Executive Summary - Year 2

FIA-FSP Project Y092187

Evaluation of the Complex Stand Simulation Model SORTIE-ND for Timber Supply Review in Sub-Boreal Forests of Northern BC

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Project purpose and management implications:

The purpose of this study was to investigate the capabilities and short comings of SORTIE-ND as a predictive model for growth and stand dynamics in sub-boreal forests of central BC, especially those impacted by the Mountain Pine Beetle (MPB) epidemic. SORTIE-ND is an individual tree, spatially explicit model of stand dynamics that originated from the small scale disturbance model SORTIE developed and tested in the mid 1990's for transitional oak-northern hardwood forests in the northeastern US. SORTIE was designed to extrapolate fine-scale/short-term field measurements to large-scale, long-term forest dynamics. In recent years SORTIE was parameterized for mixed forests in northwestern British Columbia and modified to be better suited for dealing with management issues (SORTIE/BC). SORTIE/BC has recently been restructured and reprogrammed in C++. The result is SORTIE-ND (www.sortie-nd.org) where ND signifies the model's focus on local neighbourhood dynamics.

Forest dynamics is the change of forest composition and structure over time. The spatio-temporal development of forests may be described as changes of tree populations due to birth and colonization, growth and death of trees. SORTIE-ND uses a combination of empirical and mechanistic sub-models to predict forest dynamics based on field experiments that measure fine-scale and short-term interactions among individual trees. SORTIE-ND is designed to provide growth predictions for individual trees in multi-species complex structured stands. The model is especially well suited for growth predictions in stands impacted by the MPB epidemic.

For a model to be used in timber supply analysis it is important that the model is evaluated and that efforts are made to obtain unbiased model predictions. Evaluation is defined as a process in which a model's conceptual structure and predictions are described and assessed with regard to a specific purpose, for example, individual tree or stand-level growth attributes. This definition encompasses what is often referred to as validation and verification in the modeling community. SORTIE-ND has been parameterized based on field experiments. Parameterization is the process in which the parameters in an equation are fitted to a dataset. The model has not been calibrated to independent data. Calibration is the processes in which the predictions from a model are compared with observations and afterwards one or more parameters in the model are changed to produce predictions that match the observations. The intent of this project is to evaluate overall model performance and determine if calibration of SORTIE-ND is desirable from the perspective of supporting timber supply analysis.

Project start date, length of project, former project numbers or funding sources:
This project started in April 2007 under Project number Y081187. It is a three year project, with one year remaining. The project is scheduled to be completed at the end of March 2010. This report represents accomplishments during the second fiscal year, ending March 31, 2009.

Methodology overview:
Long-term objectives of the project were to: (1) compare model predictions to independent observations of growth from permanent sample plots or other sources of long-term data. This will provide information on ranges of accuracy and precision of stand level predictions; (2) provide users with information on the model performance and model developers with knowledge on where to concentrate further model development; (3) have SORTIE-ND accepted as a model that can be used for planning silvicultural treatments including their impacts on Timber Supply Review. The emphasis will be using the model in complex structured stands resulting from the MPB epidemic, especially for prediction of mid-term timber supply opportunities; and (4) calibrate SORTIE-ND, if necessary, for use in the timber supply analysis.

The work to be performed in the second year was: (1) complete the sensitivity analysis and use the results to select behaviours that most influence model results; (2) compile and summarize independent datasets that can be used to compare with model predictions; (3) run model simulations of the independent datasets and compare results at the individual tree and stand scales; (4) calibrate different behaviours and determine model parameters that result in close alignment with independent datasets; and (5) begin to develop a SORTIE-ND website n the BV Research Centre website (www.bvcentre.ca).

We will use different forms of statistical and graphic description to characterize how the SORTIE-ND model predictions conform to independent data. Model predictions will be compared to general expectations for the stand development in sub-boreal spruce stands. This will be done to identify if obvious structural limitations exist in the model.

