Carbon Management in British Columbia Ecosystems

June 15-16, 2011
Nelson, British Columbia, Canada

Columbia Mountains Institute of Applied Ecology

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This document is available as a free PDF download from the website of the Columbia Mountains Institute, at www.cmiae.org in the “Past Events” section. Look for the write-up for this conference.

Pages have been left blank intentionally to allow for correct pagination when this document is printed in double-sided format.

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Selkirk College has recently been awarded a National Science and Engineering Research Council College and Community Innovation grant for developing forest carbon decision-support tools for the regional forestry sector.
For more information: http://selkirk.ca/research/sgrc/news-events/name-24715-en.php

The Columbia Mountains Institute gratefully acknowledges the financial support of **Columbia Basin Trust,** a regional corporation created to deliver social, economic, and environmental benefits to the residents of the Columbia Basin.
For more information: http://www.cbt.org/

Our presenters and the people who brought posters and displays travelled from various communities in British Columbia and AlbertaWe are grateful for your willingness to share your expertise with us, and for the support of your agencies in sending you to our conference.

Spokesperson Marilyn James of the Sinixt Nation of BC and Mayor John Dooley of the City of Nelson offered welcome statements.

Special thanks go to our volunteers **Raelynn Gibson, Tracy Miranda, and Dennis Lynch** for their help in keeping the event running smoothly.

We are appreciative of the work of our conference organizing committee, and others who contributed expertise as the conference developed. The members of the organizing committee were:

- **Dr. Brendan Wilson,** Selkirk College
- **Dr. Rachel Holt,** Veridian Ecological Consulting
- **Del Williams,** BC Ministry of Forests, Lands, and Natural Resource Operations
- **Dr. Ajit Krishnaswamy**, FORREX, Burnaby
- **Jackie Morris**, Columbia Mountains Institute of Applied Ecology

Table of contents

Conference description

Presentation summaries

Wednesday, June 15, 2011

Thursday, June 16, 2011

Field trip descriptions

Posters

Conference description

Climate change is one of the most important environmental challenges facing civilization. Managing how carbon is taken in, stored, and released from natural systems has the potential to mitigate the rate and extent of future climate change. This conference addressed how moving towards a low carbon economy may alter management strategies, economics, plans, and on-the-ground practices of natural resource managers.

The event included 23 presentations followed by a field trip. A poster and “social” session encouraged informal dialogue among participants and presenters. Dr. Richard Hebda of the Royal BC Museum gave an evening talk that was attended by conference people and the general public.

The conference was attended by 85 people, from a variety of backgrounds including natural resource practitioners, land management planners, conservation biologists, consultants, policy makers, academics, and businesses with an interest in the new fields of carbon management.

The conference was held at the Prestige Lakeside Resort in Nelson, British Columbia.

The summaries of presentations in this document were provided by the speakers. Apart from small edits to create consistency in layout and style, the text appears as submitted by the speakers.

The information presented in this document has not been peer reviewed.

About the Columbia Mountains Institute of Applied Ecology

www.cmiae.org

The Columbia Mountains Institute of Applied Ecology (CMI) is a non-profit society based in Revelstoke, British Columbia. The CMI is known for hosting balanced, science-driven events that bring together managers, researchers, educators, and natural resource practitioners from across southeastern British Columbia. The CMI’s website includes conference summaries from all of our events, and other resources.

Summaries of presentations

1. Carbon in forests: Climate change feedback or mitigation opportunity?

Dr. Werner Kurz, Senior Research Scientist, Forest Carbon Accounting, Canadian Forest Service, Victoria BC
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Dr. Kurz presented an overview of human-caused perturbations to the global carbon cycle, and talked about mitigation options in the forest sector. His conclusions were:

- Globally forests have been absorbing ~27% of annual fossil fuel emissions.
- Climate change impacts on forests could increase net emissions and these could completely negate mitigation efforts in all other sectors.
- Limiting climate change impacts is the first important step towards maintaining the forest sink.
- Sustainable forest management and use of wood to substitute more emissions-intensive materials such as concrete and steel can contribute to climate change mitigation efforts
- Design of climate change mitigation portfolios in the forest sector should be based on systems approach and account for all emissions and removals relative to a baseline, when and where they occur.
- Forest managers do not control use of wood – effective mitigation portfolios need to integrate forest management with wood use strategies.
- Improved science and modeling capabilities to predict future forest dynamics and to assess mitigation options require nationally-coordinated efforts.
- Mitigation incentives – and the resulting economic values of carbon and energy contained in wood – may create new opportunities for forest sector, communities and economy.
- Forests and forestry cannot solve the problem of fossil carbon emissions, but they can contribute to the solution.

For more information about forest carbon accounting, visit the website of the Canadian Forest Service at: http://carbon.cfs.nrcan.gc.ca

For a list of publications by the Canadian Forest Service and Dr. Kurz, visit: http://cfs.nrcan.gc.ca/publications and use the search function for "carbon" or "Kurz".

Back to Table of Contents

2. BC Greenhouse gas regulations and forest carbon projects

Dennis Paradine, Climate Action Secretariat, BC Ministry of Environment, Victoria BC
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The following notes are adapted from Dennis Paradine's PowerPoint presentation.

On May 6, 2011, Premier Clark posted an open letter on building on British Columbia's leadership in the green economy. To read the letter, go to: www.gov.bc.ca. Highlights are:

- Climate change is clearly having a major impact in BC.
- BC is committed to its legislated emissions reduction targets
- The current carbon tax will continue and funding of initiatives such as public transport will be considered
- We'll continue to design a cap and trade system with the Western Climate Initiative (http://www.westernclimateinitiative.org)
- We need to leverage our supply of natural resources and clean energy
- We should use our expertise and creativity in adapting to a greener economy

A Green Economy would mean:

- Highly skilled, high paying green jobs are being created in significant numbers
- An economy based on innovation and productivity
- A forestry sector that maximizes carbon value

Suggested forecasts for an economy and jobs related to a green economy:
GLOBE Report

- Green economy (2008) accounts for $15 billion (10% of GDP)
- Potential growth (by 2020) could be $20-27 billion (11-14% of GDP), and 225,000 jobs

United Kingdom Department for Business, Innovation, and Skills

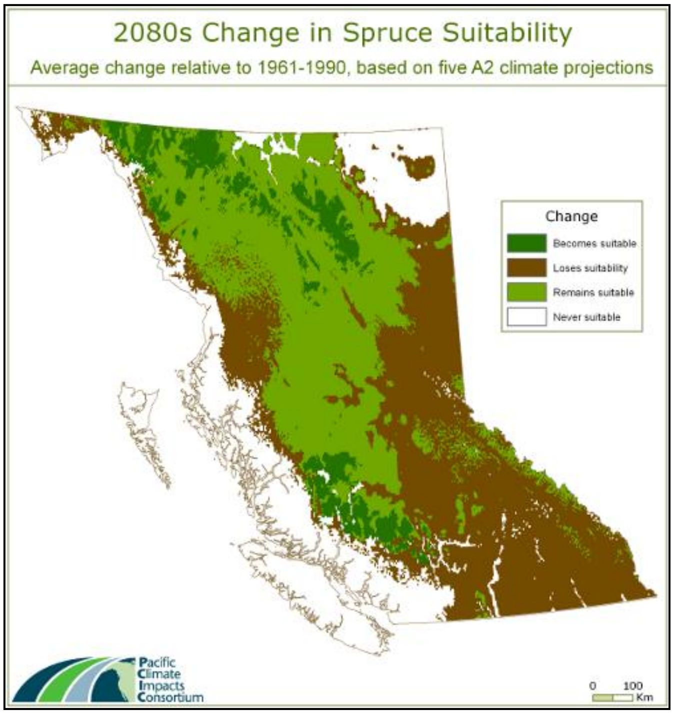
- $5.2 trillion global green economy market

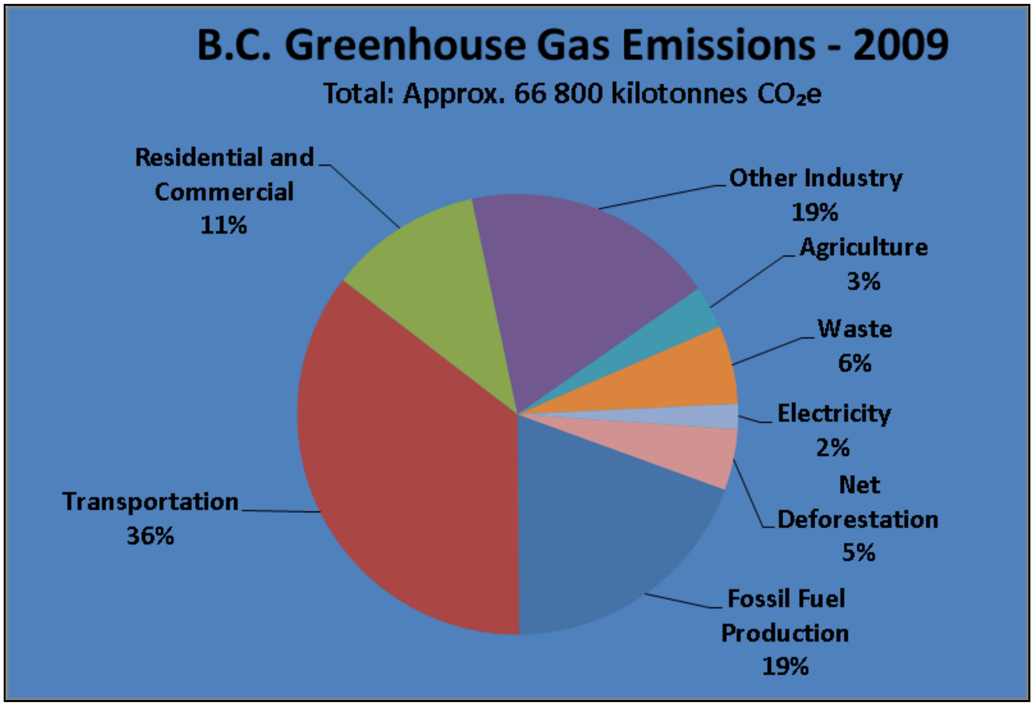
Pembina / David Suzuki Foundation

- Achieving BC's targets could result in faster annual job growth.

Impacts of climate change in BC forests:

- Increase in extreme temperature and precipitation events
- Increase in length of fire season
- Increase in spring stream flow
- Decrease in summer stream flow





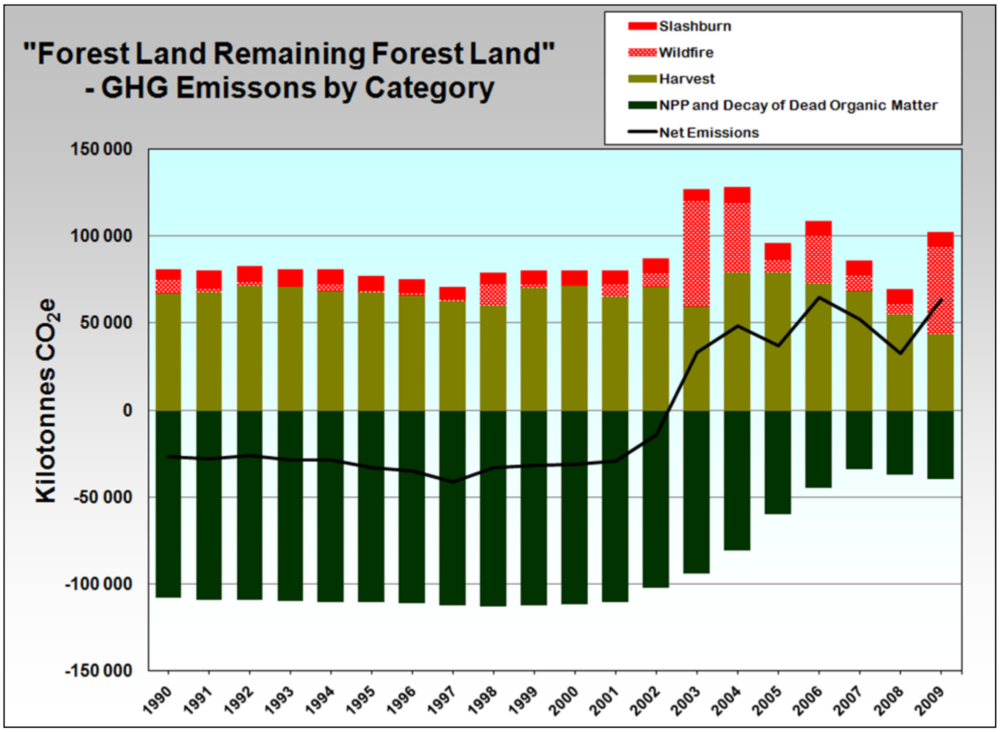
BC Greenhouse gas emissions

- Approximately 66.8 Mt CO_2e in 2009, down 3.2% from 2008
- Decrease is mainly due to recession
- Biggest source is transportation

- Forestry a memo item due to current international accounting rules
- Forestry projects can still count as progress towards targets

Emissions from forest land

- Forestry a 67 Mt source in 2009 – increase due to a high fire year
- Total net primary productivity is reduced due to ongoing impacts of mountain pine beetle
- Over time, the 67 Mt source may change to a sink



Greenhouse Gas Reduction Targets Act

- BC's aggressive reduction targets are for at least 33% below 2007 levels by 2020 and 80% by 2050
- Interim targets are for 6% below 2007 levels by 2012 and 18% by 2016
- Carbon neutral BC public sector by 2010

Greenhouse Gas Reduction (Cap and Trade) Act

- Statutory basis for establishing a market-based cap and trade framework to reduce GHG emissions from large emitters

- Details being determined in cooperation with Western Climate Initiative partners
- Reporting Regulation in force
- Western Climate Initiative offsets approach being developed as part of the cap and trade system

Other legislation and policies:

- Climate Action Plan
- Landfill gas
- Energy plan
- Green communities
- Low carbon fuel
- *Clean Energy Act*
- Tailpipe standard
- *Carbon Tax Act*

The *Greenhouse Gas Reduction Targets Act* commits BC to becoming "carbon neutral" in 2010

- 2010 is first baseline of carbon footprint, efforts to reduce emissions, and purchase of offsets
- Shows leadership on climate action
- Demonstrates clean energy and technology
- Uses offsets to fund innovative emission reductions

UNBC Biomass gasification system

- Fuel savings = $800,000/yr
- GHG Savings = 3,500 tonnes/yr
- BC technology, BC biomass fuel, BC jobs

Emission Offsets Regulation

- Sets out requirements for project GHG reductions and removals from projects to be recognized as emission offsets
- An emission offset cancels out GHG emissions from a source by reducing or removing the same amount of GHG through an offset project
- An offset represents a reduction of one tonne of CO_2e

- Assertions by proponent are evaluated by third party validation and verification bodies

Reducing emissions and energy costs

- Public Sector Energy Conservation Agreement
    - $75M in 247 projects over 3 years
    - $12.6M/yr in saved energy costs
    - 35,600 tons/yr in reduced GHGs
    - Demonstrates clean energy and technology
- Simon Fraser biomass facility
    - Burnaby Mountain's emissions to drop 83%
- Delta School District project
    - Save $500,000 and 2000 tonnes of GHGs annually
    - Bring clean energy to the neighbouring community

BC forests and wood products are natural carbon sinks, and can be augmented. Actions underway:

- Forest Carbon Offset Protocol
- “Wood is Good”
- *Zero Net Deforestation Act*
- Further policies could optimize carbon value of BC forests and parks
- Wood products & biomass carbon accounting

A typical 2500 square foot wood-frame home stores 30 tonnes of carbon

Optimizing forest carbon

- Afforestation and deforestation
- Forest management regimes:
    - Modified rotation lengths
    - Enhanced silviculture
    - Select seed, fertilizer, thinning, pruning, species selection, etc.
    - Conservation projects
    - Lifecycle accounting
- When a dollar value is placed on carbon, including in the forests, for each source of carbon what is the optimum use?

Further information

http://www.gov.bc.ca
http://www.env.gov.bc.ca/cas/mitigation/ggrta/offsets_reg.html
http://www.env.gov.bc.ca/casmitigation/carbon_neutral.html
http://www.pacificcarbontrust.com/
http://www.wci.org

Use your search engine for information on:

- BC Emission Offsets
- PCT Offsets
- Western Climate Initiative

Back to Table of Contents

3. Where is BC's hot land use change carbon?

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Are there hot land use change carbon opportunities in BC? When its forest practices are compared to other forest management jurisdictions, BC generally ranks as most sustainable. BC's ENGO community may also rank as the most critical and influential protectors of a region. As a consequence, compared to other regions, today's British Columbia has a relatively high baseline on which to propose climate positive land use change projects. Hunter-gatherers of carbon projects usually look to stop something stupid or begin something much more sustainable—management change that keeps more carbon on the landscape. This presentation will sketch where within BC's relatively sustainable and highly critiqued land use we have found some hot, some lukewarm, and some surprisingly cooler forest and ecosystem change carbon opportunities.

Back to Table of Contents

4. *Using TIPSY to predict the effect of stand management on quantity and value of biomass and carbon*

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Introduction to TIPSY

The Table Interpolation Program for Stand Yields (TIPSY) (Mitchell *et al.* 2000) is a growth and yield program that provides electronic access to the managed stand yield tables generated by the Tree and Stand Simulator (TASS) http://www.for.gov.bc.ca/hre/gymodels/TASS/index.htm (Mitchell, 1969; 1975) and SYLVER http://www.for.gov.bc.ca/hre/gymodels/SYLVER/index.htm (Mitchell *et al.* 1989). TIPSY retrieves and interpolates yield tables from its database, customizes the information, and displays summaries and graphics for a specific site, species and management regime. Yield tables are available for various even-aged coniferous species of commercial importance growing on the coast and in the interior of British Columbia.

Overview

TIPSY retrieves and interpolates yield tables from its database, customizes the information and displays summaries and graphics for a specific site, species and management regime. It is not a growth and yield model because its principal purpose is to provide electronic access to the managed stand yield tables generated by TASS and SYLVER.

TIPSY uses optional Operational Adjustment Factors (OAFs) to reduce TASS potential yields to what we might find in operational conditions. Two types of OAFs are available in TIPSY to account for elements that reduce potential yields. OAF1 is a proportional adjustment that accounts for the reduction of physical growing space due to holes created by rock outcrops, swamps, and non-commercial tree competition. OAF 2 is an incremental adjustment that accounts for pest damage that increases towards maturity.

TIPSY includes an economic analysis module, known as the TIPSY Economist which performs economic analyses on the silvicultural treatments simulated by TIPSY. A redesigned version called Financial Analysis System Including Economic Return (FAN$IER) will replace TIPSY Economist in the next program release.

TIPSY has a multiple species option oriented to timber supply applications where analysis units are aggregations of two or more species. This option is not recommended for silvicultural applications, since TIPSY does not simulate the growth of multiple species stands biologically. The only biological assumption considered is the site index conversion adjustment among species.

A batch version of TIPSY is also available for processing a large number of stands for timber supply analyses. Batch TIPSY is included in the program WOODLOT http://www.enfor.com/?Page=\software\woodlot\ for calculating even-flow harvest rates for a planning period on woodlot licenses.

New features in TIPSY Version 4.2

- Prediction of the number of well-spaced trees at common free growing heights and inter-tree distances for all species.
- Prediction of volume and percentage of juvenile wood, also called crown-formed wood or pith-associated wood
- Prediction of biomass and carbon for live and dead wood, bark, branches, foliage and roots
- Redesigned plot program (PLOTSY) with more flexible graphing capabilities for displaying growth and yield data and model trends.

Applications

TIPSY offers users a wide range of potential input values. However, clients are encouraged to rely on the guidelines and default settings provided unless local data are available. Guidelines and default values are derived from the best information available for the most common applications. Extensive on-line documentation will help users prepare customized input data. TIPSY generates managed stand yield tables, including product recovery data, batch processing, economic analysis, and supporting graphics for:

- Stand level crop planning
- Silvicultural prescriptions (e.g., espacement, pre- and commercial thinning, genetic gain, fertilization, variable retention, and windthrow)
- Forest level planning for long term timber supply projections of managed stands
- Multiple species feature aggregates stand types into the timber supply analysis units
- Jobs output (i.e. silviculture, harvesting, and manufacturing labour)
- Repressed stands of lodgepole pine
- Dead trees (i.e. standing or fallen snags) and coarse woody debris
- Biomass and carbon for live and dead wood, bark, branches, foliage, and roots.

TASS-TIPSY biomass and carbon prediction

To incorporate the biomass and carbon prediction capabilities into TIPSY, a new yield table database was generated with TASS. The growth of approximately 12 million individual trees was simulated to generate a total of 1659 yield tables with different combinations of species, initial densities, site indices and treatments. More than 2500 hours of computing time were required to generate the tables.

The above-ground biomass for each live and dead tree was calculated using the existing DBH- and height-based individual tree biomass equations originally developed by Lambert *et al.* (2005) and updated by Ung *et al.* (2008), who included additional commercial tree species sampled in BC. The following equation was used:

$$y_i = \beta_{ik} D^{\beta ik} H^{\beta ik} + \varepsilon_i \tag{1}$$

where y_i is the dry biomass of component *i* for either: stem wood, stem bark, foliage or branches (kg), *D* is (DBH, cm), *H* is total tree height (m), β_{ik} are the parameter estimates (*i* is as above, *k* = 0, 1 or 2), and ε_i is the error term for the component *i*. Total stem dry biomass was calculated as the sum of the stem wood and stem bark, while the total above-ground biomass was calculated as the sum of the total stem, foliage, and branches biomass. These models were developed for a total of 11 softwood and 3 hardwood species sampled in BC and the rest of Canada. The total below-ground root biomass for each tree was calculated as a function of the total above-ground biomass using the equations developed by Li *et al*. (2003) for all softwoods and hardwoods. The equations forms are:

(2) $RB_s = 0.222 AB_s$

(3) $RB_h = 1.576 AB_h^{0.615}$

where RB and AB are root and above-ground biomass (kg) respectively, (subscript *s* denotes the softwood species group, and *h* is the hardwood species group). A conversion factor for temperate zones of 0.5 g C/g (Mattheus, 1993; Lamlom and Savidge, 2003) was used to convert biomass to carbon stock for each individual tree component, and carbon stock is multiplied by 3.67 to convert to carbon dioxide equivalent (CO_2e) as follows:

(4) Carbon stock = biomass · 0.5

(5) CO_2e = Carbon stock · 3.67

The individual tree biomass calculated in TASS was aggregated into stand level yield tables and incorporated into a new version of TIPSY. This program now has the capability to interpolate and report the live biomass stock and dead biomass stock change in oven dry units (O. D. tonnes/ha) for the bark, branches, foliage, wood, roots, and total (above- and below-ground) stand components. Similarly, it interpolates and reports the live and dead carbon stock change in oven dry units (O. D. tonnes/ha) for the same components. The amount of dead biomass and carbon stock change represents only the mortality occurring between the selected steps (i.e. age or height) within the yield table output without the quantification of the biomass decay over time. This is also called “periodic recruitment” in TIPSY reports. In addition, mortality is partially affected when the operational adjustments factors (OAFs) are used. For instance, when an OAF2 is selected the dead biomass and carbon will increase by the same amount lost in live biomass and carbon columns. In other words, the dead trees that are moved to the mortality table are also reported as dead biomass and carbon stock. The carbon content of minor vegetation, soil, dead organic matter, and litter are not considered at the present time. All this information and other issues is documented in the on-line TIPSY help module.

Example: Using TIPSY to predict the effect of stand management on quantity and value of biomass and carbon

How does pre-commercial thinning and fertilization affect the biomass and carbon yield and economic return? To answer this question we used TIPSY to generate yield, biomass and carbon products, and the beta version of FAN$IER to generate the economic tables for the following regimes:

Stand specifications:

- Lodgepole pine stands, naturally regenerated with an initial density of 10,000 stems per hectare (sph), with 5 regimes:

Run #	**Initial density (sph)**	**Stand Regimes**	**Name**
1	10,000	none	Control
2	10,000	PCT to 1200 sph	PCT
3	10,000	Fertilization @ age 50	Fert
4	10,000	PCT 1200 sph and Fertilization @ age 50	PCT - Fert
5	10,000	PCT 1200 sph and Fertilization @ ages 25 and 50	PCT - 2 Fert

- Site index 19
- OAF1&2 =1.00
- Regeneration delay as default (2 years).

Table specifications:

- Merchantable volumes 12.5+
- Output tables using age ranging from 0 to 300 in 10 year steps.

Economic Specifications:

- Stand geography: Southern Interior, Kamloops (Region and District), IDF biogeoclimatic zone, slope 10% and distance to support centre 100 km
- Economic assumptions: discount rate 4%, real cost and price increase 0%
- Silviculture costs: default forest district averages
- Tree-to-truck costs: ground skidding and default forest district averages
- Haul costs: default interior averages

- Milling cost: default exponential milling cost
- Miscellaneous costs: default forest district averages
- Biomass prices were: 40, 60, 80 and 100$/tonne
- CO_2e prices were: 20, 30, 40 and 60$/tonne

Regime comparisons:

- Merchantable volume, total above ground biomass, and total above ground carbon over age
- Site value (SV) for different biomass and carbon prices. It represents the sum of the discounted benefits that the treatment yields, minus the sum of the discounted costs of the treatment. It is the maximum amount that someone would be willing to pay for bare land if the land was devoted to producing an infinite series of rotations of identical growing regimes (Faustmann, 1849).
- Optimum harvest ages comparing the physical rotation (maximum Mean Annual Increment—MAI) and the economic rotation considering the SV of different biomass and CO_2e prices.
- Optimum SVs by comparing the optimum SV for all the regimes considering different biomass and CO_2e prices.

