Linking Spatial Timber Supply Analysis and Carbon Budget Modelling

Methods Developed for Coastal BC

April 2011

prepared by: Andrew Fall, Gowlland Technologies Ltd.

Executive Summary

This document reports on methods developed to estimate carbon budgets in the Central-North Coast, South-Central Coast and Haida Gwaii areas of BC. Results are reported in separate documents for application areas. It is an update and extension from a previous report from December 2009. Specifically, we developed an approach to link timber supply analysis done on land- strategic land-use objectives for EBM in this coastal region with carbon budget modelling. The spatial timber supply models and scenarios were developed using the SELES Spatial Timber Supply Model (STSM) to support land-use planning in this area. The carbon budget modelling was done using the Carbon Budget Model of the Canadian Forestry Sector (CBM-CFS3).

Acknowledgements

The timber supply analysis models applied in coastal BC were assisted greatly with input from a number of people. In particular, data was provided by First Nations, licensees, Ministry of Forests, Mines and Lands, and Doug Fetherston and John Sunde (Integrated Land Management Bureau). Feedback on the analysis methods and results was provided by Jim Brown (Ministry of Forests and Range), Dennis Crockford (Integrated Land Management Bureau). Wally Eamer, Grant Scott, Rina Gemeinhardt, Dan Cardinall (Turning Point), Murray Watkinson, Nick Reynolds and other representatives from Haida First Nation, representatives from the Land and Resource Forum and EBM Working Group, and others.

The carbon budget modelling, in particular help with use of the CBM-CFS3 model, was assisted by Werner Kurz (Canadian Forest Service), Qinglin Li and Christine Fletcher (Ministry of Forests, Mines and Lands). Other feedback was provided by Jody Holmes (Rainforest Solutions Project), Dan Cardinall, Rob Draeseke (Ministry of Aboriginal Relations and Reconciliation), Cornelia Rindt (Carbon Credit Corp), Chuck Rumsey and others.

Table of Contents

1 Introduction

There is increasing interest in producing credible estimates of carbon in the central and north coastal region of BC, in particular to estimate the carbon implications of land-use decisions. Carbon budgets under various land-use scenarios can be used to provide a quantitative basis for estimating carbon credits that might be traded as part of cap-and-trade or other carbon offset mechanisms. Recent agreements between First Nations and the provincial government have included sharing of benefits that may arise from carbon credits.

The Canadian Forest Service has developed one of the most accepted carbon budget modelling tools used in Canada and other forested regions around the globe, the Carbon Budget Model of the Canadian Forestry Sector (CBM-CFS3; Kurz et al. 2009, Kull et al. 2007). This tool takes as input inventory, growth & yield, and disturbance events, and produces projections of carbon in live biomass and dead organic matter within multiple “carbon pools” in a scientifically rigorous manner.

Spatial landscape analysis tools built using the Spatially Explicit Landscape Event Simulator (SELES) have been refined and applied to support recent land-use planning in the Central-North Coast (CNC) and South-Central Coast (SCC) area (Fall and Crockford 2006), and for Haida Gwaii (Fall et al. 2009). In particular, the Spatial Timber Supply Model (STSM), implemented using SELES, has been used to project timber supply potential under a wide range of scenarios at relatively fine-scale resolution.

In 2009, the potential benefits of linking the CBM-CFS3 and STSM tools together were identified, and feasibility and methods were explored. After some pilot analyses, full-scale analysis of the CNC, SCC and Haida Gwaii areas was done for various land-use scenarios. Starting in 2010, after review and suggested refinements, the methods and analysis were updated (including use of version 1.2 of CBM-CFS3). This report details the methods used for this linkage. Updated results are documented in associated reports for each of the application areas (Fall 2011a,b,c; Central-North Coast, South-Central Coast and Haida Gwaii).

2 Methods

2.1 Study area land base

The application areas (Central-North Coast and South-Central Coast agreement areas, and Haida Gwaii) were assessed at a resolution of 1 ha per cell, where each cell is 100m x 100m square. Inventory attributes were used to define productive forest, stand age, site index, leading species and other attributes. Site index, leading species and biogeoclimatic variant were used to define site series surrogates. Data sets have been set up for each management unit (timber supply area or tree farm license block) that makes up the study areas. The management units in the South-Central Coast (SCC) agreement area include Strathcona TSA, Kingcome TSA, the southern portion of Midcoast TSA, TFL 25 block 2, TFL 39 blocks 3 & 5, TFL 45 and TFL 47 (note that only portions of Strathcona TSA, Kingcome TSA and TFL 47 are within the SCC area). The management units in the Central-North Coast (CNC) agreement area include the northern portion of Midcoast TSA, North Coast TSA, TFL 25 block 5, and TFL 39 block 7. The management units in Haida Gwaii include Queen Charlotte TSA, TFL 25 block 6, TFL 39 block 6 and TFL 58.

