Canada's National Forest Carbon Monitoring, Accounting and Reporting System: combining inventories, remote sensing and models to estimate emissions and removals

Werner A. Kurz[1] , Graham Stinson[1] and Dominique Blain[2]

[1] Natural Resources Canada
Canadian Forest Service
Victoria, BC, Canada

[2] Environment Canada
Gatineau, QC, Canada

IPCC Expert Meeting on National Forest GHG Inventories - a Stock Taking
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Natural Resources Canada | Ressources naturelles Canada

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A Team Effort!

- CFS Carbon Accounting Team in Victoria and Edmonton in close cooperation with CFS policy community in Ottawa
- For national-scale analyses input from Resource Management Agencies in all Provinces and Territories
- Collaboration with scientists in CFS, universities in Canada and abroad, IPCC colleagues, and <u>many</u> others …

Outline

- Model, methods and data
- Carbon balance in Canada's managed forest
- Stock taking (also inserted throughout)
- Conclusions

Approaches to Developing Forest Carbon Budgets

- Inventories at different Tier level.
- Choice of methods depends on national circumstances and intended use of the system
  - Difference between two inventories (e.g. USA)
  - One inventory plus change information (e.g. Canada)
  - No Inventory – process modelling (e.g. Australia)
  - Mixed approaches (?)
- Evolution and convergence of methods can be expected
- Choice of tier and approach will contribute to differences in reported estimates (e.g. Greenough et al. 1997).

Canada's National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS)

Reporting of GHG balance to EC for National GHG Inventory Reporting.

Analyses in support of policy development and negotiations.

Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)

- An operational-scale model of forest C dynamics.
- Allows forest managers to assess carbon implications of forest management: increase sinks, reduce sources

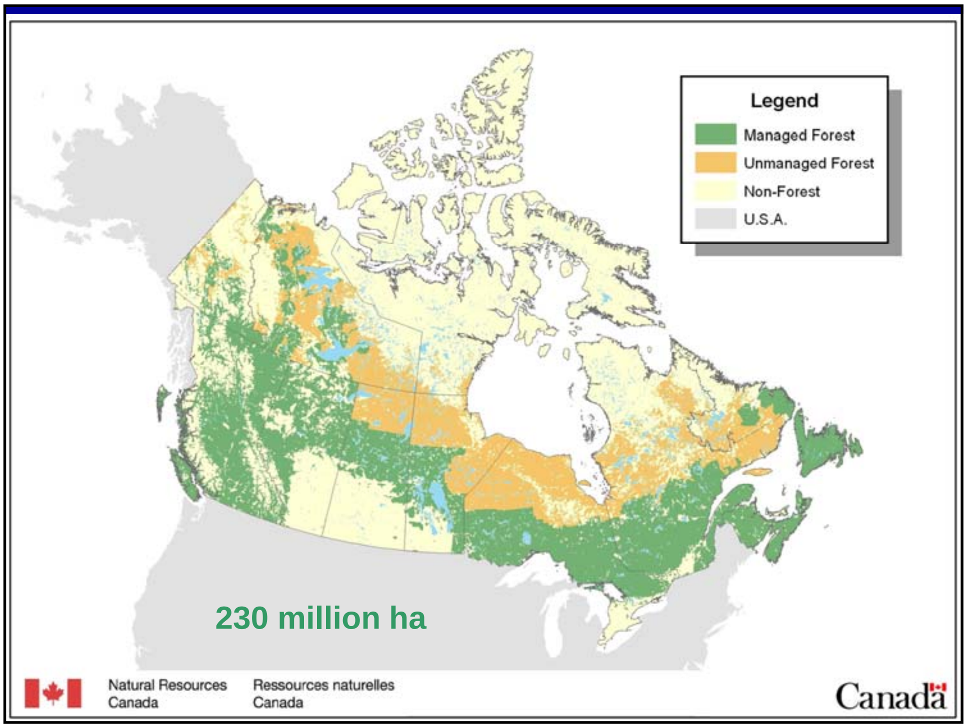
- Builds on 20 years of CFS Science
- Available at: carbon.cfs.nrcan.gc.ca

Kurz et al. 2009, Ecol. Mod.

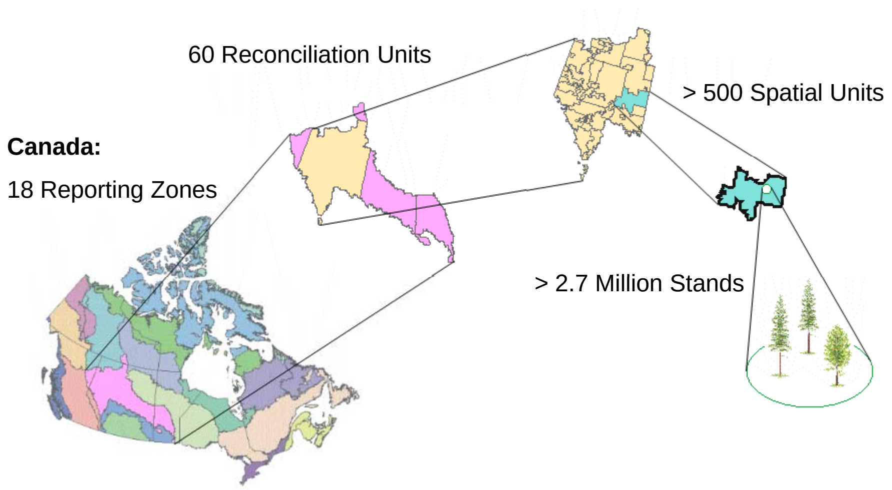
Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)

- Compliant with IPCC 2003 GPG and 2006 Guidelines
- Relies on forest inventories, empirical yield data and activity data (incl. management, disturbances and LUC)
- Links DOM (including soils) dynamics directly to biomass dynamics by simulating stand growth and mortality, biomass inputs, decomposition and disturbance impacts.
- Provides output spatially referenced to “geographic areas of land” but is not spatially explicit to the level of stand polygons.