The sensitivity analysis will provide information on the model's sensitivity to uncertainty about the parameter estimates. This analysis will indicate which parameters have the greatest influence on predictions. The sensitivity analysis will be performed with a Monte Carlo approach where all parameters are varied simultaneously and the parameter value for each model run is determined by a random draw from a distribution. The span of predicted values following a Monte Carlo style sensitivity analysis gives an indication of the error in the model predictions created due to uncertainty about the input parameters, however, this result does not directly yield a ranking of the importance of input parameters. To get at this issue, we will use regression analysis to identify and rank the most important parameters following a Monte Carlo type sensitivity analysis.

Model predictions will be compared to independent observations of growth from permanent sample plots (PSP) located in the sub-boreal spruce zone. We will use the BC Forest Service PSP database to find independent repeatedly measured plots to compare with SORTIE-ND predictions. Selected plots must: be located in the sub-boreal spruce zone; have data for at least 20-yrs; be dominated by spruce, subalpine fir, lodgepole pine or aspen. SORTIE-ND field studies used to parameterize the model were predominately from mesic sites. Comparisons will be based on PSP data from more-or-less mesic sites.

As required, the model behaviours will be calibrated by altering key model parameters. Choice of behaviours and parameters to be modified will be based on comparisons of individual tree and stand-level growth predictions from the model against growth in the PSP and growth of single-species stands projected by TISPY.

Project scope and regional applicability:
This project will be of most interest to researchers and forest professionals practicing in the central interior of BC. A special emphasis is being placed on sub-boreal spruce forests impacted by the MPB epidemic. The results of this study will also be of interest to timber supply analysts working on timber supply review for management units impacted by the MPB.

Interim conclusions:
1. Sensitivity analysis of the model (Appendix 1)
The sensitivity analysis was carried out on two general stand types common to northern BC. The first stand type was a mixed aspen-spruce stand with 7000 stems per hectare aspen with a mean diameter of 2cm and 1000 spruce seedlings between 35 and 50 cm tall. The second stand type was a pine-dominated stand that had undergone MPB attack. MPB was assumed to kill all pine trees larger than 8 cm in diameter leaving 1550 snags per hectare and a snag basal area of 26.3 m^2/ha. The remaining secondary structure was dominated by spruce and subalpine fir with minor components of pine and aspen. Understory density (<1.3 m tall) at the start of the simulations was 570 seedlings per hectare (spruce = 266, pine = 9, subalpine fir = 284, aspen = 14). The basal area larger secondary structure was 5.9 m^2/ha – representing a total of 650 stems per hectare. For each stand type 1000 simulations were completed where parameter values were randomly drawn from a uniform distribution bounded at plus minus 10% of the original value.

The sensitivity analysis illustrated that relatively small levels of uncertainty about parameter estimates can lead to large levels of variation in model predictions. SORTIE-ND model predictions were most sensitive to small changes in the adult NCI growth parameters (especially alpha) and the allometry parameters.

2. General test of model dynamics
In these simulations we looked carefully at 3 stages of stand development: a) early growth in young stand, up to 40 years old; b) intermediate stage, 40-100 yrs; and c) older stands, 100 yrs +. We varied initial densities (800 to 7200 sph) and species composition. We found undesirable model behaviour in mixed stands at higher densities where spruce and/or pine in combination with subalpine fir experienced considerably higher than

expected mortality rates resulting in unusual successional dynamics (Fig 1.). This dynamic was easily fixed with a minor adjustment to the adult competitive mortality function.

3. Comparisons of projected growth of single-species plantations of varying densities in SORTIE-ND compared to TIPSY projections.

Stand-level growth of lodgepole pine, interior spruce and subalpine fir single species stands in SORTIE-ND were consistent with projections by TIPSY. Growth projections were very similar at intermediate densities (1000-2000 sph). The greatest variation occurred at lower or higher densities than 1000-2000 sph.