Due to the size of the CNC and SCC area, for timber supply, the CNC and SCC area was divided along management unit boundaries into three sub-regions: north (North Coast TSA), central (Midcoast TSA, TFL 25 block 5, and TFL 39 block 7) and south (Strathcona TSA, Kingcome TSA, TFL 25 block 2, TFL 39 blocks 3 & 5, TFL 45 and TFL 47). For carbon analysis in CBM-CFS3, the south unit was divided into two pieces (to keep within limitations on the number of records that can be supported): south1 (the northern 3 management units: Kingcome TSA, TFL 39 block 3, TFL 45) and south2 (the southern 4 management units: Strathcona TSA, TFL 25 block 5, TFL 39 block 5, TFL 47). Also, in the central sub-region, carbon in the Midcoast TSA was tracked separately for the CNC and SCC portions.

2.2 Management scenarios to assess

Two key scenarios were selected to explore likely management in the absence of a land-use plan, and management reflecting the land-use objectives announced in March and December 2009 (i.e. base case and project scenarios in the language of a carbon project). In the pilot carbon assessment, additional scenarios were examined to explore the effects of no harvesting, protection of conservancies and biodiversity areas and previous land-use objectives.

2.2.1 Spatial baseline 2 (SBL2)

The aim for this scenario (also called the spatial base case, SBC2) was to create a spatial version of the likely management regime in the absence of a land-use plan. The start point of this scenario is the timber supply review analyses for each management unit. STSM was calibrated with the timber supply review analysis by applying the same assumptions and ensuring a match with growing stock and harvest indicators (e.g. age harvest, volume/ha harvested, area harvested), producing an aspatial baseline, ABL1, or spatial baseline SBL1, depending on the management unit. For SBL2, the timber harvesting land base was generated spatially, and spatial management constraints and behaviours were applied spatially (in some management units, this implied refinement from spatially implicit methods used in the timber supply review analysis). The main spatial constraint applied was access (road and heli), while the main spatial behaviours were road development and spatial blocks. In addition, recent protection of wildlife habitat areas and ungulate winter range areas was included, as these designations were outside the scope of the land-use planning process.

2.2.2 Current strategic land-use objectives (LUO)

This aim of this scenario is to capture the EBM objectives that formed part of the March 2009 CNC and SCC land-use objective agreements, and December 2009 Haida Gwaii land-use objective agreements. This included a number of elements:

(a) Conservancies and biodiversity areas (where harvesting is prohibited).
(b) Protection of specific EBM elements, including portions of red and blue listed ecosystems, cultural forestry values (mainly cedar), riparian habitat, wildlife habitat, floodplain buffers, stand-level retention, etc. (we collectively call these "EBM netdowns" since they are spatially identified and static). We applied a risk-managed interpretation of THLB netdowns.
(c) Old-growth targets, specified as targets for sit series or site-series surrogates (e.g. site-series surrogate CWH vm1 Cedar Medium might have a target of 70% of natural levels of old, where "natural levels of old" are based on historic natural disturbance, or "range of natural variability", RONV). We applied the default, or low-risk, interpretations of the old-growth targets.

For simplicity in the carbon analysis, we call this scenario "LUO (land-use order)", although in the land-use planning analysis different naming conventions were used. More detailed analysis of these scenarios is reported in Fall (2009) and Fall et al. (2009).

2.3 Input data

Timber supply analysis requires land base inventory (spatial data) and parameters for timber growth & yield information and management practices (non-spatial parameter files). Most of this information is based on the most recent timber supply review or management plan for the individual management units (see application area reports, Fall 2011a,b,c). Forest cover information was updated to 2008 based on recent harvest history.

2.3.1 Spatial and temporal scale

The STSM analysis models are raster based. The analyses were done at a resolution of 1 ha per cell, where each cell is 100m x 100m square. Spatial entities below this resolution, such as roads, are modelled as a percent of a cell. The main analysis was done in 10-year steps. The time horizon used to ensure sustainability of harvest levels was 400 years.

