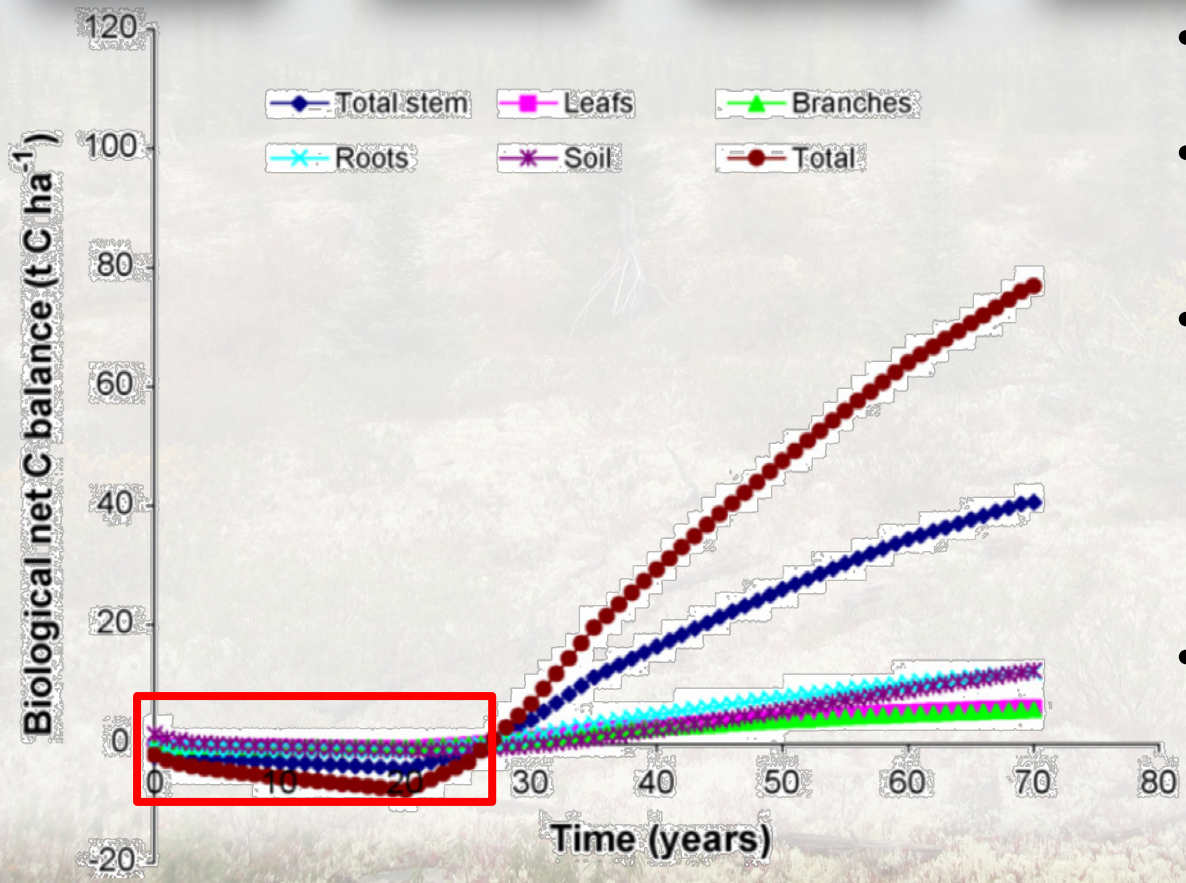
Mitigation options in the LULUCF sector in high latitude regions

	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)*	↓		

(From Nabuurs et al. 2007)

- Strategic advantage with the forest C management in the boreal zone = **few loss of opportunity, few land use conflicts, and no displacement of arable lands**
- **Disadvantages are**: slow growth rates, C debt creation, risks of reversibility associated to natural disturbances, and the albedo change related forcing

The C balance of simulated (with CO2Fix) boreal OW afforestation (Gaboury et al. 2009)



- Boreal OWs = 1.6 M ha in Québec
- End-of-project sequestration (70 years) = 77 t C ha^{-1}
- Net C balance: positive after 27 years
  → initial tree harvesting simulated
- C sequestration = **one aspect of the radiative forcing** of an afforestation project…

Albedo change related forcing can offset the C sequestration related forcing in high latitude afforestation

Agricultural and Forest Meteorology 151 (2011) 521–528

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Boreal lichen woodlands: A possible negative feedback to climate change in eastern North America

P.Y. Bernier[a,*], R.L. Desjardins[b], Y. Karimi-Zindashty[b], D. Worth[b], A. Beaudoin[a], Y. Luo[c], S. Wang[d]

GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L23705, doi:10.1029/2005GL024550, 2005

GEOPHYSICAL RESEARCH LETTERS, VOL. 28, NO. 2, PAGES 291-294, JANUARY 15, 2001

Land use Changes and Northern Hemisphere Cooling

B. Govindasamy, P. B. Duffy and K. Caldeira

Climate effects of global land cover change

rd,[1] K. Caldeira,[2] G. Bala,[1] T. J. Phillips,[1] and M. Wickett[1]

letters to nature

NATURE | VOL 408 | 9 NOVEMBER 2000 |

Offset of the potential carbon sink from boreal forestation by decreases in surface albedo