Kurz et al. 2009, Ecol. Mod.

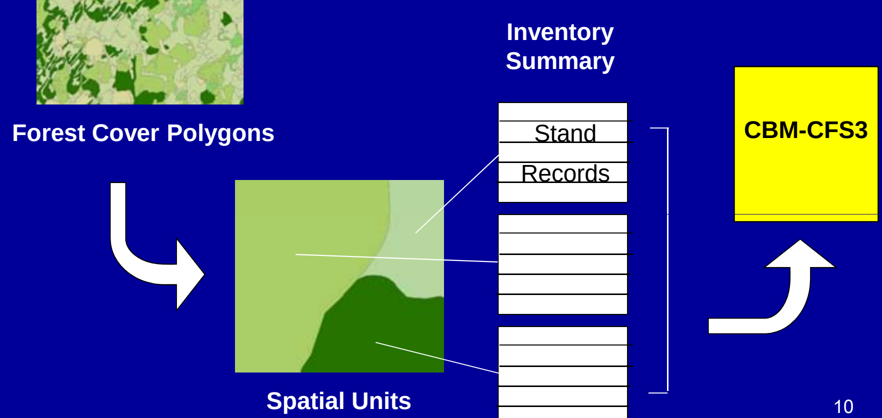


Hierarchy of Spatial Scales

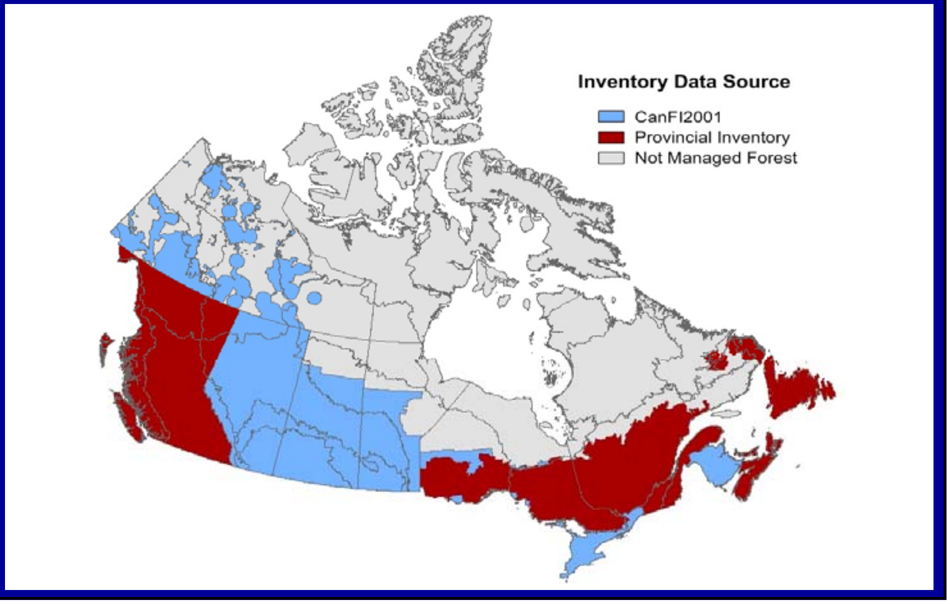


CBM-CFS3 uses spatially-referenced information about forest conditions within Spatial Units

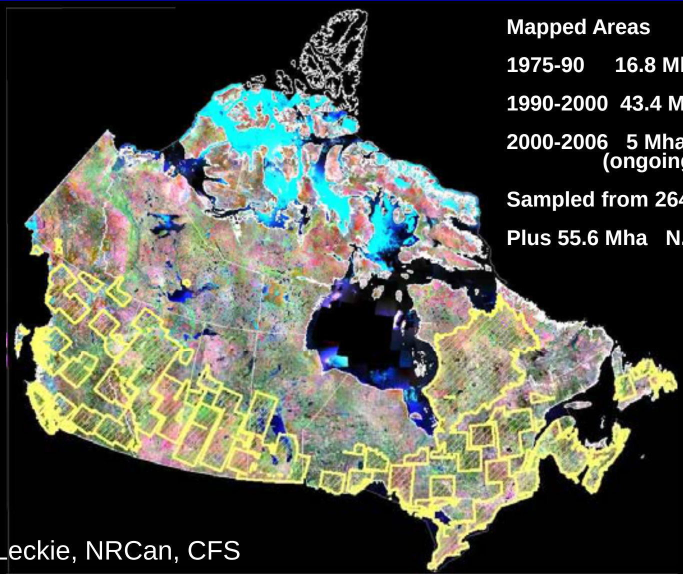
- Spatially referenced to “geographic areas of land” but not spatially explicit to stand polygons.
- Average “stand” in model is < 100 ha (large range).



