The carbon cycle and forest-climate interactions: principles and considerations

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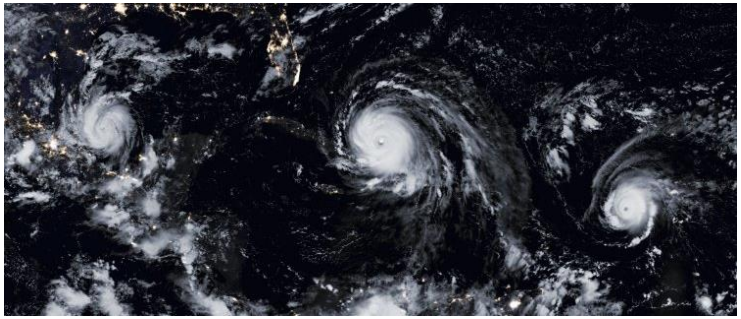
Forests and the climate:
Manage for maximum wood production or leave the forest as a carbon sink?

The Royal Swedish Academy of Agriculture and Forestry
The Royal Swedish Academy of Sciences, The Royal Swedish Academy of Engineering Sciences
March 12-13, 2018

Natural Resources Canada | Ressources naturelles Canada

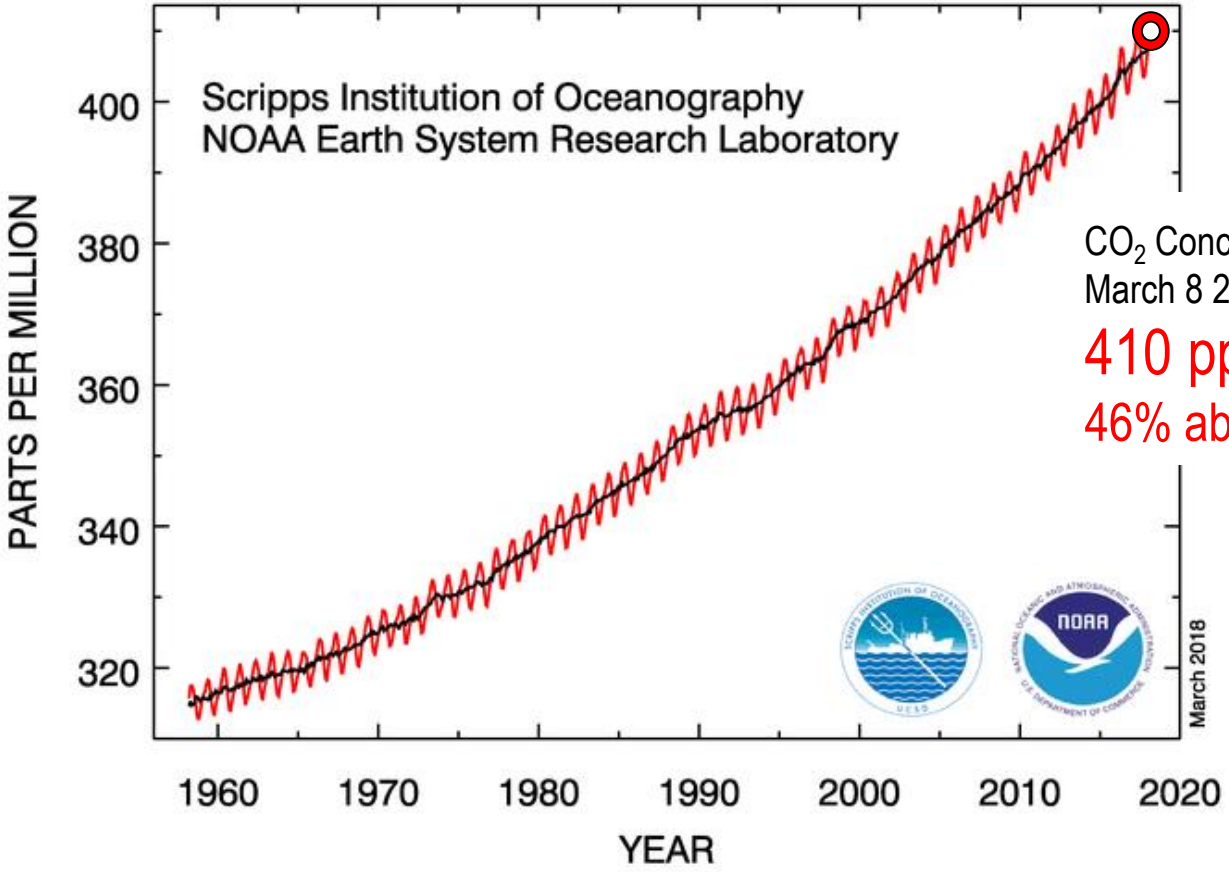
Canada

Climate change impacts are felt around the world. And much more to come!



Increase in Atmospheric CO_2 Concentration

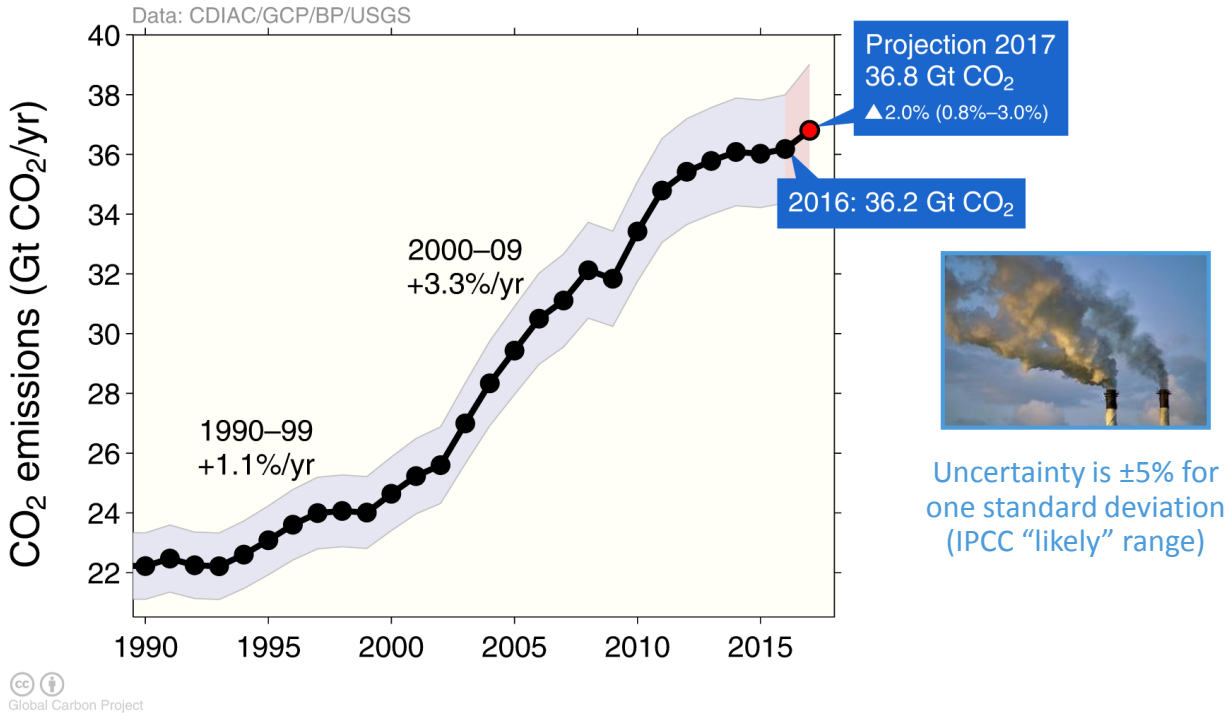
2016: first year with all weekly CO_2 levels above 400 ppm



Emissions from fossil fuel use and industry

Global emissions from fossil fuel and industry: 36.2 ± 2 $GtCO_2$ in 2016, 62% over 1990

Projection for 2017: 36.8 ± 2 $GtCO_2$, 2.0% higher than 2016



Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Estimates for 2015 and 2016 are preliminary. Growth rate is adjusted for the leap year in 2016.

Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

Fate of anthropogenic CO_2 emissions (2007–2016)

Sources = Sinks

34.4 $GtCO_2$/yr

88%

Fossil fuel burning, cement

12%

4.8 $GtCO_2$/yr

Deforestation, land-use change

17.2 $GtCO_2$/yr

46%

30%

11.0 $GtCO_2$/yr

24%

8.8 $GtCO_2$/yr

Budget Imbalance:
(the difference between estimated sources & sinks)

6%

2.2 $GtCO_2$/yr

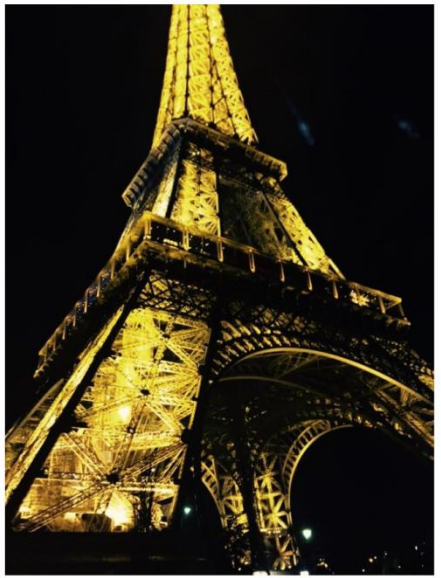
Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Le Quéré et al 2017; Global Carbon Budget 2017

United Nations

Framework Convention on Climate Change

Paris Agreement

- **Ambitious temperature target well below 2º C.**
- The submissions on intended Nationally-Determined Contributions (NDCs) from ~148 countries recognise the importance of the land sector in achieving GHG emission reduction targets.

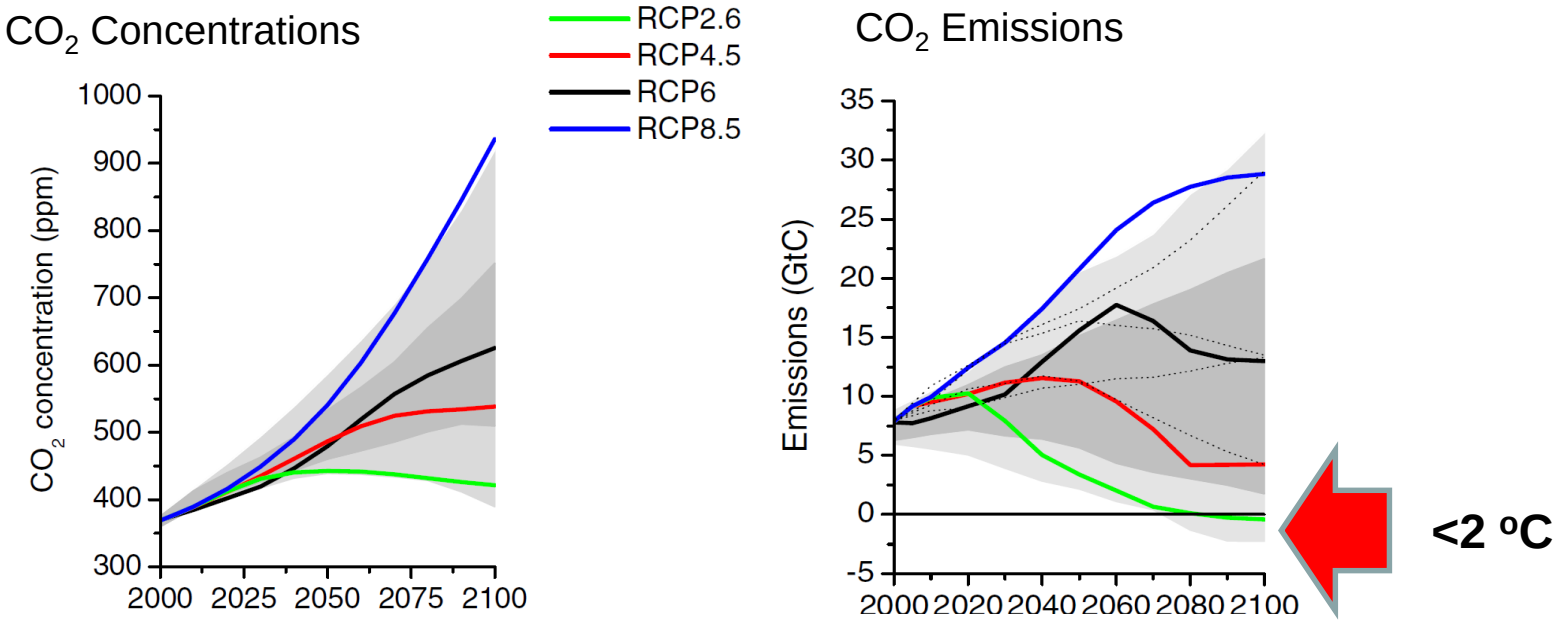


Source: K Simonson

IPCC emissions scenarios

Representative Concentration Pathways

To stay below the 2º C climate threshold **NEGATIVE** net emissions are required later in this century. Forests can remove carbon from the atmosphere cost effectively and with multiple co-benefits.



Source: Zwiers, Van Vuuren et al. 2011, Climatic Change

BECCS: Bioenergy with Carbon Capture & Storage

- Estimates of required cumulative CO_2 removal using BECCS to achieve < 2ºC increase vary by study.
- IPCC estimate ~**600** Gt CO_2 cumulative removals by 2100
- Land required for bioenergy plantations: **500+** Mha
- Competing with other wood uses, food and other land values.
- Current operational BECCS capacity: ~**ZERO**.

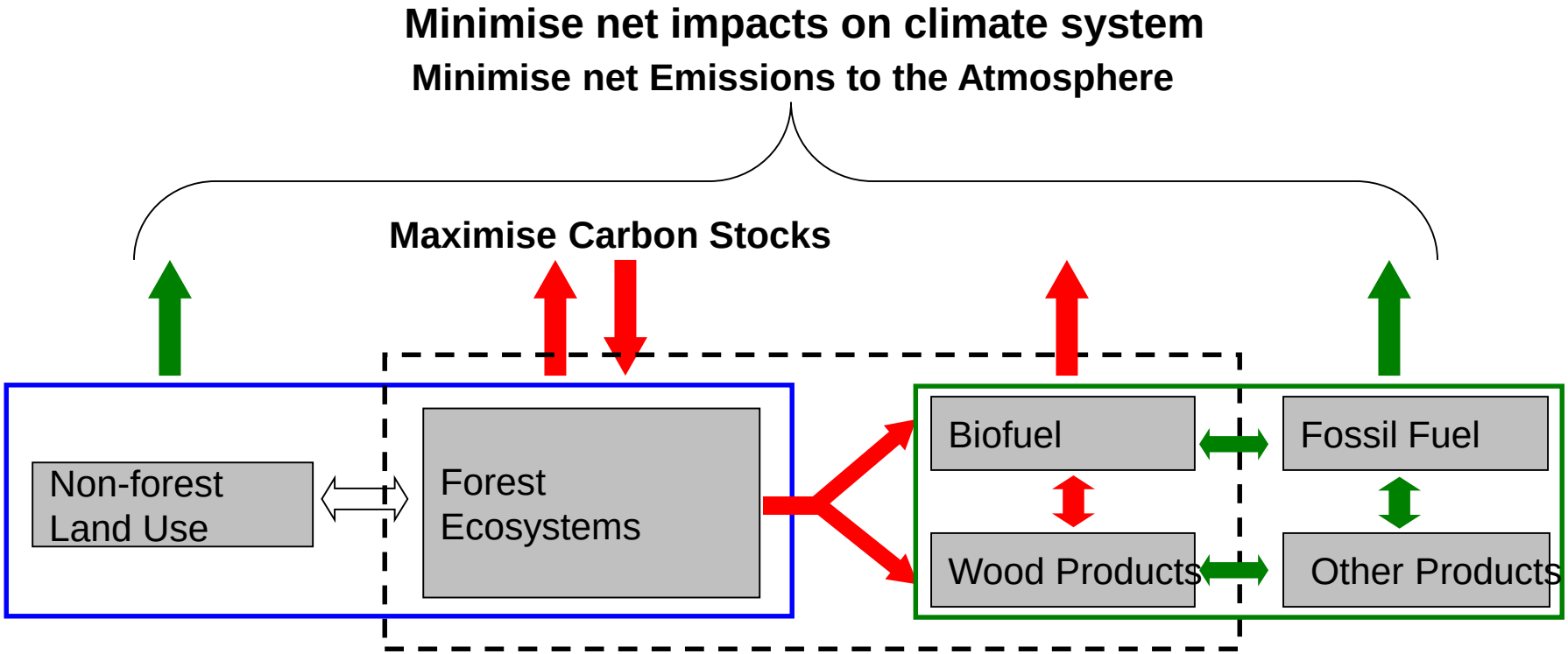
BECCS: Bioenergy with Carbon Capture & Storage

- Let the promise of unrealistically large future sinks from BECSS and the land sector not become an excuse to not reduce fossil fuel emissions.