Richard A. Betts

LETTERS TO NATURE

NATURE · VOL 359 · 22 OCTOBER 1992

Effects of boreal forest vegetation on global climate

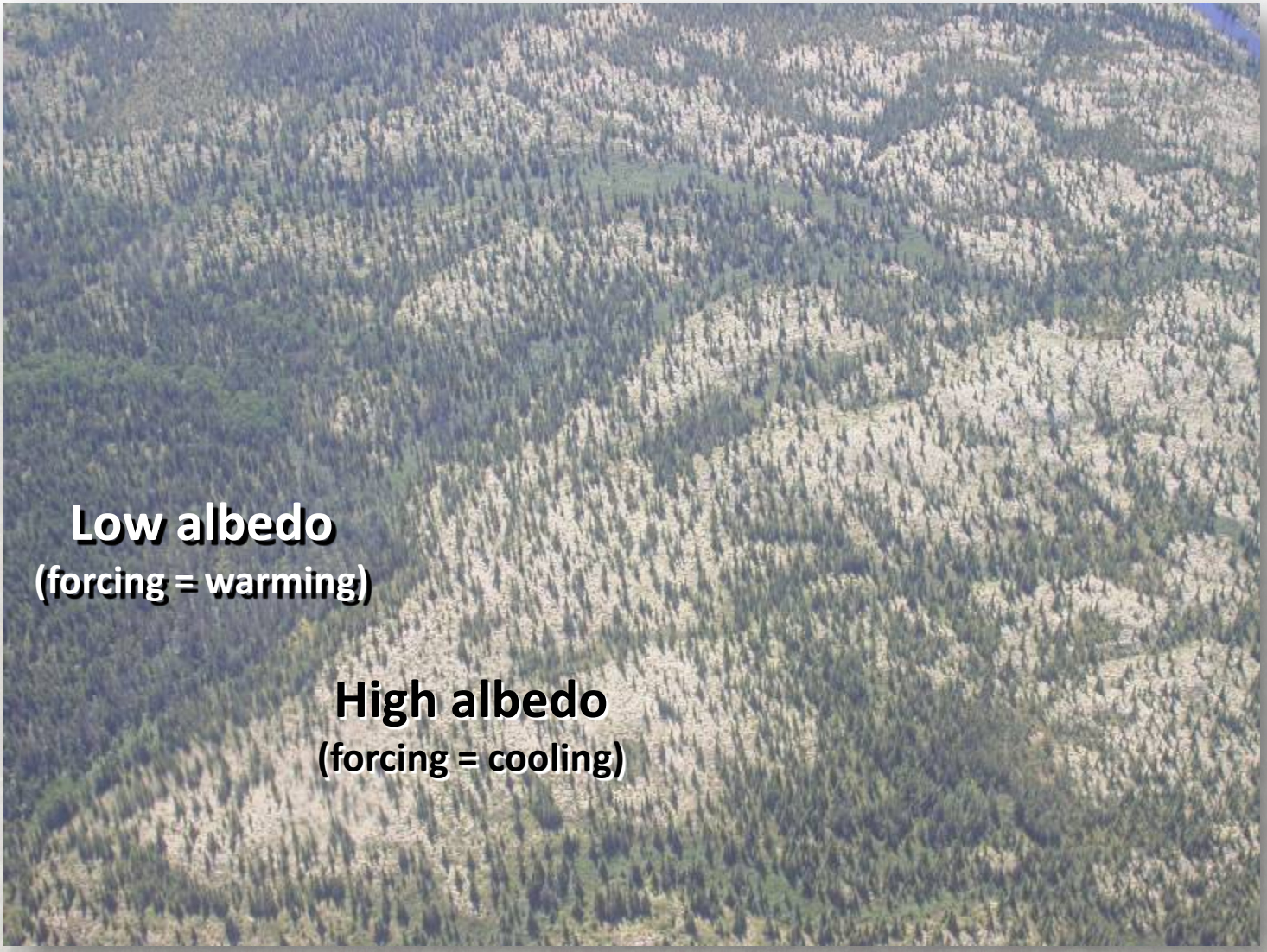
Gordon B. Bonan*, David Pollard & Starley L. Thompson

6550–6555 | PNAS | April 17, 2007 | vol. 104 | no. 16

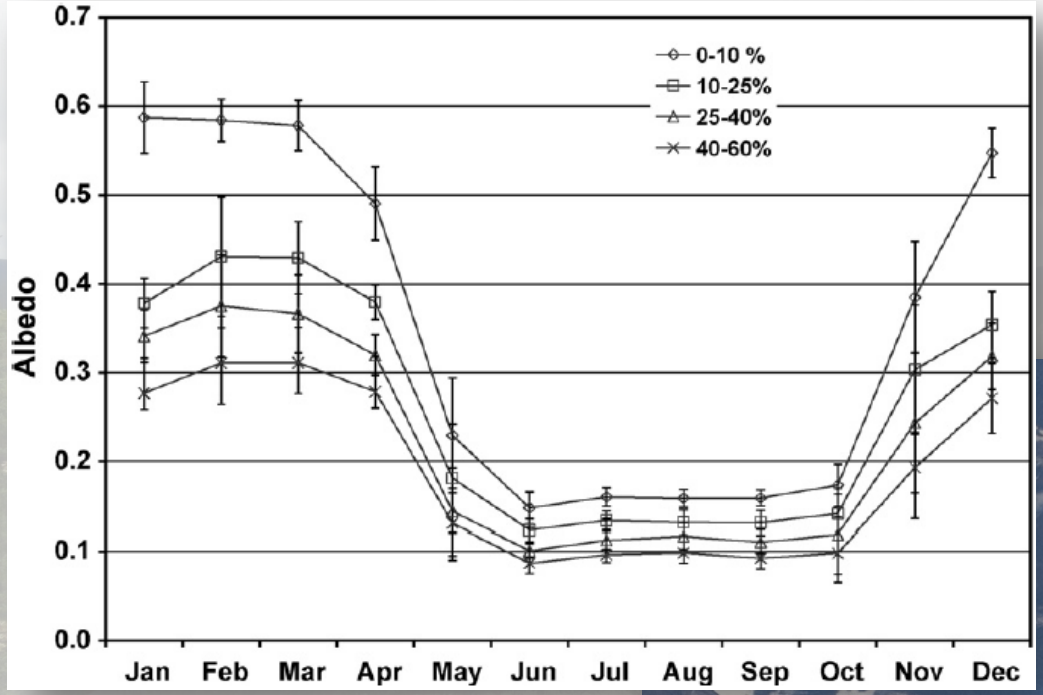
Combined climate and carbon-cycle effects of large-scale deforestation

G. Bala*†, K. Caldeira‡, M. Wickett*, T. J. Phillips*, D. B. Lobell*, C. Delire§, and A. Mirin*

Albedo change related forcing can offset the C sequestration related forcing in high latitude afforestation