4. Comparisons of projected growth and mortality in SORTIE-ND compared to independent Permanent Sample Plots (PSP) datasets.

A total of 54 PSP plots that were situated in (or compatible with) the SBSmc2 subzone variant were selected. The PSP plots were previously measured at approximately 10 years interval for a period of 30 years. The initial conditions for each plot were replicated in SORTIE-ND and the model was run for 30 year in each case and the model outputs values were compared with the PSP results.

Stand level

We assessed model capabilities at stand level with comparisons of diameter distributions (for example, see Fig. 2).

Stand level comparison of SORTIE-ND growth and mortality to that observed in PSP resulted in the following general observations.

1. Pine mortality rates were much higher in PSP than SORTIE-ND.
2. Stand-level basal area values where pine makes up a lot of the plot don't mean much.
3. Spruce, subalpine fir and aspen mortality rates were fairly similar between SORTIE-ND and the PSP.
4. Pine growth looks pretty good when stands are dominated by pine: plots 1, 2, 3, 4, 6, 7, 12, 29, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 54, 55, 66, 184, 186, 187, 200, 222.
5. Pine growth is maybe a little too slow when mixed with lots of spruce: plots 27, 33, 70, 78, 87, 165, 166, 222.
6. If aspen is mixed with the spruce, then pine growth is about right: plot 180.
7. Spruce growth seems to vary a bit depending on composition.
    a) spruce growth looks pretty good when spruce dominates the composition: plots 24, 26, 27, 78, 87.
    b) spruce growth seems high with lots of pine: plots 2, 6, 10, 47, 48, 54, 79, 165, 166, 184.
    c) spruce growth seems pretty good when some aspen is mixed in with the pine: plots 11, 12, 14, 20, 32.
    d) spruce growth seems high with lots of aspen: plots 220, 222.
    e) spruce growth seems pretty good: plots 3, 33, 55, 70, 187.
8. Aspen growth is way too high when mixed with lots of pine: plots 7, 11, 14, 15, 16, 17, 18, 20, 32, 49, 165, 184, 200, 220.
9. Aspen growth looks pretty good when mixed with pine: plot 9.

10. Aspen growth is about right when mixed with pine and spruce: plots 12, 222.
11. Aspen growth is about right when mixed with spruce: plots 24, 78, 87, 180.
12. Aspen growth seems high when mixed with lots of spruce and some pine: plots 79, 165, 166.
13. Small spruce trees may be growing too fast; plots 12, 13, 78, 79, 87, 165.
14. We have very little data on subalpine fir from the PSP.

Individual tree level

The next step in the model evaluation consisted in testing the model capabilities of representing individual tree growth (diameter growth increment of individual trees). We selected 12 representative PSP plots for detailed analysis. The model outputs were used to calculate the diameter growth increment per 2 cm diameter classes for each species. Results from this analysis supported those of the stand-level analysis and provided additional useful information. For example, small aspen trees generally grew much faster in SORTIE-ND than in the PSP. However, growth of larger aspen trees was similar in SORTIE-ND and the PSP (Fig. 3).

5. Species-specific calibration options.

Based on the sensitivity analysis, the test of general model dynamics and comparisons with TIPSY and PSP datasets we identified the adult competitive mortality behaviour and components of the neighbourhood adult tree growth behaviour as the most likely behaviours for calibration. The adult competitive mortality behaviour is directly linked to the growth behaviour – slow growing trees are more likely to die. The neighbourhood adult tree growth behaviour is a complex function with many components. In particular, we focused on the lambda function and the size function. Mini-sensitivity analysis of these behaviours suggested ways to better align SORTIE-ND growth predictions with actual growth from the PSP.

6. Calibration of the SORTIE-ND model.

We have commenced calibration of individual behaviours. The next step is to examine the effectiveness of different calibration options. We will then subject a fully calibrated parameter file to a general test of model dynamics. This will occur in the third year of the project.