- If the land sector fails to deliver these large sinks then the temperature goals will be even less attainable.

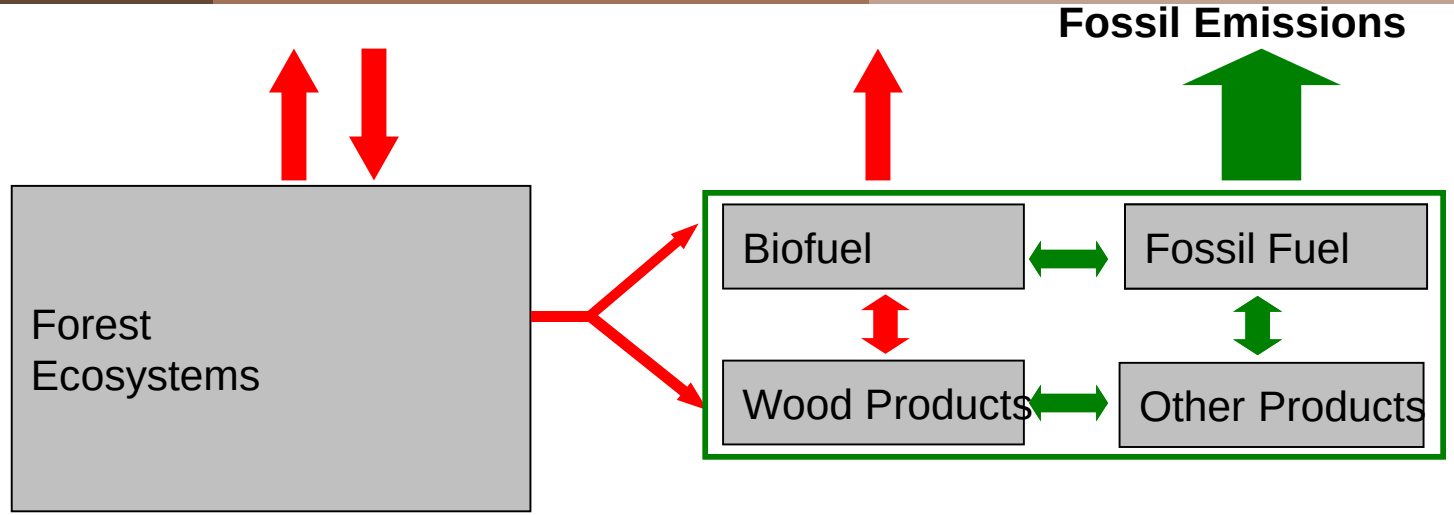
- However, the land sector and in particular forests can contribute to climate change mitigation strategies.

Mitigation Strategies: Need for Systems Perspective

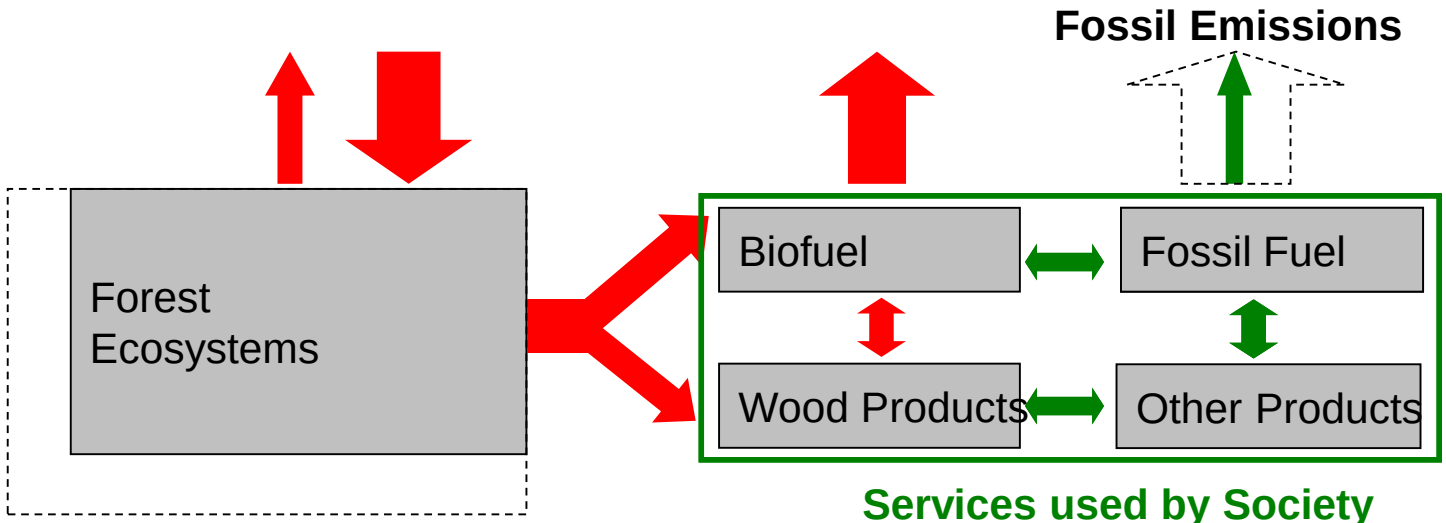


Source: IPCC 2007, AR4 WG III, Forestry

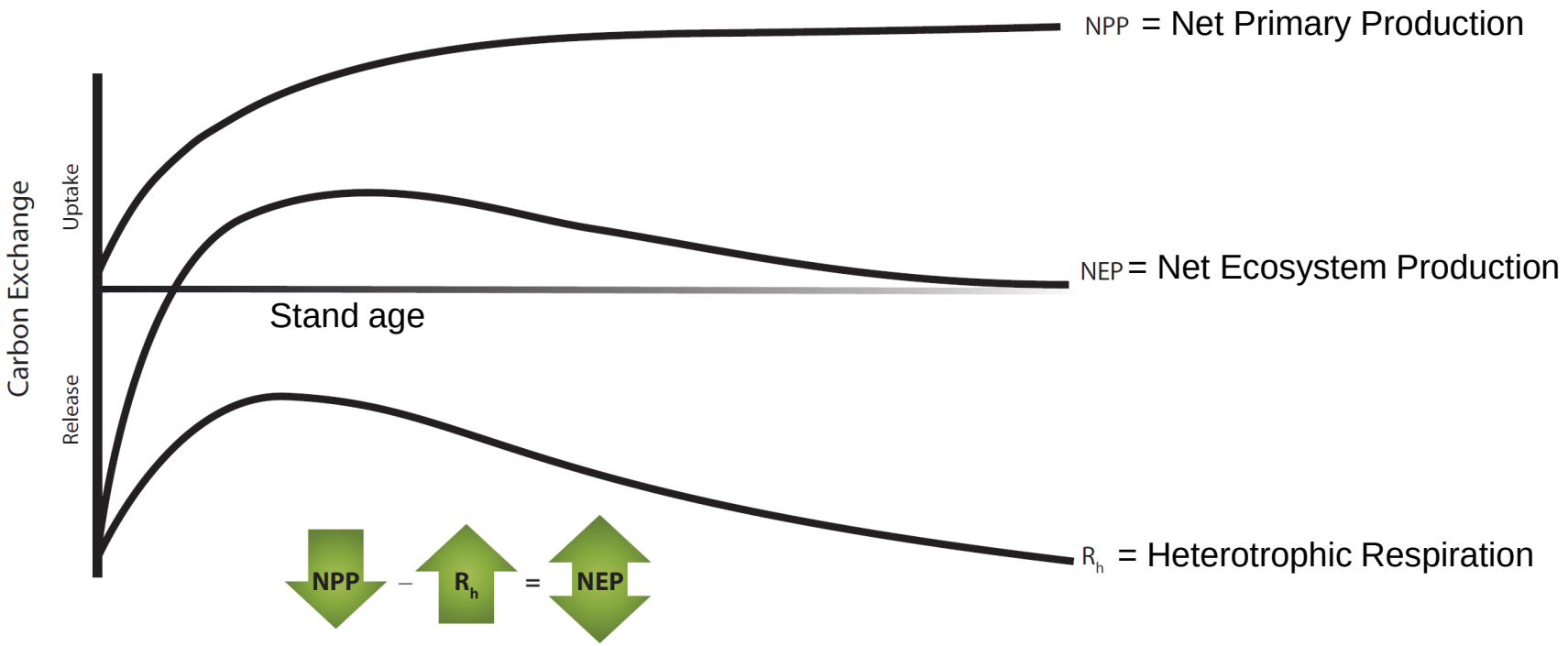
Maximise Carbon stocks



or maximise Carbon uptake?