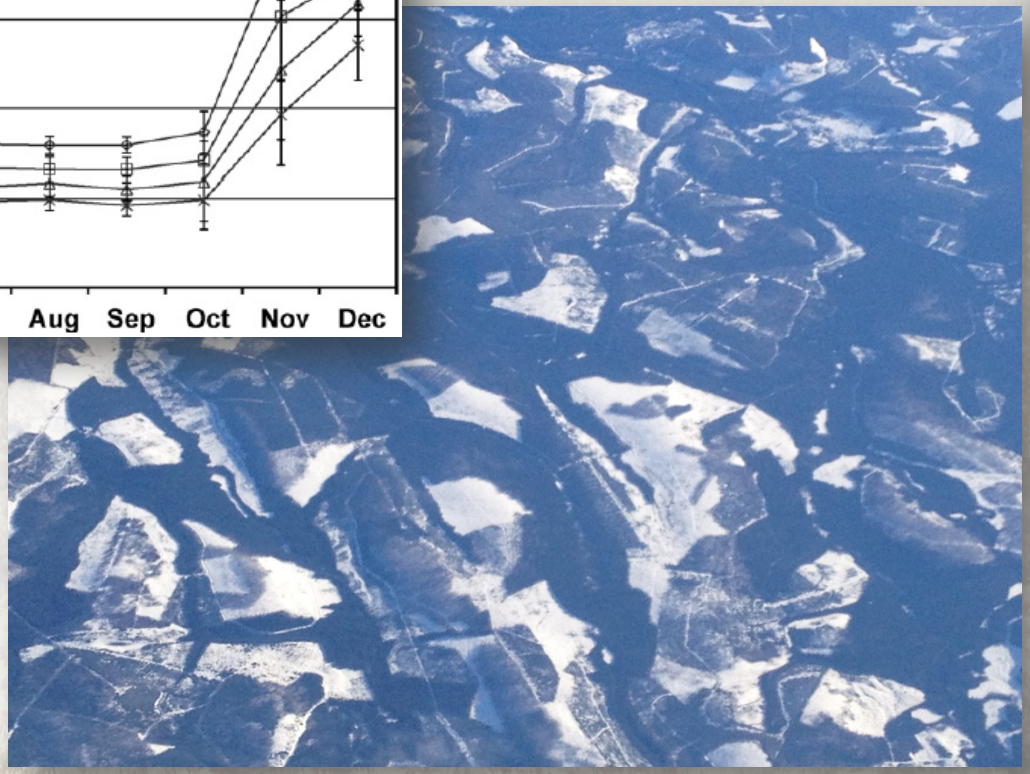


Albedo change related forcing can offset the C sequestration related forcing in high latitude afforestation



(From Bernier et al. 2011)

Aerial photo of a managed landscape, during the winter



Conversion from coniferous to deciduous composition…

Ecological Applications, 00(0), 0000, pp. 000–000
© 0000 by the Ecological Society of America

Potential changes in forest composition could reduce impacts of climate change on boreal wildfires

Aurélie Terrier,[1,6] Martin P. Girardin,[1,2] Catherine Périé,[3] Pierre Legendre,[4] and Yves Bergeron[1,5]

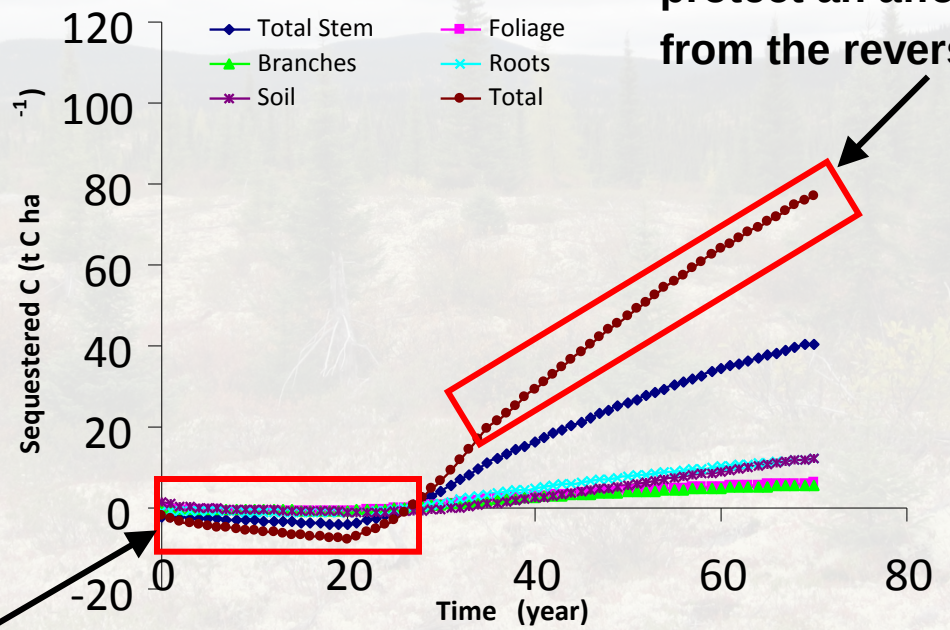
- To address both the uncertainty associated to the albedo change with high latitude afforestation AND the adaptation of boreal forests to climate change
- See the presentation from Price et al. at 11:30!!

Net C drawdown related forcing used in the literature for simulation of high latitude afforestation

Net C drawdown (t C ha^{-1})	Region considered	Reference
21–42	Boreal Québec (Canada)	Bernier et al. (2011)
60	Boreal Canada	Betts (2000)
50–75	Boreal Canada	Betts et al. (2007)
55	Boreal latitudes	Claussen et al. (2001)
100	Global	Gibbard et al. (2005)
170	Boreal Canada	Montenegro et al. (2009)
77	Boreal Québec (Canada)	Gaboury et al. (2009)