CBM-CFS3 is a non-spatial model that captures spatial entities using strata. Given the size of the land base in this analysis, the number of strata applied had to be modest, and was restricted to management unit, timber analysis unit (linking stands to growth & yield data), land status (timber harvest land base, protected area, EBM netdown, or unprotected non-contributing forest). The CBM-CFS3 model was run at a 1-year time step for 250 years.

2.3.2 Spatial data - Inventory

All digital maps came directly from or were derived from information from Integrated Land Management Bureau inventory, First Nation, licensee or from Ministry of Environment (see application area reports). Digital maps describe physiography, ecology, timber values, land-use units and roads. Except as follows, the spatial inputs were the same as in the most recent timber supply review. Stand age (and timber analysis unit) was updated to 2008 in all management units based on recent harvesting data provided by B.C. Ministry of Forests, Lands and Natural Resources Operations. This provides a common start year for all management units (even though the respective timber supply reviews were done in different years). Recent approved wildlife habitat areas and ungulate winter ranges were used as part of the updates in the spatialization process. Application of EBM rules requires several attributes, including riparian buffers, floodplain mapping, wildlife habitat (grizzly bear, marbled murrelet), and site series from Terrestrial Ecosystem Mapping data (depending on application area).

2.3.3 Spatial data - Derived

A number of attributes were generated to support the scenarios, including derivation of the timber harvest land base (see next sub-section), timber analysis units and road-related information. Productive forest and timber analysis units were defined using the timber supply analysis reports (but recent removals of private land from TFLs were excluded).

The spatial harvest rules divide the THLB into areas with ground and helicopter access (see application area reports for rules specific to each management unit). Applying spatial access rules constrains harvest to areas within 2km from an active road or ocean for ground access, and within 5km for heli access. Additional attributes generated to model access include distance to roads and ocean, and division of existing and estimated future roads into segments (to allow for incremental expansion of the road network as harvesting progresses).

Application of EBM rules requires modification of the THLB. In the CNC and SCC, a site series surrogate layer was generated based on BEC variant and ecological analysis units (leading species and site productivity) using information in Williams and Buell (2006). Red and blue-listed areas were estimated as an expected percent of each site series surrogate (Table 14 in Williams and Buell (2006); i.e., not mapped). To model these, the estimated levels of red and blue-listed communities were randomly chosen within each site series surrogate.

2.3.4 Non-spatial data inputs

The same volume yield curves and analysis units as in the most recent timber supply review for each management unit were applied (unless noted in the application area report). In some management units, old-growth analysis units had a single, constant yield value (e.g. stands of any age over 250 years in a given site index would apply a static volume yield). For timber supply analysis, this poses no problems (since harvested stands regenerate on managed analysis units). However, the CBM-CFS3 "grows" all stands from age 0 during the initialization process based in part on the yield curves. To address this, given that we had no information on appropriate dynamic yields, we constructed yield curves in such units using linear interpolation, from 0 m^3 at age 0 to the constant value used in the timber supply review at the age used for the analysis unit (e.g. if an "constant" analysis unit was defined for stands 140 years and older at 280 m^3, the linear interpolation process would increment 2 m^3/year from age 0 to age 140.

Minimum harvest age, regeneration delay and other information specific to timber analysis units were taken from the individual timber supply analysis reports, as were targets for forest cover rules (e.g. visual quality constraints, ungulate winter range constraints, community watersheds, landscape level biodiversity, etc).

2.3.5 Timber Harvesting Land Base (THLB)

The timber harvesting land base (THLB) is the portion of the land base with operable productive forest (i.e., suitable for logging) that is not specifically reserved by other land-use designations and policies (e.g. protected areas, riparian reserves, environmentally sensitive areas). The THLB was derived for each management unit. The spatial baseline THLB was derived from the timber supply review analyses, with the exception that some private land formerly in TFL 39 Haida Gwaii was excluded.

We derived THLB for the LUO scenarios based on a risk-managed interpretation of the land-use orders. The land-use order specify netdowns (reductions) to the THLB for no harvest areas (conservancies and biodiversity areas), fish habitat, active fluvial units, red and blue listed plant communities, and wildlife grizzly habitat (see application area reports for details, and section on EBM management assumptions for other elements). The starting THLB was based on the spatial baseline 2 (SBL2) scenario, which essentially spatialized some key elements of the THLB from the most recent timber supply reviews, if appropriate, and netted out recent wildlife habitat areas and ungulate winter ranges established under the Forest and Range Practices Act.