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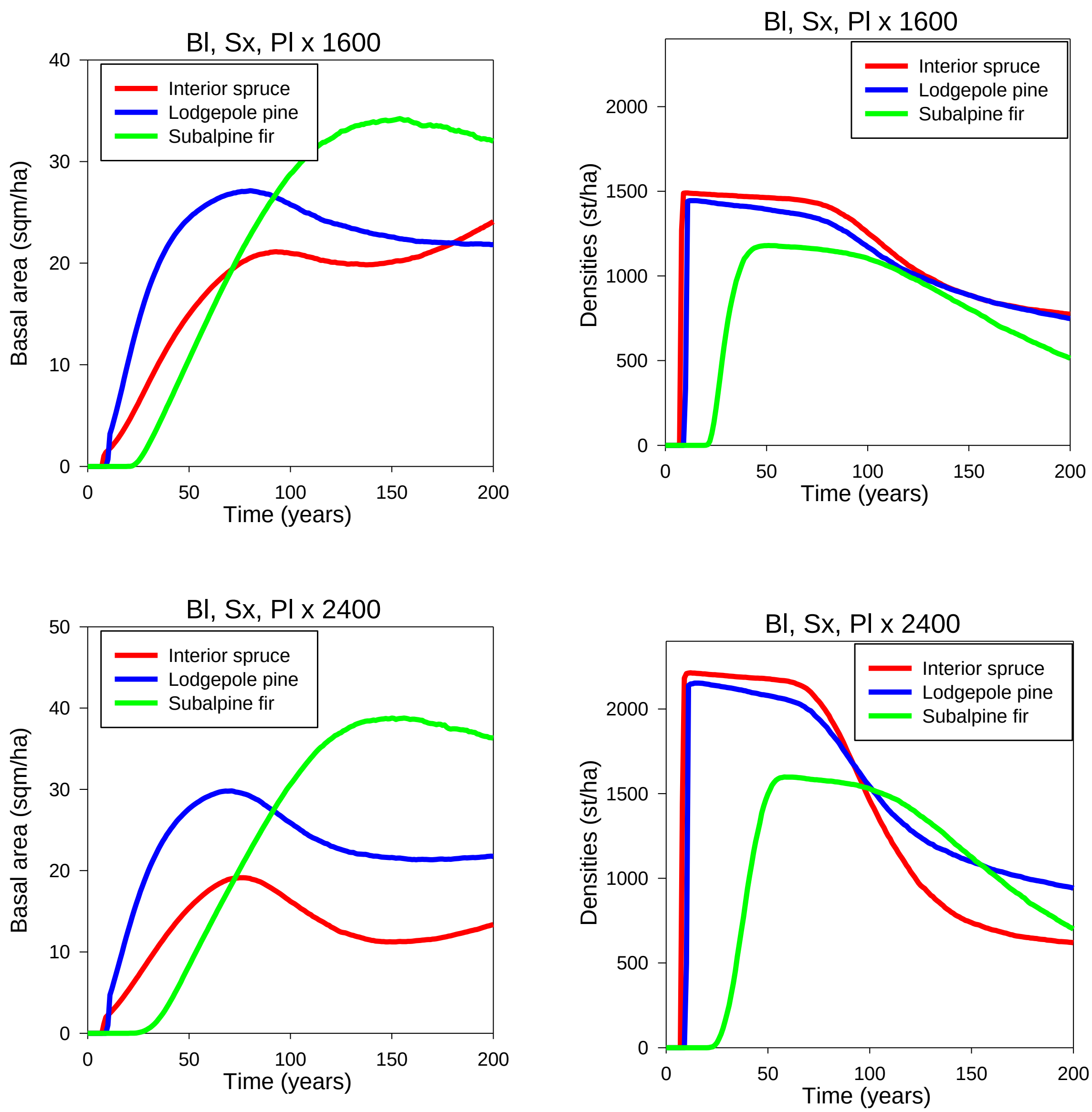


Fig 1 SORTIE outputs of Basal area (left) and densities (right) for the selected species as high density indicating unexpected dynamics.