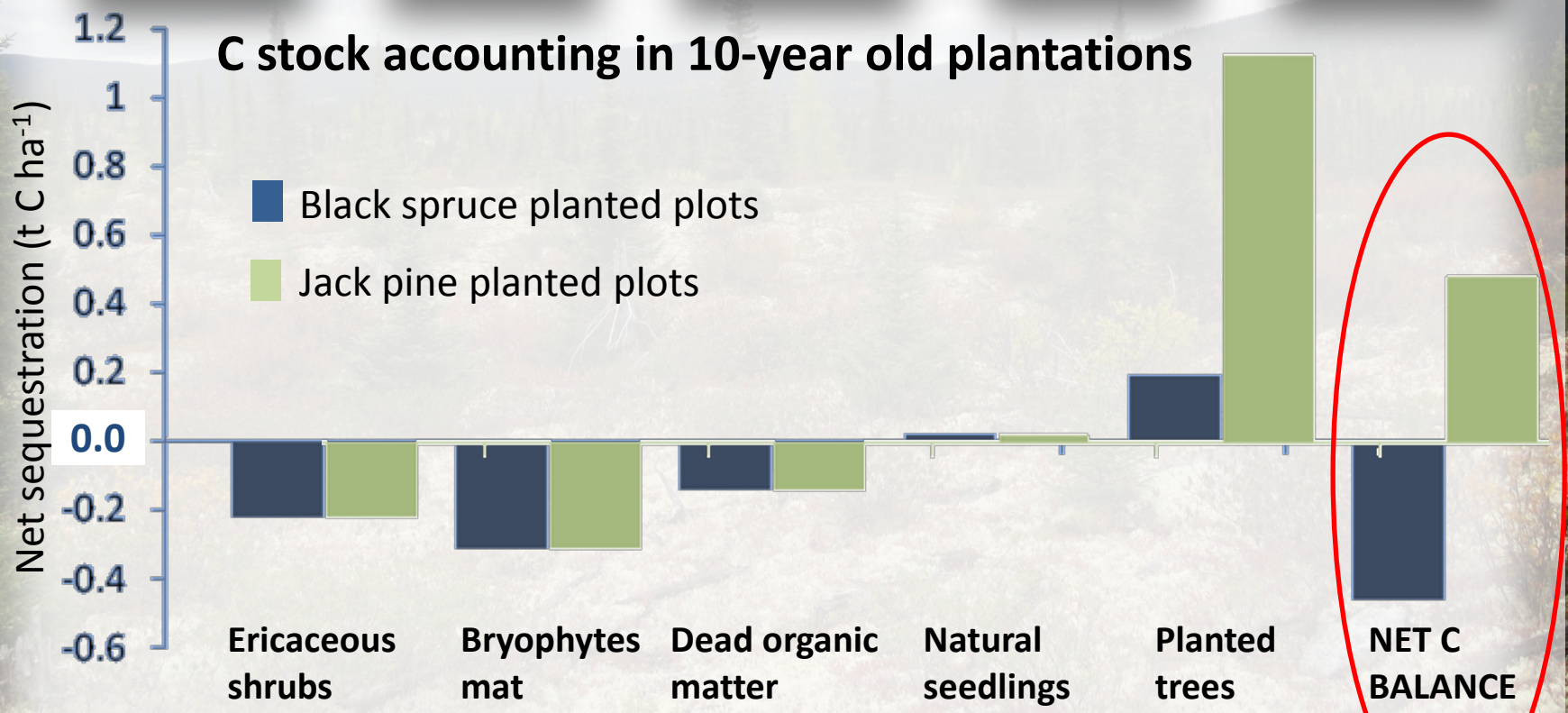
R&D on the optimization of a boreal afforestation project

How can we increase the net sequestration rate and the cumulated C stocks? How can we protect an afforestation project from the reversal risks??



How can we reduce the net emission period (the "C debt") and optimize the return on investment (ROI) of an afforestation project??

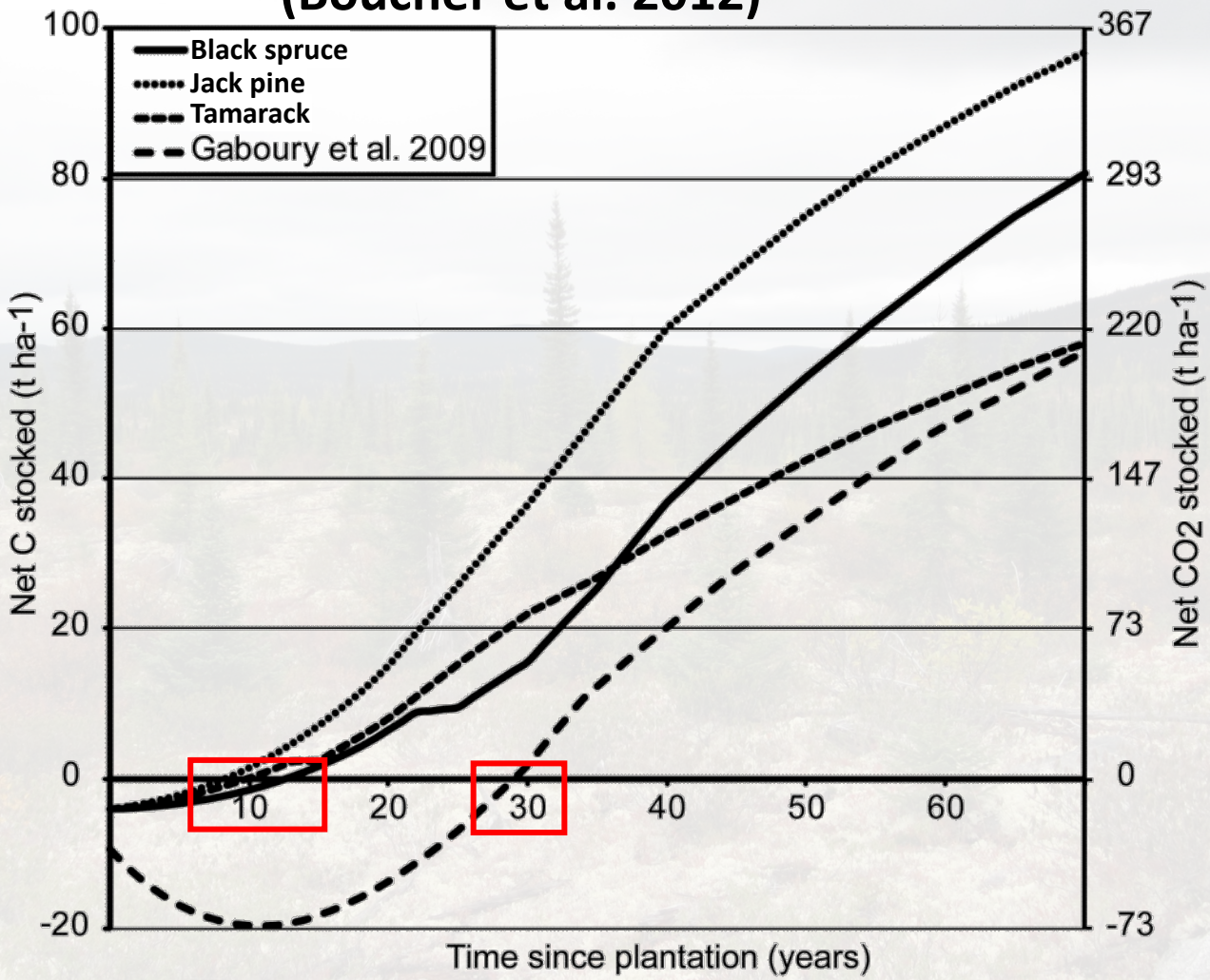
Reducing the C debt period…



- Positive net C balance after 10 years (with planted jack pines) → 16 year long reduction on the C debt