2.4 Timber supply methods

The SELES spatial timber supply model (STSM) underlies the landscape models used to support land-use planning in this area. Methods of how this was used for timber supply analysis are described in Fall and Crockford (2006). The foundation of the timber supply assessment is the land base and forest management assumptions defined in the Timber Supply Reviews (TSR) conducted between 1999 and 2006 for each management unit, updated to 2008 based to reflect recent harvesting.

To balance computational feasibility with integration across large areas, we divided the study area into four sub-regions: south (Kingcome TSA, Strathcona TSA, TFL 25 block 2, TFL 39 blocks 3 & 5, TFL 45 and TFL 47), central (Midcoast TSA, TFL 25 block 5, TFL 39 block 7), north (North Coast TSA) and Haida Gwaii. Within each of these sub-regions, timber supply was assessed simultaneously for each management unit. This allowed objectives (e.g. old-growth targets) to be met collectively, at the scale for which targets were specified. Since the Midcoast TSA has a portion in both the CNC and SCC planning areas, carbon was tracked for these sub-areas in this TSA so that carbon estimates could be reported separately for the CNC and SCC areas (Fall 2011a,b). Further, to enable feasibility of running CBM-CFS3 for these large land bases, the south sub-region was divided into two parts (Fall 2011b).

2.4.1 Forest management assumptions

Forest management assumptions were generally the same as in the most recent timber supply review. In general, forest cover constraints were applied to meet objectives for visual quality (VQOs), integrated resource management (IRM), ungulate winter range (UWR), community watersheds (CWS), landscape scale biodiversity, etc., depending on the management unit.

In addition to using a fully spatial THLB, the spatial baseline scenarios include some spatial constraints and behaviours:

- Access: Access was constrained by road and ocean access. Areas identified for ground access must be within 2km from a road or the ocean, while areas identified for heli access must be within 5km. This is not applied as an absolute constraint, but a very strong preference (i.e. areas further than these limits may be accessed within a period if no other options are available). Ground based harvest will build roads and distance to nearest road information is updated, extending areas accessible to future ground and heli access.
- Spatial blocks: blocks are placed as spatial patches on the landscape. Block size is selected randomly between 5 and 20 ha. Blocks are initiated according to harvest preference (e.g. oldest first, nearest to road) and spread to available adjacent forest until the target size is met (or no more adjacent forest is available).
- Cutblock adjacency constraints were not included to constrain harvest opportunities. Previous analysis has shown that adjacency can cause large timber impacts, and without a more complete discussion on this issue in the context of EBM, we chose to simply continue with the non-spatial approximation used in the timber supply review analyses.

2.4.2 Natural disturbance assumptions

Natural disturbance outside the THLB was captured in the by “freezing” the ages in the non-contributing of the spatial base case. This makes the assumption that the stand age distribution in the non-contributing is a result of natural disturbance – that is the age-class distribution in natural-origin forests is close to a natural structure. If natural disturbance is not explicitly modeled, then aging in the non-contributing will result in a skewed age structure. Freezing ages was only applied to cells entirely netted out (e.g. inoperable) and that had no management history. The LUO scenarios applied this to the same area as the spatial base case (since some areas with past harvesting may be protected, and should age over time). It was assumed that natural disturbance would not affect greenup constraints, so such non-contributing areas in early and mid seral condition were permitted to age until mature at 80 to 120 years, depending on BEC variant (but were thereafter frozen). Note that freezing some stand ages was only applied in the timber supply analysis (and is not possible in the CBM-CFS3, where all disturbances must be specified explicitly – see section 2.5.1).

2.4.3 EBM objectives for land-use plans

Section 2.3.5 mentions how some EBM elements were captured as THLB netdowns (e.g. fish habitat and active fluvial units). Other elements were captured using volume reductions and forest cover constraints, and include volume reductions (e.g. for cedar and stand-level retention), harvest limits (e.g. for fisheries sensitive watersheds and amount of mid-seral forest) and targets for old-growth. See application area reports for specific details.

Old-growth targets were met using the following policy. First, old forest in the non-contributing was selected followed by old forest in the timber harvest land base. The land-use orders specify that in cases where there is insufficient old-growth, a target must be met over 250 years. This was captured by recruiting any second growth in the non-contributing prior to recruiting second growth in the THLB. As old forest was modeled as a forest cover constraint, there will be an aim to overlap with non-contributing and forest reserved for other constraints (e.g. VQOs).