Max. C uptake (NEP) and max. C stocks occur at different stand ages: we cannot "maximise" both at the same time



Source: Kurz et al. 2013

Net forest carbon balance is a small difference between two large fluxes.

Systems Perspective

Design of portfolios aimed at climate change mitigation through GHG management in the forest sector should account for changes in

- **forest ecosystem carbon,**
- **harvested wood product carbon**, and
- for changes in emission from **substitution benefits**

relative to a base case (business-as-usual).

Options for forest sector mitigation activities:



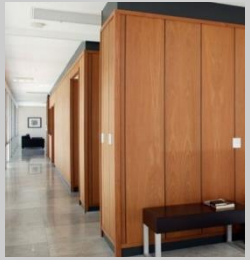
Increase sinks through forest management: fertilization, stand tending, tree selection, etc.

Rehabilitation after natural disturbances (wild fire and insects).

Reduce harvest residue burning.

Harvest less / more depending on conditions.

Increase afforestation and avoid deforestation.

Maximize carbon retention in long-lived products.

Cascading wood use.

Reduce wood waste at every stage.

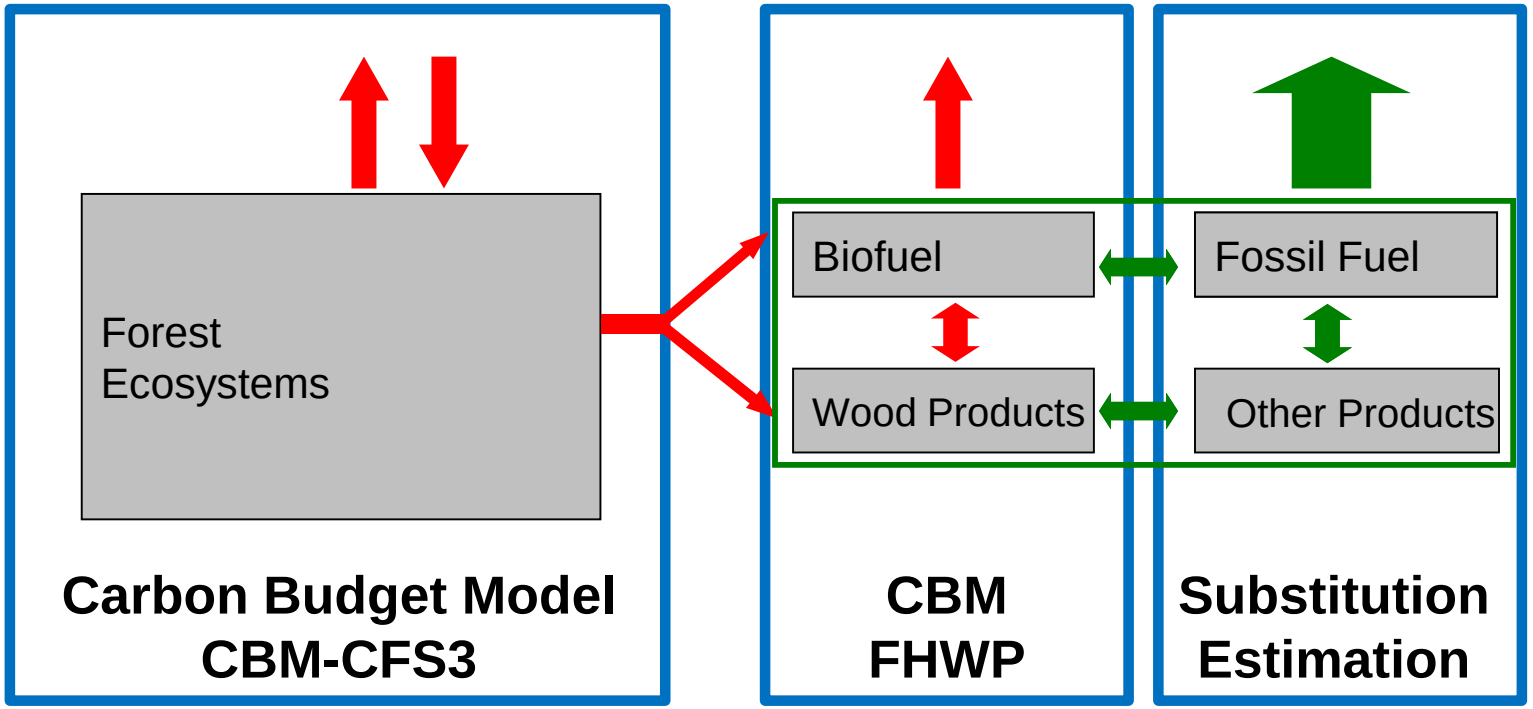
Divert wood products from landfills.


Replace emissions-intensive products such as steel and concrete with wood products.

Replace fossil fuels with bioenergy from wood waste, where appropriate.

We have modeled some of these …

Mitigation analyses: analytical framework



CBM-CFS3 and CBM-FHWP used for Canada's National GHG inventory reporting.

National-scale Mitigation Analysis

Biogeosciences, 11, 3515–3529, 2014
www.biogeosciences.net/11/3515/2014/
doi:10.5194/bg-11-3515-2014

Biogeosciences Open Access

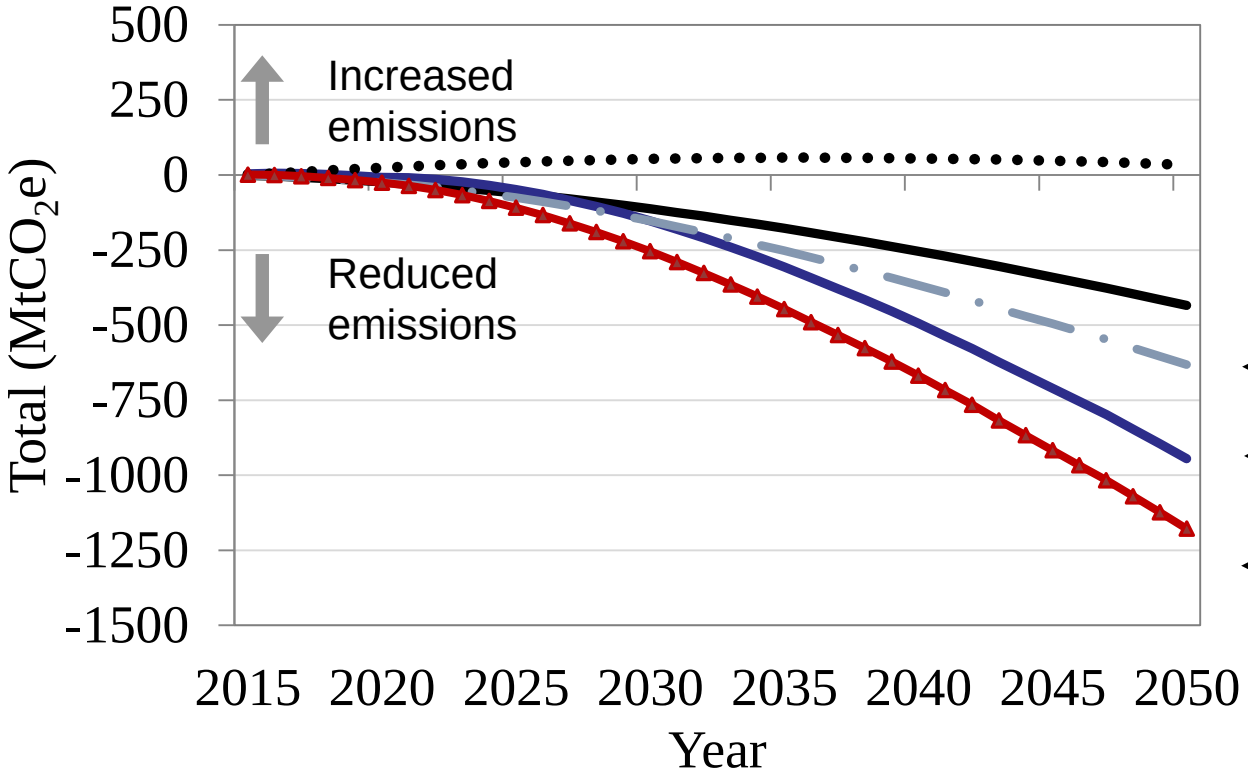
Quantifying the biophysical climate change mitigation potential of Canada's forest sector