New simulations with CBM-CFS3

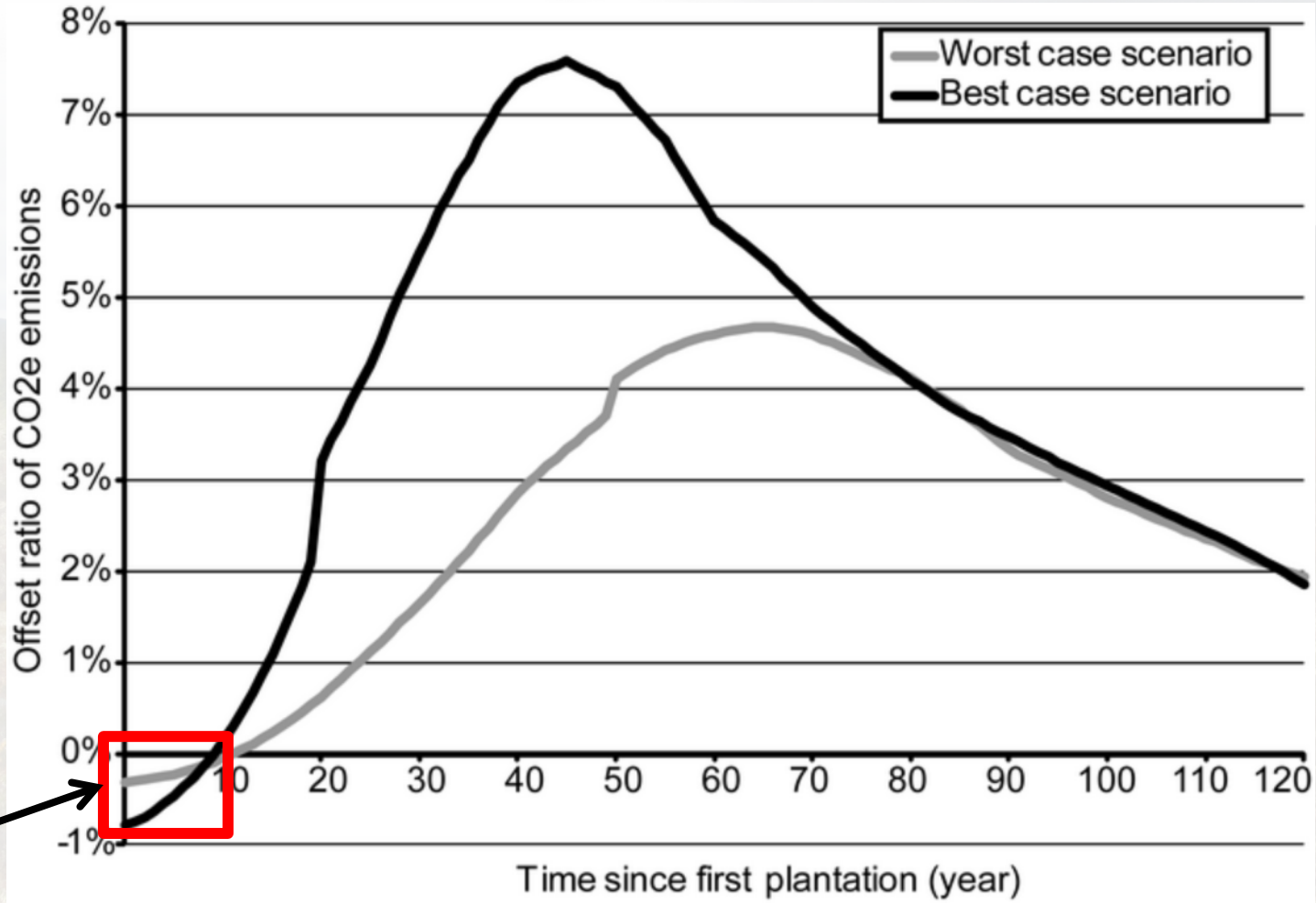
(Boucher et al. 2012)



- Faster and greater stocking with understory plantations (no harvest) with jack pine than that simulated in Gaboury et al. (2009)

Offset potential with large scale afforestation

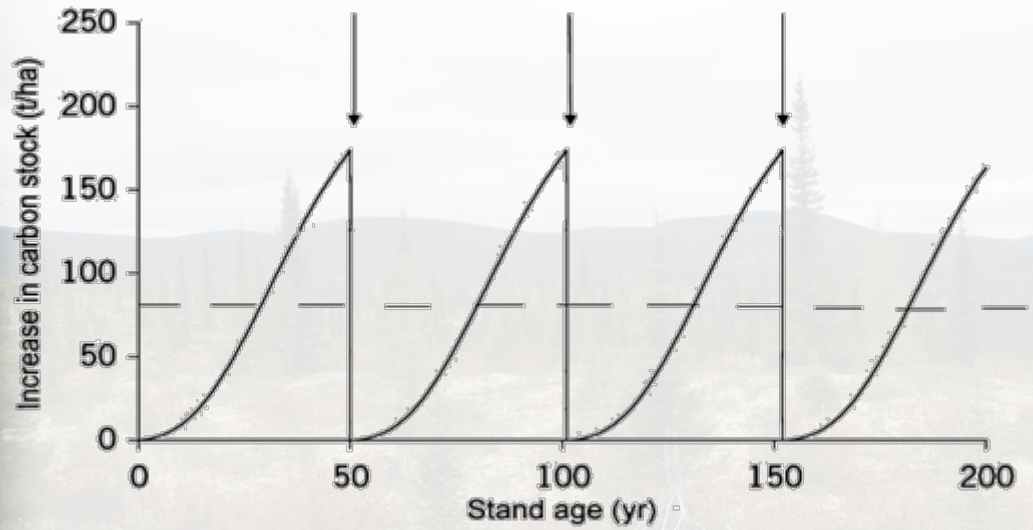
(Boucher et al. 2012)