2.5 Linking timber supply outputs to CBM-CFS3 inputs

CBM-CFS3 v1.2 (beta) uses 7 input text files to load and run a single scenario:

(1) Age classes: 10-year age classes were specified to match the growth & yield time horizon (i.e. 36 classes, from 0 to 350+)

(2) Disturbance types: disturbances specified were wildfire (for natural disturbance), harvesting, harvesting with slash burn, and roading (essentially deforestation). The default consequences in CBM-CFS3 of these disturbance events were used (i.e. the transfer of carbon between biomass and dead organic matter pools, release to the atmosphere, and removal from site).

(3) Classifiers and values: Strata were specified for:

- Leading species (required by CBM-CFS3): species labels were designed to match labels used in CBM-CFS3 to simplify loading a scenario. This included values for black cottonwood, trembling aspen, amabilis fir, subalpine fir, western red-cedar, red alder, birch, Douglas-fir, western hemlock, mountain hemlock, big leaf maple, western white pine, sitka spruce, white spruce and yellow cypress (yellow cedar).

- Timber analysis units: unique identifiers were specified for each growth & yield curve in each management unit. Generally, these classifiers were the same numeric value as used in the timber supply models.

- Forest status: THLB (timber harvest land base), NCunprotected (unprotected non-contributing forest), NCnetdown (netdown, or removal, from base timber harvest land base for EBM objectives of land-use plan, such as critical grizzly habitat), NCwha (netdown for recent wildlife habitat areas and ungulate winter ranges), PA (netdowns for no-harvest areas, specifically conservancies and biodiversity areas).
- Management unit: KingcomeTSA, MidcoastTSA, NorthCoastTSA, StrathconaTSA, TSA25 (Queen Charlotte TSA), TFL25_blk2, TFL25_blk5, TFL25_blk6, TFL39_b lk3, TFL39_blk5, TFL39_blk6, TFL39_blk7, TFL45, TFL47, TFL58 (formerly TFL47 block 18).

(4) Inventory: inventory table for initiating a simulation showing area, historical disturbance type and last disturbance type for each stratum (leading species, analysis unit, forest status, management unit, and age in years) updated to 2008.

(5) Transition rules: specify changes from each stratum caused by disturbance (e.g. post-harvest planting). For each stratum (leading species, analysis unit, forest status, management unit) and each disturbance type (wildfire, harvesting, roading), specify a consequence stratum, a regeneration delay in years, a reset age and a percent. The age ranges to which the transitions apply were always for all ages.

(6) Growth & yield: volume in cubic metres per hectare for 10-year age-class from 0 to 350+ for each stratum (leading species, analysis unit, forest status and management unit). Note that growth & yield information must be provided for both current strata specified in the inventory file as well as any future strata created by transition rules.

(7) Disturbance events: specify the harvesting, roading and natural disturbance activities. For each year (1 to 250), applicable strata (leading species, analysis unit, forest status and management unit), and applicable starting & ending ages, specify the area disturbed by harvesting, roading or natural disturbance. For stands younger than 350, starting and ending ages were specified as the precise stand age in years. For stands 350 and older, the age range was for all stands 350+.

The age class, classifiers & values and disturbance type files were created manually. The inventory, transitions and growth & yield files were created using a translation model (built using SELES) that loaded spatial inventory layers, growth & yield tables, analysis unit information, and generated the text files automatically. The disturbance event files were also produced using a translation model built in SELES (see following section).

2.5.1 Disturbance event model

To translate management disturbances, the SELES STSM was first run for a given scenario (in a given sub-region), and parameterized to output a time series of spatial data for stand age, analysis unit and timber harvest land base. This time series could be generated using an annual or decadal time step. The disturbance event translation model loaded base inventory and analysis unit information as well as these spatial time series (incrementally). The stand age maps were used to identify location and year of logging (i.e. where stand age at time *t* was less than the stand age at time *t-1* – note that different regeneration delays by analysis unit have to be taken into account, as well as year within a decade when using a decadal time step), as well as the age to specify for harvest. The timber harvest land base maps were used to identify area harvested as well as area of roading (which is modelled in part as a reduction in timber harvest land base upon harvest, and hence can be identified as a difference between two time steps).