Forest Inventory Data Sources use best available data



CFS Deforestation Monitoring Program



Mapped Areas

1975-90 16.8 Mha

1990-2000 43.4 Mha

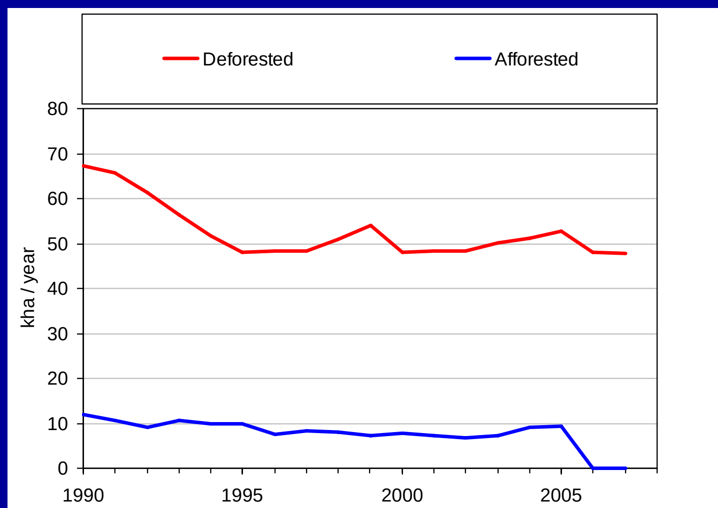
2000-2006 5 Mha to date (ongoing)

Sampled from 264 Mha

Plus 55.6 Mha N. Quebec

Source: D. Leckie, NRCan, CFS

Area Affected by Land-Use Change



Source: Deforestation: D. Leckie, NRCan,
Afforestation: White and Kurz, 2005

Deforestation Emissions in Developed Countries

Country	Mt CO_2e	%*
Australia	76.8	14.2
Germany	26.6	2.2
Canada	19.7	2.6
Finland	3.3	4.2
Japan	2.4	0.2
Russia	?	?
United States	?	?

* % of total emissions excluding LULUCF

Source: UNFCCC for 2007

Stock Taking

- Estimation of deforestation rates using remote sensing (and many other) data is possible, as is the estimation of resulting emissions.
- In Canada only ~0.015% of forest area deforested per year. Finding these events is very expensive. Large events (hydro-electric reservoirs) are easy to find.
- Challenge is to process large volumes of data over short time periods to meet reporting requirements.
- Obtaining afforestation data also proves more difficult than anticipated despite internet-based National Afforestation Inventory for voluntary submission of afforestation data.

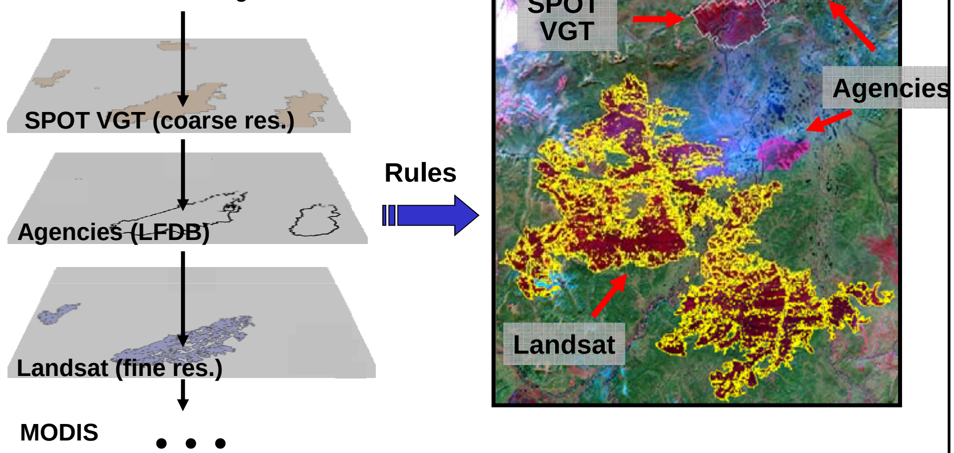
Canadian Wildland Fire Information System

- Daily monitoring of hotspots during fire season
- Complete coarse resolution mapping of area burned.
- Additional high-resolution mapping of burn area perimeters and unburned areas.
- Combination of data from multiple sources to estimate national burn area.
- Estimates improve as more high-resolution mapping becomes available in subsequent years.