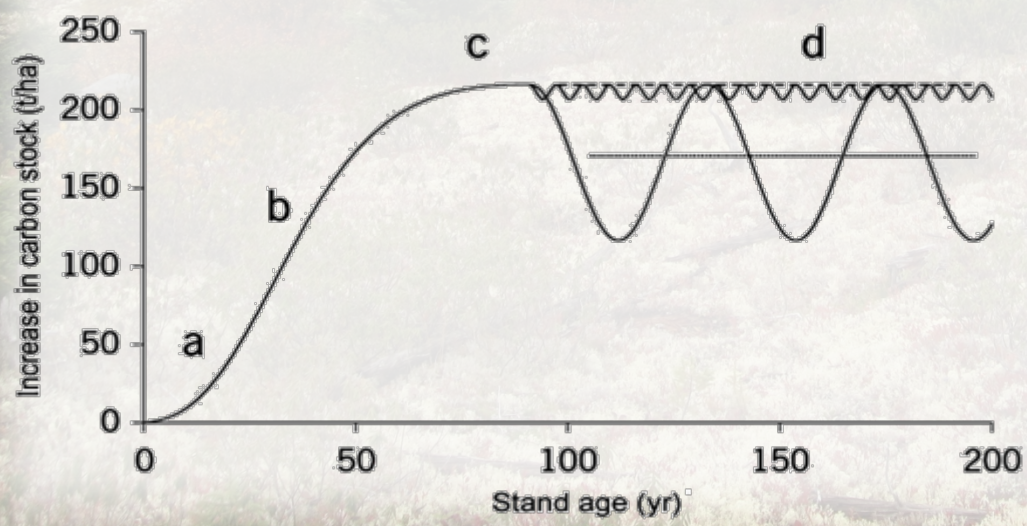


A C debt remains…

- A **large-scale afforestation of boreal OWs** – scheduled at 20 kha per year during 20 years for a maximum of 400 kha – could provide capped industrials with a significant offset potential, for instance **up to nearly 8% offset of all Québec industrial process emissions (2009 data) after 45 years**.

Management of the C debt





- The management of the C debt created by afforestation initiatives could include **joint-ventures within the forest management on the landscape**, for example by increasing the rotation length or replacing clear cutting by partial cutting (beyond business as usual practices) → **incentives** (eg. C markets) and juridictions should be flexible enough…

Mature OWs VS mature BSFM stands

Mature OWs
(=Baseline scenario)

Mature BSFM stands
(≈Afforestation scenario)

Comparable stand characteristics (stand age, soil deposits, slope, aspect, drainage, etc.) on 10 pairs of OWs and BSFMs

Mature OWs VS mature BSFM stands

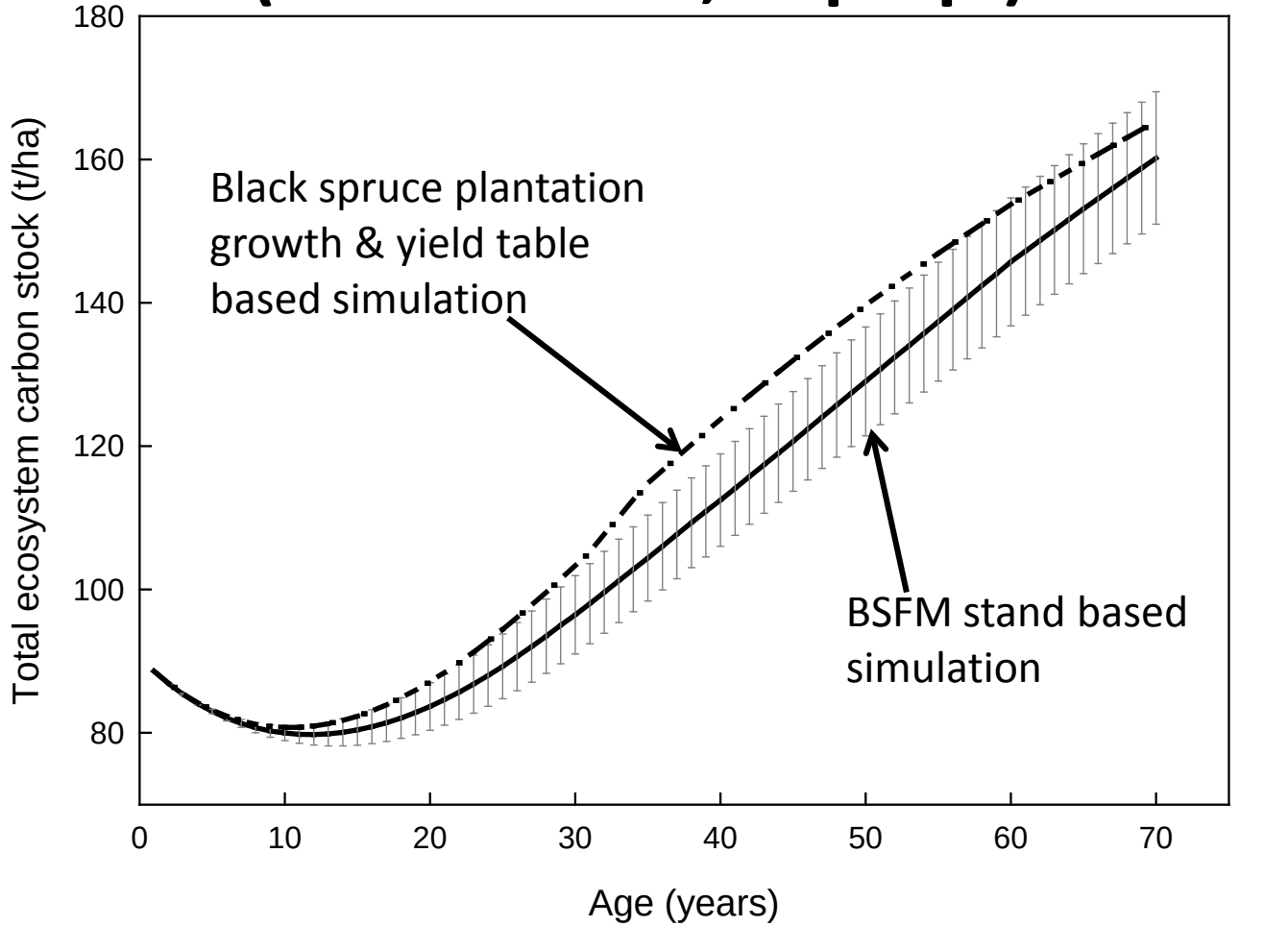
(Dufour et al., in prep.)