Results

Figures 1 and 2 show the merchantable volume, mean annual increment, total above ground biomass and CO_2e that includes stem, bark, branches, and foliage. At age 100 all these relationships show that the PCT - 2 Fert regime was the most productive followed by PCT - Fert, Fert, PCT, and the control. It generated 88 m^3/ha of merchantable volume, 37 O. D. tonne/ha of biomass and 69 tonne/haCO_2e more than the control. The optimum Mean Annual Increment (i. e. max mean MAI, red dots) for all the treatments occurs at age 70 and it ranged from 4.8 to 5.2 m^3/ha/yr for the control and PCT - 2 Fert regimes respectively.

Figures 3 to 7 show the Site Value (SV) over age for the different biomass and CO_2e prices for each regime. For all the regimes the SVs increase as the prices for both biomass and CO_2e increase. These figures also included the harvest age at which the stand's SV is maximized (i. e. max, red dots), and it is known as the economic rotation age. In all the regimes the economic rotation ages decrease as the prices of both biomass and CO_2e increase.

Figure 8 shows the maximum harvest ages or economic rotation for all the regimes considering different biomass prices and including the maximum

MAI or physical rotation. The physical rotation for all the regimes was 70 years and the economic rotation in average ranged from 208, 62, 50 and 46 years for biomass prices of 40, 60, 80 and 100\$/tonne respectively. The economic rotation occurs earlier than the physical rotation for all biomass prices larger than 60\$/tonne. Figure 9 shows the maximum harvest ages or economic rotation for all the regimes considering different CO_2e prices and including the maximum MAI or physical rotation. The physical rotation for all the regimes was 70 years and the economic rotation averaged from 202, 56, 46 and 46 years for CO_2e prices of 20, 30, 40 and 60\$/tonne respectively. The economic rotation occurs earlier than the physical rotation for all CO_2e prices larger than 30\$/tonne.

The optimum SV for all the regimes considering different biomass prices is shown in Figure 11. SV for biomass prices of 40 and 60\$/tonne were negative for all the regimes. Biomass price of 80\$/tonne generated positive SV for the first two regimes and negative for the combined PCT and Fert regimes. Finally, all the SV were positive for biomass price of 100\$/tonne for all the regimes.

Figure 11 shows the optimum SV for all the regimes considering different CO_2e prices. SV for CO_2e prices of 20 and 30\$/tonne were negative for all the regimes. CO_2e price of 40\$/tonne generated positive SV for the Control and Fert regimes and negative for the remaining regimes. Finally, all the SV were positive for CO_2e price of 60\$/tonne for all the regimes.

In summary, these results represent an example of how TIPSY and FAN\$IER can be used to predict the effect of stand management on quantity and value of biomass and CO_2e. In assessing the economics of silviculture investments, we not only need to assess the stand's conversion value at each harvest age, but also need to consider any costs associated with the regeneration and tending of the stand. The price of the forest products generated also is critical as demonstrated in the above example. Biomass prices larger than 80\$/tonne and CO_2e prices larger than 40\$/tonne generated positive SV returns. TIPSY and FAN\$IER are the only tools available in BC that allow users to compare costs and benefits for a variety of wood products which occur in different time periods to facilitate forest management decision making.

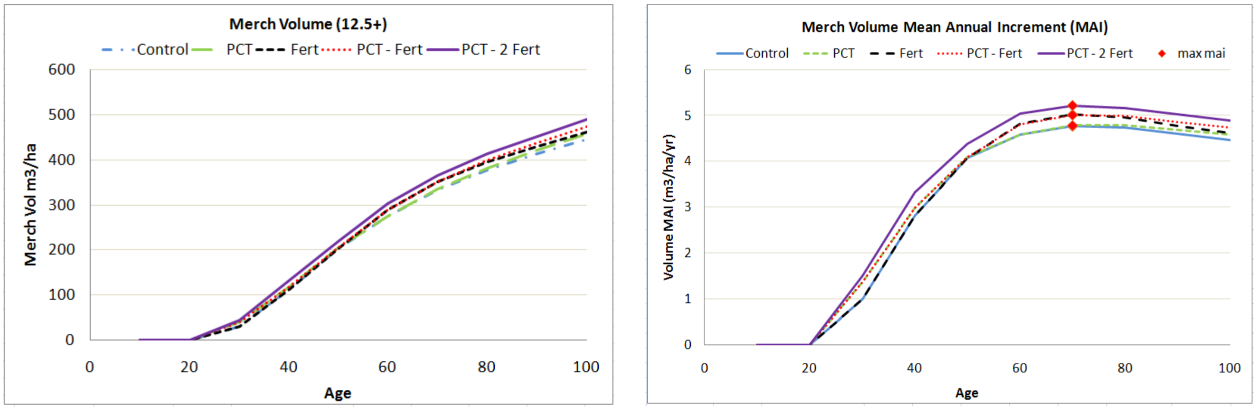


Figure 1. Merchantable volume and Mean Annual Increment

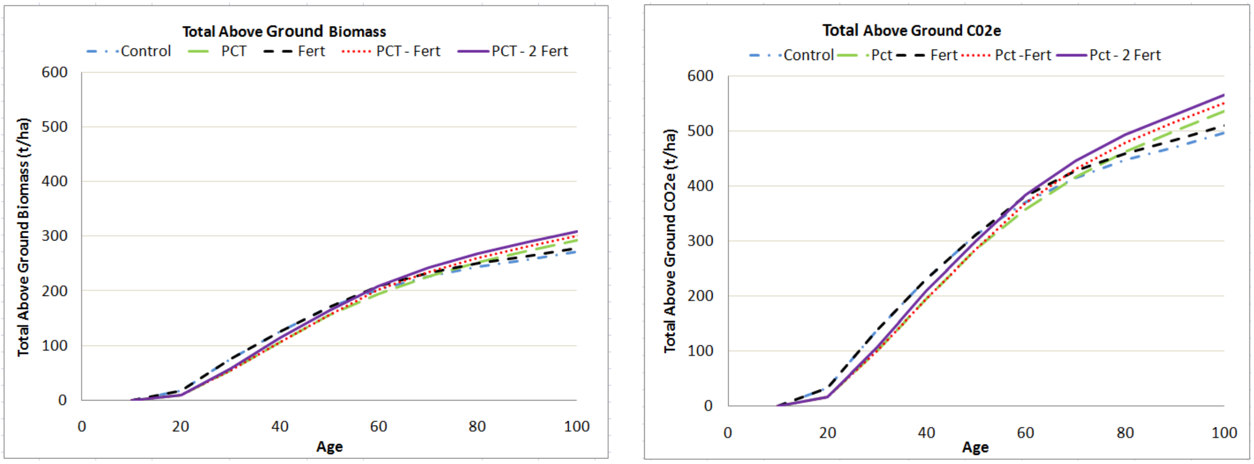


Figure 2. Total above ground biomass and CO_2e

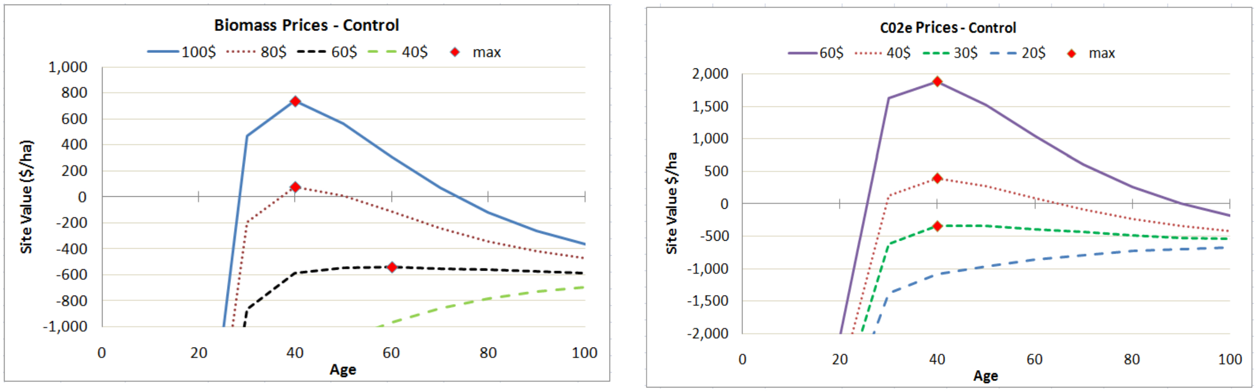


Figure 3. Site Value for different biomass and CO_2e prices for control

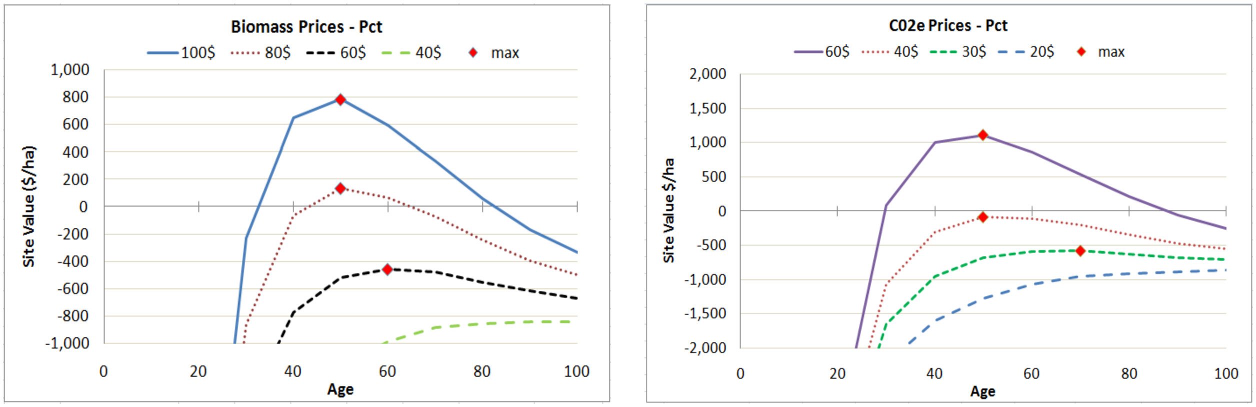


Figure 4. Site Value for different biomass and CO$_2$e prices for PCT

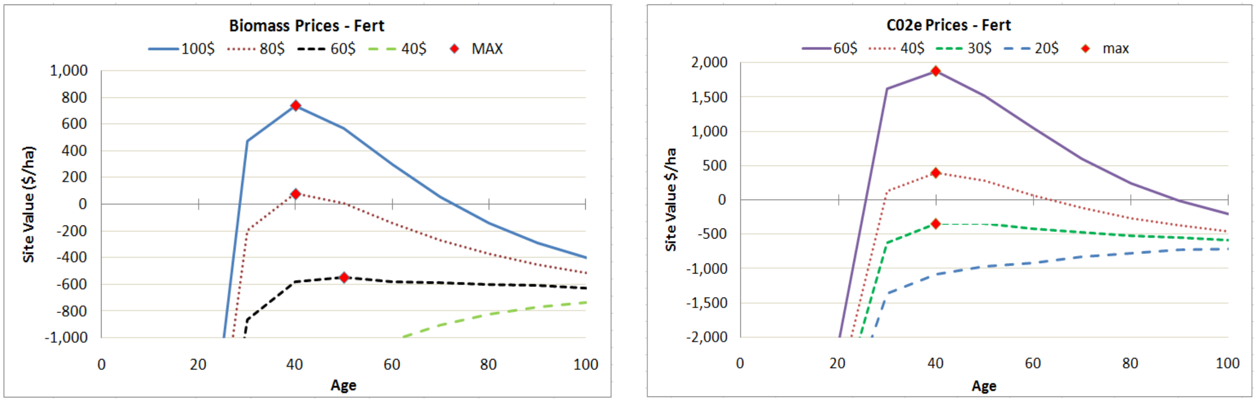


Figure 5. Site Value for different biomass and CO$_2$e prices for Fert

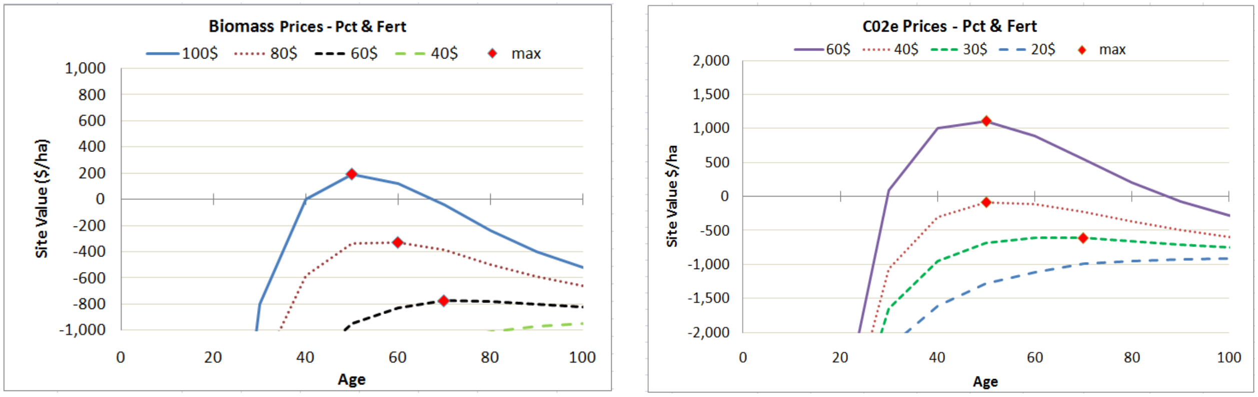


Figure 6. Site Value for different biomass and CO$_2$e prices for PCT & Fert

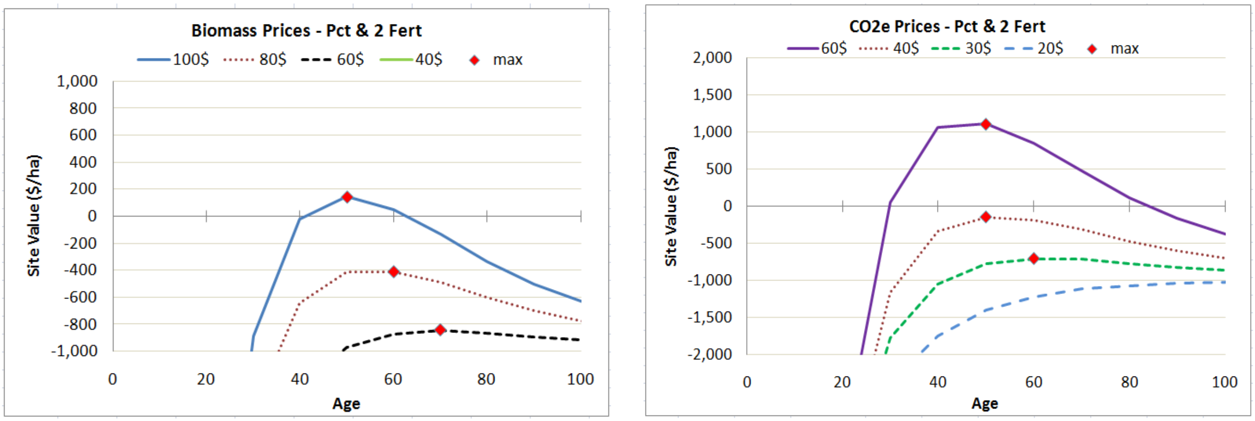
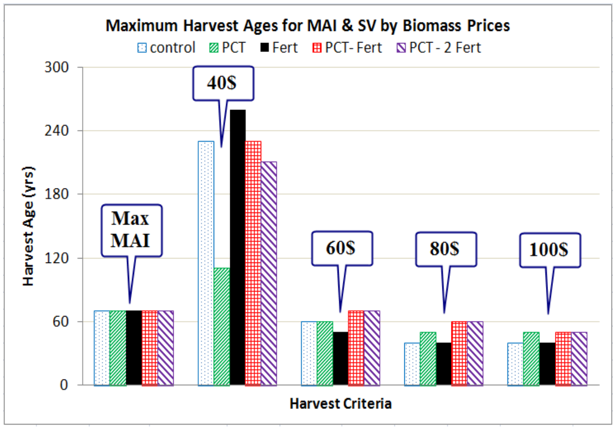


Figure 7. Site Value for different biomass and CO_2e prices for PCT & 2 Fert



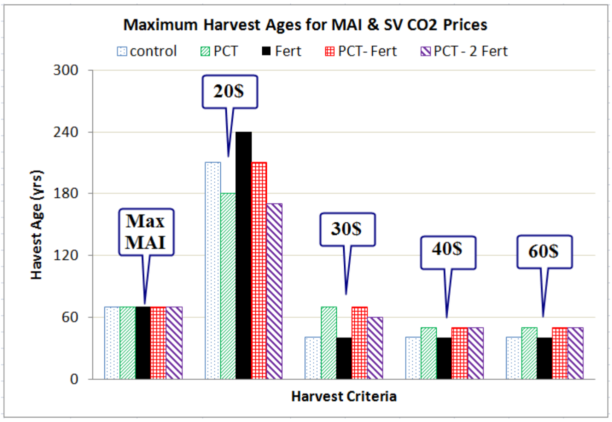
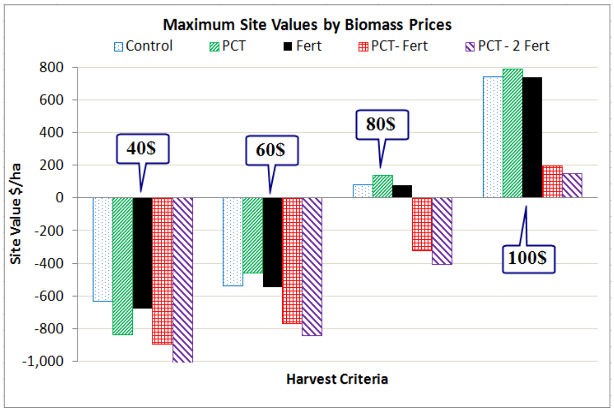


Figure 8. Maximum harvest ages for MAI and Site Value by biomass prices

Figure 9. Maximum harvest ages for MAI and Site Value by CO_2e prices



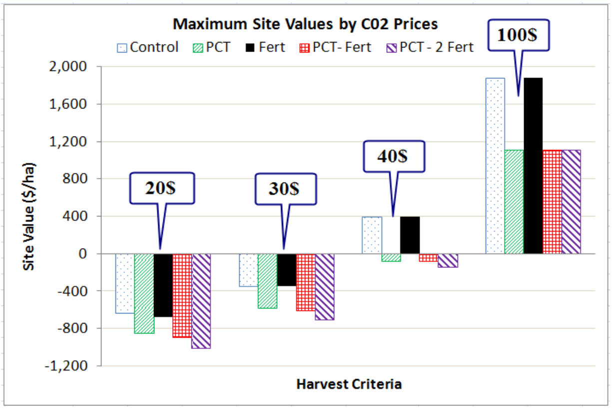


Figure 10. Maximum Site Values by biomass prices

Figure 11. Maximum Site Values by CO_2e prices

Future features

FAN$IER

A beta version of the Financial Analysis System Including Economic Return (FAN$IER) is currently being tested and it will be available in the next TIPSY release expected to be in the fall of 2011. It is designed to provide improved economic analysis options to help foresters and planners to evaluate the impact of selected silviculture events on the discounted value returned by end products at the stand level. FAN$IER, developed by the Stand Development Modelling Group, Forest Analysis and Inventory Branch to replace the TIPSY Economist and the Financial Analysis System (FAN$Y), includes updated costs, prices, methods and financial information. It is designed to run with data from TIPSY, TASS, SYLVER and data sets from other growth and yield models that can produce output in the appropriate file format. FAN$IER can be launched either from a parent growth and yield application such as interactive TIPSY, TASS, and SYLVER, or from the user's desktop as a standalone application.

Users start the analysis process by running the parent application to select silviculture events, growth and yield parameters, and forest products to create a regime file to be sent to FAN$IER (Figure 12). The regime file contains location information, silviculture events, output yield responses and forest products data. Current forest products available in this version include dimensional lumber by quality grades, residual wood chips, logs by grades, biomass, and carbon dioxide equivalent (CO_2e). The program can be easily modified to include other forest products such as custom dimensional lumber, veneer, sawdust and hog fuel. In FAN$IER, users can view the data sent in the regime file, edit costs and values and select economic assumptions to perform their economic and financial analysis. Financial indicators include: net present value (NPV), site value (SV), internal rate of return (IRR), benefit cost ratio (B/C) and site value sensitivity analysis on the base case economic assumptions. Results can be viewed on the screen and sent to PLOTSY for graphing. The summary of the economic analysis report, data, and results can be printed or saved in a user friendly format that can be readily used for spreadsheets. The general flow of FAN$IER is illustrated in Figure 12.

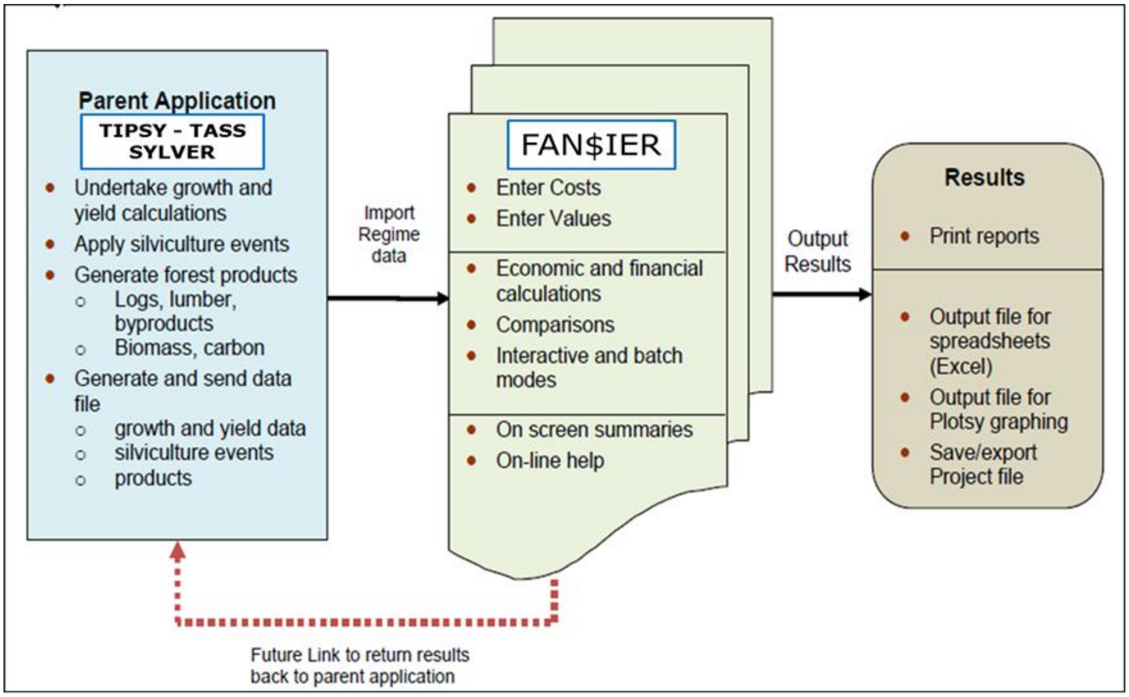
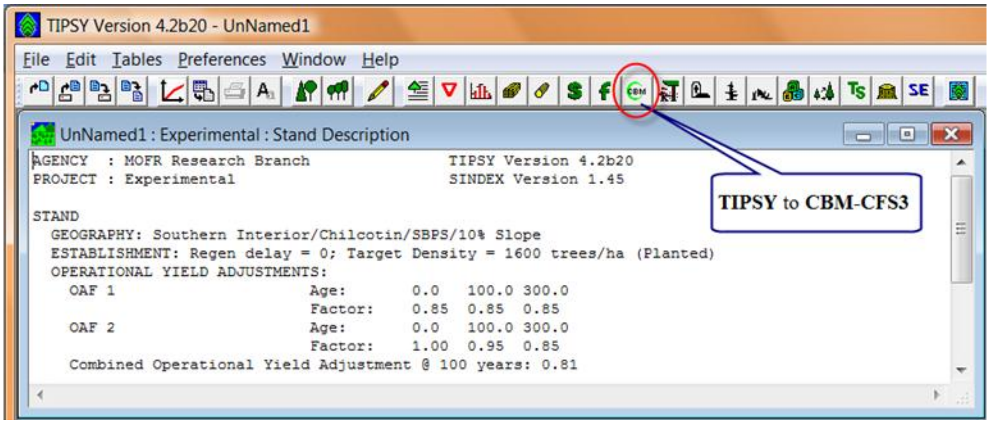


Figure 12. General flow of FAN$IER

TIPSY to Carbon Budget Model (CBM-CFS3) link

A second improvement in the upcoming TIPSY release will facilitate carbon modelling by providing users the functionality to link the interactive TIPSY and batch TIPSY forestry growth and yield outputs with the Canadian Forest Service Carbon Budget Model (CBM-CFS3) Kurz *et al.*2009. TIPSY to CBM-CFS3 is a standalone application that can access CBM-CFS3's databases directly. This application will work on systems that have "Operational-Scale Carbon Budget Model of the Canadian Forest Sector" version 1.2.4158.75 or greater installed. For instance, once a yield curve has been created with TIPSY, a regime file can be sent to CBM-CFS3 via the TIPSY to CBM-CFS3 application by simply clicking on the CBM button located on the TIPSY's toolbar (Figure 13). A regime file contains the run parameters, stand yield and location information.