The objective of the disturbance event file was to encourage CBM-CFS3 to harvest *exactly* the same sequence of stands as in the timber supply model (at the resolution of stand ages with the strata applied). To do this required specifying stand age in years, and creating a disturbance event file in annual steps (even if the spatial time series data was in decadal steps). Details of processes such as timber licence reversions had to be captured correctly.

2.5.2 Harvesting with slash burn

A survey of some operations in the study area indicated that 0.5% to 1% of harvesting applied burning of logging slash (Q. Li pers. comm.). Burning slash affects greenhouse gas emissions and on-site carbon dynamics. To capture this, we added a parameter to the disturbance event translation model to randomly select 1% of harvest patches as applying slash burning.

2.5.3 Volume adjustments

Volume adjustments in timber supply analysis are commonly used to capture loss of growth in a stand (e.g. due to fine-scale diseases), increased growth of a stand (e.g. due to genetic improvement or fertilization), trees left standing post-harvest but below the resolution for forest cover constraints (e.g. wildlife tree patches), and trees removed during harvest that don’t contribute to the harvest target (e.g. some cultural use cedar). From a timber supply perspective, these different cases all result in the same consequences for timber supply and so are generally handled as a simple multiplier on the growth & yield data. In carbon budget modelling in general, and in CBM-CFS3 in particular, these different cases have very different carbon impacts. To handle this appropriately, the translation models load a table for each timber analysis unit that specifies the proportion of each volume adjustment attributable to either (a) actual volume effects, (b) volume left on site post-harvest or (c) volume removed, but not attributed to the harvest target. These elements must multiply together to reach the volume adjustment used in the timber supply analysis. Actual volume effects are captured as multipliers on the growth & yield table loaded into CBM-CFS3. Volume left on site is captured as a reduction in the area disturbed by logging. Volume removed but not attributed to the harvest target is included in the area disturbed by logging.

2.5.4 Natural disturbance

Natural disturbance rates are generally low in the study area, with rotations on the order of millennia, with most disturbances being fine-scale gap dynamics (Dorner and Wong 2003). Nonetheless, stand-scale natural disturbance does occur (mainly wildfire and wind throw). In the timber supply analysis, natural disturbance was addressed in two ways: in the timber harvest landbase, salvage was assumed to occur with a specified amount of “unsalvaged losses” (as specified in the timber supply review analysis reports for each management unit), and in the non-contributing landbase, age was assumed to be in quasi-equilibrium with natural disturbance and ages were frozen. In principal, it would be preferable to model natural disturbance explicitly, but the site-specific nature of natural disturbance in the study area (Dorner and Wong 2003) would require effort to improve accuracy (at the aggregate level) over the approach taken to freeze ages.

In the CBM-CFS3, however, it is not possible to simply freeze stand ages. Unless a disturbance event is specified, stands will continue to age. Therefore, unless natural disturbance is accounted for explicitly, there is a risk of over estimating carbon in unmanaged portions of the landscape. To address this:

(a) As in the timber supply analysis, we assumed that natural disturbance in the timber harvest landbase would either be salvaged or lost as unsalvaged losses (both of which are accounted for in the harvest disturbance events).

(b) Outside the timber harvest landbase, we assumed stand-replacing natural disturbance based on the range of natural variability (RONV) numbers for each site series surrogate specified in the land-use orders. These RONV numbers are estimates of the proportion of the forest expected to be at least 250 years old under natural conditions. Given the relatively fine-scale of natural disturbance in this study area, these can be used to estimate expected annual disturbance rates as follows:

(i) Assume that every stand (in a given site series surrogate) has an equal annual probability X (between 0 and 1) of experiencing stand-replacing disturbance.

(ii) The probability of "surviving" (i.e. not being disturbed) in a year is then 1-X, and the probability of "surviving for 250 years" to reach assumed old-growth is $(1\text{-}X)^{250}$, which is the RONV natural level of old according to the land-use order.

(iii) Hence, the annual disturbance probability is $X = 1 - RONV^{(1/250)}$. For example, if RONV for a given site-series surrogate in the land-use is 90%, then the disturbance rate X is 0.042%/year, for a rotation of about 2,400 years (1/X).

The disturbance event model was adapted to create natural disturbance events based on a table of input rates, and a map of site series surrogates. For each step, natural disturbance events are applied randomly based on the estimated rates, and output interspersed with the harvesting and roading events.

2.6 Running CBM-CFS3

In general, default carbon dynamics assumptions were used when running CBM-CFS3 v1.2, as these were deemed to represent the most accurate carbon information available for this region (W. Kurz, pers. comm.).