National Burn Area Composite (NABC)

Evolving compilation of best available data on area burned

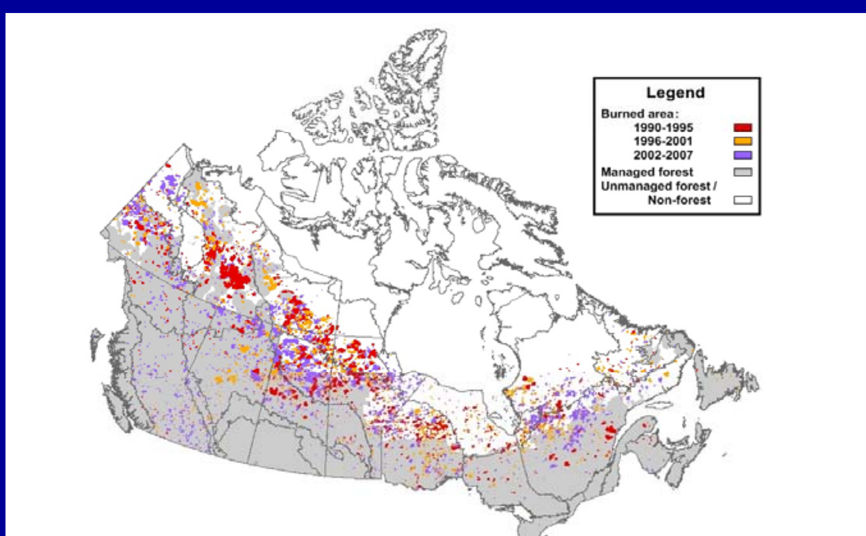
Use best available burn area products – Source can change over time



Source: R. Landry et al., NRCan-CCRS

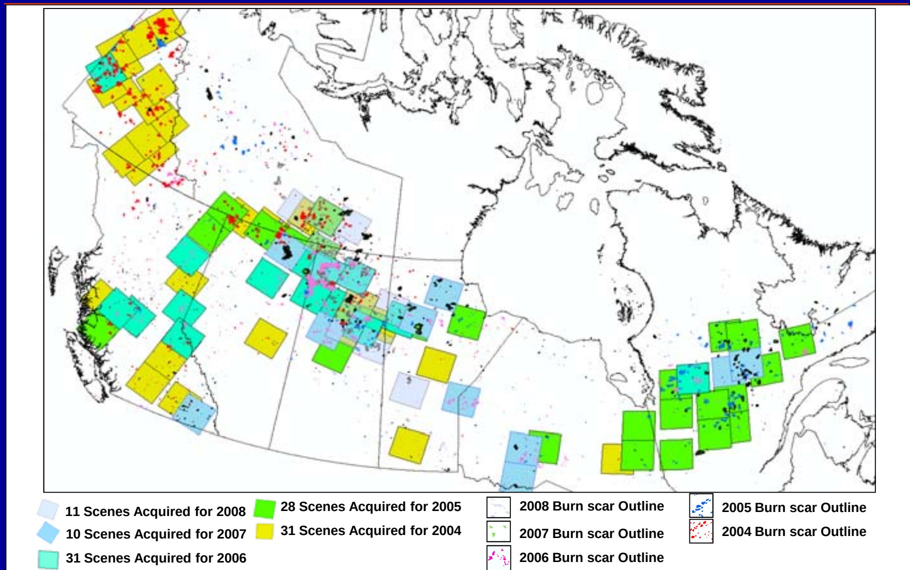
Monitoring all fires

but emissions reported only for managed forest



Source: Stocks et al. 2001, and CWFIS

Distribution of Landsat Scene Acquisitions Fire Seasons 2004-2008



Source: R. Landry et al. CCRS

Stock Taking

- Pre-burn conditions in forest inventories are not spatially referenced beyond spatial unit boundaries.
- Uncertainty in emissions estimates because pre-burn conditions (fuel loading) is sampled from entire forest inventory in spatial unit affected by known fire area.
- Repeated simulations used to quantify uncertainty of emission estimates.
- Because emissions depend on fuel loads, emission factors vary between fire events and by regions, but regional averages can be calculated and compared to emission factors used in Tier 1 and 2 approaches.
- Future reductions in uncertainty possible by building on 30 m resolution land cover map for all of Canada (ca. 2000).

NFCMARS

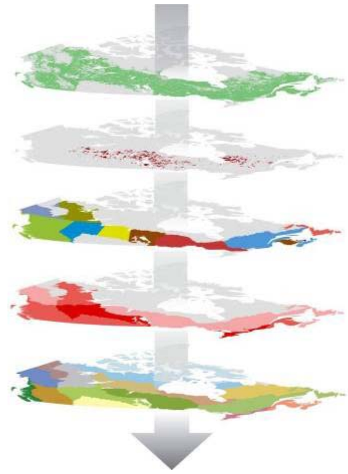
Forest inventory and growth & yield data