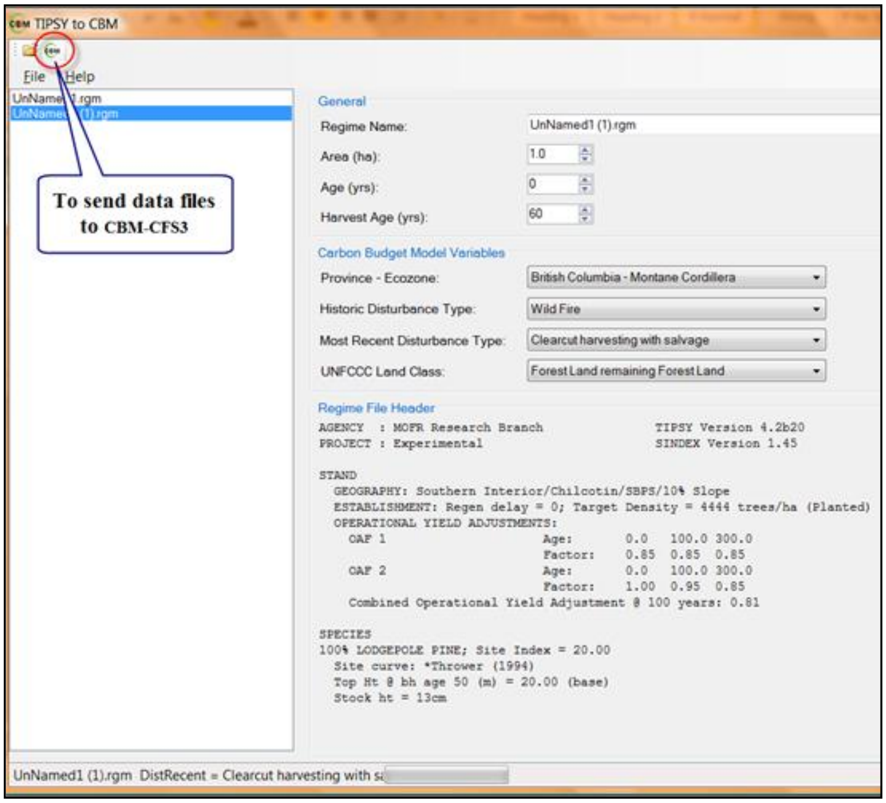


```
AGENCY  : MOFR Research Branch               TIPSY Version 4.2b20
PROJECT : Experimental                       SINDEX Version 1.45

STAND
  GEOGRAPHY: Southern Interior/Chilcotin/SBPS/10% Slope
  ESTABLISHMENT: Regen delay = 0; Target Density = 1600 trees/ha (Planted)
  OPERATIONAL YIELD ADJUSTMENTS:
    OAF 1                     Age:       0.0   100.0 300.0
                              Factor:    0.85  0.85  0.85
    OAF 2                     Age:       0.0   100.0 300.0
                              Factor:    1.00  0.95  0.85
    Combined Operational Yield Adjustment @ 100 years: 0.81
```

Figure 13. CBM button located on the TIPSY toolbar

In the TIPSY to CBM-CFS3 dialog window box (Figure 14), The “General” and “Carbon Budget Model Variables” sections contain user adjustable variables that are not part of TIPSY but are required by CBM-CFS3. These variables have been set to default values and may need to be adjusted by the user including area, age, harvest age, Province/Ecozone, Historic Disturbance Types and UNFCCC Land Class. Additional regime files can be loaded from the Open toolbar button, or sent from TIPSY by going back to TIPSY and creating and sending another regime. Once the data editing is completed a set of files is sent to and automatically load it into CBM-CFS3 by clicking the CBM button located on the TIPSY to CBM-CFS3 toolbar (See caption in Figure 14).



To send data files to CBM-CFS3

General

Regime Name: UnNamed1 (1).rgm
Area (ha): 1.0
Age (yrs): 0
Harvest Age (yrs): 60

Carbon Budget Model Variables

Province - Ecozone: British Columbia - Montane Cordillera
Historic Disturbance Type: Wild Fire
Most Recent Disturbance Type: Clearcut harvesting with salvage
UNFCCC Land Class: Forest Land remaining Forest Land

Regime File Header

```
AGENCY  : MOFR Research Branch                  TIPSY Version 4.2b20
PROJECT : Experimental                          SINDEX Version 1.45

STAND
  GEOGRAPHY: Southern Interior/Chilcotin/SBPS/10% Slope
  ESTABLISHMENT: Regen delay = 0; Target Density = 4444 trees/ha (Planted)
  OPERATIONAL YIELD ADJUSTMENTS:
    OAF 1                          Age:      0.0   100.0 300.0
                                   Factor:   0.85  0.85  0.85
    OAF 2                          Age:      0.0   100.0 300.0
                                   Factor:   1.00  0.95  0.85
    Combined Operational Yield Adjustment @ 100 years: 0.81

SPECIES
100% LODGEPOLE PINE; Site Index = 20.00
  Site curve: *Thrower (1994)
  Top Ht @ bh age 50 (m) = 20.00 (base)
  Stock ht = 13cm
```

UnNamed1 (1).rgm DistRecent = Clearcut harvesting with s

Figure 14. TIPSY to CBM-CFS3 dialog window box

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Back to Table of Contents

5. The Carbon Budget Model of the Canadian Forest Sector (3) and its application at the national, regional, and operational scale.

Eric Neilson, Canadian Forest Service, Victoria, BC
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In Eric Neilson’s absence, Dr. Juha Metsaranta presented the talk.
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The Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) implements a Tier 3 approach of the Intergovernmental Panel on Climate Change Good Practice Guidance for reporting on carbon stocks and carbon stock changes resulting from land use, land-use change, and forestry. The CBM-CFS3 is a generic modeling framework that can be applied at the stand, landscape, and national levels. Several ecosystem structure and processes are explicitly modeled by CBM-CFS. These include:

(1) An expanded representation of dead organic matter and soil carbon, particularly standing dead trees, and a new algorithm for initializing these pools prior to simulation;
(2) A change in the input data requirement for simulating growth from biomass to readily available merchantable volume curves, and new algorithms for converting volume to biomass;
(3) Improved prediction of belowground biomass; and
(4) Improved parameters for soil organic matter decay, fire, insect disturbances, and forest management.

We have undertaken a series of mitigation analyses in which we estimate future forest carbon stock changes under various levels of protected areas and future harvesting levels. The CBM-CFS3 was used to report the stock changes for use in international negotiations support. As well as national or provincial scale analyses, we have also undertaken management level analyses where we have investigated the use of residual biomass for use as bio-energy in coal fired power plants. While carbon neutrality was never attained from using biomass as energy, the overall impact on the atmosphere was lesser than coal after a certain amount of time due to the re-growth within the forest area.

Back to Table of Contents

6. Dynamics of CForCS – a New Carbon Model for Simulating Climate Change

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Introduction

The balance of evidence indicates that forest managers and other stakeholders need to consider the forecasts of a changing climate seriously and undertake both mitigation and adaptation activities. Forests can play a role as a carbon sink or source, depending on many natural and human dynamics. However, as a community, people interested in forest ecosystems have few tools to understand carbon dynamics. We identified a need for a model to simulate climate change impacts on forest ecosystems including carbon.

In order to simulate climate change impacts on forest carbon dynamics we established a set of criteria for selecting a model. These criteria were (in no particular order):

- Dynamic feedback of changing vegetation on management and disturbances because we know from the climate-envelope modelling of BC that we can expect large structural changes to the types of vegetation in our ecosystems. Therefore, it makes sense to use a model where fire size and severity, harvest rates, etc., will respond to those changes.
- The model must maintain a mass-balance. This term means that all the changes in ecosystem carbon stocks can be accounted for in the inputs and outputs.
- A model needs to have a spin-up or simulation initialization of dead organic matter and soil pools. Without this kind of initialization you tend to get modelling artifacts such as large sinks.
- Neighbourhood effects on regeneration, fire spread and harvesting which allows for more realistic model outputs and therefore makes it easier to communicate with the management community.

- Having a built-in random or stochastic variability in growth and disturbances over time and space simplifies the modelling of many different futures. This functionality allows for answering questions about the likelihood of a given outcome and estimating uncertainty.
- The model needs to work at a landscape or management unit scale to be useful for the Ministry decision makers, land managers, and interested stakeholders.
- Must be inexpensive.

Unfortunately, we were unable to find a model which met these criteria and therefore developed the Canadian Forest Carbon Succession v1.0 beta (CForCSv1) as a new extension to the Landscape Disturbance and Succession II (LANDIS-II). The CForCSv1 is built from the Biomass Succession v2 extension to LANDIS-II (Scheller and Mladenoff 2004) and the Carbon Budget Model of the Canadian Forest Sector v3 (CBM-CFS3) (Kurz *et al.* 2009).

Model description

The LANDIS-II is a forest landscape simulation modelling framework (Scheller *et al.* 2007). When used with the Biomass Succession v2 extension it tracks multiple species, their age classes, and their biomass in each site. Its most often used at a large spatial scale (typically > 10 ha) and a longer time scale (> 10 years). It simulates succession, i.e. regeneration, growth, competition, and mortality, based on life history characteristics. It emphasizes spatially dynamic processes. The disturbance and harvesting occurrence and impact are influenced by the forest conditions. It has climate change functionality.

The CBM-CFS3 is also a forest landscape simulation modelling framework. It is limited to leading species in even-aged stands. In addition to biomass it also tracks deadwood, soil, and carbon. It is typically used at similar spatial and temporal scales as LANDIS-II. The succession, disturbance, and harvesting occurrence and impact are prescribed by the user, i.e. it is a deterministic model. It has limited climate change functionality, although Dr. Kurz and his team would like to improve that in the future. It is easier to get input data and parameters for the CBM-CFS3 than for the LANDIS-II.

The CForCSv1 uses the following from the Biomass Succession v2 extension to LANDIS-II:

- Seed rain and natural regeneration

- Growth and mortality
- Competition
- Climate change functionality

As an extension to the LANDIS-II modelling framework, the CForCSv1 is compatible with the disturbance extensions to simulate: fires, harvesting, planting, insects, and disease.

From the CBM-CFS3, the CForCSv1 uses:

- Dead organic matter and soil
- Decay functions
- Carbon

Uniquely implemented in the CForCSv1, although informed by the parent models, are the simulation of disturbance impacts and the way mass-balance is maintained.

Conclusion

The CForCSv1 allows you to simulate future climate change impacts on forest carbon dynamics including feedback of changing vegetation on management and disturbances. This model can be used to assess what-if scenarios, management or offset project ideas, uncertainty, identify opportunities, and risks. It is not suitable for C-offset quantification or other reporting purposes due to the built-in random functions. It also does not deal with anything outside of the ecosystem (e.g. wood products).

The next steps in this project are to address some known issues on root turnover and review the Biomass Succession v3 which is currently in testing. We are looking for people interested in testing the model. Furthermore, we expect to have a project with Dr. Nicholas Coops at UBC where a graduate student will use the CForCSv1 in a pilot study.

Acknowledgments

We would like to thank the British Columbia Forest Investment Account for funding this project. In addition, thanks to Dr. Werner Kurz who shared the code from the CBM-CFS3, Mr. Greg Rampley, Mr. Graham Stinson, Dr. Carolyn Smyth, Mr. Eric Neilson, Mr. Michael Magnan, Mr. Gary Zhang, & Mr. Stephen Kull who developed, tested and documented CBM-CFS3. We also thank Dr. Rob Scheller & Mr. Brian Miranda who developed, tested, and

documented LANDIS-II, the Biomass Succession and Fire Extensions. They answered many questions, changed code, and overall provided tremendous support for this project.

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LANDIS-II web site
http://www.landis-ii.org/

Back to Table of Contents

7. A general framework to evaluate the suitability of a carbon accounting tool for application in an offset project

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Introduction

Properly implemented, forestry-based offset projects have the potential to mitigate a significant proportion of carbon emissions and to simultaneously protect a suite of ecosystem services, including biodiversity and water. An accurate calculation of the carbon balance is, however, a prerequisite to the success of any project. Typically, this will require the application of one or more computer-based modeling tools. To date, the number of models designed specifically to calculate carbon dynamics in forest ecosystems is relatively small. In some cases, tools developed for purposes of forest management (growth and yield models, for example) have been adapted for use in carbon-offset projects by modifying their output to include the main ecosystem carbon pools. For project developers and individuals with limited technical expertise in carbon modeling, evaluation and selection of the most appropriate tool can be daunting. Is a “carbon model”, for example, likely to provide better estimates than a “growth and yield model” adapted for such purposes? In principle, not necessarily—since carbon accrual (or loss) is calculated from ecophysiological processes that dictate the net gain or loss in biomass. What is most important is the ability of the model to represent those processes. Hence, even models developed specifically to simulate carbon dynamics may not be as accurate or useful as alternative models designed originally for a different purpose. Although, in most cases, it will be prudent for project developers to engage modeling experts in the actual application of a model, ultimately it is the developer who is in the best position to determine which model best suits the needs of the project. Relatively few models are suitable for consideration by project developers at present but the number of potential candidate models is likely to grow significantly as the offset market gains traction. What determines a “good” or “suitable” model, and how do alternative models compare? Here I provide a general framework for addressing these questions, which can be used by those without a modeling background.

The application domain

The suitability of a model for use in a carbon-offset project depends on its domain of application. The application domain reflects the ecological concepts represented in the model, the spatial representation and temporal scale at which the model can be meaningfully applied, and the management activities it can represent. It is the application domain that sets limits on the nature of the carbon project a particular model is best suited to address. There is one proviso, however. Using a model with the appropriate application domain does not guarantee its acceptability as a carbon tool or that its projections are indeed accurate. Acceptance of a given model depends, in part, on successful verification (is the model structure and function consistent with project requirements) and validation (how accurate are its predictions).

For convenience, each component of the application domain can be considered as constituting a subdomain. Hence, a carbon model has a minimum of four subdomains representing:

- Ecology
- Space
- Time
- Management activities

The relationship of a model’s subdomains to associated project features is shown in Figure 1. The latter are determined from characteristics associated with the particular standard and/or associated protocols (the Verified Carbon Standard, the Climate Action Reserve, and the BC Forest Carbon Offset Protocol, are examples) under which the project is being developed, as well as the characteristics of the project and baseline case. The most suitable model is that which has the greatest overlap between the project features and its application subdomains. Since each carbon project is unique, it is incumbent on project developers to fully understand the set of features that characterize their project.

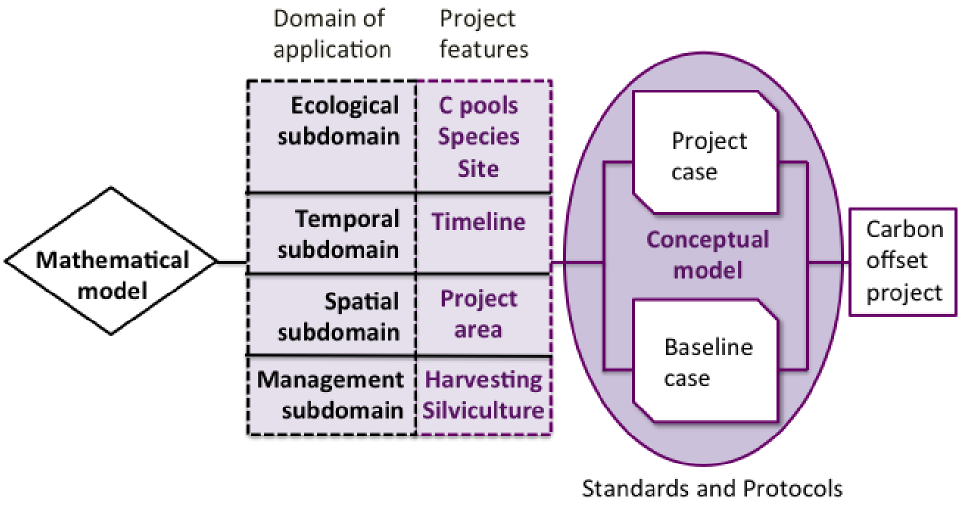

Figure 1. A schematic representation of how model subdomains map onto project features.

The ecological subdomain

From the point of view of a carbon project, this domain refers to the ecological processes and mechanisms that underlie the rates of loss and accumulation of carbon in a forest ecosystem.

Within a forest ecosystem, carbon is stored in four pools, aboveground live biomass, belowground live biomass, dead organic matter (litter and dead wood), and soil organic matter. All projects require as a minimum that the carbon balance in aboveground live biomass and dead wood be accounted for. Depending on the standard, other pools may be classed as required or optional. Ideally, the ecological subdomain of a model should include an explicit simulation of the processes that drive the carbon balance in all four pools regardless of whether or not they are included in the project. This is simply because each pool is interrelated and its carbon content may be dictated by feedback processes with other pools. Try to avoid models or modeling techniques that rely on allometric biomass equations or expansion factors (for example, root:shoot ratios) to calculate pool sizes. This approach can introduce significant errors in the carbon balance.

Other aspects of your project that may need to be represented in the ecological subdomain are:

- Single species or multiple species (which species?). Make sure the model can represent the species or species combinations you want to use.

- Single cohort or multi-cohort. Do you have, or are you creating, conditions that result in development of multi-aged stands?
- Understory dynamics. Particularly important in agroforestry applications.
- Nutrient cycling. Relevant when carbon additionality is derived from improvements in site conditions through, for example, fertilization or planting of nitrogen-fixing species.
- Light dynamics. Particularly important for simulating productivity in multi-age cohort systems created from variable retention harvesting, for example.
- Competition. Can the model simulate competition for light and nutrients among different species and age-cohorts (if these are important features of the project)?
- Starting site conditions (bare ground, land conversion, post-harvest etc.). What initial conditions can the model simulate? Many of the better models must undergo a “spin-up” phase, whereby the characteristic features of the starting conditions (the size of the carbon pools, for example) are defined. Make sure that the spin-up phase can create the starting conditions appropriate to your project.

The spatial subdomain

This is the minimum and maximum physical space to which a model can be meaningfully applied. In terms of the number of carbon offset projects, the majority will likely be relatively small in size (20,000 ha, or less) with very few developed over large scales (100,000 ha, and more). The importance of the spatial subdomain to selecting the most appropriate modeling tool is illustrated in Figure 2. You should expect that models designed to represent the carbon balance over smaller areas include much more explicit detail of the underlying processes than models that are applied at larger spatial scales (Figure 2). This can mean that the former require more detailed data for calibration than the latter. Conversely, large landscapes tend to be highly heterogeneous in terms of the carbon density among stands, typically have substantial inventory error (both of which are sources of calibration error), and their carbon balance is dominated by disturbance events that can be catastrophic but which are difficult to predict. For these reasons, smaller-scale models generate less uncertainty in carbon projections than the latter. Identify the area of your project and when considering a model, balance its calibration requirements against the uncertainty in projections using the general relationships outlined in Figure 2. Construction of a meta-model can improve the level of detail and reduce uncertainty. This is discussed further in a later section.

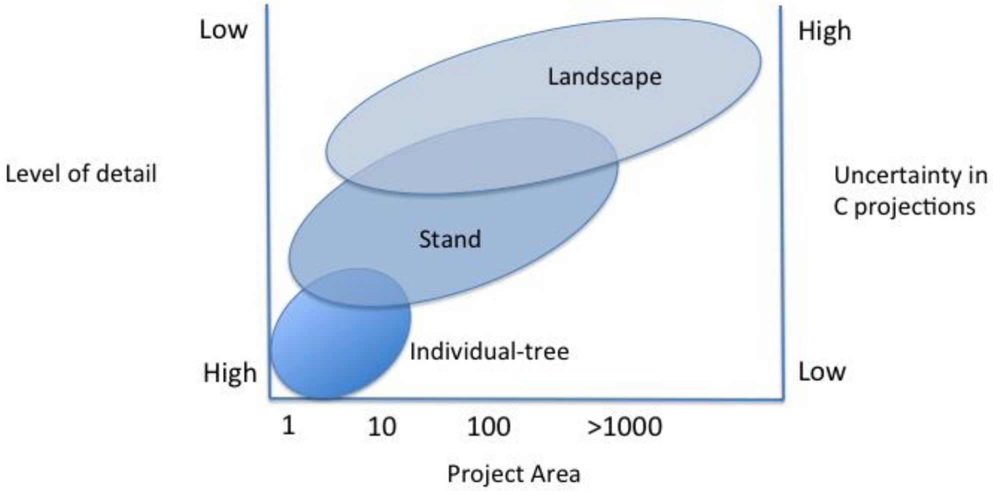

Figure 2. Model type (individual-tree, stand, and landscape) and its relation to the area over which it is best applied. Also shown are its relationship to the level of ecological detail that the model represents and the uncertainty (predictive error) in carbon projections.

Keep in mind that uncertainty will have a direct impact on the total credits generated from a project. This is because many methodologies apply a deduction from the number of credits that can be claimed that is proportional to the level of uncertainty or predictive error (the difference between model predicted carbon amounts and what is measured from field plots or through remote sensing).

The temporal subdomain

The temporal subdomain is the minimum and maximum time frame that a model can meaningfully represent. In forest carbon offset projects, a minimum temporal subdomain is one year. This is because in *ex-poste* carbon projects, credits are usually generated on an annual basis. The maximum period represented by a model should be a century or more. A number of the leading standards require that sequestered carbon be stored for a minimum of 100 years (Climate Action Reserve, for example) though the Verified Carbon Standard permits projects that are as little as 20 years duration. Ideally then models should simulate the carbon balance on an annual time step, for a duration of 100 years, and with the simulation results reported annually. Some models report the carbon balance on 5 or 10-year intervals. This is less desirable in cases where the carbon balance is changing quickly year-over-year (which often occurs early in a project) since model output will need to be interpolated across intervals to generate a yearly estimate, and which may represent a source of error.

The management subdomain

Refers to the management activities that a given model can represent. Many carbon projects generate additionality from project activities that deviate from historical practices. This will be problematic for empirically based models whose applications are limited to traditional management activities because that is the only data available for their calibration. Make sure you have a clear understanding of the harvesting and silvicultural practices that characterize both the baseline and project scenarios, particularly when the latter differ significantly from “business-as-usual”. Check to ensure the model can indeed simulate the project activity requirements. The stand-level model, FORECAST, for example, has a well-defined management interface that allows considerable flexibility in simulating one or more potential options. For illustrative purposes, a partial list from FORECAST is as follows:

- Site preparation
- Planting / Regeneration
- Weed control
- Stocking control
- Pruning
- Intermediate harvests
- Thinning
- Final harvests
- Utilization level
- Partial harvesting/shelterwood
- Fertilization
- Nurse crops
- Alternating Species
- Mixed species
- Rotation length
- Seedling size and quality
- Wildfire / broadcast burn
- Insect defoliation
- Wildlife browsing
- Organic waste recycling

Reducing uncertainty in carbon projections by expanding the domain of application

In principle, including aspects of one or more subdomains that are currently lacking or poorly developed can enhance a model’s domain of application thus improving its suitability as carbon accounting tool. In practice, however, this approach is impractical for current projects because (a) it requires a considerable investment of time and resources, and (b) any changes to model structure should be validated for accuracy. A practical alternative, however, is to link models with different application domains (termed a meta-modeling approach) to expand the overall domain of application and thus reduce uncertainty in model carbon projections (see Figure 2).

An example of this approach is the linkage between the (stand-level) FORECAST model and the landscape-level model, FPS-ATLAS. The resulting meta-model was used to simulate the carbon balance on the Darkwoods property near Nelson, BC, the largest carbon offset project to date in North America (for further information, see http://www.3greentree.com). At 55,000 ha, the property is a large landbase that includes a broad diversity of stand types. Calibrating FPS-ATLAS using only a crude set of carbon curves was likely to generate a carbon projection for the landbase with a level of predictive error that was unacceptable. FORECAST was therefore used to simulate management activities and provide detailed and accurate projections of the carbon balance for a series of analysis units (an analysis unit is comprised of a subset of stand types grouped by common attributes). A data library of carbon curves for each analysis unit was created that included both potential management and an unmanaged condition. The library was then accessed by FPS-ATLAS. The latter model simulated disturbance regimes (both natural and through management) and calculated the carbon balance across the entire landbase for a 100-year simulation period. A meta-model approach should always be considered when the project area is sufficiently large that a landscape model is required to calculate the carbon balance (see Figure 2).

Final thoughts

A summary of the steps involved in choosing the appropriate modeling tool(s) is as follows.

Step 1. Make sure the model fulfills the following criteria:

- It is consistent with accepted theory, based on well-documented fundamental science, and integrated across disciplines and scales, as appropriate. One way to evaluate this is to ensure the model has been published in independent peer-reviewed journals where its structure and application have been documented. Ask for copies of the appropriate reprints.
- The model makes predictions relevant to the offset project and that are based on inputs that can be measured and managed. In other words, do

you have the data necessary to calibrate the model and does the model generate the type of data the project requires?

- The model quantifies uncertainty in the predictions based on uncertainty in model inputs, parameters, and structure. Expect that model projections will not always provide a good match to field measurements (this comparative exercise is a critical component of project validation). Make sure you, or the modeller you hire, understand thoroughly how the model inputs are translated into outputs (i.e., the carbon estimates).
- The model is subject to continuous improvement both in terms of its ability to capture reality and its utility as a guide to management. An ongoing publication record is the strongest evidence of this.