To run CBM-CFS3 on a given scenario for a given sub-region involved first loading the prepared input files. During this process, leading species was specified as "special classifier" to link with internal species information. The region of application was the Pacific Maritime zone of BC. A singe spatial planning unit (SPU) was used. Once loaded, a scenario was simulated for the 250-year time horizon.

The main results assessed were annual carbon amounts (biomass, dead organic matter and total). Output indicators for "unrealized disturbance" and "area disturbed" were also used to ensure that the area specified for disturbance was actually achieved.

2.6.1 Parameters

Default values for all CBM-CFS3 parameters were applied (see spreadsheet in folder with associated CBM-CFS3 documentation) with one exception: the roading "disturbance matrices" were modified to be consistent with the parameters for wood products from harvesting (i.e. 85% of the merchantable volume assumed to transfer to wood products instead of the default of 97%).

2.6.2 Common non-contributing land base and potential operable land base

The "*common non-contributing*" land base was defined as the portion of productive forest that is outside the timber harvest land base (i.e. non-contributing) in *every* scenario. In general, this can be thought of as the non-contributing forest in the SBL2 scenario (but it's somewhat smaller due to reversal of some netdowns in TFL 39 from the Forestry Project that are superseded by current EBM objectives; see Fall 2007 for details). This common non-contributing land base has no harvest or roading activity modelled in any scenario, and hence has identical carbon dynamics. For efficiency, we separated this portion of the land base. In the previous analysis, we made a single run through CBM-CFS3 with no disturbance events. Since there are no potential carbon credits on this portion of the forest, we didn't assess it in the current analysis, as the same disturbance events are expected to occur in both the baseline and project scenarios.

We define the "*potential operable*" land base as the remainder of the forest after removing the common non-contributing. This includes forest that is included in the timber harvest land base of at least one scenario. In general, this can be thought of as the timber harvest land base of the SBL2 scenario (but it is somewhat larger due to reversing some netdowns in TFL 39 from the Forestry Project that were superseded by current EBM objectives). To ensure that carbon budget results can be compared among scenarios, all were run on the potential operable land base. Note that some of this is not harvested in some scenarios due to netdowns, such as conservancies and critical grizzly habitat, or forest cover constraints, such as old-growth targets.

2.7 Summary for process

The entire process of linking spatial timber supply with carbon budget modelling involved the following steps:

(i) Set up a land-use/management scenario in STSM, and perform a timber supply analysis as specified in Fall and Crockford (2006). This involves multiple simulations that converge on a harvest flow. The result is the maximum sustainable harvest flow for the scenario, consistent with policies used by Forest Analysis and Inventory Branch.

(ii) Re-run STSM for a single simulation, using an annual or decadal time step, and specify parameters to output spatial time series for stand age, timber harvest land base and analysis unit.

(iii) Run the static and dynamic translation models to generate CBM-CFS3 input files. Introduce natural disturbance events during this step.

(iv) Run CBM-CFS3 to load the input files, run the scenario, and generate carbon budget outputs.

A general overview of this process is shown in Figure 1. For a given study area (e.g. each of the sub-regions north, central, south1, south2 and Haida Gwaii), the age classes, classifiers & values and disturbance type files were identical. Each scenario had unique inventory, transitions, growth & yield and disturbance event files, and required a separate run of CBM- CFS3. Hence, for the each scenario, we needed to run this process once per sub-area.