C. E. Smyth[1], G. Stinson[1], E. Neilson[1], T. C. Lemprière[2], M. Hafer[1], G. J. Rampley[3], and W. A. Kurz[1]

http://www.biogeosciences.net/11/3515/2014/bg-11-3515-2014.pdf

Maximize Forest Management and HWP mitigation

Cumulative emission reductions to 2050 (relative to baseline)



Bioenergy feedstock

Longer-lived Products (LLP)

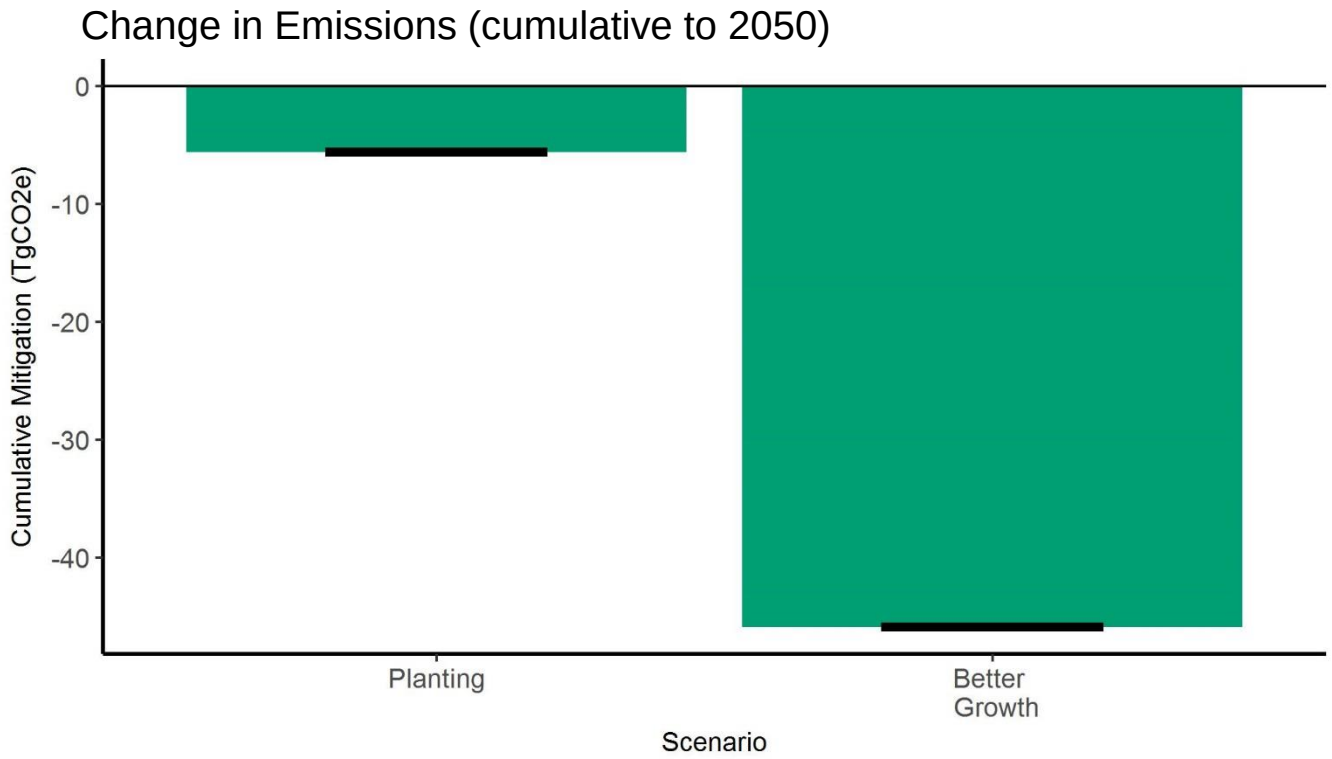
Harvest Less + LLP

Better Utilization+ LLP

Portfolio Mix: 1180 $MtCO_2e$

Results

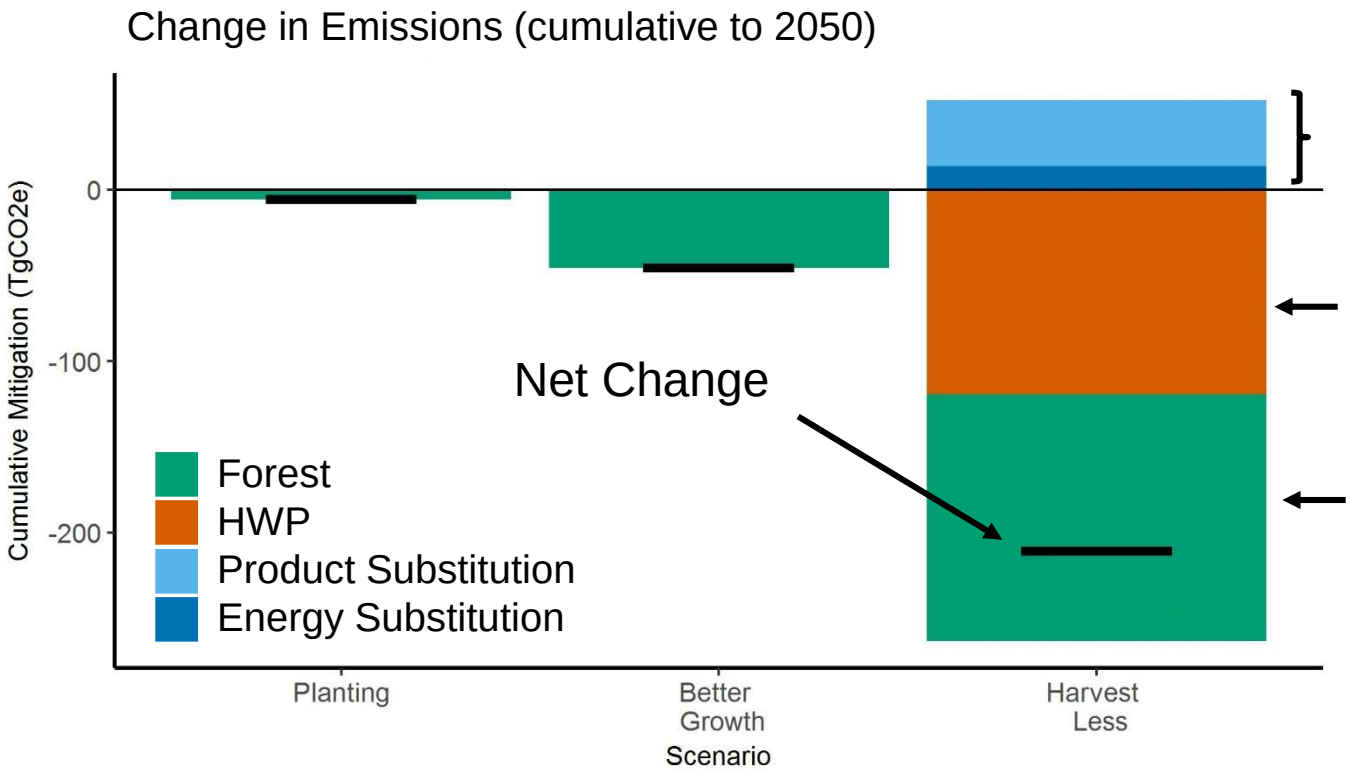
Scenarios: Planting and ‘better growth’.