Natural disturbance monitoring data

Forest management activity data

Land-use change data

Ecological modelling parameters

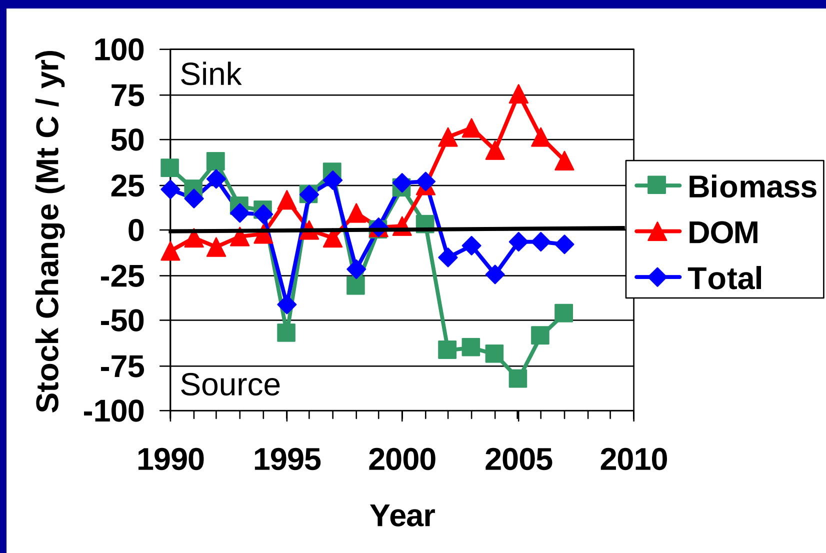


CBM-CFS3

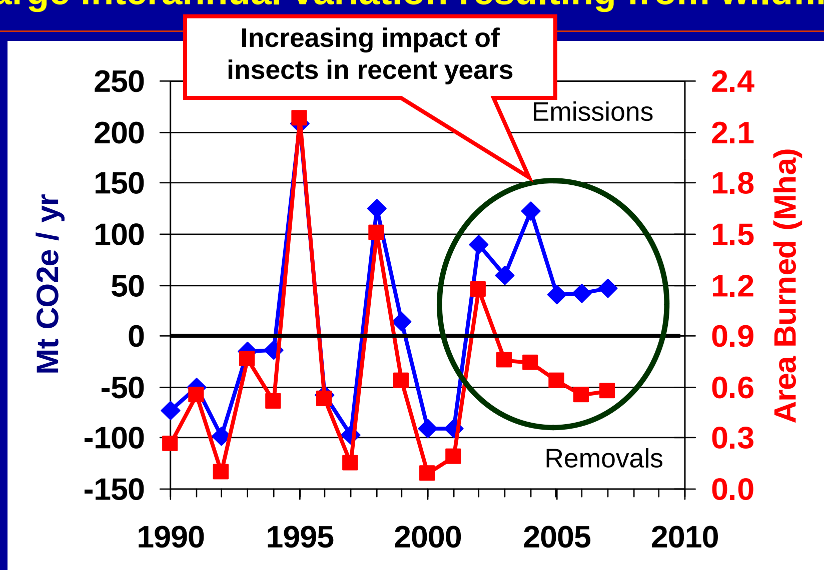
Source: Kurz and Apps, 2006, Kurz et al. 2009

C Stock Changes and non-CO_2 GHG emissions and removals in Canada's Managed Forest (1990 – 2007)

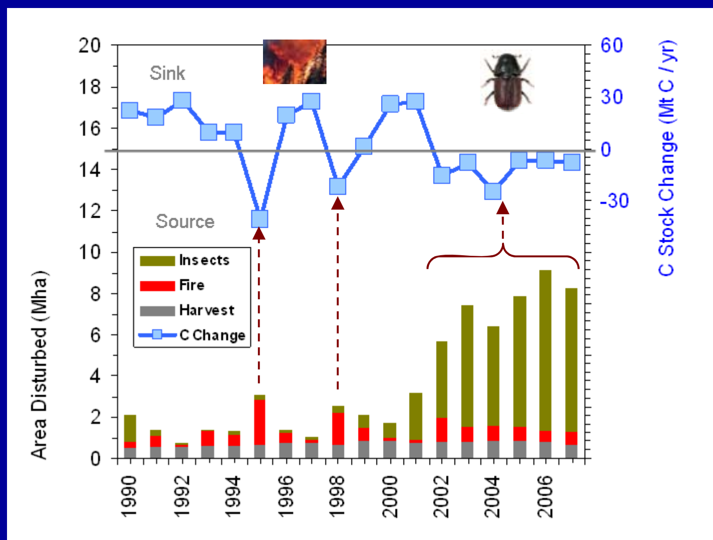
Managed Forest Ecosystem Stock Changes (NIR 2009)



Large interannual variation resulting from wildfires



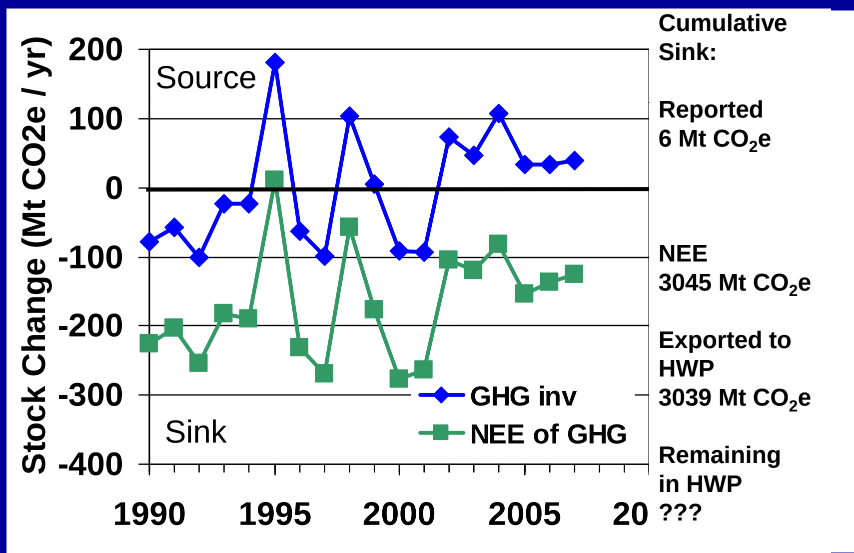
Managed Forest C balance (1990-2007)



Stock Taking

- Natural disturbances strongly affect interannual variation in emissions and removals in Canada's managed forest.
- "Managed Land Proxy" used to report GHG fluxes to UNFCCC from anthropogenic activities confounds anthropogenic fluxes with those from natural disturbances.