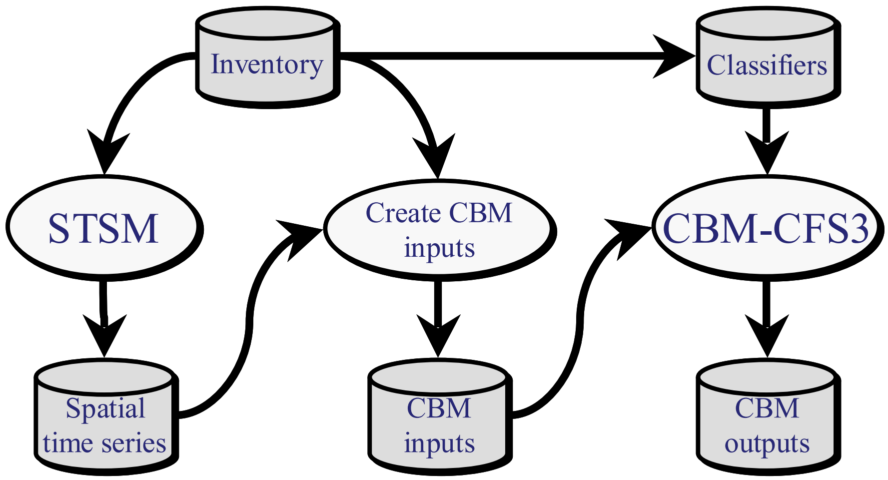

Figure 1. Overview of how the STSM spatial timber supply model was linked to the carbon budget model CBM-CFS3. Modelling tools are shown in ovals, data stores are shown as "drums" and data flow is shown as arrows. The static and dynamic translation models (implemented in SELES) are combined in the oval labelled "Create CBM inputs".

3 Conclusion

The two primary objectives of this analysis were (a) to develop a methodology to link spatial timber supply modelling with carbon budget modelling, specifically the STSM model applied in coastal BC and CBM-CFS3, and (b) to apply this methodology to generate estimated carbon dynamics under the land-use orders in the South-Central Coast, Central-North Coast and Haida Gwaii areas of British Columbia, under presumed management in the absence of these land-use orders, for the purpose of providing supporting information for decisions regarding potential carbon credits. This report addresses the first objective: namely the methods developed to make these assessments. Separate reports were produced for application areas.

The methodology presents a robust, general and reasonably streamlined approach to linking spatial timber supply and carbon budget analyses. This method has gone through a review process, and updates/refinements have been incorporated. The application quantifies estimates of carbon on this large landscape that result from the interaction of inventory, growth & yield estimates, modelled land-use objectives and forest activities, and carbon pool dynamics.

4 Literature Cited

Dorner, B. and C. Wong. 2003. Natural Disturbance Dynamics in Coastal British Columbia. Report to Coast Information Team.

Fall, A. 2007. DSP Decision Support Report 10 TFL 39 blocks 3, 5 and 7 Baseline Analysis. B.C. Report to Integrated Land Management Bureau, B.C. Ministry of Agriculture and Lands. Nanaimo, B.C.

Fall, A. 2009. DSP Decision Support Report 24. Analysis of Strategic Land-Use Objectives. B.C. Report to Integrated Land Management Bureau, B.C. Ministry of Agriculture and Lands. Nanaimo, B.C.

Fall, A. 2011a. Assessing Carbon Offset Potential of Land-Use Plans in Central-North Coastal BC. Report to Great Bear Initiative and Coastal First Nations, Vancouver, B.C.

Fall, A. 2011b. Assessing Carbon Offset Potential of Land-Use Plans in South-Central Coastal BC. Report to Great Bear Initiative and Coastal First Nations, Vancouver, B.C.

Fall, A. 2011c. Assessing Carbon Offset Potential of Land-Use Plans in Haida Gwaii, BC. Report to Great Bear Initiative and Coastal First Nations, Vancouver, B.C.

Fall, A. and D. Crockford. 2006. DSP Decision Support Report 1. B.C. Report to Integrated Land Management Bureau, B.C. Ministry of Agriculture and Lands. Nanaimo, B.C.

Fall, A, J. Sunde and N. Reynolds. 2009. Haida Gwaii Detailed Strategic Planning Decision Support. Analysis of 2009 Strategic Land-Use Objectives. Report to Haida First Nation, Haida Gwaii, and Integrated Land Management Bureau, B.C. Ministry of Agriculture and Lands. Nanaimo, B.C.

Kull, S.J., W.A. Kurz, G.J. Rampley, G.E. Banfied, R.K. Schivatcheva, and M.J. Apps. 2007. Operational-Scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). Version 1.0: User's Guide. Northern Forestry Centre, Natural Resources Canada. ISBN 978-0-662-47029-8.

Kurz, W.A., C.C. Dymond, T.M. White, G. Stinson, C.H. Shaw, G.J. Rampley, C. Smyth, B.N. Simpson, E.T. Neilson, J.A. Trofymow, J. Metsaranta, and M.J. Apps. 2009. CBM –CFS3: A model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecological Modelling 220: 480-504.

Williams, D and M Buell. 2006. Analysis of the Impact on Timber Supply and Critical Habitat of the Central Coast LRMP Government-to-Government Draft Proposed Interim Legal Objectives. Report to B.C. Ministry of Agriculture and Lands.