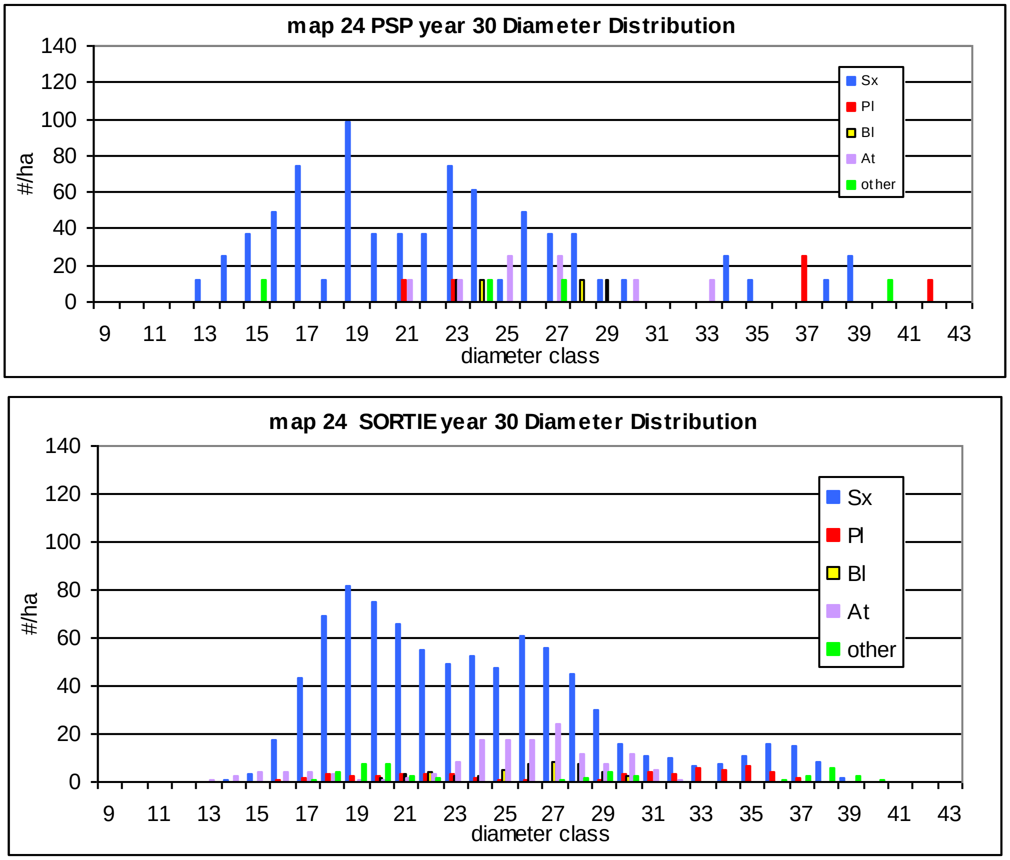
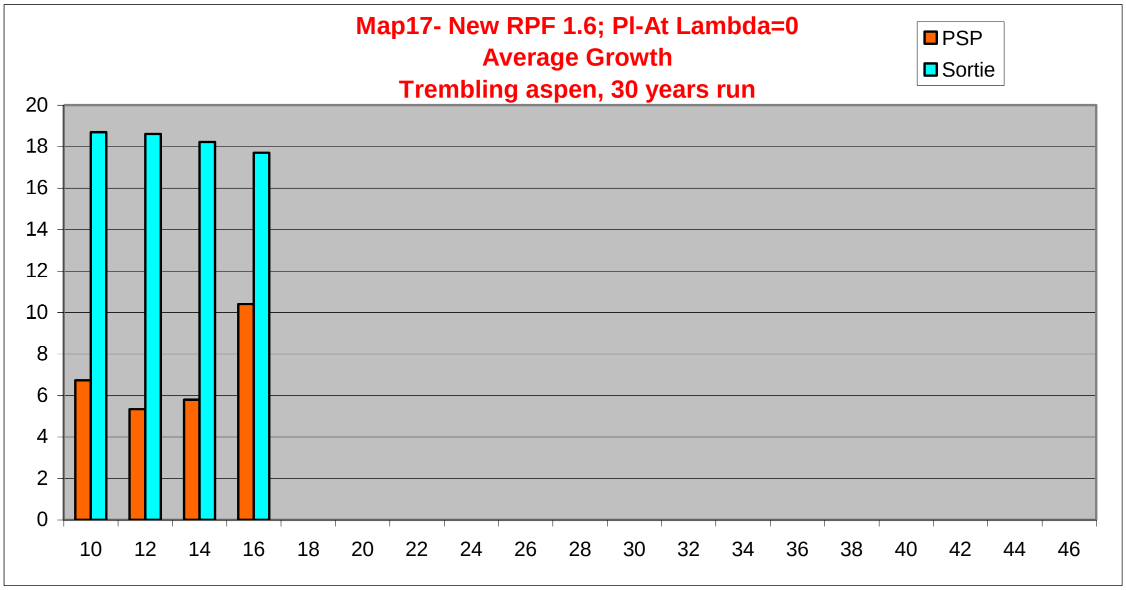