GHG Fluxes Reported with (GHG inv, UNFCCC) and without (NEE) immediate HWP emissions



Stock Taking

- Current default assumption that harvest input to HWP sector equals HWP emissions from prior harvest (and that therefore all harvested transfers are assumed immediately emitted) captures neither the timing nor the location of the actual emissions.
- In Canada (1990 – 2007) over 3,000 Mt CO$_2$e are reported as emitted – but much of this remains stored in HWP and/or has been emitted outside Canada.
- Same issue for all (net) wood exporting countries.
- Also creates verification problems as “carbon trackers” do not see UNFCCC reported fluxes but net ecosystem exchange (NEE).

Ongoing Model Improvements

- Many ecological parameters are developed from Forest Ecosystem Carbon database (Shaw et al. 2005) but is was a compilation of existing data.
- Data from ~1000 National Forest Inventory ground plots will provide opportunity to compare plot-level CBM-CFS3 carbon stock predictions against observations.
- Ongoing improvement to inventory and yield input data.

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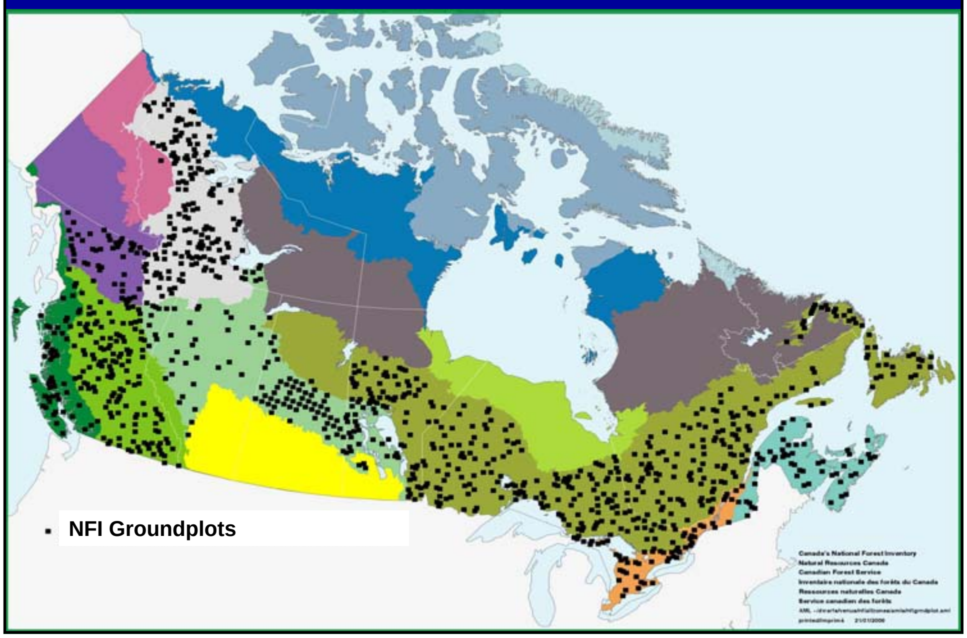
National Forest Inventory Ground Plots



NFCMARS Conclusions

- CBM-CFS3 is core model of NFCMARS to estimate C stocks & non-CO_2 emissions in Canada's managed forest.
- Relies on forest inventories, empirical yield data, process simulation of dead organic matter dynamics, and detailed data on forest management, natural disturbances and land-use change.
- CBM-CFS3 currently also evaluated and/or used in several other countries.
- Remote sensing plays important role in estimating forest cover changes (fire, insect impacts) but remote sensing cannot estimate DOM and soil C stocks or stock changes.

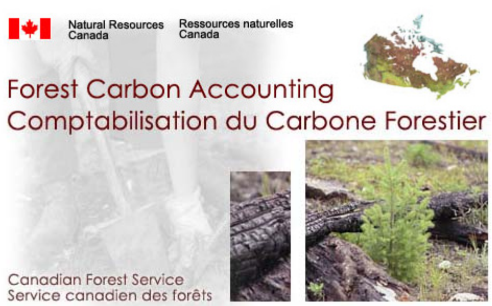
NFCMARS Conclusions

- Although significant progress has been made over the past decade in estimating and reporting managed forest C stocks in Canada, major uncertainties remain.
- Global change impacts poorly known.
- Expansion of approach into "unmanaged forest" will be difficult because quality of estimates depends on quality of forest inventory data.
- Several ongoing science and development activities expected to further improve systems.

Conclusions for Stock Taking

- Failure to report C stocks retained in HWP creates public misunderstanding of forest mgmt contribution to C cycle.
- Managed land proxy is pragmatic but imperfect approach to estimating GHG fluxes from anthropogenic activities.
- Impacts of methodological choices (pools, Tiers, data sources, processes represented) need to be quantified.
- While still imperfect, 2003 GPG and 2006 Guidelines are big improvements over revised 1996 Guidelines.
- Progress to date benefitted from existing data – future progress will require new (expensive) monitoring data.
- Monitoring of C stocks and stock changes requires substantial and sustained investments.