Stand type	Site index (m)	Mean DBH (cm)	Density (stems/ha)	Spruce density (stems/ha)	Basal area (m^2)	Volume (m^3/ha)	Measured C stocks in biomass (t/ha)
OW	9.9	5.59	597.5	550.0	8.79	36.78	23.2
BSFM	12.6	11.79	2587.5	2350.0	42.95	230.40	114.0
Diff.	2.7	6.2	1990	1800	34.16	193.62	**90.8**

- New allometric equations developed for OWs (Fradette 2013)
- The difference between OWs and BSFMs in measured C stocks in the biomass (90.8 t ha^{-1}) is somewhat **higher than that estimated (65 t ha^{-1}) in Gaboury et al. (2009)**

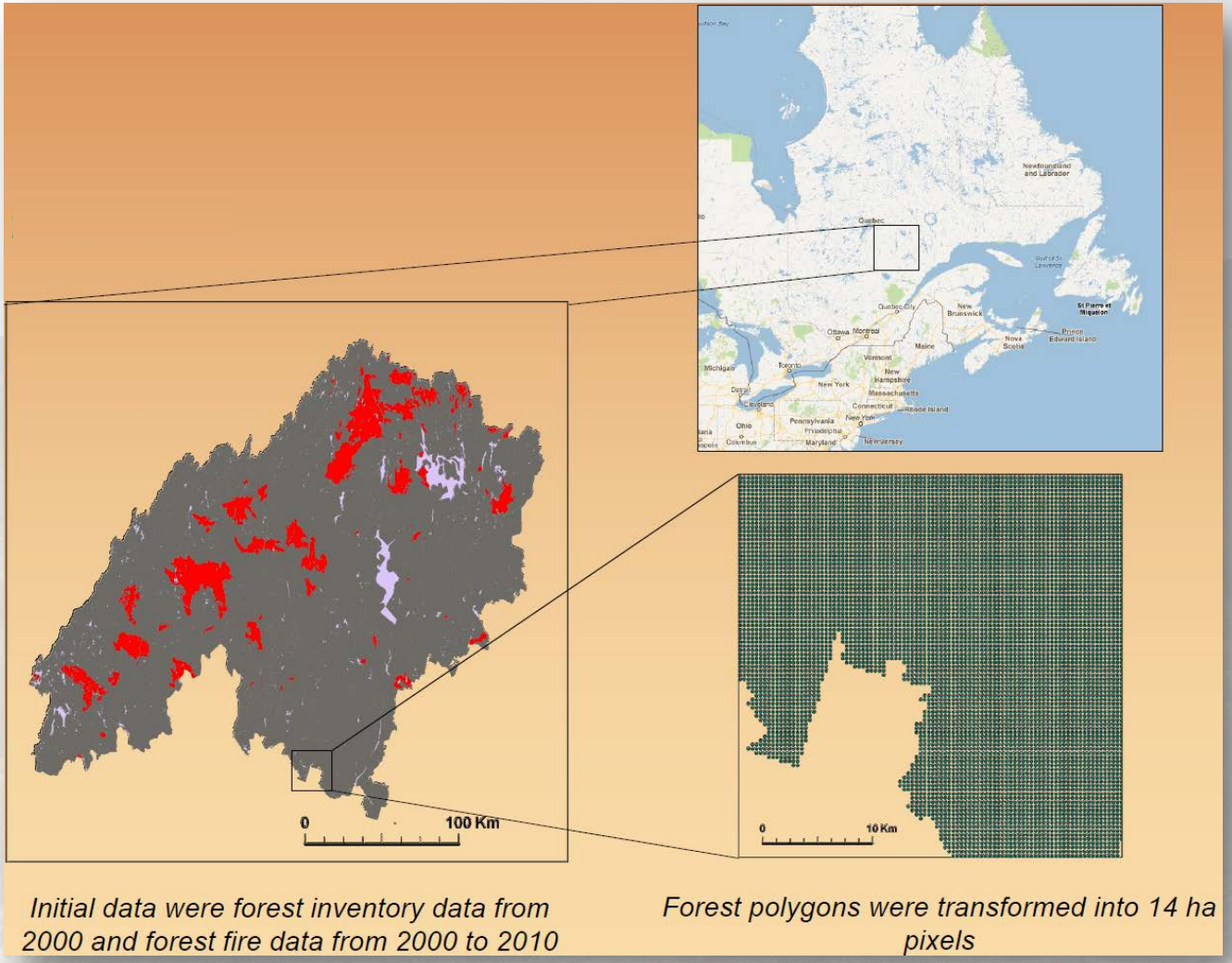
Mature OWs VS mature BSFM stands

(Dufour et al., in prep.)



- Reconstruction of ecosystem C stocking of the afforestation scenario using CBM-CFS3 = equivalence between a BSFM stand based simulation and a black spruce plantation growth & yield table based simulation

Accounting for fire risks in the C budgets of afforestation projects within the continuous boreal forest (Cavard et al., in prep.)