Planting and better growth enhanced forest sink

Results

Scenarios: Harvest Less



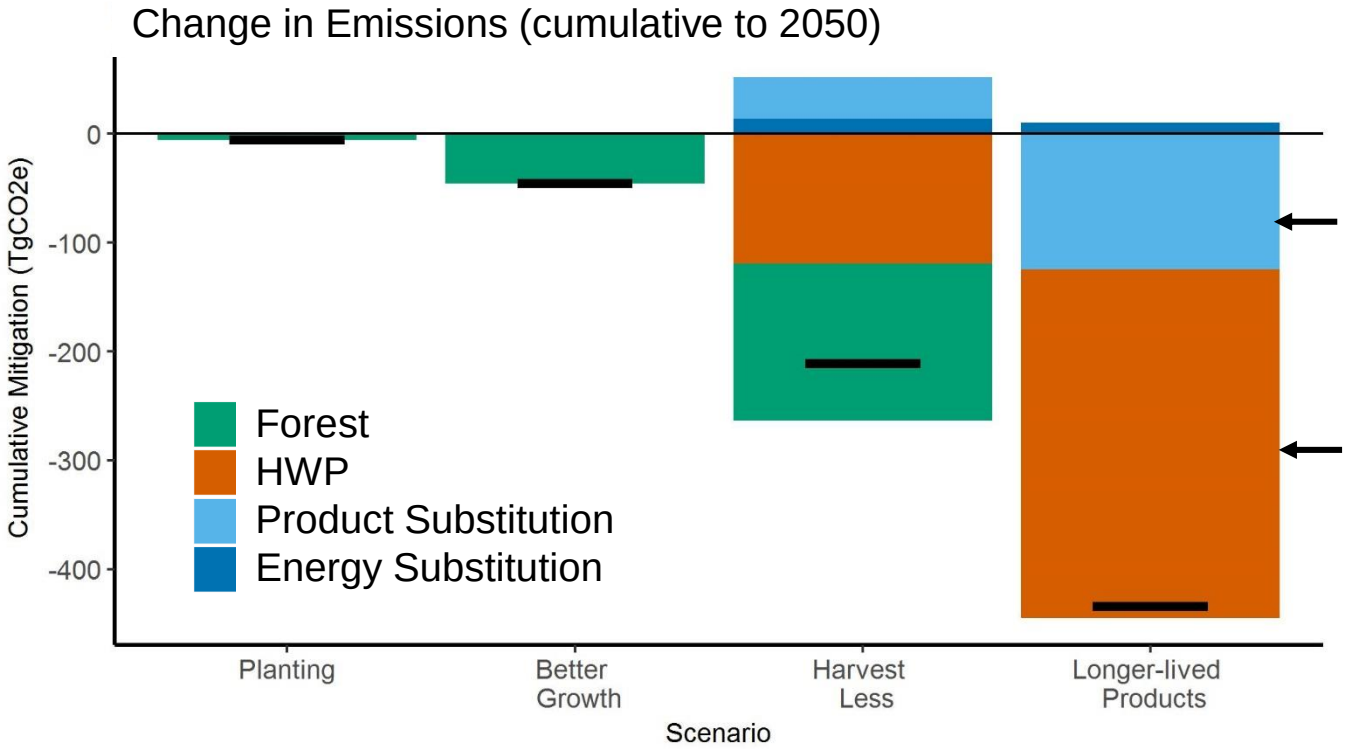
Increased emissions from non-wood energy and products,

but reduced emissions from wood products,

and enhanced forest sinks.

Results

Scenarios: Longer-lived wood products



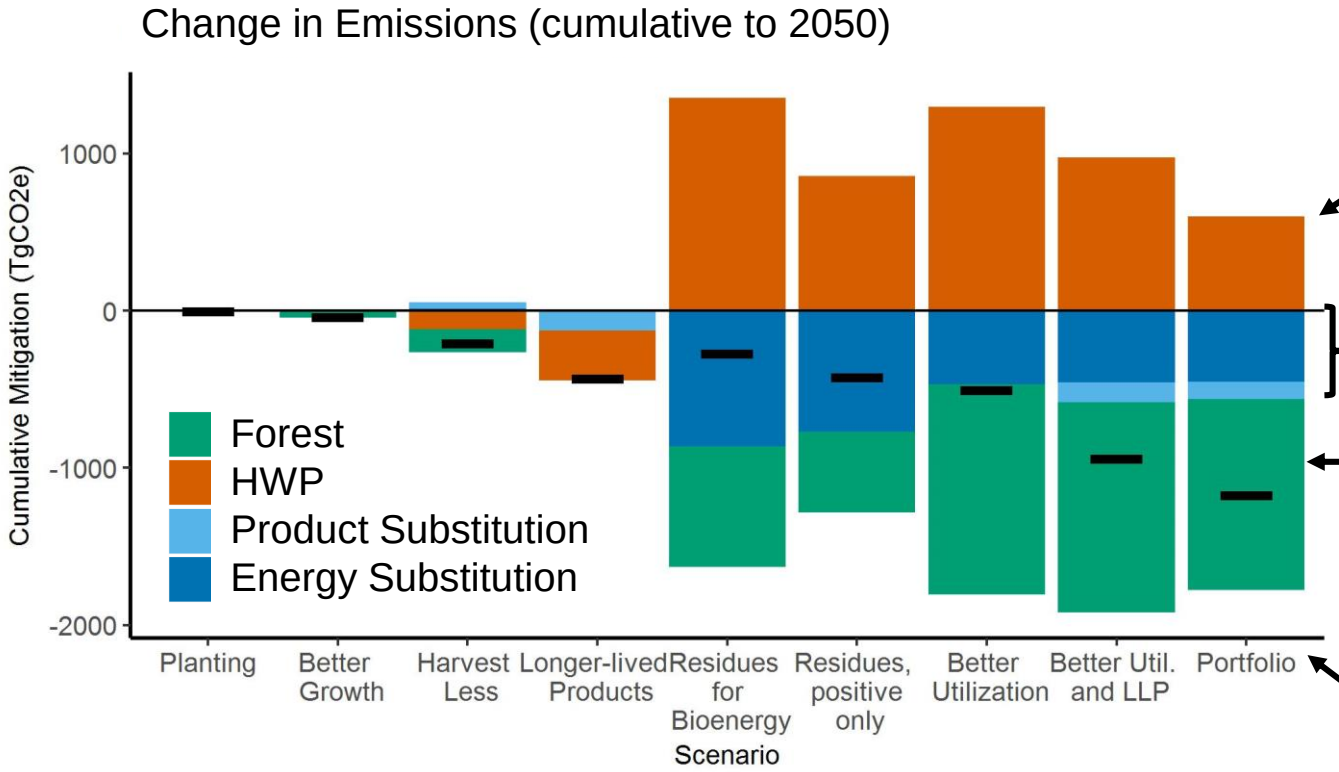
Created more long-lived structural wood products, to

reduce emissions from energy-intensive materials,

and reduce emissions from wood products

Results

The best mitigation activities vary by region: create a portfolio of regionally-differentiated forest management and wood-use strategies to maximize GHG reduction.



Increased wood product emissions,

but these reduced emissions from non-wood sources,

and reduced emissions or enhanced sink in the forest.