Thank you very much!



http://carbon.cfs.nrcan.gc.ca
Publications: http://bookstore.cfs.nrcan.gc.ca
e-mail: wkurz@nrcan.gc.ca

Related Publications

Greenough, J.A., M.J. Apps, and W.A. Kurz. 1997. Influence of Methodology and Assumptions on Reported National Carbon Flux Inventories: An Illustration from the Canadian Forest Sector. Mitigation & Adaptation Strategies for Global Change 2: 267-283.

Kurz, W.A. and M.J. Apps. 2006. Developing Canada's National Forest Carbon Monitoring, Accounting and Reporting System to meet the reporting requirements of the Kyoto Protocol, Mitigation and Adaptation Strategies for Global Change, 11: 33–43.

Kurz, W.A., Dymond, C.C., White, T.M., Stinson, G. , Shaw, C.H., Rampley, G.J., Smyth, C., Simpson, B.N., Neilson, E.T., Trofymow, J.A., Metsaranta, J., Apps, M.J., 2009, CBM-CFS3: a model of carbon-dynamics in forestry and land-use change implementing IPCC standards, Ecological Modelling, 480-504.

Kurz, W.A, C.C. Dymond, G. Stinson, G. J. Rampley, E.T. Neilson, A. L. Carroll, T. Ebata, and L. Safranyik, 2008, Mountain pine beetle and forest carbon feedback to climate change, Nature 452:987-990,

Kurz, W.A., G. Stinson, G.J. Rampley, C.C. Dymond and E.T. Neilson, 2008, Risk of natural disturbances makes future contribution of Canada's forests to the global carbon cycle highly uncertain. Proc. of the National Academy of Sciences, 105: 1551-1555.

White, T.M. and W.A. Kurz. 2005. Afforestation on private land in Canada from 1990 to 2002 estimated from historical records, The Forestry Chronicle, 81: 491-497.

White, T. N. Luckai, G.R. Larocque, W.A. Kurz, C. Smyth. 2008. A practical approach for assessing the sensitivity of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3), Ecological Modelling 219: 373–382.

- Remaining slides for questions only

Uncertainty Analysis

Monte Carlo Simulation
- 100 simulations for Canada’s managed forest
- 20 CBM-CFS3 projects
- ~ 1 month of computing time on 10 PC’s

Varied disturbance data:
- fire (+/- 10%),
- harvest (+/- 10%),
- insects (+/- 25%), and
- deforestation (+/- 38%)

Varied biomass increment
- +/- 50%

Metsaranta et al., in preparation

Uncertainty Analysis

Varied some litterfall, decay and C transfer parameters

Table 1 – Variation in the parameters of interest for an uncertainty analysis using the CBM-CFS3 model in northwestern Ontario, Canada

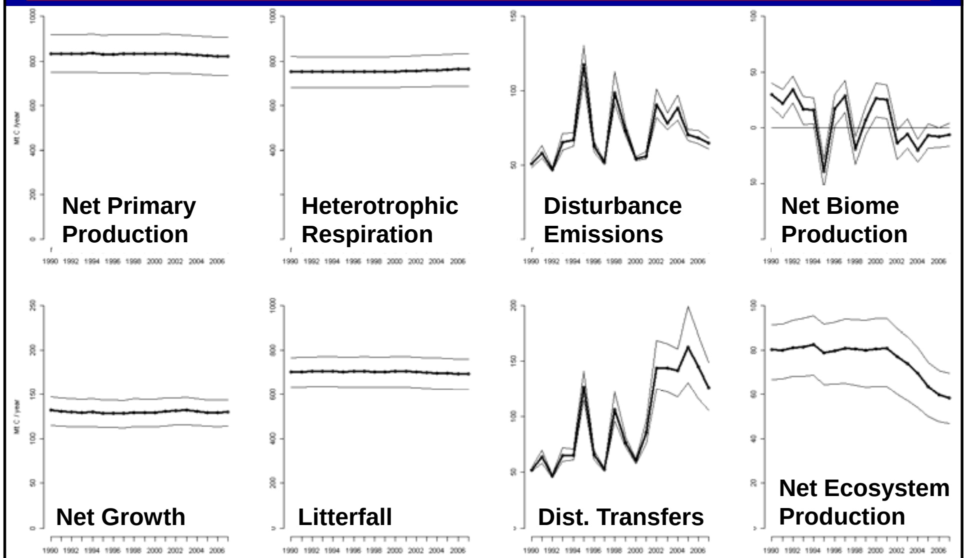
Parameters	Default	Minimum	Maximum	Reference/comments
Branch turnover rate	0.04	0.012	0.04	Adapted from Peltoniemi et al. (2006)
Coarse root turnover rate	0.02	0.007	0.023	Peltoniemi et al. (2006)
Fast above-ground base decay rate	0.1435	0.1	0.29	Adapted from Liski et al. (2005)
Fast above-ground proportion of C respired	0.83	0.7	0.9	Liski et al. (2005) and Smyth (submitted)
Fast below-ground base decay rate	0.1435	0.1	0.29	Adapted from Liski et al. (2005)
Fast below-ground proportion of C respired	0.83	0.7	0.9	Liski et al. (2005) and C. Smyth, personal communication
Fine root turnover	0.641	0.6	0.92	Adapted from Peltoniemi et al. (2006)
Foliage turnover rate for hardwoods[a]	0.95	0.8455	0.999	
Foliage turnover rate for softwoods[a]	0.1	0.1	0.2	Adapted from Peltoniemi et al. (2006)
Mean annual temperature	−0.435	−3.555	2.684	Mean ± 2S.D. for ecological unit
Medium base decay rate	0.0374	0.01	0.08	Adapted from Yatskov et al. (2003) and Bond-Lamberty et al. (2003)
Medium proportion of C respired	0.83	0.7	0.9	Liski et al. (2005)
Slow above-ground base decay rate	0.015	0.002	0.02	Liski et al. (2005)
Slow below-ground base decay rate	0.0033	0.0008	0.004	Adapted from Liski et al. (2005)
Stand-replacing disturbance interval	75	65	85	Used only in the spin-up sub-routine
Stem annual turnover	0.005	0.003	0.007	Peltoniemi et al. (2006), Hennon and McClellan (2003)
Stem snag turnover	0.032	0.032	0.14	Based on 1/2 life or rates reported in Vanderwel et al. (2006), Wilson and McComb (2005), Russell et al. (2006), Garber et al. (2005)
Very fast above-ground base decay rate	0.355	0.284	0.426	±20%
Very fast above-ground proportion of C respired	0.815	0.742	0.888	Smyth (submitted)
Very fast below-ground base decay rate	0.5	0.4	0.6	±20%
Very fast below-ground proportion of C respired	0.83	0.55	0.85	