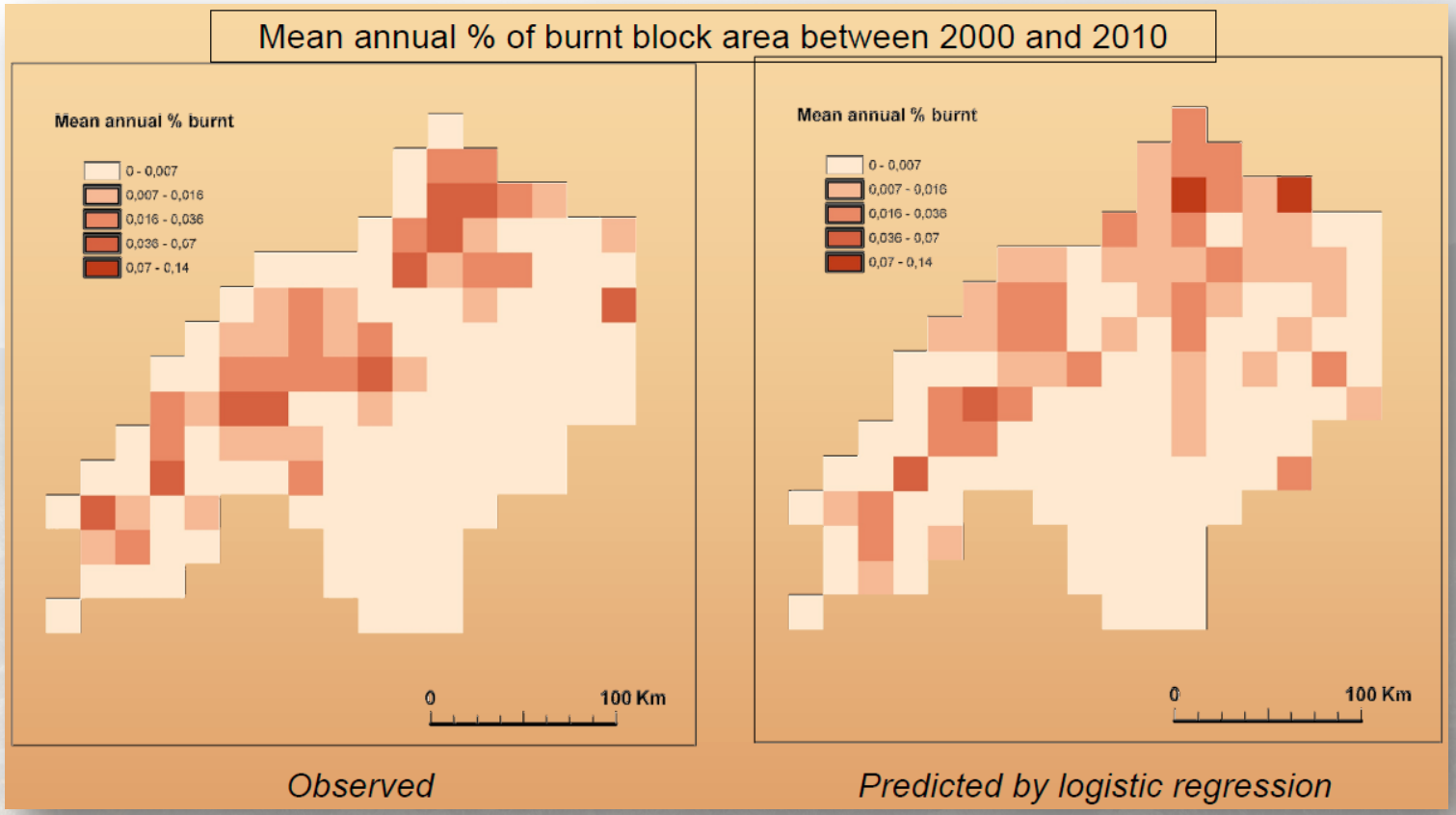


Initial data were forest inventory data from 2000 and forest fire data from 2000 to 2010

Forest polygons were transformed into 14 ha pixels

- Study objectives:
  - Identify risk factors that contribute to wildfire occurrence
  - Estimate average C loss due to wildfires in open woodlands vs. dense afforested areas

Accounting for fire risks in the C budgets of afforestation projects within the continuous boreal forest (Cavard et al., in prep.)



➢Main conclusions:

- Increased tree density in the landscape with **afforestation projects in open woodlands tends to diminish fire risks**
- A logistic regression can predict mean annual burnt areas at a temporal resolution of 11 years and a spatial resolution of 350 km² with acceptable accuracy, which will **allow to include impact of fire in C budgets, and eventually better comply with reversal risk calculations and management in regulated carbon markets or standards**

The economical potential of the carbon offset opportunity offered with the afforestation of boreal open woodlands

(Dufour et al., see poster 153)

Main hypothesis tested: Optimized silvicultural solutions of boreal open woodland afforestation can produce feasible and profitable offset opportunities on mid- to long term horizons (20-50 years), with respect to plausible carbon price scenarios and discount rates.

Incomes
- Carbon credits
- Wood products

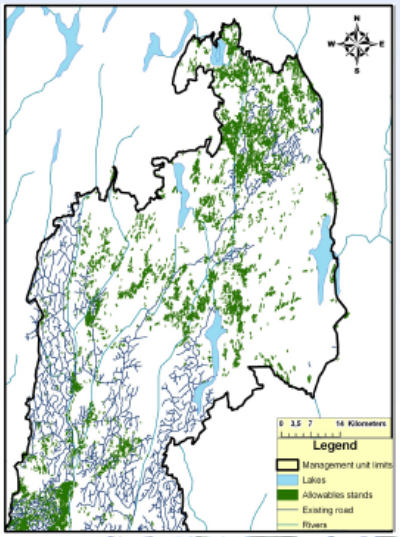
Expenses
- Field operational costs
- Monitoring costs
- Road construction

REMSOFT®

Woodstock spatial optimization

Parameters:
- Spatial distribution of OWs and roads
- Land productivity
- Planted species
- Forest fires
- Wildlife management plans
- Backup plantations extent (risk of reversion)
- Forest carbon allometry (CBM-CFS3)
- Anticipated carbon value (TIMES Canada)

Optimized **NPV** (Net Present Value)



Partners

UQAC Université du Québec à Chicoutimi

GENIVAR

HEC MONTRÉAL GERAD Groupe d'études et de recherche en analyse des décisions

Conclusions

- Rapid and important mitigation from the **tropics**… however, **problems with land-use conflicts, loss of arable lands, leak risks, poverty, lack of accounting approaches and tools**
- Mitigation with **high latitude activities** = few loss of opportunity, few land use conflicts, and no displacement of arable lands… but **problems with slow growth rates, C debt creation, risks of reversibility, and the albedo change related forcing**
  - Management at the landscape level can help mitigate (offset) these limitations and **promote the creation of new forested areas, new valuable GHG offset opportunity, and eventually increased flow of wood products in the market** to face increasing demand for building materials with low C intensity

Merci!

NSERC CRSNG
RioTinto Alcan
Fonds de recherche sur la nature et les technologies Québec
eco conseil
UQAC
Chaire en éco-conseil
Université du Québec à Chicoutimi
carbone boréal