Step 2. Verify that the domain of application is suitable to the offset project using the techniques outlined above.

Step 3. Ensure the user or user-group has the requisite skills to apply the model.

- Remember, the merit of an offset project depends on the additionality clause (the difference in carbon storage between the baseline and project case) and the ability to convince the project auditors of its validity. Given the complexity of forest ecosystems, it is often cost effective to employ experts to apply a model with a level of sophistication appropriate to a particular project.

Finally, all of the leading standards for offset projects require validation of model projections by comparison with measurements derived from a plot network. The guidelines provided in this document will help ensure the best tool(s) have been selected such that model precision and accuracy has the potential to achieve the highest-level possible and thereby maximize the available offset credits.

Websites for specific models

The following page has a list of websites about specific models, in no particular order. Note that many of these models do not generate carbon estimates directly and thus their use in a carbon project will require the addition of allometric biomass equations and/or expansion factors.

TASS/TIPSY	http://www.for.gov.bc.ca/hre/gymodels/
FORECAST	http://www.forestry.ubc.ca/ecomodels/index.htm
CBM CFS3	http://carbon.cfs.nrcan.gc.ca/CBM-CFS3_e.html
FPS	http://www.forestbiometrics.com/
FVS	http://www.fs.fed.us/fmsc/fvs/
MGM	http://www.ales.ualberta.ca/rr/Research/MixedwoodGrowthModel.aspx
ORGANON	http://www.cof.orst.edu/cof/fr/research/organon/index.htm
PrognosisBC	http://download.essa.com/Register.aspx?product=12
SORTIE-ND	http://www.bvcentre.ca/sortie-nd
UNBC models	http://forestgrowth.unbc.ca/
CO2FIX	http://www.scribd.com/doc/25070776/Description-Co2fix-3-2

Back to Table of Contents

8. *Implementing forest carbon offset projects at the management unit level in British Columbia: Results and recommendations from testing on pilot areas in BC's Interior and Coastal Regions*

Cameron Brown, Forsite Consulting Ltd., Salmon Arm, BC
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The Forest Sector Climate Action Steering Committee, a collaborative initiative of the BC forest industry and the BC Government, view "Forest Management Regime" (FMR) carbon offset projects as having the potential to significantly reduce greenhouse gas emissions and enhance CO_2 sequestration and carbon storage in British Columbia's forests and wood products. This concept was recently tested using in the Kamloops TSA and in TFL 25 on the central coast using the current draft BC Forest Carbon Offset Protocol. Key learnings were gained in three broad themes:

- Does the FMR approach add value?
- How do different forest management activities impact offset project viability
- How could the current regulatory and quantification framework in BC be improved.

Cam Brown's conclusions at the end of his presentation were:

- The FMR carbon offset approach is expected to work well and have several key advantages over multiple smaller scale, single focus projects (e.g. bundling complementary activities).
- It is not a panacea as forest level projects involve more assumptions and complexity and may require higher levels of uncertainty to be accepted.
- All forest offset projects on BC crown land face critical barriers. There are no clear ownership structure for projects, and thus little clarity around who will benefit and hold associated reversal liabilities.
- Once resolved, it is expected that viable projects will take place. Research support will be required to better understand cause and effect relationships in natural systems.

Back to Table of Contents

9. *Forest carbon offset opportunities using a carbon management regime*

Kelly Sherman, Ecora Resource Group Ltd., Kelowna, BC
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With the recent release of the Forest Carbon Offset Protocol, there are significant new opportunities for local governments and/or forest tenure holders to capitalize on carbon credit opportunities. Kelly discussed those opportunities, using community forests as an example of how local governments can generate forest carbon to meet their climate action charter commitments.

The presentation will reference a carbon optimization analysis project that was carried out to help understand how resource management decisions can consider carbon. The analysis combined the optimization strengths of the spatial forest estate model (Patchworks), with the carbon accounting strengths of the CBM-CFS3. The analysis used CBM-CFS3 to make carbon curves (biomass, dead organic matter, and total carbon) for each stand type. These carbon curves were incorporated into the Patchworks model and used along with along with all other landbase objectives. Other carbon variables included in this analysis were carbon storage as wood products and carbon emitted by forestry activities such as harvesting, fertilization, etc..

Using this framework a "Carbon Management Regime" can be created that gives direction on how to manage to maximize carbon credits. There is potential to secure carbon offsets under the Forest Carbon Offset Protocol.

Back to Table of Contents

10. *Exploring the dynamics between timber management, forest certification and management for carbon on private land in the West Kootenays*

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Two managed forest properties in the southern Columbia Mountains were modeled to compare the outcome of three different management strategies:

1. Timber management and business as usual
2. Timber management under FSC certification
3. Timber and carbon management under FSC certification.

Almforest Timber Co. is a managed forest predominantly in the ICH dw (and the ICH mw2). The business as usual operation is intensive even-aged and uneven-aged forest management. The present forest cover regenerated from a large fire in 1888 and from several subsequent harvest entries.

Erie Creek Forest Reserve is a managed forest predominantly in the ICHmw2 (with a smaller land base in the ESSF) and the business as usual is even-aged management. Extensive fires burned the area in 1928, 1934, and 1937.

Improved forest management was modeled as one single fertilization treatment over 800 ha of 25 year old forests in Almforest. In Erie Creek, modelling was for 127 ha of afforestation of old burns. Both activities created a small account of carbon credits over a 40 year period.

Stream buffers and forest cover constraints in accordance with FSC principles created a much larger amount of carbon credits for both properties. The timber management land base shrunk by 6 – 7% and the Annual Allowable Cut dropped in both cases by 15 – 20%. The value of carbon credits will have to rise to 17$/ton – 34 $/ton of carbon to break even with timber management in the business as usual scenario.

The cumulative benefits from carbon credits, improved forest management, and certification can create an economic benefit to the land owner.

The assumptions about the future value of timber *vs.* the future value of carbon offsets are critical for the development of forest carbon programs. The development of carbon credits offset should always precede any forest certifications.

Back to Table of Contents

11. How forest carbon created an opportunity for a protected area on Denman Island – A case of innovation in land acquisition

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Rob Friberg, ERA Ecosystem Restoration Associates, North Vancouver BC
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Eva Riccius was unable to attend the conference. Rob Friberg presented the talk.

Southeastern Vancouver Island, several Gulf Islands, and a narrow strip of the Lower Mainland are dominated by the smallest biogeoclimatic zone in BC, the Coastal Douglas-fir zone. Almost half of this zone has been converted to other land uses. Less than 10% of this zone lies on public (Crown) lands, while over 90% is privately owned.

The combination of high population density, private land, and small size of the Coastal Douglas-fir zone has created substantial pressure on the area's natural ecosystems. The 2008 report on biodiversity in BC, "Taking Nature's Pulse", found the Coastal Douglas-fir zone to be the rarest zone in BC and one of the most endangered ecosystems in Canada. The zone also has the highest density of species of conservation concern in BC, with 208 species listed at risk.

Just under 6% of the land base in the Coastal Douglas-fir zone is protected through a variety of tools including parks (4.2%) and private conservation lands (1%). As a result, BC Parks is interested in acquiring new lands in this special ecological zone to further conservation goals.

In 2008, a large area (492 ha) of private land on northern Denman Island was put on the market. Concurrently, fiscal restraints caused by the global economic slowdown were reducing BC Parks' ability to acquire land by outright purchase. There was little hope that the Ministry of Environment could afford the $6.7 million required. BC Parks staff got creative.

BC Parks capitalized on two tools that had not been previously used by the Province: a municipal rezoning tool and carbon offsets financing. In September 2010, using these innovations and a cash donation, BC Parks was able to acquire private lands valued at over $6.7 million for $233,000. This presentation focused on the carbon financing piece, and described the challenges and solutions that we encountered as the first such project supporting protected lands in Canada.

Carbon quantification aspects of the project

(Text is from Rob Friberg's PowerPoint slides)

- A feasibility assessment was conducted in January 2010
    - By 3GreenTree Ecosystem Services Ltd.
    - Baseline scenario confirmed by an independent professional land planner
    - Gap analysis done
- Carbon offset agreement signed
- Legally binding covenant
- $1.2 million toward land purchase by ERA
- Detailed forest inventory
    - 16 forest inventory strata identified
    - Regeneration surveys
    - Timber cruise
    - Site index study
- Three models used
    - Growth and yield modeling (and carbon outputs) with TASS II: Forest Analysis and Inventory Branch
    - Custom TASS II runs (Ian Cameron)
    - CBM-CFS3 (support from Canadian Forest Service)
    - FORECAST (3GreenTree)
- Results
    - Ecosystem Restoration Associates arrived at a project minus baseline assertion:
      438,900 tonnes CO_2e 100 years *ex-ante*

    - Holdbacks related to dead organic matter
        - Risk of reversal (Verified Carbon Standard tool)
        - Modeling uncertainty
    - Increase to buffer for underperformance
- Monitoring Plan
    - Every 5 years (reversal events)
    - Three re-measurement and re-quantifications, in years 30, 70, and 100
    - Re-quantification at any time for 10% changes
    - Increase to the buffer for underperformance
    - Net Present Value funding set aside in 2011
- Third party verified to ISO 14064-2
    - (generic greenhouse gas standard)
    - Forestry-specific Good Practice Guidance from appropriate sources
- Offsets sold into the voluntary carbon market
    - Client is not offsetting a mandated emissions reduction
- Some specific challenges and solutions
    - Taylor’s Checkerspot Butterfly
        - SARA listed
        - 10ha reserve established
        - Flexibility in project development document and covenant (for recovery plan initiatives)
    - Deer browse
        - A series of delays was applied to the growth curves
        - Monitoring
    - Ensuring reliability of *ex-ante* carbon stock estimations
        - High level of detail applied to modeling parameters
        - Site index reductions in certain cases
        - A 7% modeling uncertainty added to the buffer
        - Re-measurement and re-quantification at 3 intervals
        - Hold backs
    - Increase to buffer for underperformance

Back to Table of Contents

12. Managing community forests: A strategic approach to sustainability in climate change in Kaslo, BC

Dr. Romella Glorioso, Glorioso, Moss & Associates, Kaslo BC
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The *Greenhouse Gas Reductions Target Act* of British Columbia, Canada became law on January 1st, 2008. It aims at reducing the province's greenhouse gas emissions below 2007 levels by 33% by 2020, and 80% by 2050. This made BC the first government in North America to require public entities to report their greenhouse gas emissions levels, actions they have taken to reduce them, and plans to continue minimizing emissions.

In response, all local governments must revise their "Official Community Plans" and "Regional Growth Strategies" to include reducing greenhouse gas emissions. For rural communities in the Kootenay region, targets were set at 15% by 2020, 25% by 2030 and 80% by 2050. "One policy fits all" needed to take into account that many communities in BC have small populations surrounded by forest land with no major polluting industries. Therefore, greenhouse gases emitted by them should readily be absorbed by the forest ecosystem — providing the forest remains healthy. Thus, a strategic way for these communities to adapt to climate change for sustainability is through appropriate management of the forest ecosystem. But this is easier said than done, especially as it likely entail harmonizing the opposing perspectives of "anthropocentric" and "biocentric" groups in a community.

The Kaslo and Area Community Forest Society's ten-year sustainability strategy demonstrates a solution. Using a multiple scenario strategic planning approach, the strategy focuses on adapting forest management to climate change impacts through increased ecological sustainability, meeting the "greening" demand for forest products and services, and strengthening the Society's management skills and outreach. This talk described the process and outcome of crafting Kaslo community forest's 2011-2020 sustainability strategy.

Back to Table of Contents

13. Dry low-elevation forests of southern interior BC: Addressing the conundrum of fuels, fire, and carbon emissions and uptake

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Co-author
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Visualize the Okanagan valley and Rocky Mountain Trench where fire has been a natural ecosystem process for thousands of years. Forests around the communities of Grand Forks, Kamloops, Lillooet, Merritt, and Princeton share a similar history.

Forests across the landscape take in carbon dioxide from the atmosphere as they grow, but when they burn, much of that carbon dioxide returns to the atmosphere and contributes to the greenhouse gas effect. With climate change, longer fire seasons and increased drought are anticipated, which may result in more fire ignitions, larger wildfires, and increased fire severity and duration. In addressing climate change, we need to understand the relationships between fire management and carbon emissions and storage.

As land managers, we can make choices as to how we manage fire-prone landscapes. There are ways of managing fire-prone forests to maintain and protect the carbon stored in them, protect people and their communities, and reduce the costs of fire-fighting.

In fire-prone forests, most above-ground carbon is stored in the trunks of the largest trees. Removal of small-diameter trees results in a relatively minor reduction of carbon pools. Basic techniques that can be used in these forests include: thinning small trees, removing fire-sensitive tree species and ladder fuels, and conducting controlled burns to reduce surface fuels, while retaining large fire-resistant trees.

When fuel hazards are reduced, numerous other forest values can be maintained or protected, including water and air quality, aesthetics, recreation, tourism, native vegetation and habitat, site productivity, and forest health.

It will be a challenge to weigh the tradeoffs when striving for maximum carbon pools and minimizing carbon emissions while addressing fuel hazards and fire risk and considering other forest values and the impacts of climate change. Strategic application of management treatments will be required.

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Back to Table of Contents

14.Climate change and its impacts: Why should we care?

Dr. Richard Hebda, Royal BC Museum, Victoria, BC
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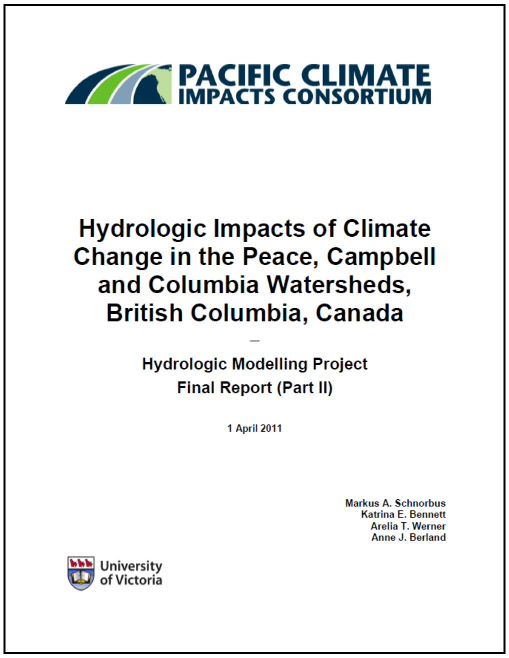
Dr. Hebda's evening talk was open to the public. About 55 people attended.

The global climate is beginning to change. Arctic winter temperatures are warming markedly. Weather events are intensifying with huge economic impacts. Some even argue that the price of food is rising in part because of shifting climatic conditions. Our changing climate has begun to affect British Columbia ecosystems including our forests. Projections into the upcoming decades suggest major impacts, and with current trends in carbon dioxide emissions we already may be committed to crossing critical thresholds or tipping points. Join Dr. Richard Hebda as he explores some of the major changes we may face in British Columbia and considers strategies to prepare for the impacts and reduce the degree of climate transformation.

Dr. Hebda recommends the following two documents: *(next page)*


PACIFIC CLIMATE IMPACTS CONSORTIUM

Hydrologic Impacts of Climate Change in the Peace, Campbell and Columbia Watersheds, British Columbia, Canada

–

Hydrologic Modelling Project
Final Report (Part II)

1 April 2011

Markus A. Schnorbus
Katrina E. Bennett
Arelia T. Werner
Anne J. Berland

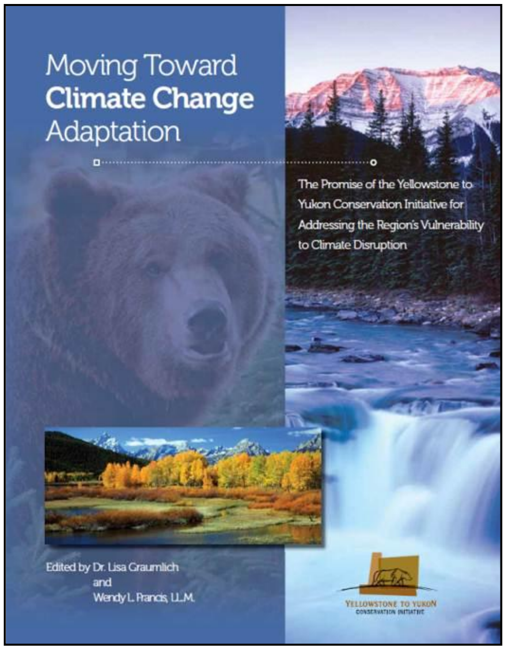
University of Victoria

This document is available at the Pacific Climate Impacts Consortium website:

http://pacificclimate.org/sites/default/files/publications/Schnorbus.HydroModelling.FinalReport2.Apr2011.pdf

A summary of this report is available at:

http://pacificclimate.org/sites/default/files/publications/Zwiers.HydroImpactsSummary-CampbellPeaceColumbia.Jul2011-SCREEN.pdf


Moving Toward
Climate Change
Adaptation

The Promise of the Yellowstone to Yukon Conservation Initiative for Addressing the Region's Vulnerability to Climate Disruption

Edited by Dr. Lisa Graumlich
and
Wendy L. Francis, LL.M.

YELLOWSTONE TO YUKON CONSERVATION INITIATIVE

This document is available at the Yellowstone to Yukon website:

http://www.y2y.net/data/1/rec_docs/898_Y2Y_Climate_Adaptation_Report__FINAL_Web.pdf

Back to Table of Contents

15. No time to waste: forest conservation is essential for climate change mitigation

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Introduction

Forests are natural carbon engines: they have the greatest photosynthetic capacity of all terrestrial ecosystems, storing 86% of the above-ground carbon and 73% of the world's soil carbon. They also represent some of the biologically richest ecosystems on earth. The forests of British Columbia, for example, are home to 76% of Canada's bird species, 70% of its freshwater fish, and 60% of its evergreen trees. Hence, healthy forests are the foundation for both carbon storage and biodiversity. However, these two life-sustaining gifts are under increasing threat from deforestation, fragmentation, and climate change stresses. When old forests are harvested, they become a source of CO_2 as the living biomass is converted to fast-cycling carbon products, and the carbon long locked in soils is decomposed. Losses of forests to fire, insects, or disease, which are becoming more extensive, frequent, and severe as temperatures rise, also release massive amounts of CO_2. With forest loss, the biological networks that facilitate energy flow within and among ecosystems are disrupted because the plant, animal, and microbial communities shift, often to simpler, opportunistic ones. Forests have the capacity to recover, but they remain CO_2 sources for several decades post-disturbance.

The cumulative effects of human disturbances and stresses on the landscape are rapidly approaching a tipping point: witness the annual increases in greenhouse gases (http://climate.nasa.gov/) and the rapid decline in biodiversity (http://gbo3.cbd.int/).

This presentation covers three areas. First, global trends in climate change are briefly reviewed. Second, the carbon cycle is reviewed with particular emphasis on forests and soil carbon. Third, forest management options for mitigation and adaptation to climate change are suggested.

Global change

Global change, which includes climate change, ecosystem shifts, nitrogen addition, and biodiversity loss as a result of explosive human population growth and consumption, is emerging as one of the most important issues of our time (Vitousek, 1994). Climate change especially is altering the function, structure and stability of the earth's ecosystems (Lovelock, 2009). It has been marked by an 80% increase in atmospheric CO_2 level and a 0.74° C increase in average global near-surface temperature over the period 1906–2005, with average temperature projected to increase by an additional 1 – 6^{o} C by 2100 (IPCC, 2007). The past four months have been the warmest on record (NAOO, 2010). Warming is expected to continue for centuries, even if greenhouse gas emission are stabilized, owing to time lags associated with climate processes and feedbacks. The changes in climate have resulted in higher sea levels, reduced extent of snow and ice, earlier timing of species spring events, upward and pole-ward shifts in species ranges, increased and earlier spring run-offs, and increased forest disturbances by fires, insects and diseases (Parmesan, 2006; IPCC, 2007).

The alarming implications of climate change, and global change in general, have mobilized scientists world-wide to more effectively research and communicate their impacts, as well as options for mitigation and adaption. Complexity theory, for example, has emerged as a promising discipline for investigating and understanding the effects of global change on our socio-ecological systems, and for managing them sustainably as complex adaptive systems (Folke *et al*., 2004; Levin, 2005). In spite of scientific efforts, there has also been little meaningful action from governments or the public to curb the rate of global change (Friedman, 2010); this is apparent in our inability to meet Kyoto Protocol goals, despite the compelling evidence from the International Panel on Climate Change. The socio-political reasons for this inaction are multi-faceted, and are rooted in the human disposition and cultural memes for expansion and consumptive growth (Rees, 2011).

The importance of forests and soils in the global carbon cycle

Forests are vitally important in the carbon balance of the Earth. Even though forests comprise only 30% of the terrestrial ecosystems, they store 86% of the above-ground carbon and 73% of the world's soil carbon (Sedjo, 1993). On average, forests store two-thirds of their carbon in soils, where much of it is protected against turnover in soil aggregates or in chemical complexes (FAO, 2006). Forest soils not only absorb and store large quantities of carbon, they also release greenhouse gases such as CO_2, CH_4 and N_2O. The carbon sink and source strengths of soils have been considered relatively stable globally, with the strong sink strength of northern-mid latitudes roughly balanced by the strong source strength of the tropics (Houghton *et al*., 2000). However, climate change can upset the soil carbon balance by reducing carbon storage and causing a large positive feedback to atmospheric CO_2 levels. Indeed, the amount of CO_2 emissions being sequestered by terrestrial ecosystems, including soils, is declining and they may become a source by the middle of the 21st century (Cox *et al*., 2000; Kurz *et al*., 2008). When this happens, the atmospheric carbon trajectory will become less dependent on human activities and more dependent on the much larger carbon pools in terrestrial ecosystems and oceans (Cox *et al*., 2000).

To underscore the gravity of this shift, the magnitude of total belowground respiration is already approximately 10 times greater than fossil fuel emissions annually (Lal, 2004). The effect of climate change on soil functional stability is particularly concerning in high latitude ecosystems (boreal forests, taiga, tundra and polar regions) because these systems store 30% of the earth‘s carbon, and are currently warming at the fastest rates globally (IPCC, 2007; Schuur *et al*., 2009). The tundra-polar regions recently became a net source of atmospheric CO_2 (Apps *et al*., 2005).

The soil carbon pool is 3.3 times larger than the atmospheric carbon pool and 4.5 times larger than the biological carbon pool (Lal, 2004). As a result, the global carbon balance is strongly influenced by soil carbon flux dynamics. The global soil carbon pool is 2,500 Gt, and is comprised of 1,500 Gt organic carbon (70%) and 950 Gt inorganic carbon (30%) (Schlesinger & Andrews, 2004; Lal, 2004). The organic portion of the soil pool is comprised of plant roots, fungal biomass, microbial biomass, and decaying residues. It includes fast-cycling sugars, amino acids, and proteins, and slow-cycling cellulose, hemicellulose, and lignin. The soil organic pool is highly dynamic, variable, and greatly influenced by land use practices (Rice *et al*., 2004).

Carbon storage in soils involves complex feedbacks between plants and soil organisms. Carbon storage depends on the balance between carbon inputs through photosynthesis and outputs through autotrophic (root and mycorrhiza) and heterotrophic (soil microbial) respiration (Bardgett *et al*., 2008). Both photosynthesis and respiration are directly affected by climate change factors; including atmpospheric CO_2 level, soil nutrient availability, and temperature and precipitation patterns. They are also clearly affected by tree mortality. The direct effects of these climate change factors on plants then feed back to indirectly affect the structure and activity of soil microbial communities, which drive nutrient cycling, soil carbon storage, and soil stability. The intimate cascading interaction between plants and soil microbes in their response to climate change factors is likely of critical importance in predicting the consequences of climate change to ecosystem stability and the carbon balance. Although the feedbacks are complex and poorly understood, we are already measuring climate change effects on soil carbon in high latitude ecosystems (Schuur *et al*., 2009) as well as on the composition and activity of soil communities involved in soil nutrient cycling in northern forests (Treseder, 2008).

Forest management options for mitigation and adaptation to climate change

The easiest and least risky solutions for mitigating the dual threats of climate change and biodiversity loss lie in the conservation management of our remaining forests and reclamation of those that are lost. The following is a list of forest conservation management options that may be useful in maintaining stability and mitigating carbon and biodiversity loss from our forests.

Recognize and manage forests as complex adaptive systems (Levin 2005; Puettmann et al. 2009)
This entails managing our forests with respect to their range of natural variability, and introducing changes (e.g., new species mixes) incrementally. In other areas of the world, this approach has similarities with ecosystem management, close-to-nature, continuous-cover, or variable retention management.

Increase the amount of forested area
The most basic practice is reforestation of harvested or naturally disturbed areas with adaptive tree species mixes. Afforestation of grasslands or alpine meadows would likely have negative effects on biodiversity and carbon storage due to accelerated decomposition of rich organic mineral soil horizons.

Reduce the allowable annual cut to account for the increasing level of disturbance and tree diebacks on the landscape.
The greatest conservation of carbon and biodiversity will occur if cutting of old-growth forest, in particular, is sharply curtailed. Where cutting occurs, it should be focused in second-growth stands; rotation lengths should be lengthened to facilitate deep soil, old carbon storage; and stands should be

harvested using variable retention or continuous cover approaches where possible to mitigate carbon losses due to rapid decomposition.