Unit for turnover rates and decay rate is yr^{-1}.

[a] None of the scenarios included both softwoods and hardwoods.

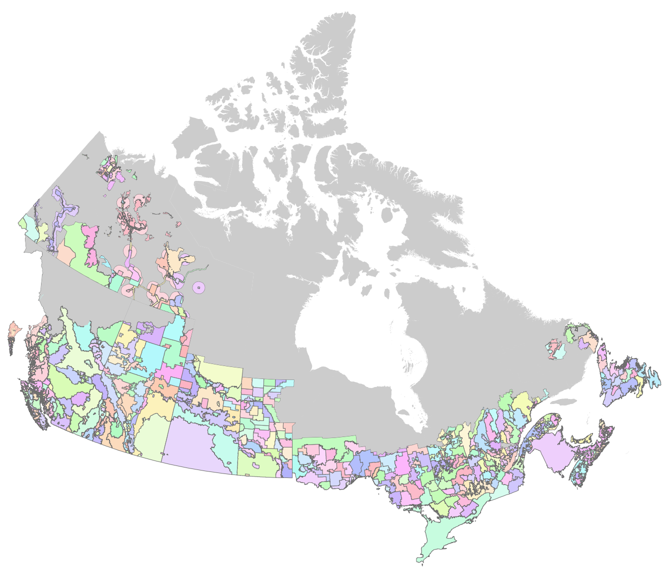
White et al., 2008

Ecosystem Production with Uncertainty



Metsaranta et al., in preparation

Managed forest area stratified into > 500 Spatial Analysis Units



CBM-CFS3 reports …

Five IPCC Carbon Pools:

Biomass

1. Aboveground Biomass
2. Belowground Biomass

Dead Organic Matter

3. Dead Wood
4. Litter
5. Soil Organic Carbon

Net Carbon Balance

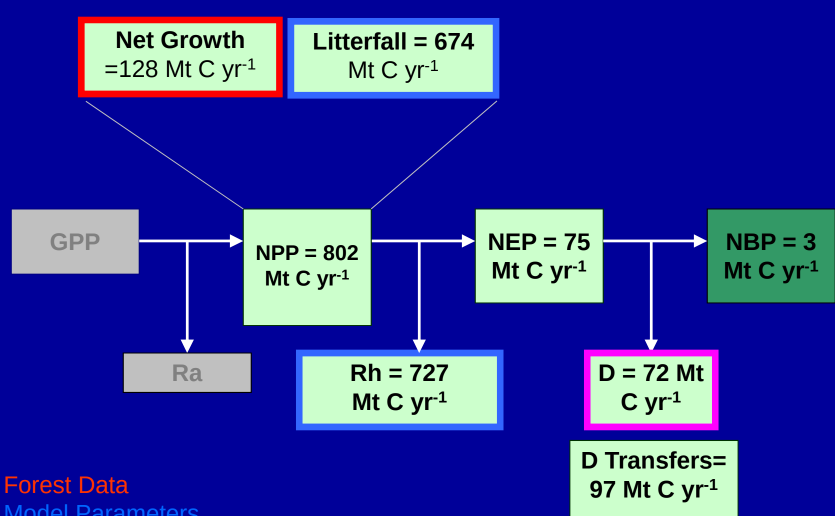
Emissions by CO_2, CH_4, CO (and N_2O)

Area changes for forest-related land categories

Annually by spatial unit, reporting zone and nationally

…. And many more indicators.

Ecosystem Production (MF, FL-FL, 1990 – 2007)



Forest Data
Model Parameters
Activity Data and Impacts

Stinson et al., in preparation

Stock Taking

- Although CBM-CFS3 is an inventory-based empirical model of forest carbon stock changes, it also produces estimates of NPP, NEP, heterotrophic respiration and other scientific indicators for comparison with process models.