Portfolio

Mitigation Analysis for BC

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Climate change mitigation strategies in the forest sector: biophysical impacts and economic implications in British Columbia, Canada

Zhen Xu[1] · Carolyn E. Smyth[2] · Tony C. Lemprière[3] · Greg J. Rampley[4] · Werner A. Kurz[2]

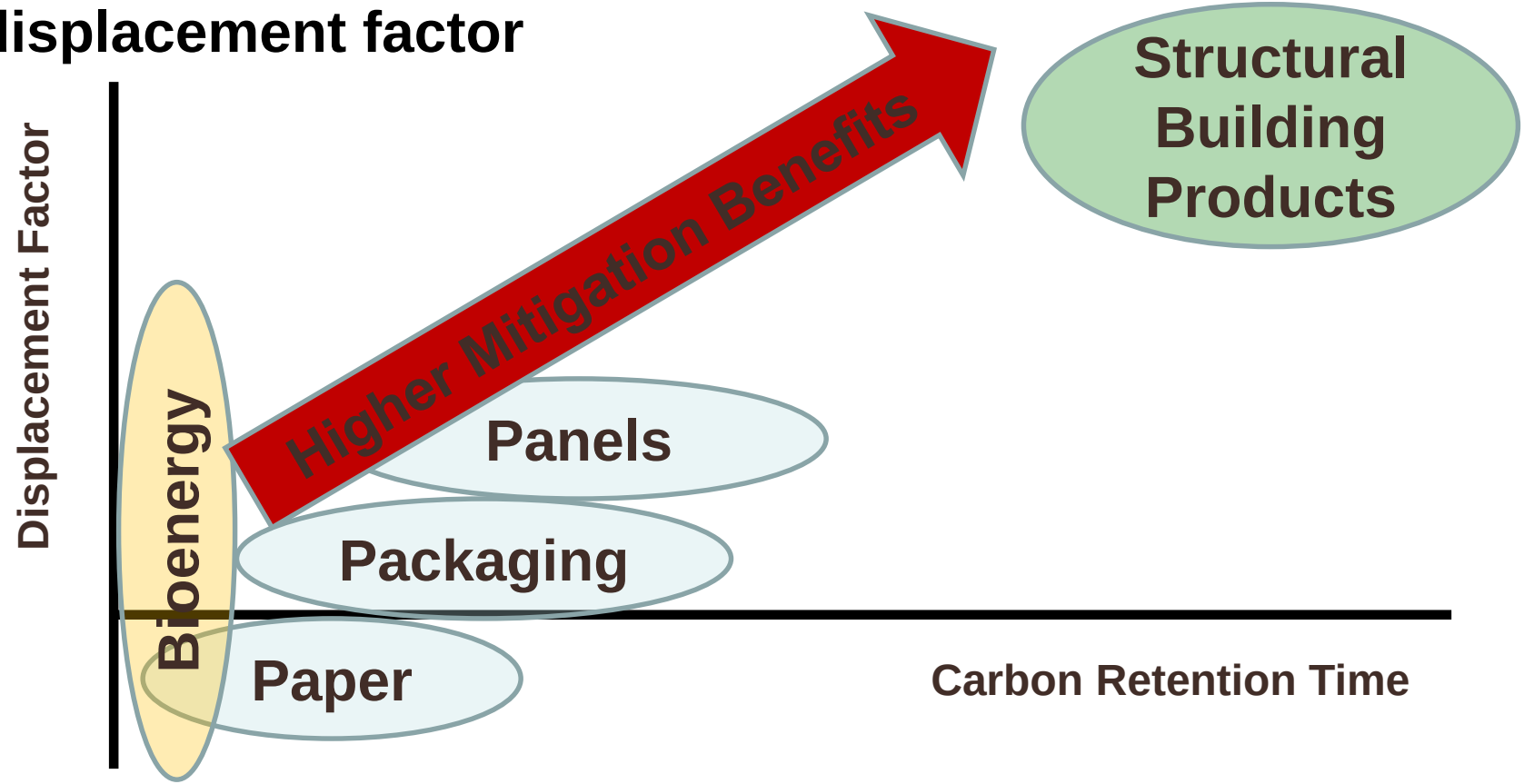
Mitigation and Adaptation Strategies for Global Change: 2017

By 2050,18.2 MtCO_2e/yr or **35% of BC's emission reduction target can be contributed by the forest sector** at less than $100/tonne of CO_2e with additional socio-economic benefits.

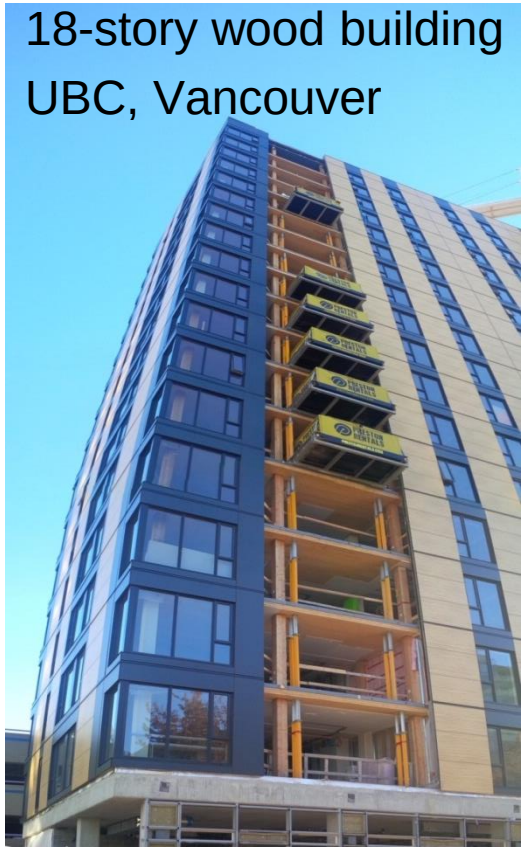
Greater contributions are possible with more ambitious actions.

Open Access at http://link.springer.com/article/10.1007/s11027-016-9735-7.

Mitigation benefit increases with carbon retention and displacement factor



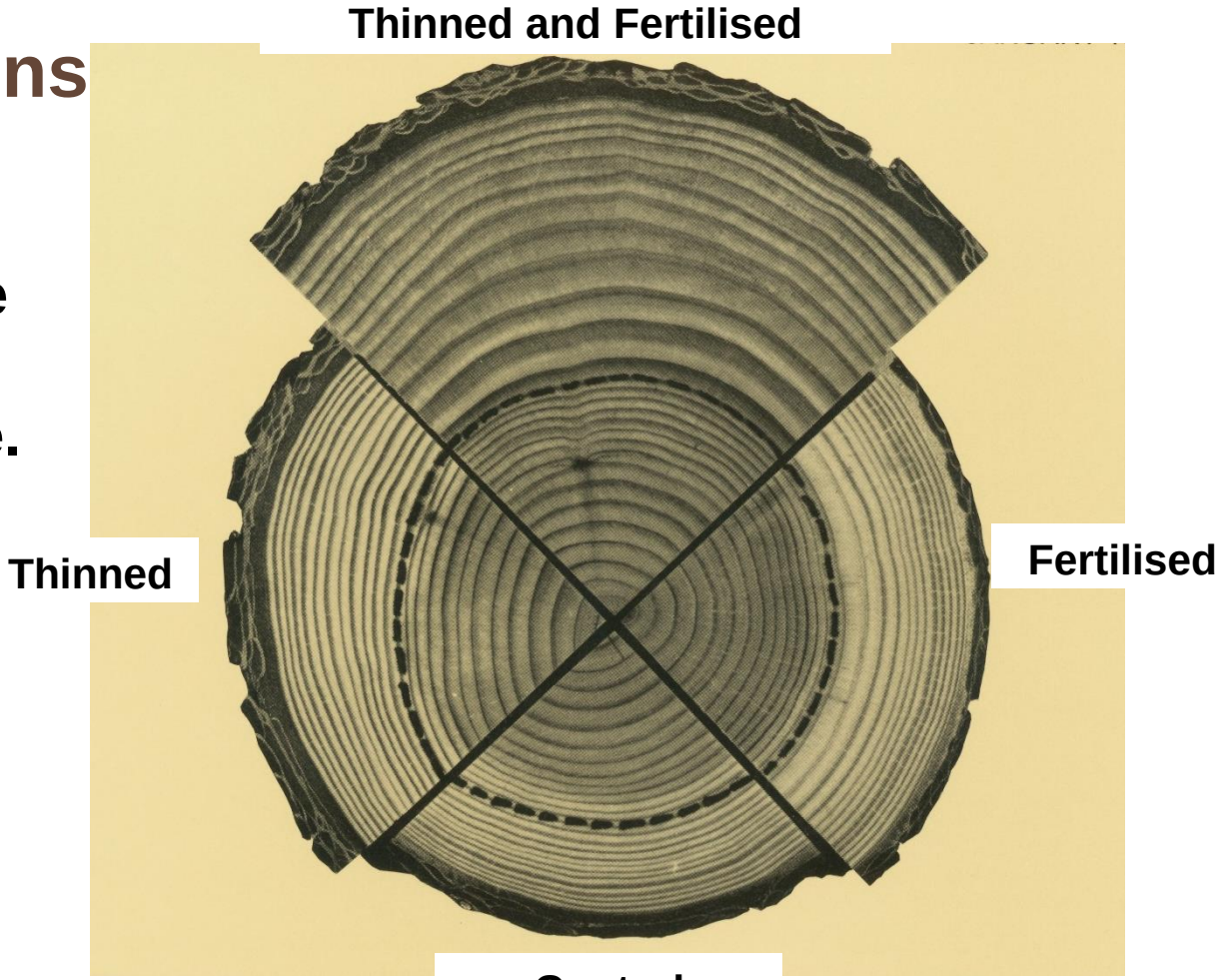
Mitigation benefits by displacing emissions from concrete and steel through the use of wood products