Practice conservationist silviculture
This includes:

- Avoiding soil degradation;
- Maintaining coarse woody debris;
- Retaining snags and green trees;
- Planting suitable mixes of tree species;
- Planting or thinning to variable densities;
- Thinning to remove stressed or susceptible trees or other species;
- Encouraging natural regeneration; and
- Avoiding intensive silviculture practices such as fertilization and pruning as much as possible, or applying these practices with caution, full carbon accounting, and careful monitoring.

Other adaptive practices that can be tried include: facilitating migration by including a small portion of genotypes from warmer climates; under-planting to shift genetic composition or facilitate survival; increasing flexibility in silviculture prescription for altering species or management options; protecting unique habitat features, such as riparian areas or wetlands.

Conclusions

Global change and biodiversity loss underpin the loss of ecological complexity. Plant carbon, soil carbon, and biodiversity losses are expected to continue to increase with time (human population growth and consumption). These losses are expected to have strong positive feedbacks to climate change. Soil carbon is the largest and most stable terrestrial carbon pool. Its size and stability increase with time since disturbance and soil depth. However, the soil carbon pool is diminishing with increasing temperature due to increased respiration. Increasing extent and severity of disturbances can be expected to increase these losses. Clearcut harvesting has been shown to increase carbon losses in the forest floor by 30%. Continuous cover or variable retention harvesting can greatly diminish soil carbon losses.

The application of forestry to mitigate and adapt to climate change requires a paradigm shift in forest management, away from a top-down commodity-driven equilibrium approach to a bottom-up complex adaptive system approach. Several strategic decisions need to be made to help with this paradigm shift. For example, the annual allowable cut should be reduced to account for current losses to disturbances. Harvest of old-growth should be sharply curtailed to protect old, stable carbon stocks and protect biodiversity. Harvesting should be restricted to second-growth forests. Variable retention forestry that protects old trees for their biodiversity feedbacks and soil carbon protection should be practiced. Rotation lengths should be increased. Silviculture should be practiced from a conservationist perspective, including protection of soils, encouragement of natural regeneration, and planting of native species mixes that include a small component of warmer genotypes. Intensive silviculture, including brushing, thinning and fertilization, should be applied very cautiously because the unintended consequences have historically been high. Afforestation opportunities are limited and must be applied only with an understanding of its effects on soil carbon potential.

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Back to Table of Contents

16. Carbon uptake and landuse change – A Columbia Basin case study

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Introduction

This presentation is a summary of information from various reports listed in the references. A more complete summary prepared by Utzig and Schmidt (2011) is available on the Fish and Wildlife Compensation Program website at: http://www.fwcpcolumbia.ca/version2/reports/pdfs/FWCP-CB_Impacts_Summary.pdf .

The Columbia River has been extensively altered by dams built for flood control and hydroelectric power production in both Canada and the United States. The Fish and Wildlife Compensation Program (FWCP) was established to offset footprint impacts of BC Hydro dams and reservoirs on fish and wildlife in the basin. Objectives of the FWCP include compensating for fish and wildlife impacted by dam construction in the Columbia Basin, and undertaking projects related to sustaining and enhancing the impacted fish and wildlife populations. The FWCP area includes the BC portions of the Kootenay and Columbia drainages, east of the Monashee Mountains.

In 2005 the FWCP undertook a project to update our understanding of the impacts of the dams and support ongoing strategic planning and program development. Study objectives included: improved quantification and increased understanding of the significance of the impacts to fish and wildlife, their habitats, ecosystem function and fish-wildlife interactions, and the identification of a range of compensation options.

The project was composed of five broad elements:

1) mapping of basic aquatic and terrestrial ecosystems within the dam footprints;
2) assessing changes in primary productivity;
3) assessing changes to aquatic and terrestrial habitats;
4) assessing impacts on individual fish and wildlife species; and
5) the identification of compensation options.

This presentation focused on changes in primary productivity.

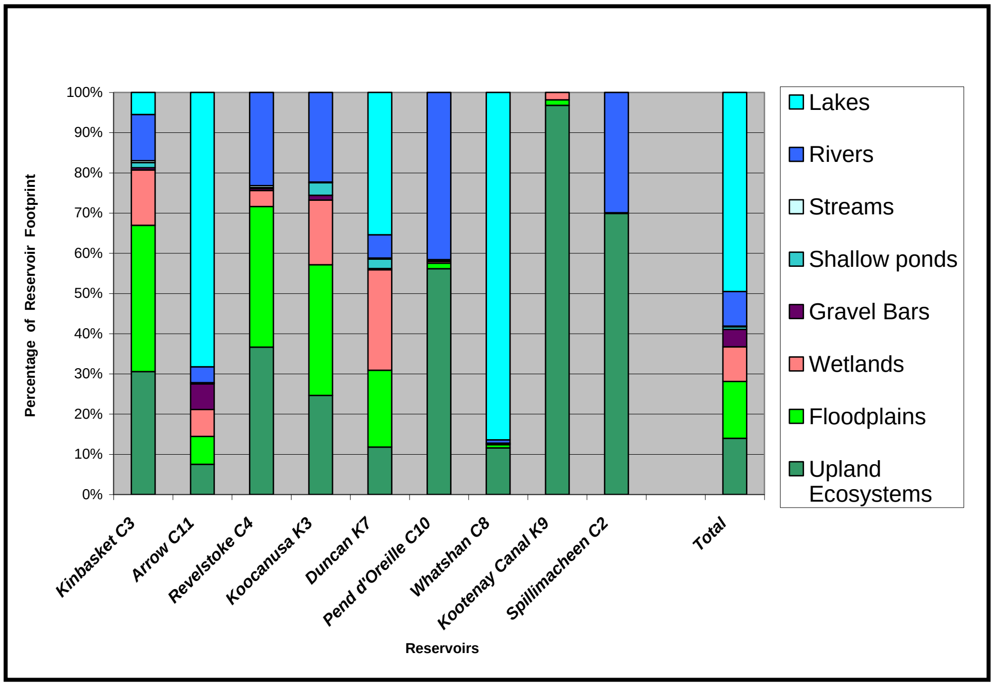
Habitat mapping and assessment

Pre-dam aquatic, wetland/floodplain and terrestrial ecosystems were mapped from pre-dam information sources, including aerial photographs, topographic maps and land class mapping (Ketcheson *et al.* 2005). The ecosystem mapping demonstrated that each reservoir was unique with regard to the types, amounts, and proportions of ecosystems impacted. The Arrow and Kinbasket Reservoirs occupy the largest footprints at 51,270 and 42,650 ha respectively. The Revelstoke (11,450 ha), Duncan (7,300 ha) and Koocanusa (6,685 ha) reservoirs are also fairly extensive. The Whatshan (1,770 ha) and Pend d'Oreille (430 ha) are somewhat smaller, and Kootenay Canal, Aberfeldie, Elko, Cranberry, and Spillimacheen reservoirs are less than 50 ha each. The pre-dam ecosystem composition of the Arrow and Whatshan Reservoirs were dominated by pre-existing lakes, while the Kinbasket, Revelstoke, Koocanusa, Pend d'Oreille, and Spillimacheen were dominated by forested ecosystems and large river systems, and the Kootenay Canal by forested ecosystems. The Duncan footprint included a complex mix of lakes, forests and wetlands. All footprints included varying lengths of river and/or stream ecosystems (see Figure 1).

Impacts on aquatic habitats were assessed by comparing pre-dam habitats within the footprints with the total aquatic habitats within the Columbia Basin (Thorley 2008). Significant areas of lotic (riverine) habitats were lost because of flooding (1600 linear km or 12,000 ha), with low elevation, low gradient rivers having the most significant losses. Lentic (lake/reservoir) habitat has been significantly increased in area, from 41,450 ha to 110,800 ha. However, the diversity and type of lentic habitats has been altered, with 12 lakes being replaced by 12 reservoirs. Changes in littoral habitats vary from reservoir to reservoir. Littoral habitats within storage reservoirs are subjected to larger variations in water levels than natural lakes, while most of the run of the river reservoirs and regulated Kootenay Lake have water level stability similar to comparable natural lakes in the region, including some lakes that were inundated.

A risk assessment, based on losses as a proportion of similar terrestrial habitats available in the Columbia Basin, demonstrated that across the various dam units, loss-induced risks were: very high for very wet forests (4,780 ha, 19%), wetlands (7,700 ha, 26%) and gravel bars (3,660 ha, 53%); high for wet forests (28,760 ha, 10%), cottonwoods (5,530 ha, 21%) and shallow water/ponds (1,070 ha, 31%); and medium high for intermediate forests (15,660 ha, 2%). Losses of lake and river shoreline habitats were rated high for Kinbasket (980 km) and Arrow (680 km) reservoirs, while Revelstoke (350 km), Duncan (200 km) and Koocanusa (310 km) were rated medium high (MacKillop *et al.* 2008). Within the drawdown zones of some reservoirs there have been new ecosystems established, especially in the Revelstoke Reach of the Arrow Reservoir. Even though some of these simplified communities produce large quantities of vegetation, their value for higher trophic levels is limited.

Figure 1. Percentages by area for various pre-dam aquatic and terrestrial ecosystems by reservoir (from Ketcheson *et al.* 2005, Moody *et al.* 2007, Utzig and Holt 2008).



Productivity impacts

Primary production is the conversion of solar energy into organic carbon by plant photosynthesis over time. Primary productivity is reported in various ways, depending on the type of ecosystems under scrutiny and the objectives for the calculations. Gross primary productivity (GPP) refers to the total amount of carbon fixed per unit time, while net primary productivity (NPP) refers to GPP minus the amount of carbon lost through autotrophic respiration. In practical applications, NPP is often used for describing primary productivity in terrestrial ecosystems, as it is generally correlated with common measures such as mean annual increment in trees or annual biomass production in other plants. In aquatic systems GPP is the more common tool for reporting primary production because of the methods for measuring primary production (e.g. light/dark bottle). Both GPP and NPP are generally reported as the weight of carbon per unit area per year.

The estimates of primary production calculated in the dam impacts studies followed the well-established trends, with terrestrial primary production being reported as NPP (MacKillop and Utzig 2005; Utzig and Holt 2008), and aquatic primary production being report as GPP (Moody *et al.* 2007).

Methods

Both terrestrial and aquatic primary productivity calculations for pre-dam conditions were based on historic aerial photographs and maps that depicted conditions prior to dam construction, correlations with measured GPP from other similar ecosystems, theoretical or modeled GPP relationships, and discussions with scientists and local residents who were familiar with the areas at that time. Digital mapping used in the primary productivity analysis was produced in the earlier footprint mapping phase of the project.

To prepare a complete summary of primary production changes with reservoir flooding it was necessary to convert the terrestrial and aquatic estimates to compatible values. Given the general lack of information on NPP for aquatic systems, and the recent developments in assessing NPP/GPP ratios in terrestrial ecosystems, the decision was to convert the terrestrial values from NPP to GPP. Following a review of relevant literature, a series of NPP/GPP ratios were assigned to each of the terrestrial ecosystem types.

Historic pre-dam terrestrial NPP was calculated based on estimated NPP for each of the Site Series that were identified during the footprint mapping. The methodology was a multi-step process involving use of Biogeoclimatic

Ecosystem Classification guidebooks to identify appropriate tree species for each Site Series, BC Ministry of Forests (MoF) site index relationships (SIBEC) to determine site index for each tree species/site combination, MoF's Variable Density Yield Prediction Model to estimate yield curves for each of the site/species combinations, and the Canadian Forest Service Carbon Budget Model to calculate NPP values based on the growth and yield outputs (MacKillop and Utzig 2005). Non-forested Site Series were estimated using NPP values for early seral stages of similar forest sites. Outputs were verified by comparing the predicted values with measured values derived from a literature review of relevant NPP studies.

Literature reviews revealed that there was little relevant information available on NPP or GPP for wetland ecosystems within the Columbia Basin. Based on the limited literature available and expert opinion, Moody *et al.* (2007) estimated NPP values for non-forested wetlands and forested wetland/floodplains. Forest site series that were identified as floodplain ecosystems based on moisture regime and structural stage were assumed to provide wetland carbon to the aquatic realm from foliar materials and understory components during flood events. This resulted in partitioning of the NPP of these ecosystems, where part was assigned to "forested wetlands", and the remainder to the upland terrestrial realm (see Moody *et al.* 2007 and Utzig and Holt 2008 for more details).

Most of the pre-dam limnological information for the lakes that existed prior to flooding in the affected dam units was anecdotal, and mainly related to fisheries habitat. Therefore, the pelagic GPP estimates for lakes were primarily derived from expert opinion and analysis of a database of primary production measurements from over 50 lakes in BC. Additional information on seasonal sediment patterns, flow regimes and turbidity was also derived from examination of pre- and post-dam sediment core data, and discussions with scientists and local residents who were familiar with pre-dam conditions.

Because of the lack of information on periphyton littoral production from the impacted dam units, Moody *et al.* (2007) had to rely on estimates of percentages of pelagic carbon production from the literature. Primary productivity estimates for pre-dam rivers and streams were primarily based on a regression equation relating stream order and GPP. The regression equation outputs were adjusted based on a review of BC benchmark stream characteristics, including factors such as: chlorophyll *a* concentrations, soluble reactive phosphorus concentrations, bryophyte and macrophyte presence, glacial meltwater and/or high sediment load impacts on turbidity, flow variations, kokanee carcass inputs, incidence of large woody debris, known fish species use/abundance, and the distribution of higher quality side-channel environments. The estimates for rivers should be considered conservative, as there were likely significant areas of side-channels that were not accounted for.

Post-dam Arrow Reservoir and Kootenay Lake GPP estimates were based on measured daily carbon production. Kinbasket Reservoir GPP values were taken from published literature. Estimates for Revelstoke Reservoir GPP were derived from chlorophyll measurements made in 2003. Professional judgment was used to provide GPP estimates for Duncan, Koocanusa and other smaller reservoirs.

Results and discussion

Based on the results of the earlier primary production studies, and conversion of terrestrial NPP values to GPP, a summary of total historic pre-dam and post-dam GPP values are provided in Figures 2 and 3. The values for terrestrial NPP pre-dam baseline are taken from a “long-term average” scenario of forest age class distribution, and aquatic values for the post-dam Arrow Reservoir and Kootenay Lake are without fertilizer treatments. The region-wide losses of primary production are mainly related to the loss of forested ecosystems in the big three reservoirs, Kinbasket, Revelstoke, and Arrow. The only gains in terrestrial GPP have been associated with the minor amount of vegetation in the drawdown zones of some reservoirs. Large rivers, lakes, and tributary streams have been replaced by a larger area of reservoir aquatic ecosystems. Overall aquatic production has increased, because of the extensive area of reservoirs, and increased water clarity in some cases.

Although Kootenay Lake was affected by dams upstream, no changes in GPP for terrestrial, river or stream ecosystems are shown, as no areas in that dam unit were directly flooded by BC Hydro dams. Because of the conflicting effects of reduced nutrients and increased water clarity, Moody *et al.* (2007) estimated that the Duncan and Libby dams have produced a negligible change in GPP for the North and South Arms of Kootenay Lake (Figure 2). Over the last century, changes in GPP for the North and South Arms of Kootenay Lake have been quite complex, including those from upstream and downstream dam construction. Other factors such as fertilizer plant pollution, introduction of mysids, fisheries management and present-day fertilization have also periodically impacted GPP, and its redistribution among higher trophic layers.

Primary production within the reservoir footprints has been reduced by over 90%, moving from riverine, lake, wetland, and terrestrial systems of primary production, to a reservoir ecosystem and low diversity drawdown vegetation communities, some of which include introduced exotic species.

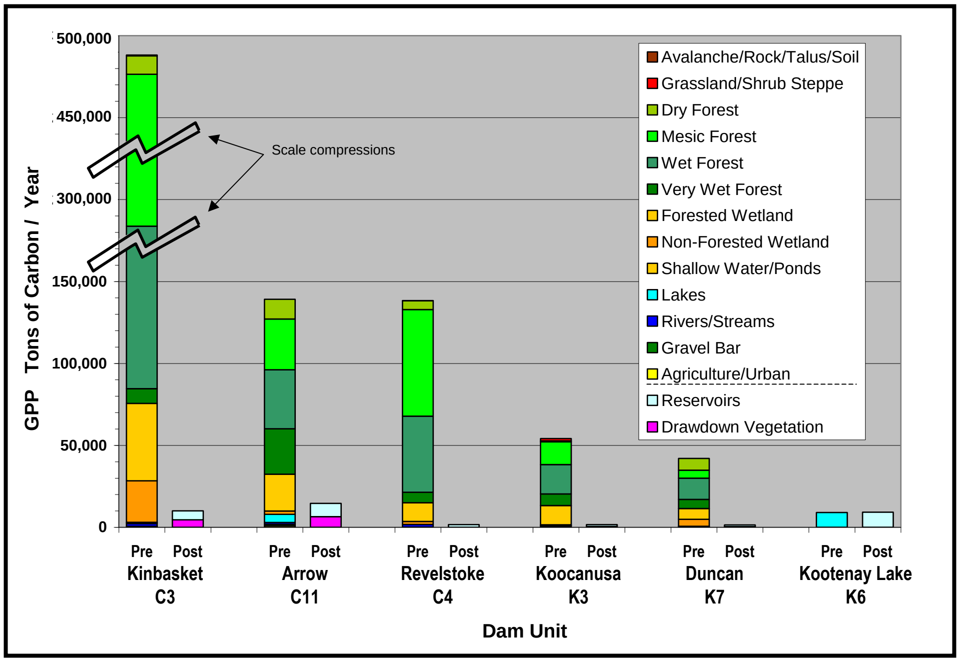


Figure 2. Gross primary productivity (GPP) before and after flooding for each of the larger reservoirs and Kootenay Lake (from Moody *et al.* 2007 and Utzig and Holt 2008). Note scale compressions on Kinbasket values.

A complex system of terrestrial primary production that included trees, shrubs, herbs, mosses, lichens, and micro-organisms has been lost from the reservoir footprints. These ecosystems accounted for the largest percentages of pre-dam primary productivity. Primary productivity of the pre-dam wetlands and floodplain ecosystems has also been significantly reduced. The transfer of carbon and nutrients between floodplain and wetland ecosystems, and the aquatic system, has also been altered.

River and stream productivity in the footprint areas has also been lost, except for short segments that are exposed seasonally during drawdown periods. In dam units where lakes with relatively stable water levels were present, littoral primary productivity has been severely decreased, especially the macrophyte contributions, due to the fluctuations in water levels in most of the reservoirs.

The exceptions are run of the river reservoirs with more stable water levels, such as the Revelstoke, where littoral productivity is estimated to be significant, and pre-dam lakes with significant water level fluctuations such as Arrow Lakes and Kootenay Lake.

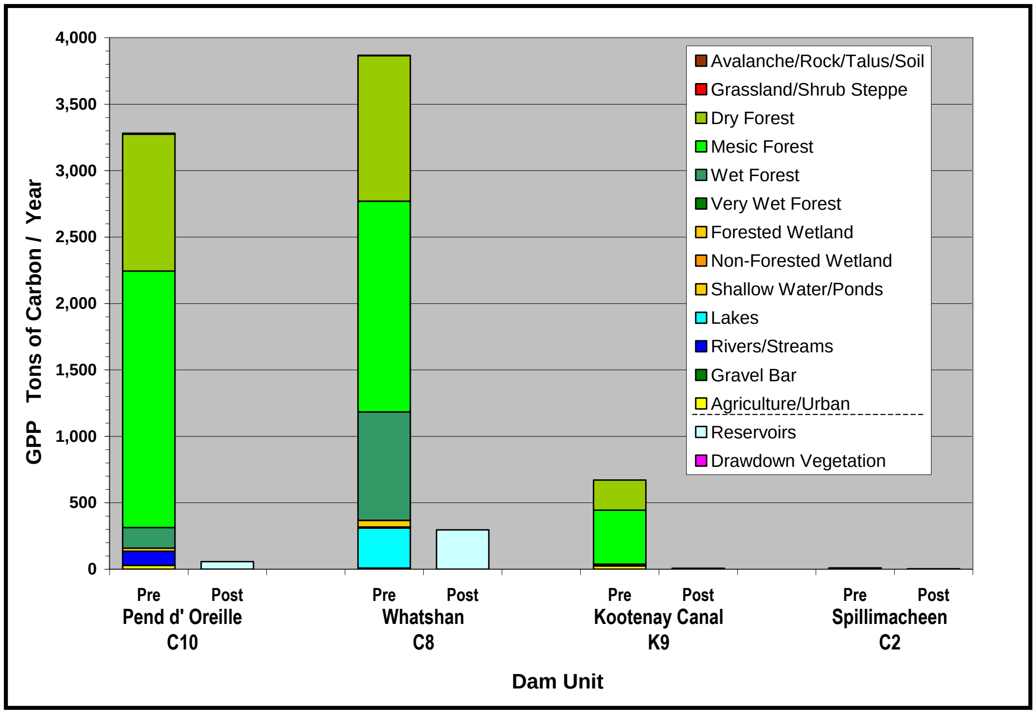


Figure 3. Gross primary productivity (GPP) before and after flooding for each of the smaller reservoirs (from Moody *et al.* 2007 and Utzig and Holt 2008). Note the scale difference from Figure 2.

Because of the large flooded areas, reservoir pelagic productivity has become the dominant source of primary productivity within the flooded portions of the dam units. Arrow Lakes and Kootenay Lake were large pelagic producers prior to dam construction. The degree of change in pelagic primary productivity is dependent on the specific conditions of each reservoir, including area and character of lakes prior to flooding, character and area of reservoir post-flooding, water retention rates, sediment and nutrient inputs, turbidity, water temperatures and water level fluctuations.

Opportunities identified for compensating/ mitigating lost productivity included lake, reservoir and stream fertilization, restoration of degraded wetlands, creation of new wetlands in drawdown zones or as floating islands, restoration of degraded forests and establishment of fast-growing plantations.

Conclusions

The assessment demonstrated that landuse changes can have significant implications for carbon dynamics and carbon management opportunities. The conversion of forested, wetland and natural aquatic ecosystems to reservoirs has altered carbon storage pools and shifted carbon pathways within the reservoir footprints. The project has also identified the need for collection of basic data related to carbon cycling, particularly in wetland and stream ecosystems.

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Back to Table of Contents

17. From carbon to conifers and sawmills to salmon: Climate change and forest ecosystems in the northwest Skeena region, British Columbia

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Project funding

- Future Forest Ecosystems Council of British Columbia (FFESC)
- Mitacs
- ESSA Technologies
- Coast Tsimshian Resources LP

The northwest Skeena region is among the world's most important commercial forest production areas, provides critical habitat for salmon and other wildlife, and is increasingly used as a key transport corridor and industrial area. Faced with accelerating climate change over the current century, communities and industry urgently need a local-scale scientific basis for strategic planning and eventual adaptation to changing environmental conditions. Under the aegis of the British Columbia Future Forests Ecosystem Council (FFESC) project Climate Change Adaptation Planning for Northwest Skeena Communities, and in cooperation with Coast Tsimishian Resources LLP and the Lax Kw'alaams First Nation, we are performing an interdisciplinary study of social and natural science issues surrounding environmental change in the northwest Skeena. Our sociological study assesses a spectrum of local residents to quantify perceptions of how environmental and socioeconomic issues have changed in the recent past, and the values placed on diverse natural resources at the present. The natural science component of our project applies a state-of-the-art dynamic vegetation model to simulate the potential future of forest ecosystems in the northwest Skeena, with a focus on how climate change and management strategy interact to influence forest productivity, species composition, and carbon storage.

The social science component of the project was initiated in 2010 through a series of interviews with community leaders and natural resource managers from both First Nations and settlers groups in Prince Rupert, Terrace, and Lax Kw'alaams. The goal of these interviews was to gauge and understand the local populations' needs, desires, and perceptions with respect to environmental change. The interview process is ongoing, but based on the data we have collected to date we can highlight some of the preliminary findings. Over the past 20 years, the people we interviewed believe, on average, that their most important environmental resources and the way they have changed over the recent past are: the timber industry (declining); small business (improving), Salmon and Oolichan fisheries (declining), and water quality (improving).

When asked about the drivers of these changes, the most important and influential of these were: "natural resource policies", "availability of natural resources", and "global economy". Climate change as a driver of economic and environmental change was perceived as being neither particularly influential at present nor very important for the future of the region.

Despite its perceived low importance for the people of the lower Skeena, we nevertheless attempted to quantify recent trends in climate change, and to understand how future climate could further impact the forests of the region. Analysis of weather station data collected at Prince Rupert and Terrace over the past century (Figure 1) showed that, in particular, winters have become warmer, snowfall has decreased, and spring precipitation has increased, especially since about 1970.