Fig. 2 Diameter distributions comparison by species in PSP plot (map) 24 and SORTIE output at year 30.



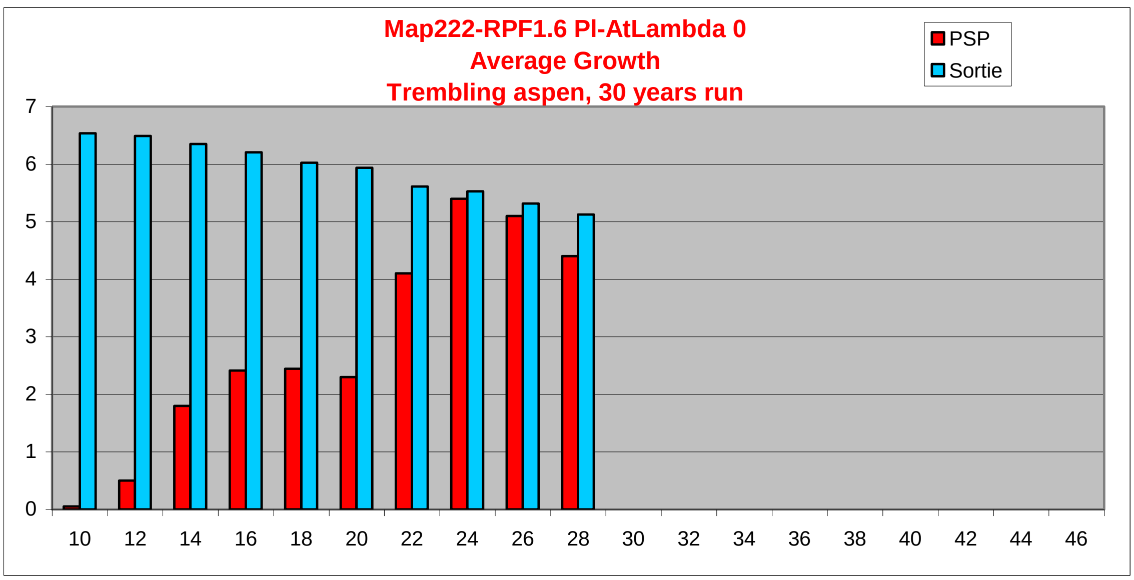


Fig. 3 Comparison between PSP and SORTIE outputs of growth behaviour over 30 year run for aspen in plot (maps) 17 and 222.