Canada

Management options

Silvicultural treatments to increase carbon accumulation per tree or per hectare.



Source: Brix 1993

Accounting vs. atmospheric benefits

- Climate change can only be mitigated if human actions bring about **real reductions** in atmospheric GHG concentrations.
- Some policy-based accounting rules exaggerate apparent benefits of actions.
- For example, importing biomass for bioenergy can result in reduced fossil fuel emissions in a national account (which assumes carbon neutrality of bioenergy).
- However, the wood exporting country has to report the emissions from biomass burning in the land sector of their national GHG inventory.
- Even if the importing country can account the apparent emissions reduction, the increased emissions in the wood exporting country are generally greater than the fossil fuel emissions reductions by the importing country.
- Thus **the net benefit to the atmosphere will be much smaller than the accounted amount** and can even be negative, i.e. greater net emissions.

Climate change impacts affect mitigation options

- Impacts of environmental changes on forests will be **both positive and negative**: growth, mortality, disturbances.
- Understanding **where, when and how** these impacts will occur is necessary to design effective climate change mitigation and adaptation strategies for the forest sector.
- Ongoing CFS research, in collaboration with universities and provincial agencies, will inform the design of regionally-differentiated mitigation strategies.

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2017 BC wildfire emissions estimated at ~3 times the emissions from all other sectors in BC

Source: Hessburg et al. 2015

Conclusions

- The Paris Agreement's goal of keeping global temperature increases well below 2ºC cannot be reached without net negative emissions.
- The forest sector has both the opportunity and the responsibility to contribute to reductions in atmospheric GHG concentrations.
- Effective GHG mitigation strategies involve sustainable forest management, and the use of long-lived products for C storage, and substitution of emissions-intensive materials.
- Because forests can make important but limited contributions towards net negative emissions – we can only meet Paris goals with rapid and immediate reductions in fossil fuels use.
- Failure to do so will increase the risks for further positive climate feedbacks from forests, requiring even greater future mitigation efforts.

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Publications at:

http://cfs.nrcan.gc.ca/publications/search?query=Kurz

Recent Publications

Kurz et al. 2016. **Climate change mitigation through forest sector activities: principles, potential and priorities**. Unasylva 246 (67): 61-67. www.fao.org/3/a-i6419e.pdf

Lemprière et al. 2017. **Cost of climate change mitigation involving's Canada's forest sector.** Canadian Journal of Forest Research. DOI: 10.1139/cjfr-2016-0348 http://www.nrcresearchpress.com/doi/pdfplus/10.1139/cjfr-2016-0348

Smyth et al. 2016. **Climate change mitigation potential of local use of harvest residues for bioenergy in Canada**. Glob. Chg. Biol. Bioenergy. DOI: 10.1111/gcbb.12387 http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12387/abstract

Smyth et al. 2016. **Estimating product and energy substitution benefits in national-scale mitigation analyses for Canada**. Glob. Chg. Biol. Bioenergy. DOI: 10.1111/gcbb.12389 http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12389/abstract

Xu et al. 2017. **Climate change mitigation strategies in the forest sector: biophysical impacts and economic implications in British Columbia, Canada**. Mitigation and Adaptation Strategies for Global Change. DOI: 10.1007/s11027-016-9730-z http://link.springer.com/article/10.1007/s11027-016-9735-7.

Uncertainties and research needs

- Develop and assess forest sector climate change mitigation strategies, including interactions with, and risks from climate change impacts.
- Quantify interactions between land management and non-GHG impacts on the earth system.
- Evaluate the potential, costs, and impacts of strategies aimed at protecting forests and enhancing their productivity through active forest management.
- Design bioeconomies that are based on principles of sustainable land management, cascading wood uses, and high substitution benefits while also meeting other socio-economic goals.
- Quantify substitution benefits through wood use by improving life cycle analyses and the understanding of consumer responses to changes in product availability.
- Develop monitoring programs that determine the GHG benefits of mitigation actions relative to the business-as-usual baseline, and quantify cost per tonne of CO_2 mitigation to inform the public about the mitigation outcomes.

10 steps towards forest sector mitigation

- Grow more trees, faster, to increase carbon stocks
- Avoid land-use change (deforestation)
- Use harvested trees first for long-lived harvested wood products (HWPs)
- Maximize carbon retention in HWPs and reduce wood waste at every stage
- Maximize avoided emissions through wood use
- Do not burn residues or waste unless energy is captured
- Conserve forests in areas of high conservation value and of low risk of natural disturbance
- Anticipate climate change impacts and align mitigation and adaptation objectives
- Monitor consequences of carbon management actions
- Obtain public support to use forest sector in climate change mitigation strategies

The future of forest carbon management?

- Placing a price on carbon enables protection, planting and silvicultural activities that in the past have been considered “uneconomical”.
- Will a carbon price lead to shifts in societal values?
- Climate change impacts (fire, insects, drought) will create many dead trees: salvage logging, site rehabilitation, assisted tree migration and enhanced silviculture can help increase C sinks relative to the “no action” scenario.
- Government investments to enhance forest carbon sinks can contribute to climate-effective, cost-effective mitigation portfolios.
- **Forest carbon management demonstration areas** can help improve public understanding and acceptance of carbon-focused management.
- Monitoring of carbon dynamics required to demonstrate value of mitigation investments.

Conclusions (1/3)

- Design of GHG reduction portfolios in the forest sector should account for changes in C in **forest ecosystems,** in **harvested wood products**, and for **substitution benefits**, relative to a base case.
- Efficiency of mitigation activities varies among activities and by region, and no single strategy is best everywhere.
- Best strategies focus on substitution and HWP C storage.
- **Forest managers do not control use of wood** – effective mi ent wi n of HW els.

Conclusions (2/3)

- Substantial mitigation potential by 2050 if the implementation of strategies starts soon.
- Forest sector provides unique opportunities to manage sinks and contribute to negative emissions.
- Even if costs per ton are competitive with others sectors, the total required investment into increased forest sinks is proportional to required sinks – and will be measured in hundreds of millions of dollars.
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Conclusions (3/3)

- Regional differences (disturbance rates, ecology, response to climate change, management intensity) likely to affect choice of most efficient mitigation options.
- Design of mitigation strategies needs to anticipate climate change impacts and consider contributions to adaptation.
- As societies seek to reduce GHG emissions and inc
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Uncertainties and research needs

- How sustainable is forest management in a changing climate (regeneration)?
- Changes in disturbance rates (fire, insects) and risk to mitigation strategies?
- Life cycle analyses of wood products, substitution and elasticity of demand?
- Upper bounds of forest sector contribution to net negative emissions?
  - Expansion of forest area, enhancement of forest productivity,
  - Optimum use of long-lived wood products and biomass for energy.
- Costs of mitigation actions (relative to other options)
- Co-benefits and trade-offs?
- Responses of unmanaged forest lands (forests, peatlands, permafrost)?