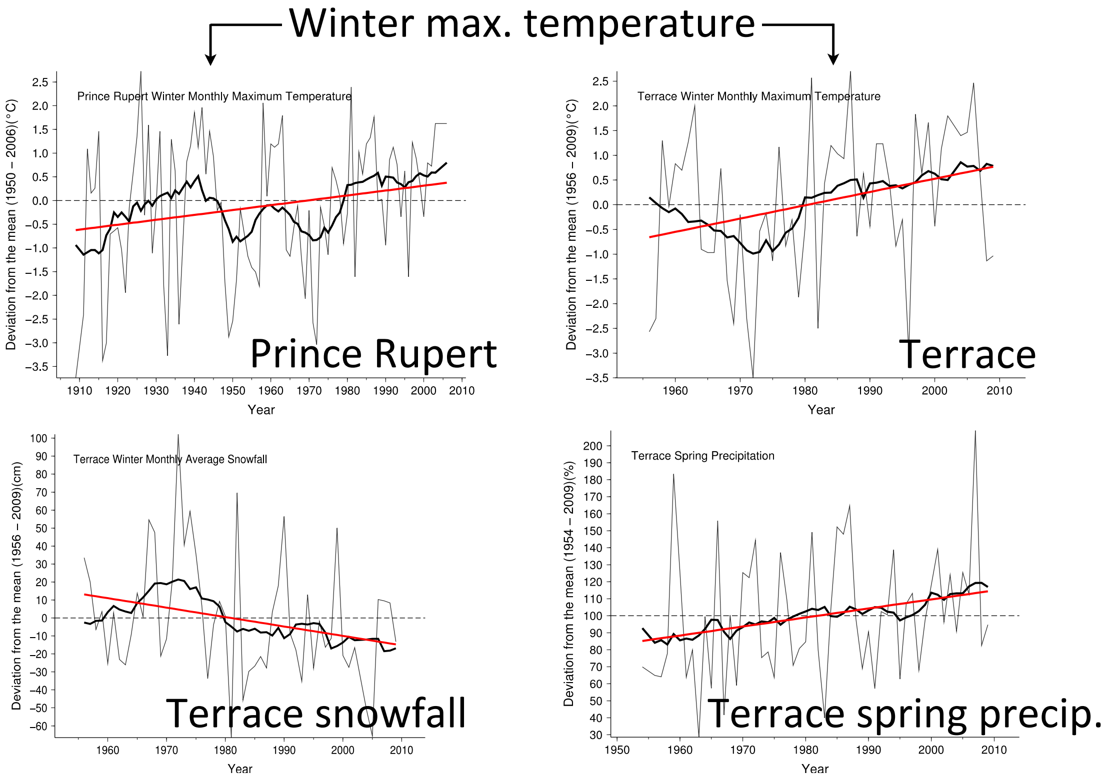

Figure 1. Selected patterns in 20th century climate observed at Prince Rupert and Terrace

To investigate future potential forest responses to climate change, including changes in disturbance frequency, hydrology, species composition, and carbon storage, we customized the LPJ-GUESS dynamic vegetation model with the physiological properties of 19 northwestern BC forest tree species. LPJ-GUESS is driven by monthly climate data, a soil map, an optional forest management scenario, and operates at a 30 arc second (~1km) spatial resolution. We collected data on individual species characteristics, including climatic preferences, morphology, and shade tolerance from a variety of sources in the silvics literature, and from other detailed forest models. We used the CGCM3 A2 future climate simulation as a first attempt scenario to look at forest responses to climate change. Compared to other global climate models, this scenario results in an increasingly warm and wet Skeena region over the next 100 years. For these first model runs, we did not use a management scenario, i.e., we considered potential changes in natural (unmanaged) vegetation.

We applied the model over the northwest Skeena region, roughly the lower watershed of the river, plus Prince Rupert and coastal areas to the north, an area of about 32,000 km^2 (Figure 2). We evaluated the LPJ-GUESS simulations for the state of forests at the present day using the provincial vegetation resources inventory and other forest inventory data. Our model evaluation was limited by reliable data on forest stand history and composition, especially dates of past harvest and replanting strategies. Nevertheless, preliminary results indicate that, in the absence of major disturbances such as fire or insect outbreak, changes in forest species composition over the next 100 years are likely to be small. Common tree taxa at the present day, especially western hemlock, may increase in their range, generally moving up mountainsides to higher elevation, and possibly further inland. The core habitat for western hemlock at present, in the valley bottom around Terrace, could see a slightly reduced concentration of these trees, in favour of more thermophilous taxa, including Douglas-fir. The area of alpine tundra is projected to shrink significantly in the future, especially over the 2060-2080 period of our future simulation.

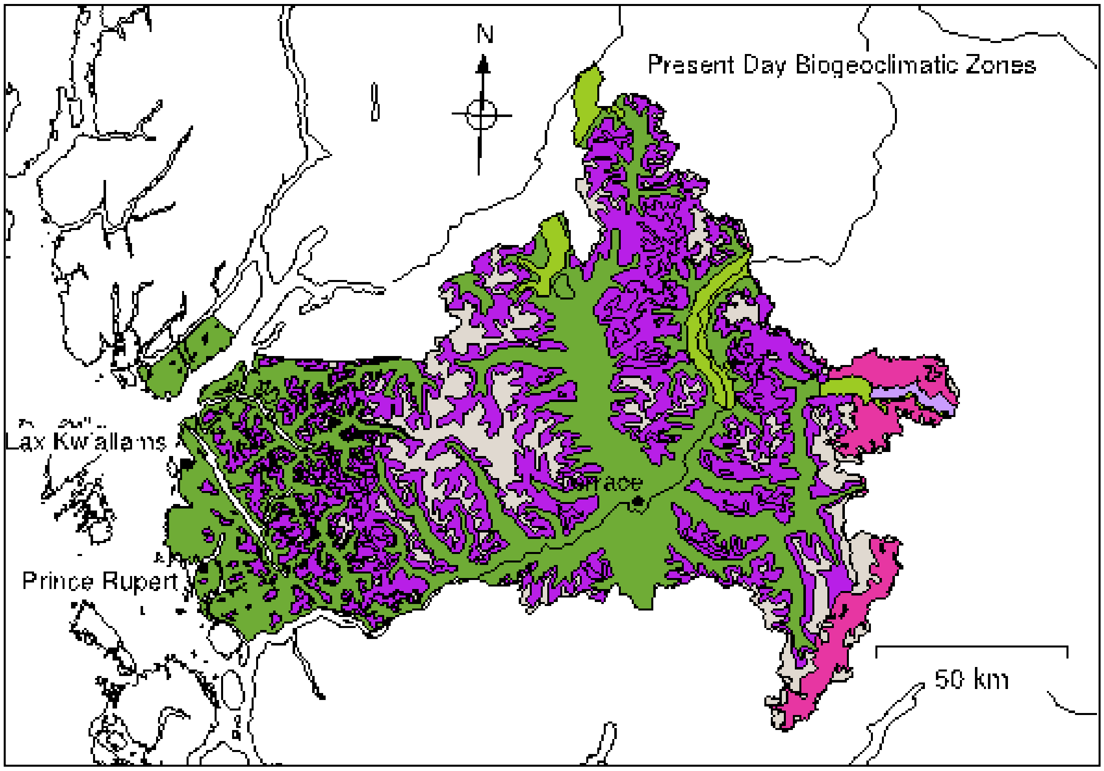

Figure 2. Biogeoclimatic zones map of the lower Skeena study area

Carbon storage in the Skeena forests is relatively insensitive to climate change over the past decades or projected into the near future in the scenario we used

(Figure 3). Modest decreases in dead organic matter mainly in litter and in the labile soil organic matter pool, caused by faster microbial decomposition under warmer temperatures, are offset by increases in living biomass, stimulated by longer growing seasons and CO_2 fertilization. On the other hand, simulated winter runoff increases significantly into the future, related to decreases in wintertime snowfall. Autumn runoff decreases, caused by increases in summertime evapotranspiration as a result of increasing temperatures in all seasons (Figure 4).

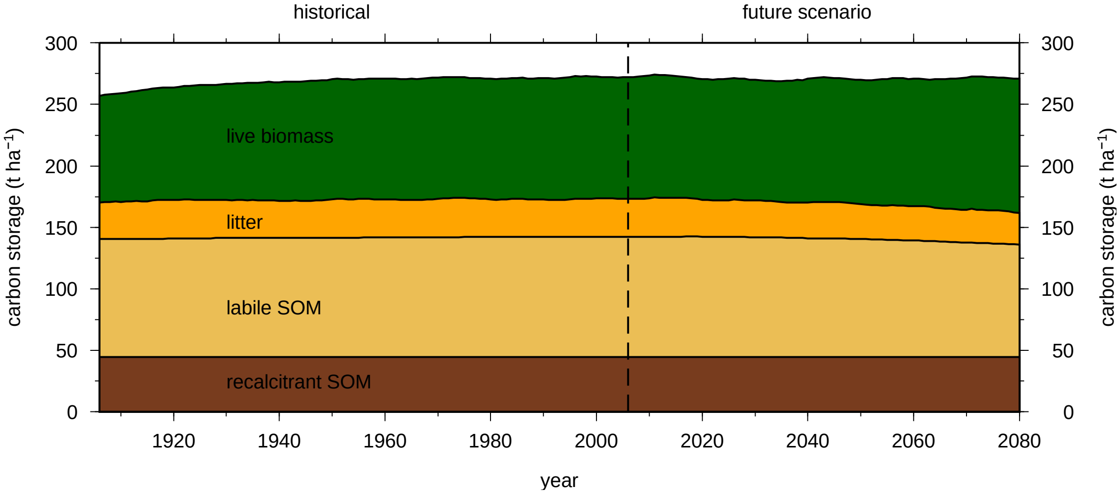

Figure 3. Changes in terrestrial carbon storage simulated by LPJ-GUESS for the 20th century and future CGCM3 A2 scenario

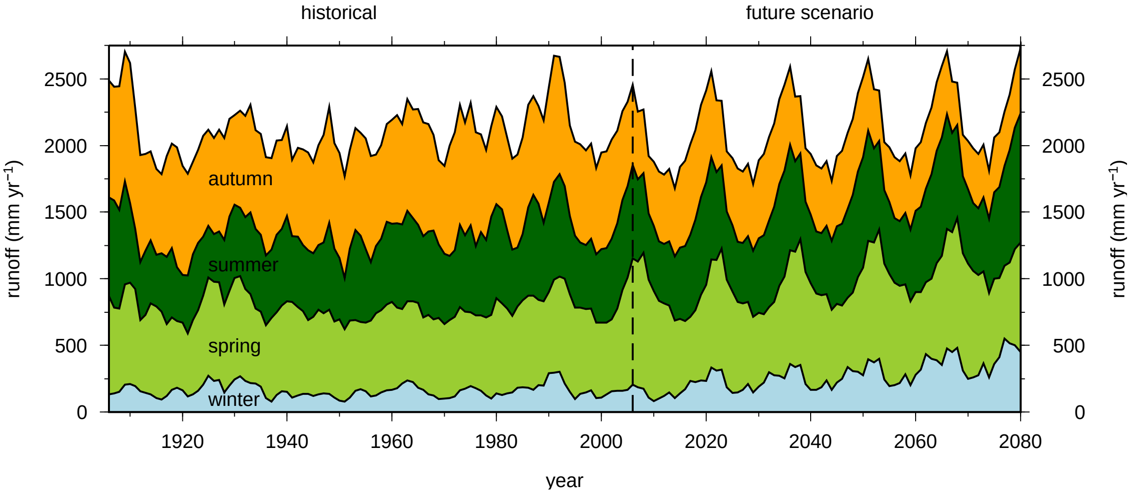

Figure 4. Average seasonal and annual changes in runoff for the lower Skeena region simulated for the 20th century and future CGCM3 A2 scenario

Forest management strategies to maximize carbon uptake include accelerated harvest cycles and replanting with appropriate species for changing climate.

Future climate change in the northwest Skeena could have its greatest impact on hydrologic rather than carbon cycle, and management for optimal productivity would have important impacts on hydrology, ultimately affecting fisheries and other valuable natural resources.

Back to Table of Contents

18. Ecological restoration and carbon: Sequestration, storage, and risk management

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Introduction

The global initiative to use market-based mechanisms to assist with controlling the atmospheric concentration of known anthropogenicly increased greenhouse gasses (GHGs) such as CO_2 and CH_4 is often seen as providing natural pathways to financing initiatives which also have other "green" goals, such as ecosystem preservation, ecosystem restoration, etc. While the marketing of carbon credits can provide such financing modalities, too often the assumption is made that all things "green" must be complementary. In fact, whenever we deal with humans or the environment we are dealing with complex systems where simple inputs may result in multiple, sometimes divergent outcomes in various parts of the system.

A simple example of such a problem is found in the analysis of potential ecosystem carbon sequestration and storage modalities. While the biological and chemical processes through which atmospheric carbon is captured by living organisms are clear, the relationship of that capture with long term reduction of atmospheric carbon is much less clear. Once carbon has made the transition from gaseous forms to organic forms, the complexity of the systems, processes, and pathways through which that carbon is stored, transmuted, and released is enormous. Feedback mechanisms mean that long term optimization of ecosystem carbon is highly complex. In the simplest terms, for instance, it can be expected that there is often, although not always, a relationship between the amount of carbon stored in an ecosystem and the risk of large scale atmospheric release of carbon through burning in any ecosystem where fire is a major component of ecological processes. At the extremes, the truth of this supposition can easily be demonstrated. For instance, a recently burned field contains less carbon than a dense unburned grassland, and is less likely to emit carbon into the atmosphere through fire. However, as soon as we examine less extreme examples, the validity of the supposition becomes dependent on a much subtler and more diverse set of factors, such as fuel continuity, fuel size, amount of heat released during burning, topography, barriers to fire transmission, micro- and meso- climatic variation, etc.

In light of these issues, this presentation focuses on the potential for carbon finance to assist the undertaking of needed ecological restoration in BC, and the barriers which currently exist to realizing this potential.

Simple opportunities

There are a few simple opportunities to generate carbon credits and revenue from restoration projects in BC. Restoration of shrub or tree communities on degraded land, or low productivity farmland, for instance, easily fits within the well understood general model of A/R (Afforestation/Reforestation). Quantification methods are well defined for these project types.

Slightly more complex, but still fairly clear, would be opportunities such as restoration of grassland ecosystems on degraded land, with associated increases in soil carbon. Although methodologies for these project types are still in development, because the project follows the basic A/R route—increase of the total carbon stored in the ecosystem—accounting may be expected to be fairly simple and non-controversial.

However, the difficulty with these A/R-like project types in BC is the limited opportunity to undertake such projects. The vast majority of BC land consists of forest which remains forest, as well as of rock and ice. Degraded lands are a tiny portion of the BC landscape.

The big opportunities

The much larger opportunities in BC consist of projects which undertake to reduce the risk of losses of carbon already in the ecosystem. These projects are essentially "REDD-like" (United Nations program for Reducing Emissions from Deforestation and Forest Degradation, see http://www.un-redd.org)—they are aimed at stopping the loss of already sequestered carbon, and the essential accounting problem lies in the rigorous demonstration of the expected losses which would occur in the absence of the project. These project types thus consist fundamentally of reduction of risk. As was discussed in the introduction, the pathways of carbon transmutation and release in ecosystems are highly complex. Furthermore, rigorously demonstrating the likelihood of a risk occurring requires significant actuarial data.

An example

In BC, a prime example of this type of project is thinning and understory burning in NDT4 (Natural Disturbance Type 4) (fire maintained forests) primarily in the IDF and drier CDF zones, which were naturally open forests or savannahs prior to the introduction of fire control measures.

An example of such a stand is shown in Table 1 below.

Layer	# trees / hectare	Gross stem volume/tree, m3	Layer volume/ha, m3
1	150	1.53	229
2	250	0.48	120
3	450	0.001	0
4	300	0.0001	0
		Total/ha.	350
		Merch/ha.	266
		$C0_2e$/ha	416

Table 1. An example NDT4 stand prior to restoration

This stand probably consisted of around 80 large layer 1 trees, and smaller numbers of layer 2,3, and 4 trees prior to fire control. Over the subsequent 80 to 100 years, many of the smaller trees have grown to layer 1 size. A new cohort of trees established after the commencement of fire control now forms the layer 2 trees, and subsequent cohorts have established relatively dense layer 3 and 4 stands. The resulting stand is likely to be highly vulnerable to stand replacing crown fire, due to the density, and the presence of nearly continuous fire ladders. The future of this stand could consist of any of:

- Stand replacing fire followed by regeneration as a single aged, probably relatively dense stand
- Clear-cut harvest followed by regeneration
- Continued growth

Or, the stand could be restored to a structure more similar to that which existed prior to fire control through a combination of thinning from below, slashing of non-commercial stems, and controlled understory fire, leaving an open forest of Layer 1 and some layer 2 trees. Each of these possible scenarios has a different carbon outcome, as shown in Figure 1.

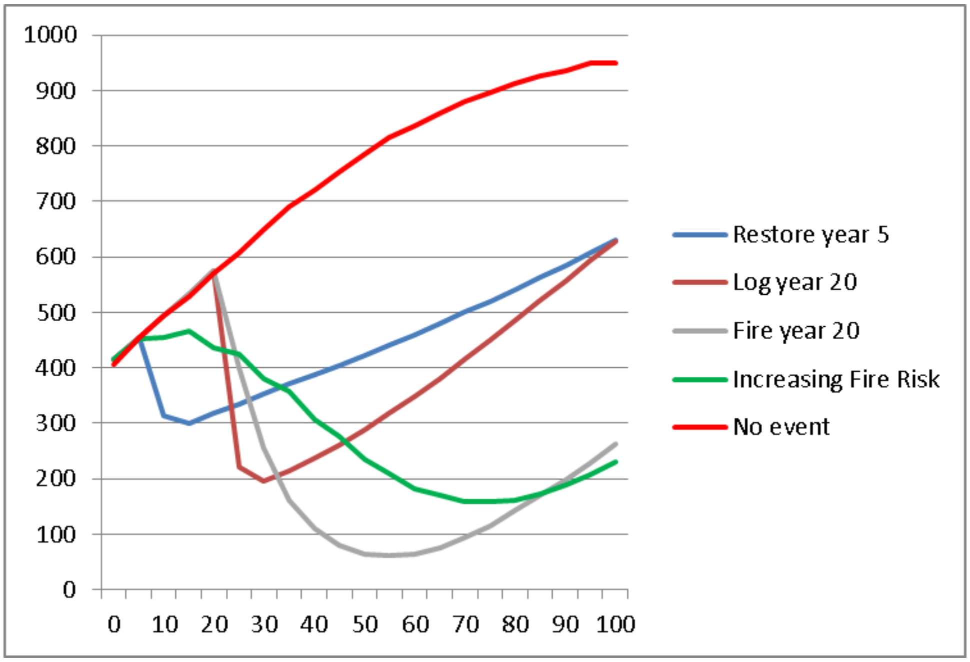

Figure 1. Carbon curves for possible stand scenarios

In Figure 1 two different possible fire scenarios are shown. In the first, it is assumed that a catastrophic crown fire occurs in year 20. However the odds of this exact event occurring are relatively slim. The other approach to quantifying fire risk is to develop a fire risk curve, which shows the likelihood that the stand will have burned by a given time. The cumulative fire risk curve used to generate the "Increasing Fire Risk" scenario in Figure 1 is shown in Figure 2 below.

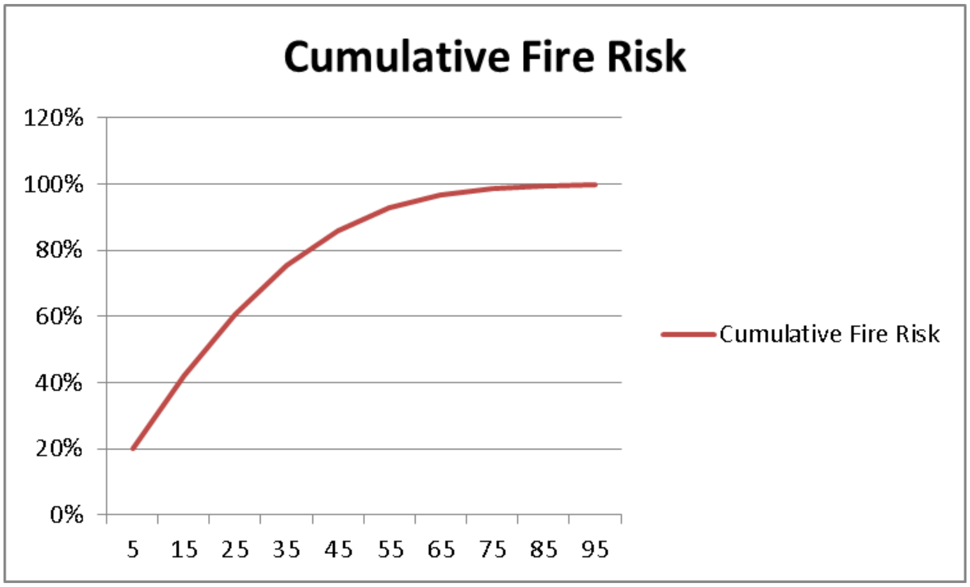

Figure 2. Example cumulative fire risk curve

As can be seen, by year 100 there is an almost 100% chance that a fire will have occurred. Thus the likelihood of the “No Event” curve in Figure 1 representing the actual carbon curve for the stand is extremely remote.

Comparing each of the possible baseline scenarios with the restoration scenario produces the potential carbon and financial benefits shown in Table 2.

Gross Credits/ha, sustained through the 100 year timeframe					
Baseline	Difference in the means	Credits to year 100	First credits year	Last Credits year	NPV @ 15%, $10/credit
Log year 20	39	2.7	25	25	$2
Fire year 20	212	368.5	30	55	$84
Increasing Fire Risk	160	400.9	35	100	$26
No event	0	0.0	0	0	$0

Table 2. Gross credits with 100 year permanence, and resulting economic benefits

Because we are assuming a 100 year permanence requirement, the relatively large difference between the clear-cut and restoration scenarios in the early years is cancelled out by the subsequent regrowth of the logged stand, combined with the carbon retained in products generated from the harvested timber, and the result is almost no available carbon credits.

As well, as Table 2 shows, for the scenarios examined carbon credits are not available for 25 to 35 years, and the resulting Net Present Value (NPV) of the credits is small, using commercial discount rates.

In addition to these direct enhancements of the amount of carbon stored on the landscape over the long term, for restoration as compared with the proposed baseline scenarios, there is another significant effect. If we examine what happens if a stand replacement fire occurs at year 100 for each of the scenarios, we discover that there are some significant differences in the subsequent release of carbon, as shown in Table 3.

	Immediate loss	1 - 10 year loss	10 - 30 year loss	30 - 100 year loss	Loss > 100 years
Restore year 5	10%	35%	33%	10%	12%
Log year 20	13%	42%	20%	5%	20%
Fire year 20	15%	50%	25%	7%	3%
Increasing Fire Risk	17%	62%	15%	1%	5%
No event	13%	40%	37%	10%	0%

Table 3. Loss profile following a stand replacing fire at year 100

Of particular interest is the higher amount of carbon which is still retained in the ecosystem 100 years after the fire for the logging and restoration scenarios. In the case of the logging, this occurs because carbon has been converted into products and moved offsite, while in the case of the restoration scenario, more carbon has been captured in the soil because of healthier grass communities in the understory of the restored stand.

On the other hand, the fire scenarios show more losses soon after the fire, because greater proportions of these stands consist of smaller trees, which rot faster, and of which a greater percentage burns during the fire.

These combined effects demonstrate that restoration has potential carbon benefits, through its ability to reduce the risk of catastrophic loss, and the storage of a higher percentage of the carbon in relatively low risk forms.

The problem

However, in order to demonstrate this to the accounting standards required for generation of saleable carbon credits, it would be necessary to be able to attribute with a high degree of certainty the specific fire or other risk curve which would apply to the site under the baseline scenario. Currently in most cases we simply do not have enough data and knowledge of risks and ecosystem processes to demonstrate this to the standards required. Thus we are currently unlikely to be able to demonstrate credible carbon benefits from this sort of restoration program, not because the benefit doesn't probably exist, but because we don't know how big the benefit is.

This example thus demonstrates the vital need for intensive data collection and analysis to quantify carbon benefits of ecosystem management. This need exists not only for the example given, but for many other ecosystem carbon pools and processes as well. Furthermore, the data is needed primarily not to allow us to generate carbon credits from projects, but to allow us to undertake intelligent management of our ecosystem carbon stores as a whole. Unlike forgone industrial emissions, there is always some risk that ecosystem carbon pools may be lost. In fact, our national ecosystem carbon accounting should properly be done on a risk adjusted basis, to encourage appropriate management actions. However, until we have a great deal more data on pool processes and risks, we cannot begin to undertake such accounting, or such management.

Back to Table of Contents

19.Soil considerations in carbon management

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Globally and locally, the soil represents a major sink or source for atmospheric carbon. In addition, terrestrial and aquatic life, including any biomass production to store carbon, depend upon maintaining soil integrity. Soil disturbance concerns exist and are described in regard to carbon management activities, ranging from conventional harvesting to intensive biomass harvesting and even some forms of site preparation. Soil interpretations for soil disturbance sensitivity exist, and ones for "suitability for intensive biomass harvest" are currently under development and the latest versions were presented and are available from the author. Existing local soils research, projects and networks that are relevant to carbon management were described, along with recent results on tree growth on rehabilitated soil disturbance (a form of afforestation), the long-term soil productivity network, and stump removal trials. Opportunities for further study and recommendations for operational application of knowledge gained to date were presented and are available in various guidance documents, some of which are listed in the references below.

Recommended references

A number of guidance documents are currently in preparation and draft sections are available from the author. For a slightly larger list also see the soils part in Chapter 7 of the Association of BC Forest Professionals policy reference guide: http://www.abcfp.ca/practice_development/continuing_education/policy_seminars.asp#REFG

Legislation

Forest Planning and Practices Regulation, includes sections 3, 5, 35, 36, 37 to 40, and Schedule 1 Factors discussed in this chapter:

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Ministry of Forests and Range – Legislation and Regulations:
http://www.for.gov.bc.ca/tasb/legsregs/

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Forest Practices Board audits and special investigation on soil disturbance

Forest Practices Board staff have undertaken audits on soil disturbance and also a “Special Investigation of Soil Disturbance from Forest Activities”. This report is currently “in progress” and will be released at a future date. The following link takes you to the location of reports on the Forest Practices Board website:
www.fpb.gov.bc.ca/landingpage.aspx?menuid=14

Back to Table of Contents
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20. Forest carbon management and user needs in the Kootenays

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Introduction

The forest sector in the Kootenay Columbia region has historically contributed substantially to the regional economy, but in recent years it has suffered financially from global economic and environmental challenges. In addition to market challenges (e.g., collapse of the US housing market), multiple impacts of global climate change are being felt by regional forest companies. However, the development of carbon markets may be leading to new opportunities for businesses and communities. Forest carbon management has become of increasing interest over the past two decades. While forest carbon management is quite advanced in many parts of the world and is steadily evolving in British Columbia, it is becoming apparent that a wide range of forest practitioners, especially in the Kootenay Columbia region, need more knowledge transfer to further their opportunities in forest carbon modelling, accounting, marketing, and management.

Recently, Selkirk College was awarded a National Science and Engineering Research Council (NSERC) College and Community Innovation Grant especially targeted to support the regional forest sector. The project will focus on development of customised tools that will allow local small and medium forest enterprises to access, evaluate, and analyse potential opportunities in forest carbon markets in the Columbia Mountains region. As part of this research project we have conducted an online forest carbon management user needs survey. The goals of this survey were to assess:

- Regional knowledge about forest carbon management, finance, and accounting tools;
- Regional knowledge about spatial carbon management tools;

- What proportion of managers or consultants are actively engaged in carbon management;
- Which tools users presently use to aid in carbon accounting, forest planning, and day to day operations;
- What the biggest obstacles are in accessing the carbon economy (knowledge, field based issues, software problems, data management, certification process?); and,
- How many groups are trying to gain more expertise?

The target population for the survey was private and public land managers, researchers, government employees, and consultants in the Kootenay - Columbia who presently or potentially manage, or work, with forest carbon budgets.

Methods

We developed 16 questions designed to profile the strengths and needs of people working in the forest industry with respect to carbon management. We asked and received feedback from a steering committee comprised of a representative sample of the forest research and management community in the southern interior of BC. This was an online survey hosted by the Selkirk College's Institutional Research Branch and participants were recruited by web-based solicitation, with email invitations sent to professional list serves in British Columbia for biologists, foresters, government employees, appropriate non-profit memberships, and private organisations associated with our steering committee. The most interesting questions and results are presented here.

Results

The survey initially queried the occupation of the respondent and the geographic area in which they mainly worked. The majority of people were government employees who worked in the forest sector (Figure 1), and over 70% of all respondents' work was focused in the Kootenay Columbia region.

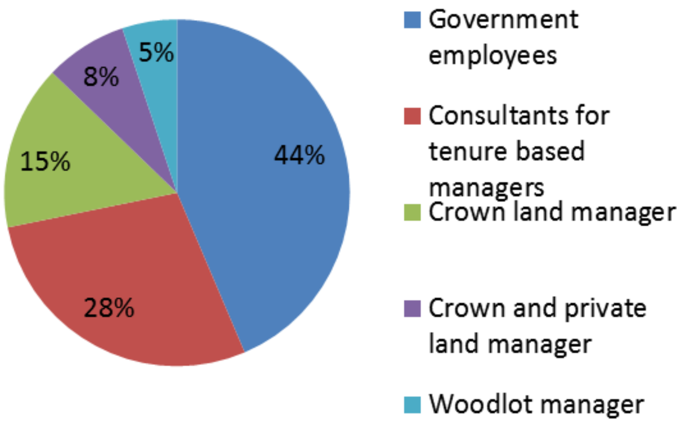

Figure 1: Distribution of people in land management roles

Next we asked about a person's level of awareness with carbon management, and whether they were actively trying to gain more expertise in the area. We found that less than 15% of the people surveyed had little personal knowledge or involvement, and that 42% were either currently, or previously involved in a carbon project (Figure 2). Overall, 87% of respondents indicated they were actively trying to gain more expertise in carbon management.

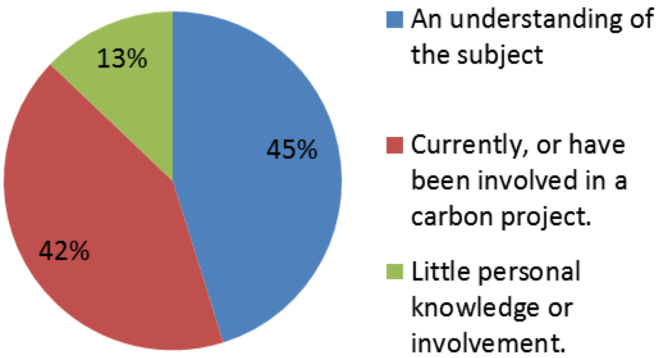

Figure 2: Level of awareness with carbon management

For those not interested in pursuing carbon management options, we asked what their reasons were. Although this was a small proportion of people, the overwhelming response could be summarized as a sense that there are no incentives, or tenure options, when operating on Crown land. A lack of expertise in carbon management was noted as an impediment to initiating projects.

We then asked respondents about what aspects of carbon management they were interested in. Of the categories we offered, carbon accounting and economic modelling were the most popular, followed by more education and financing options (Figure 3). Some important feedback we received was that it would be useful to draft a tool that would provide a way of attaching different measurable ecosystem values (including carbon) to the land base so that balancing changes in policy could be streamlined.

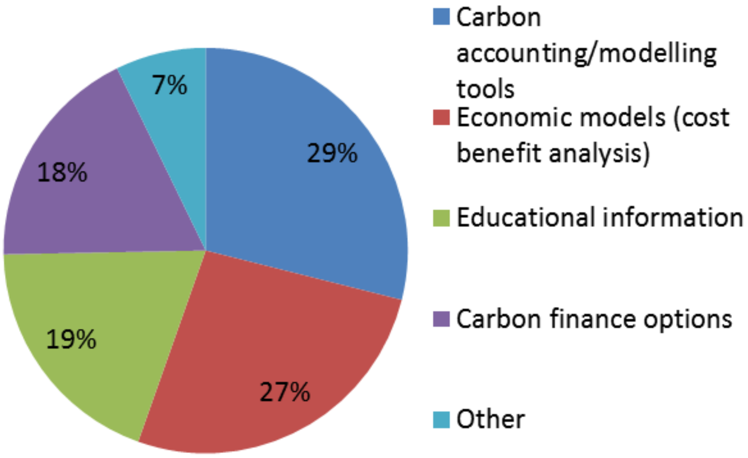

Figure 3: Areas of carbon management interest.

For people who had participated in a carbon offset project in BC, we asked them to identify which step(s) provided the greatest challenges (Figure 4). Here the responses where spread out over all of the categories, but the initial startup areas of project screening and addressing the different plan components were highlighted.

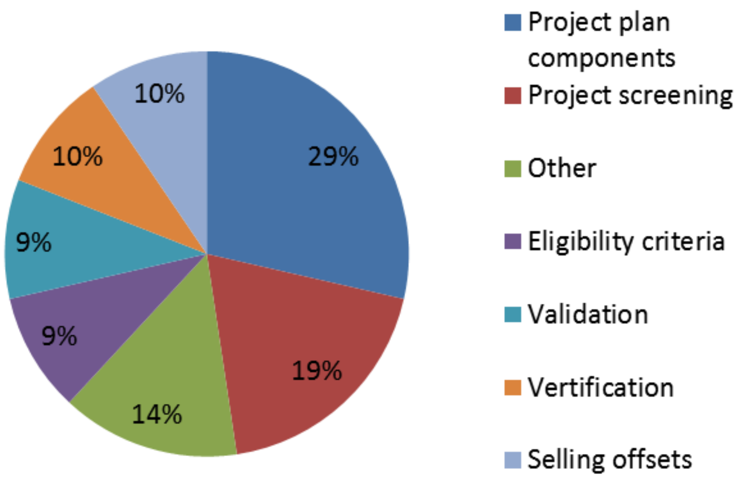

Figure 4: Greatest project challenges

For those people who used a model to generate carbon estimates, we wanted to know which models were most commonly used. Nearly 50% of respondents used the Canadian Forest Service's CBM-CFS3. The remainder of people used a variety of other models, including UBC's FORECAST, private woodland planner, TIPSY, Forest and Agricultural Sector Optimization, and CO2FIX.

When we asked what the biggest challenges were for using the carbon modelling tools, we found that the main challenges were: gaining experience and training in the use of the models; determining land available for afforestation; getting access to provincial data, and knowing what data was needed to start the process.

Data from the carbon modeling process was largely used for further spatial analyses with GIS (Figure 5), although there was some difficulties noted connecting output with the GIS data sets. Some of the other noted post-carbon-modeling issues were:

- Relating carbon modeling to climate change analysis
- Integrating CBM output data with forest estate models
- Dealing with uncertainty (disturbances, process simplification, policy)
- Steep learning curve in GIS programs
- How to analyze the copious data output
- Understanding the assumptions made when implementing the model (how to interpret the results)
- Relating the results to laypeople.

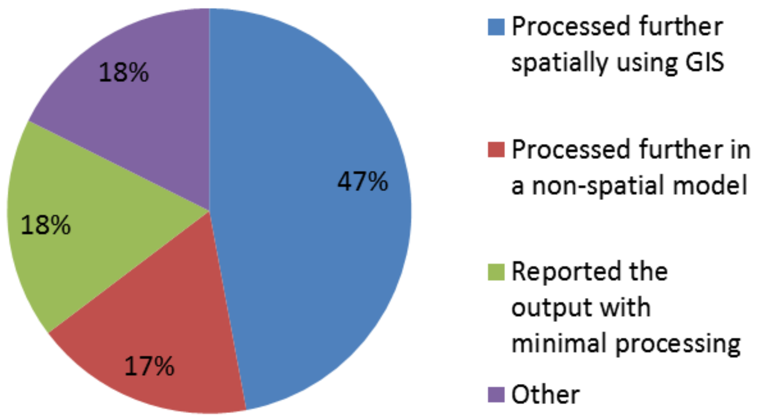

Figure 5: Use of post carbon model data

Discussion

The main message from our survey is the real lack of basic information about carbon science, management, and policy available to forest managers. Knowledge ranged considerably; some people wanted know what a carbon credit was and who owned them. Many others were interested in existing Crown carbon tenure and possible changes to that might favour licensees. There seemed a need for information on how to get started with a carbon project (plan components, screening) and what carbon models can be used and how do you use them (what data, where to get it). Economic and ecological cost benefit analyses were also of interest, as were available carbon finance options.

We believe that our results from our survey and conversations with professionals in the area indicate a real need for a carbon information portal aimed at Kootenay-Columbia forest professionals and the general public. As part of our next steps at Selkirk College, we are planning to create this web-based portal that will include an accessible knowledgebase, example case studies (college lands, others) where people can explore how others have put projects together, a tools site (Internet mapping, economic, data collection), links to expertise, models, and available regional data. We are also planning a step by step, publicly available carbon offset project on Selkirk College land that will be an “open classroom” for students, local consultants, and forest managers. We hope that with the development of user-friendly forest carbon decision-support tools and the documentation of this College project on our web portal, we will be able to fill some of the information gaps that have been identified.

Acknowledgements

We wish acknowledge NSERC and Selkirk College's Institutional Research Branch for funding support for this project.

Back to Table of Contents

21. A model for carbon management using community land trusts and covenants: Lessons and tools in managing carbon and biodiversity for perpetuity

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Summary

Forest carbon projects with conservation covenants registered on them have lower risks, better success, and higher credibility and therefore, better value. Currently, the Climate Action Reserve forest protocol recognizes a 33% less chance of failure of a project that is registered with a conservation covenant ("easement" in the US) than without—which translates into more credible projects with a higher return to the landowner. In addition to the economic benefits, there are important social, cultural, and ecological benefits from having local land trusts provide the long-term, annual monitoring and oversight for forest carbon projects, including providing legitimacy for offsets to the public in a volatile carbon market.

Definitions

- **A land trust** is a non-profit, charitable organization committed to the long-term protection of natural and/or cultural heritage. A land trust may own land itself, or it may enter into conservation covenants with property owners to protect or restore natural or heritage features on the owner's land. The words "land trust" and "conservancy" are often used interchangeably. (See the website of Land Trust Alliance of BC at http://landtrustalliance.bc.ca)

- **A conservation covenant** is a legal agreement between a landowner and authorized land trusts (usually two). This legal agreement remains attached to the title of the lands in perpetuity, and defines allowable and restricted uses for the property. With conservation covenants, the title of the property usually remains with the original landowner. (See the website of Land Trust Alliance of BC at http://landtrustalliance.bc.ca)

Carbon protocols such as Verified Carbon Standard and Climate Action Reserve have recognized key benefits of having legally-binding conservation covenants registered on forest carbon projects. (See http://www.v-c-s.org/program-documents/afolu-non-permanence-risk-tool and http://www.climateactionreserve.org/how/protocols/adopted/forest/current/) They provide long-term, third-party oversight with annual monitoring requirements that are carried out by community land trusts with an interest in the long term health of lands and community. Covenants are enforced both through goodwill of community involvement and legal deterrents such as fines and court actions. Sometimes tax advantages are also awarded with covenants for restricting land uses and, therefore, there are both internal and external financial disincentives. Covenants provide an addition layer of guarantee on top of the five-year verification process. With covenants there are no surprises after five years!

Conservation covenants also provide a legal tool to prove the difference from business-as-usual practices (requirement for additionality of all carbon projects)—local oversight of landowners by community land trusts with a legal obligation to protect land. Conservation covenants held by communities provide much needed arms-length independence from changing land ownership, corporate values, and political priorities—all of which create high levels of risk, even in Canada. For example, in the case of riparian zone covenants held solely by the BC government (Section 215 covenants), they were found ineffective in protecting fish habitat with 75% non-compliance due to lack of enforcement and monitoring (Inglis, S.D. *et al*, 1995). Land trust held covenants have very high compliance. (Personal comm, K.Dunster)

Covenants and the involvement of land trusts can also mitigate reputational damage to the offset market generally through affiliation with organizations which are known to be a credible and have a commitment to biodiversity, social justice, and atmospheric reductions (Peters-Stanley, M. 2011) . Credibility at all levels increases economic value back to landowners.

The following is a review of standards and the explicit benefits of registering conservation covenants on projects:

British Columbia has adopted Forest Carbon Offset Protocol for BC, which recommends that proponents use existing forest reversal risk assessment approaches, including:

- Verified Carbon Standard Tool for Agriculture Forestry and Other Land Use Non-Permanence Risk Analysis and Buffer Determination,
- Climate Action Reserve Forest Protocol Version 3.2 Appendix D.

Under the Climate Action Reserve Forest Protocol, Version 3.2 all avoided conversion projects must have a Qualified Conservation Easement (US equivalent of covenant). While covenants are not mandatory for Improved Forest Management and Reforestation Projects, those with a conservation covenant receive 8% more credits for improving the risk of failure—financial risk or risk of change in landuse, e.g., from 24% (without) to 16% (with). Climate Action Reserve Forest Protocol expects projects that have an easement will have a 33% less chance of failure/ noncompliance then integrated forest practices that do not have an easement.

Under the Verified Carbon Standard Tool for Agriculture Forestry and Other Land Use Non-Permanence Risk Analysis and Buffer Determination, any project with a legally binding agreement that covers at least a 100 year period shall be assigned a score* of:

- 0 for project longevity
- -2 for landownership rights
- -5 for community engagement (demonstrating employment for local community, this is created with a flow of credits designated to the community trust for providing the oversight)
- -2 for plan to resolve conflict (through the legal terms set out in the covenant

*low scores award more credits and can also determine eligibility.

Obviously, lower the risk, the lower the buffer and therefore the greater the returns of the project. In smaller projects, this can significantly increase viability. For example, in a 1,000 hectare forested project in British Columbia, where conservatively 100 tonnes per hectare of emissions are avoided by conserving the property, the 8% increase in project value with a covenant, can offset the cost of the project development, which in projects of this size are typically between 8-10% of carbon revenues. This is a substantial benefit especially now where project feasibility is very marginal in smaller projects.

Long term benefits of having community trusts and oversight involved mean that there are more people engaged on the land, managing it, sharing the benefits locally instead of profit flows out of the country to large corporate developers.

References

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Personal com. Dr. K. Dunster, past Chair of Land Trust Alliance of BC and board of Canadian Land Trust Alliance. Research into compliance of conservation covenants is currently being initiated.

Peters-Stanley, Molly, Katherine Hamilton, Thomas Marcello, and Milo Sjardin. 2011. State of the Voluntary Carbon Markets. Forest Trends' Ecosystem Marketplace and Bloomberg New Energy Finance. http://www.ecosystemmarketplace.com/reports/SOVCM2011

Back to Table of Contents

22. A review of oceanic carbon sinks

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Climate change impacts associated with a 2°C global average temperature increase are now considered to occupy the threshold between dangerous and extremely dangerous, and there is a very high likelihood of average temperature increases into the 4 – 6°C range (Anderson, 2011). Atmospheric CO_2, oceanic temperature and pH data reveal we have not responded appropriately to this critical knowledge; our rates of emissions release continue to increase. More than 90% of trapped heat has entered the ocean and increasingly is detected at depths as great as 3,000 metres (IPCC, 2007). Oceanic pH is the lowest (most acidic) it has been in 23 million years, and its rate of decrease is geologically unprecedented (Turley, 2006) , and may exceed capacities of ecosystems to respond. The major impacts are on species with carbonate skeletons, but impacts can also affect the physiology of respiration and reproduction in a variety of species. In this context, all sinks for carbon achieve crucial importance.

Fundamentals of ocean process are not widely understood yet are critical to understanding and managing the carbon challenge. Atmospheric oxygen, nitrogen, and carbon levels are managed primarily by marine micro-organisms. Indeed, the biogeochemistry of the world in which we all live was constructed and is maintained primarily by marine life.

A shift of 0.5% in the amount of CO_2 dissolved in the ocean could either remove all post-industrial CO_2 from the atmosphere—or double it (Denny, 2008 p255-256). We need to understand this precarious balance and whether it could be manipulated in our favour. Experiments with iron fertilization have caused increases in biological productivity, but the necessary sequestration of this new biomass has not been proven (Denny, 2008 p264).

Carbon chemistry in the ocean

Carbon dioxide enters the ocean at the rate of 1 million tonnes every hour, and within hours 99% of it has reacted chemically with water to form bicarbonate, carbonate, and hydrogen ions. Without this reaction the oceans would hold 99% less carbon.

Equation 1.

$$\begin{array}{ccccccccc} CO_2 & + & H_2O & = & HCO_3^- & + & CO_3^{=} & + & H^+ \\ 1\% & & & & 93\% & & 6\% & & \end{array}$$

Carbon stored in the cold deep waters amounts to 38,000 GtC and is effectively inert except on millennial time scales, while the 70 million GtC (i.e. 70 million billion tonnes) of geologically stored carbon resulting from 3 billion years of volcanic emissions has entered the plate tectonic cycle and is beyond our considerations here. The active carbon inventory of the ocean resides in its well mixed surface waters, down to about 700 m, and totals about 1,020 GtC, comparable with the other active repositories in the atmosphere (750 GtC) and terrestrial plants and soils (2,250 GtC). The rate of addition from human activity now exceeds volcanic input by more than 100 times, approaching 10 GtC/yr, with 25% of that going to the oceans, slightly more to the terrestrial sinks, and the remainder staying in the atmosphere. Less than 1% enters the geological cycle via the sea floor (Hansen, 2009).

GtC – gigatonnes of carbon.
1 gigatonne = 1 billion metric tonnes
To express a carbon mass as an equivalent mass of carbon dioxide, multiply x 3.67

The chemical reaction of CO_2 with seawater also results in acidification, which affects the physiology of many marine species (H^+ in equations 2 – 4) (Denny, 2008, p271).

Equation 2. $CO_2 + H_2O = H_2CO_3$ Carbonic acid

Equation 3. $H_2CO_3 = H^+ + HCO_3$ Bicarbonate

Equation 4. $HCO_3^- = H^+ + CO_3^{2-}$ Carbonate

Acidification restricts access to the share of carbonate ions needed by species with calcium carbonate skeletons (Equation 5), including key primary producers at the base of the food chain and important food species like pteropod snails for fish, such as salmon higher up the trophic pyramid.

The solubility pump

Equations 2 – 4, plus the dissolved CO_2, prime the solubility pump—those chemical and physical processes that bring carbon into seawater. Global ocean circulation is driven by the cold, dense, highly saline waters enriched with carbon dioxide and oxygen sinking down at the poles then flowing toward the equator, a cycle that isolates carbon for up to 1,000 years. Meanwhile water at the poles is becoming warmer, less dense, and less prone to sinking. Glacial melting is diluting the surface waters, also reducing density and increasing stratification. These factors conspire to reduce CO_2 capacity and uptake rate of the world ocean.

The biological pump

Two related biologically processes sink carbon in the ocean. Called the “soft tissue” and “hard tissue” pumps, they refer to photosynthesis (Equation 5) and the biological formation of calcium carbonate (Equation 6).

Equation 5 $6CO_2 + 6\,H_2O + e = C_6H_{12}O_6 + 6O_2$ Carbohydrates + oxygen

Equation 6 $Ca^{++} + CO_3^{2-} = CaCO_3$ Calcium carbonate

Unlike the atmosphere, photosynthesis in the ocean is not limited by carbon, so providing more carbon does not stimulate higher levels of primary productivity and carbon sequestration. Iron however is another matter.

Iron fertilization

Iron has critical biochemical functions. It is not a component in the formation of new cellular material, so the amounts needed are very low – as are the amounts available. In certain places it is nevertheless too low, while nitrate is not. Hence the famous experiments to “fertilize the ocean”.

When supplemented with Fe, CO_2 is indeed converted into protoplasm and calcium carbonate. However it has not been demonstrated that this fixed carbon gets into the deep waters. Furthermore:

- If it did it would eventually decompose releasing CO_2 or methane;
- If the fertilization process worked it would have to be continuous;
- Nutritional supplements on this scale would change the ecology of the plankton;
- Other nutrients would eventually become limiting e.g. nitrate.

Carbon residence times

University of Victoria climatologists have shown that more than half of all CO_2 emissions will remain in the atmosphere for an average of 1,800 years, and around 25% will have a lifetime there of more than 5,000 years (Montenegro, 2007). The ocean will continue to absorb CO_2 long after we stop (if we stop) producing it, and eventually would return CO_2 to the atmosphere as the concentration there decreased. The early impacts could radically diminish the biodiversity of marine ecosystems, and negatively affect human food security.

Conclusion

All modes of biological carbon sequestration should be protected and enhanced, in concert with emissions reductions. All should be viewed as necessary components of ocean management as well as mitigating global warming.

An example of enhancing carbon sequestration in the ocean ("Blue Carbon")

Enhancing biologically fixed carbon stored in mangrove, salt marsh, and eelgrass ecosystems has a small inventory (a few GtC) because the burial process only started during the rising sea levels accompanying the last glacial melt-out. Coastal vegetated ecosystems are nevertheless important conservation targets both for their per-area sequestration capacities and the fact that their buried carbon is generally secure for millennia.

Photosynthesis in the ocean is responsible for 55% of biologically fixed carbon, and 50-75% of this activity occurs in just 0.5% of the world ocean area. These coastal ecosystems bury carbon in their underlying sediments where it is commonly held for millennia. Efficiencies can be up to 50 times those of terrestrial forests by area (Nelleman, 2009).

Global blue carbon capture and storage is estimated to be 0.235 – 0.450 GtC/yr, which is equal to 50% of annual emissions from the transportation sector (and 3 – 4% of all anthropogenic carbon emissions). These habitats are approximately 40% gone already, and declining at ~7% each year—4 times faster than rainforest loss.

British Columbia's 442 estuaries have a combined area of 745 square kilometres (km^2). Of the various estuarine habitats, the most critical for carbon sequestration is eelgrass, especially the native *Zostera marina*, followed by salt marsh. Estimates based on the areas and annual average carbon sequestration for each of these habitats indicate a minimum 180,200 tonnes of carbon sequestered each year in BC. Meanwhile, only 13.5% of the area of this already very limited environment is protected, amounting to 123 estuaries with conservation areas present within the intertidal zone, while the remaining 317 estuaries, mostly medium and small, have no conservation protection at all.

For more information about conservation and enhancement of estuarine processes and sediments in BC, read Dr. Colin's paper at: http://www.sierraclub.bc.ca/quick-links/publications/seafood-oceans-1/Blue%20carbon%20bc%20report%20final_web.pdf

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Back to Table of Contents

23. Potential climate change impacts on growing stocks and greenhouse gas balance of forests in British Columbia in the 21st century

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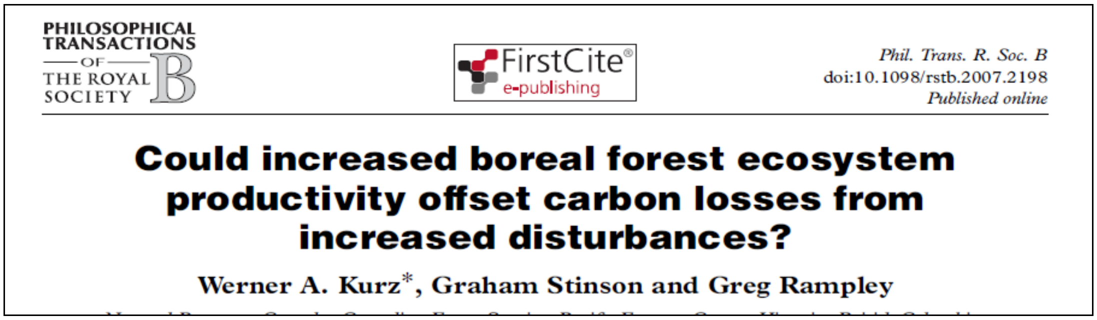
The future greenhouse gas balance of forests will influence the strength of the land sink and the effort needed to stabilize atmospheric greenhouse gas concentrations. If the sink strength of terrestrial ecosystems is reduced, it will become more difficult to achieve global atmospheric CO_2 stabilization targets. Over the coming decades, climate change will increasingly affect forest ecosystem processes, but the future magnitude and direction of these responses is uncertain. We reported here on an analysis of 12 scenarios combining possible changes in tree growth rates, decay rates, and area burned by wildfire with forecasts of future harvest to quantify the uncertainty of future (2010 to 2080), timber growing stock, ecosystem carbon stock, and greenhouse gas balance for 67 million ha of forest in British Columbia. Each scenario was simulated 100 times with the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). Depending on the scenario, timber growing stock over the entire land-base may increase by 14% or decrease by 9% by 2080 (a range of 2.8 billion m^3), relative to 2010. Forests were an annual greenhouse gas source in 2010 due to an ongoing insect outbreak. If half of the carbon in harvested wood was assumed to be immediately emitted, then 0-95% of simulations returned to annual net sinks by 2040, depending on scenario, and the cumulative (2010-2080) greenhouse gas balance ranged from a sink of -4.5 Pg CO_2e for the most optimistic scenario, to a source of 4.5 Pg CO_2e for the most pessimistic. The difference in total ecosystem carbon stocks between the most optimistic and pessimistic scenarios in 2080 was 2.4 Pg C, an average difference of 126 Tg CO_2e yr^{-1} over the 70-year

simulation period, approximately double the total reported anthropogenic greenhouse gas emissions in British Columbia in 2008. Forests risk having reduced growing stock and being greenhouse gas sources under many foreseeable scenarios, thus providing further feedback to climate change.

These results indicate the need for continued monitoring of forest responses to climatic and global change, the development of mitigation and adaptation strategies by forest managers, and global efforts to minimize climate change impacts on forests. However, because forest managers can only affect a small proportion of the total forest area per year, while climate change will affect all forests every year, limiting the magnitude of climate change and the resulting impacts on forests is of primary importance if the desire is to reduce the likelihood of potential positive feedback to climate change from forest ecosystems.

The following articles were noted during Dr. Metsaranta’s PowerPoint presentation.



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Could increased boreal forest ecosystem productivity offset carbon losses from increased disturbances?

Werner A. Kurz*, Graham Stinson and Greg Rampley

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ELSEVIER

Uncertainty of 21st century growing stocks and GHG balance of forests in British Columbia, Canada resulting from potential climate change impacts on ecosystem processes

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Back to Table of Contents

24. A systems approach to forest analysis: a landscape tool to assess ecological change, carbon, and multiple forest values in the Cranbrook TSA

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We wish to thank the Province of British Columbia for providing financial support for this project.

Introduction

Climate change is expected to substantially alter forest ecosystems in British Columbia. Proactive forest management may help reduce the negative impacts of climate change on forest values, and could enhance forest sequestration of greenhouse gases. This requires an understanding of climate change effects on forest ecosystems, its implications for the cycling of carbon between forests and the atmosphere, and potential outcomes of management decisions affecting both forest adaptation and climate change mitigation at broad spatial and temporal scales. Given these complex interactions, there is a need to co-ordinate forest management decision processes, such as timber supply review and the determination of carbon credits, supported by strategic landscape-scale tools that can project an array of potential changes in forest ecosystem services over time (e.g., timber, wildlife habitat, carbon storage).

The Cranbrook model is a strategic, landscape-scale model that applies a systems approach to assess the potential for multi-scale effects of climate change on forested ecosystems. It includes linkages to stand-level models of forest change and regional downscaled projections of climate change. Ecosystem responses to climate change are examined *via* altered regeneration patterns of tree species, tree growth and succession, interactions with shifting natural disturbance agents (fire, mountain pine beetle), alternative responses of human management, and varying climate change scenarios. The spatially dynamic outputs of the Cranbrook model are then linked to the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) to generate temporal projections of carbon stocks under various management and climate change scenarios, as well as spatially dynamic projections of carbon. Using this linked meta-modelling approach, we can evaluate the potential consequences of forest management and climate change on forests and ecosystem services.

While various elements of such multi-scaled analyses have been implemented elsewhere, we provide an integrated approach to examine a forest as a complete system. By combining analyses of climate change effects, interactions among ecological processes, forest management, timber supply analysis, and carbon projections, we believe our approach takes a key step towards supporting strategic regional forest management planning and decision making in a changing climate.

In this extended abstract, we provide an overview of the Cranbrook case study, and some preliminary example spatial and non-spatial carbon outputs.

Cranbrook case study

The Cranbrook study area in southeastern BC comprises the Cranbrook timber supply area (TSA) and some private managed forest land owned by Tembec Ltd (Figure 1). This is a complex area in terms of ecosystems, ranging from dry ponderosa pine / Douglas-fir open forests and grasslands in the bottom of the Rocky Mountain Trench, to extensive lodgepole pine forests in the Flathead and upper Elk Rivers, and wet, mountainous areas in the St Mary’s River and Fernie areas. A range of disturbance agents, including fire, insects, harvesting, road building, mining, grazing, hunting, and recreation affects the forests. This complexity provides an opportunity for understanding a variety of dynamics within a relatively small area.

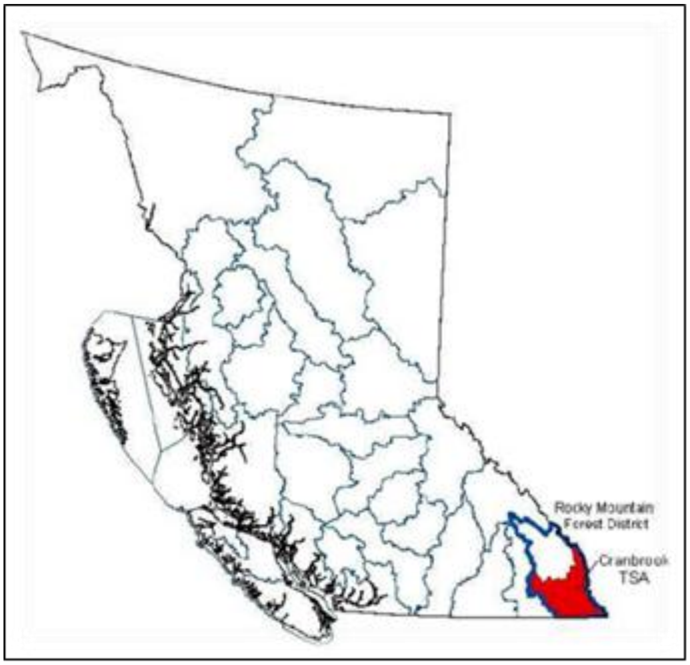

Figure 6. Cranbrook study area in southeastern BC.

Our aim in building the Cranbrook Landscape Model is to examine landscape scale interactions and effects of natural processes, climate change, and management. A second goal is to develop the approach in a general manner that can be applied elsewhere in BC. The grid-based Cranbrook model (1 ha cell size) captures landscape-scale processes for tree species succession, natural disturbance (fire, mountain pine beetle), logging (including salvage), and road building. The natural disturbance sub-model parameters are based on historic disturbance records. The tree species succession sub-model is an empirically based, semi-Markov chain (state change) model, where the cell state includes up to three tree species plus stand age. The logging model is based on a spatialization of the most recent timber supply review analysis (Forsite 2004). Climate change is introduced dynamically during a simulation by changing underlying spatial and non-spatial parameters (e.g., modifications to the natural disturbance type information changes the regime driving the fire sub-model). For model details, interested readers are referred to Morgan (2011). It should be noted that we do not use landscape scale models as a crystal ball. The key to complex scenario modelling is building an understanding of what *could* happen: plausible futures based on a range of interacting management options and natural system assumptions.

We apply a meta-modelling approach to link the Cranbrook model with other models (also called a toolkit approach, Sturtevant *et al.* 2007). That is, rather than building a single, very complicated model, a metal-model links output from one model as input to another. This is commonly done when linking models across different scales (e.g. using output from stand growth models as input to a timber supply model or downscaling output from a global circulation model to drive a landscape fire model). We also apply meta-modelling to link models operating at the same scale, in order (a) to simplify overall model architecture; and (b) to enable use of existing models. As an example of the former, spatio-temporal outputs from the Cranbrook model can be used as inputs for a grizzly security area assessment model (Morgan 2011).

Linking the Cranbrook model to the Carbon Budget Model of the Canadian Forestry Sector (CBM-CFS3, Kurz *et al.* 2009) was a natural extension. In essence, the Cranbrook model is able to capture complex interactions between disturbance and management, and these are transformed into inputs to drive the "disturbance events" required by the CBM-CFS3. Outputs can be produced for carbon across the entire landbase, or stratified by sub-area, for multiple scenarios (and multiple replicates when scenarios include stochastic elements such as wildfire). Figure 2 shows an example output comparing carbon stocks among several scenarios.

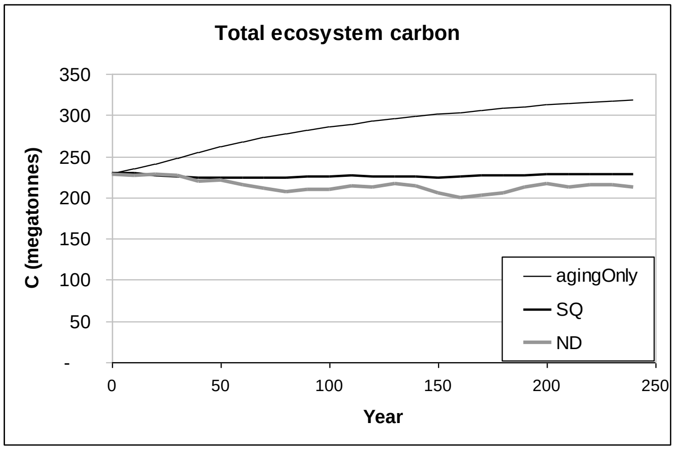

Figure 7. Preliminary example output of carbon stock estimates for the entire productive forest of the study area over 250 years for a single simulation of three baseline scenarios: aging only (no natural disturbance or logging), SQ (status quo harvesting, as represented in the most recent timber supply review analysis) and ND (natural disturbance only). All are run on historic climate conditions.

We are also developing methods of re-linking the CBM-CFS3 back to the landscape dynamics model to provide a flexible approach to estimating and projecting the spatial distribution of carbon across the landscape. This can be used, for example, to identify areas of the landscape where carbon stocks are likely to increase or decrease over time in a given scenario (Figure 3).

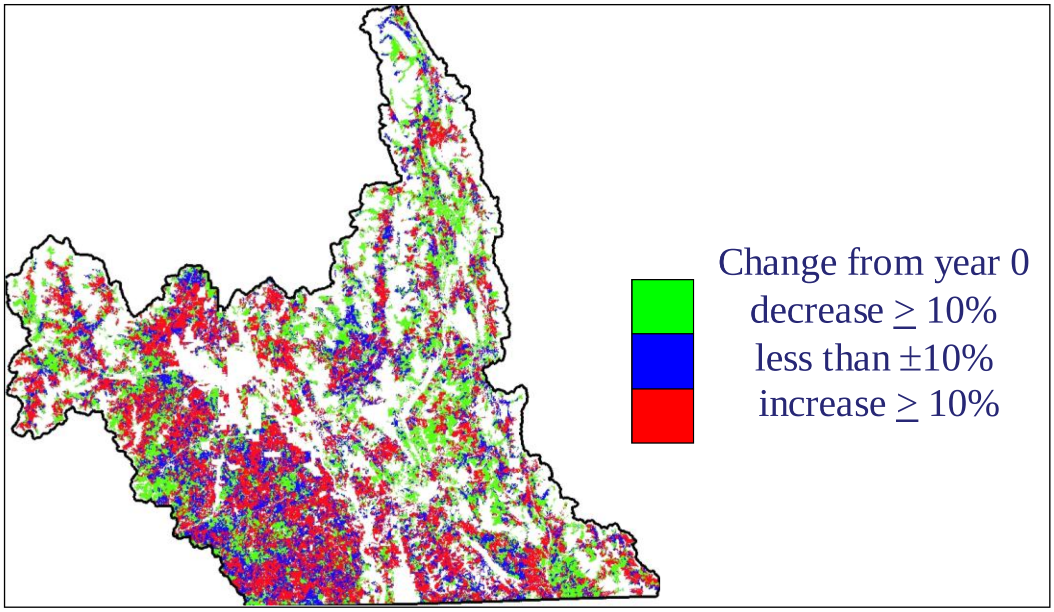

Figure 8. Preliminary example spatial output of changes in carbon over 100 years under the natural disturbance-only scenario for a single run. Absolute differences from year 0 were stratified into 3 classes: decrease of over 10% from the year 0 level (green), increase of over 10% from the year 0 level (red) and change less than 10% (blue).

Discussion

Carbon is just one piece of the management puzzle, along with a host of other values including biodiversity, resilience, aesthetics, and timber. Carbon adds a new challenge to this already challenging mix because carbon management may be in direct competition with other values. If forest carbon is sold, it has to be retained, which may in turn affect timber supply, grizzly bear habitat, ecological representation, etc. There may also be risks of loss due to climate change.

We believe that landscape-scale forest management decisions should be coordinated as part of an adaptive management cycle. This would not only allow decisions to be based on a common understanding of system dynamics, but would also support explicit recognition of the inter-dependencies among decisions.

The tools we are developing, by integrating the whole host of values, allow for assessments of different values within the scope of traditional planning tools. By linking carbon, timber supply, biodiversity values, improved natural disturbance models, and climate change, we hope to provide tools that make planning more complete, but also makes trade-offs more transparent.

One of the novel pieces of our approach is that we are building a process rather than a single model; a meta-model not a mega-model. This provides for tools that can be transferred to other areas as well as updated over time as improved data becomes available. We are also able to incorporate higher levels of complexity with climate change driving shifts in natural disturbance levels, and both climate and disturbance driving tree species succession patterns. And because it is a collection of models that feed into one another, if one model or module improves, those improvements can be linked into the overall meta-model.

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Back to Table of Contents

Field trip description

Rover-Sedlack Long-term Soil Productivity site

Dr. Mike Curran, BC Ministry of Forests, Lands, and Natural Resource Operations, Nelson BC
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The site was visited by about 20 people, immediately after the conference. It is part of an international network studying long-term effects of compaction and organic matter removal on soil productivity and also has a stump removal and organic matter addition plots. The site is 9 years old this year and is scheduled for a re-measurement next year (in year 10).

More background information on the plot is available from Mike Curran and also on the general BC Long-term Soil Productivity website, currently located here: http://www.for.gov.bc.ca/hre/ltsp/index.htm

Back to Table of Contents

Posters

1. The greenhouse gas impact of burning post-harvest debris piles on Vancouver Island

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Abstract

It is increasingly important to identify climate change mitigation opportunities at different scales within all sectors. Avoiding slash burning may be a viable regional-scale mitigation strategy within the forestry sector. The greenhouse gas (GHG) impacts of burning debris piles are examined, with particular attention to their duration. The Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) is used to simulate alternate burning scenarios over 2008-2050 and their subsequent carbon consequences over 2050-2250.

Results show two important GHG benefits of avoided debris pile burning. First, while the delayed release of carbon (through decomposition rather than burning) is inherently a temporary benefit, some of this benefit persists for decades to centuries. Second, burning debris releases a fraction of the carbon as CH_4 and releases N_2O, both of which are more powerful greenhouse gases than CO_2. Burning therefore has a greater climate impact than decomposition, even when the same amount of carbon is eventually released. Counting the full temporary component of the net impact would overestimate the long-term benefits of avoided slash burning, yet full exclusion of the temporary

component would underestimate those benefits. The duration of temporary impacts is an important attribute. The quantity, form, and timing of carbon released are all critical components that must be addressed when evaluating the net climate impact of human activities. Avoiding debris pile burning is a strategy that, when applied across a large landscape over several decades, could potentially contribute to a regional mitigation portfolio.

Back to Table of Contents

2. *Exploring the potential of temperate grasslands in Southern Interior of British Columbia, Canada to sequester carbon*

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Abstract

Grassland ecosystems are the most widespread terrestrial ecosystems in the world, with an estimated amount of 200-300 Pg carbon stored in grassland soils (1 Pg = 1 pentagram = 1 billion tonnes). There is a large variation of predicted rates at which additional carbon may be sequestered by grasslands, depending on the grassland type, vegetation, disturbance, and range management. We explored the capacity of temperate grasslands in the southern interior of British Columbia, Canada to sequester carbon. Our study was a controlled climate manipulation experiment with three hypotheses:

(1) High elevation (upper) grasslands have higher soil carbon content than low elevation grasslands;
(2) A decrease in soil water availability decreases the soil carbon load and potential for carbon sequestration; and,
(3) Clipping (a surrogate of grazing) will increase soil respiration and reduce the carbon load of soils.

The experimental design was factorial, and allowed us to test interactions of the following factors: elevation (lower, mid, and upper) x precipitation (seasonality and frequency) x clipping (clipped at 5 cm). Total carbon increased significantly ($P \leq 0.005$) with each increase in elevation, and decreased with soil depth, supporting our first hypothesis. There was a decrease in changes in total carbon in clipped treatments. Interacting effects of clipping and frequency (P=0.02) and frequency and season (P = 0.06) were found for changes in total carbon. Net carbon exchange significantly increased with elevation (P ≤0.005), and there was an increase of net carbon exchange due to the seasonality of watering.

Back to Table of Contents

3. Carbon stocks in old-growth stands of western redcedar and western hemlock of Canada's inland temperate rainforests

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Abstract

This study was conducted to fill a knowledge gap in assessing forest ecosystem carbon of old-growth stands of western redcedar and western hemlock in central British Columbia known as "Inland Temperate Rainforests", which are characterized by the large size and high incidence of heart-rots. Carbon stocks of live tree and dead organic matter (snag, coarse woody debris, and forest floor) were quantified in three study sites designated as ICH (Interior Cedar Hemlock) biogeoclimatic zone. The carbon stocks were evaluated among stands treated with four different retention-harvesting methods: clear-cutting (0%), group retention (30 %), group selection (70 %), and control cut (100 %). A Monte Carlo approach was used to obtain the probability distribution of the carbon stocks and test the effects of harvesting across the study areas. As a result, mean total ecosystem carbon stock in uncut was 454 t C ha^{-1} similar to the regional average of the Pacific Northwest (540 t C ha^{-1}). Live-tree and dead-organic-matter carbon stocks accounted for 76 and 24 % of the total carbon, respectively. Old inland temperate rainforests were found more vulnerable to intensive harvesting (clear-cutting and group retention), potentially losing the carbon stocks and sink strength of live trees in the long-term. In contrast, low-intensity harvesting (group selection) has the potential of maintaining long-term total ecosystem carbon through sustaining the productivity of the forest. This study showed that old inland temperate rainforests are important carbon reservoirs, and low-intensity harvesting (group selection) provides the best compromise between forest harvesting and forest carbon stocks.

Back to Table of Contents

4. *Monitoring the effects of climate change on alpine vegetation in the north Columbia Mountains*

Federico Osorio (PhD candidate) Faculty of Forestry, University of British Columbia, Revelstoke BC
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Abstract

High mountain environments are particularly sensitive to human-induced climate change (warming temperatures) because they are determined by low temperature conditions. Alpine and sub-alpine ecosystems in British Columbia provide a good setting for monitoring climate-induced changes in flora since they are largely devoid of human impacts and because they are composed of very diverse environments (e.g., productive forests to non-vegetated tundra) within a small geographic extent. This project has two general objectives:

(1) to broaden our understanding of the composition and distribution of vascular plants at high-elevations, and
(2) to understand the relation of some abiotic factors that influence high-elevation vegetation.

The data collection for this project began in the summer of 2007 and will end in the summer of 2011. In the first phase, I conducted approximately 130 Relevés in order complete the biogeoclimatic classification of alpine and sub-alpine ecosystems in the West Cariboo Mountains. For the second and main phase of the project, I followed the Global Observation Research Initiative in

Alpine Environments methodology to establish seven permanent monitoring sites, in the same project area, for examining changes in soil temperature, soil nutrients and plant distribution along elevation gradients. In each of the seven summits, located between 2030 and 2490 m.a.s.l (with a total of 112 - 1m^2 plots), I am observing soil temperature, soil nutrients, and vascular plant cover. In meeting its two objectives, this study will provide a comprehensive scientific basis to help researchers and land managers understand the changing patterns in distribution of high-elevation vascular plants, the relationship of these changes to climatic, edaphic and topographic gradients, and to explore the vegetation's role in ecosystem function.

Back to Table of Contents

Summary of conference evaluation forms

Of the 85 conference feedback forms distributed, 22 were returned.
Not all respondents entered a comment for each question.

1. How well did the conference meet your expectations?

10 people indicated the event "fully met" their expectations.
12 people indicated the event "met most" their expectations.
0 people indicated the event "met only a few" of their expectations.
0 people indicated the event "did not meet any" of their expectations.

Additional comments:

- Great job (2 comments)
- Excellent conference
- Hoped to see more forest industry reps present, just to learn about C management even if offset projects aren't possible for them.

2. The papers presented at this conference were the result of a Call for Papers. If we run a sequel to this conference, what topics would you like to see included?

- More about grasslands, not so much about forests
- Perhaps something on hydrology and relation to carbon management, e.g. streamflow, fisheries, etc.
- More worldwide examples of projects
- Carbon sensitivity studies
- Carbon policy
- Carbon modelling
- Field trips
- Social science on public perception to uptake of climate change action details
- More ENGO speakers
- A review of the most successful/influential examples from other jurisdictions e.g. for carbon sequestration and offsetting
- More field data and site-level examples related to landscape level
- Something aimed at private land, local government, and covenants with provincial reps to contribute.
- More real project examples and how to do carbon projects
- More on oceans

- More on climate change and climate change adaptation – focussed on forestry and conservation
- Monitoring approaches, trade-offs, and value: the sliding scale of looking at the benefit/cost of verification for realizing CO_2 emissions.
- Field skills required to carry out carbon projects
- More info regarding fire and fuel management options and implications for carbon management
- Changing land use, example: unmanaged forest to agroforestry, and walk us through a few different scenarios (different uses, different BEC zones, etc.)
- Field verification of carbon models and accuracy assessments
- Fundamental principles of forest carbon offsetting
- Likes the idea of a sequel
- Less on the modelling, more on real life case studies like Darkwoods

3. Do you have comments for us to pass onward to specific presenters?

Comments were personal and passed on privately.

4. Do you have any other comments about the conference?

- This conference would have benefitted from a handout or primer on carbon so the terminology was defined and understood by all.
- It was an excellent conference in all respects. Great presentations, venue, food. Need more opportunity for questions.
- It might be helpful to have access to the presentation slides before the conference to avoid and minimize overlap.
- More time for questions
- Fantastic
- Very well organized, useful information
- Have posters in the same area as drinks were served to encourage engagement
- Thanks (2 comments)
- It was worthwhile and good value
- Good venue
- Longer breaks would have been better
- Perhaps fewer presentations and longer, more in-depth presentations.
- It was a coup to have Hebda speak
- It was an inspiring gathering
- It was a pleasure to be in Nelson

- Really an excellent achievement
- More time for panel discussions
- Nice to have fruit platters
- Scale/size of room fit well with group size
- Wished it would have been longer
- Wanted more academia involved
- The panel discussion was good and there should have been more of these
- You did a great job of bringing together a wide range of disciplines and practitioners. All that was missing were the social scientists and non-profit, non-government sector who would have learned some of the public attitudes and answers.
- Trends in ENGO responses to forest carbon management and tools.

5. If you would like to receive announcements about future CMI events by email, please provide your email address. Look for us on Facebook! (no summary provided for this question)

6. The Columbia Mountains Institute is always looking for suggestions for courses and workshops. Our niche is providing continuing education for ecologists, foresters, biologists, educators, and resource managers, with the aim of improving management in regional ecosystems. We offer skill upgrading, and workshops to address current ecological issues. Do you have any suggestions for events or courses you'd like to see us organize?

- Aquatic topics
- Water/land use, hydro dams?
- Carbon verification, ISO certification, Environmental Management System certification, basic forestry certification courses that are not readily available through Selkirk and Okanagan Colleges.
- There is so little training available on for forest practitioners re: fire and fuel management!
- Interface forest management: fire, wildlife, biodiversity, climate change adaptation, landscape connectivity, etc.
- We in MFLNRO dearly miss participating in the Silviculture Institute of BC program, which was eliminated over a decade ago. It was a great connection with young practitioners. In our (area) there is a big gap in knowledge of stand dynamics. We would love to participate in such a program again.

Back to Table of Contents