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

FSP No.: Y09-3187

Project Description: The purpose of this study is 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 (Pacala et al. 1996). SORTIE was designed to extrapolate fine-scale/short-term field measurements to large-scale, long-term forest dynamics (Pacala et al. 1996). 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; Coates et al. 2004). 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. The model structure is that of an ecological model rather than a traditional empirical growth and yield model. This model structure makes SORTIE-ND well suited for growth prediction in complex stands and recent model development (snag dynamics sub-model developed with a recent FSP grant) have made the model especially suited for growth predictions in complex structured MPB attacked stands.

In order to practice sustainable forest management, it is a necessity to have growth models that can project future growth of stand types, including complex structured stands. A given growth model can never be good at predicting growth under all the different stand conditions found throughout BC in natural and managed stands. Thus, it is important to have a host of models that each have there strengths and weaknesses but can be utilized under the conditions where they are most suitable. In this way, SORTIE-ND would provide a good addition to the models that currently are most frequently used for timber supply analysis in BC. 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, volume development of MPB affected stands over time. Consequently, this definition encompasses what is often referred to as validation and verification in the modeling community.

Currently, SORTIE-ND is parameterized, but not calibrated. Parameterization is the process in which the parameters in an equation are fitted to a dataset. 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. Most traditional growth and yield models have some kind of calibration performed in order to make the predictions realistic. Equally, SORTIE-ND will likely conform better with, for example, permanent sample plot (PSP) data if the model was calibrated. Calibration is, however, against the basic ideas from which the model was developed. As a research tool used to understand basic ecological questions such as successional dynamics, calibration is not appropriate as is does not necessarily allocate the changes to the correct processes. For predicting growth for Timber Supply Review the calibration of SORTIE-ND is more appealing since it could reduce biases in critical predictions, for example, volume development over time. 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.

The topic of model evaluation and validation has a rich literature. For example, a recent paper by Pinjuv et al. (2006) discusses an approach to the quantitative validation and comparison of different forest growth models. We will carefully review this paper and other related literature for insights into how to best evaluate a complex hybrid forest dynamics model like SORTIE-ND.

Coates, K.D. Canham, C.D., Beaudet, M., Sachs, D.L. & Messier, C. 2003. Use of a spatially explicit individual-tree model (SORTIE/BC) to explore the implications of patchiness in structurally complex forests. For. Ecol. Manag. 186(1-3): 297-310.

Pacala, S.W., Canham, C.D., Saponara, J., Silander, J.A., Jr., Kobe, R.K, Ribbens, E. 1996. Forest models defined by field measurements: II. Estimation, error analysis and dynamics. Ecol. Monogr. 66:1-43.

Pinjuv, G., Mason, E.G., Watt, M. 2006. Quantitative validation and comparison of a range of forest growth models. Ecol. Manag. 236:37-46.

Project Objective: Long Term Objectives:

(1) To 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) To provide users with information on the model performance and model developers with knowledge on where to concentrate further model development.
(3) To 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.
(4) To calibrate SORTIE-ND, if necessary, for use in the timber supply analysis.

Current Year (2009-2010) Objectives:
(1) Determine availability and accumulate independent datasets that can be used to compare with model predictions.
(2) Compare model simulation results to independent datasets and determine need for calibration.
(3) Using results from the sensitivity analysis select behaviours that most influence model results.
(4) Calibrate different behaviours and determine model parameters that result in close alignment with independent datasets.

Experimental Design and Methods: There have been no significant changes to the methods proposed for the third year.

There are many tests designed for model validation (Kleijnen 1999; Yang et al. 2004). Most tests are designed to compare model predictions with independent observations. Since we know a priori that a model is false it makes little sense to test that the two are the same (Reynolds and Chung 1986). Statistical tests will have a limited role in our evaluation. The alternative to statistical tests is statistical estimation and description (Reynolds and Chung 1986). Statistical description can be more informative than statistical tests and it leaves the choice of acceptability up to the individual user. We will use different forms of statistical and graphic description to characterize how the SORTIE-ND model predictions conform to independent data. The evaluation proposed in this study will not result in a simple “yes or no” answer.

First, the model will be evaluated in terms of its logic and conceptual structure. We will explore the conceptual structure of the model for gaps in realistic representations of forest stands. This will be done by identifying model structures that result in counterintuitive growth patterns. 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.

Second, a sensitivity analysis will be performed. Sensitivity analysis is an important part of model evaluation (Vanclay and Skovsgaard 1997; Kleijnen 1999). This will provide information on the model's sensitivity to uncertainty about the parameter estimates and will indicate the parameters with 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 (e.g. Lexer and Hönninger 2004). The alternative to the Monte Carlo approach is to vary one parameter at the time. This is a simple approach, but does not detect interactions between different factors (e.g. Kleijnen 1999; Frey and Patil 2002). This type of sensitivity analysis is often used to rank the importance of factors, but for nonlinear models it is not certain that a reliable rank ordering of factors is provided (Frey and Patil 2002). In the majority of cases there is a superior approach to varying one factor at the time (Montgomery 1997). 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 (Frey and Patil 2002).

The results from the sensitivity analysis will be assessed in two steps. First, an analysis will assess the amplitude of variability caused by uncertainty in parameter estimates. This will be performed through visual assessment of species-specific plot results (e.g., basal area, stems/ha). The second step of the analysis will rank the relative importance of parameters on, for example, final basal area or stems/ha. Each of the output variables will be regressed against the predictor variables and the parameters ranked according to R2.

Third, model predictions will be compared to independent observations of growth from permanent sample plots (PSP) located in the sub-boreal spruce zone. This will provide graphic description and summary statistics on the ranges of accuracy and precision of stand level predictions. 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. Thus, initial comparisons will be based on PSP data and SORTIE-ND predictions on mesic sites followed by dryer and then wetter sites.

Lastly, we will calibrate the model to the PSP data by altering key model parameters. Choice of parameters will be partly based on the sensitivity analysis and partly on

knowledge of the model structure. For the calibrated model, we will calculate the summary statistics and redo the graphics that were produced for the non-calibrated model. The change in predictions due to calibration can then be assessed by comparison of summary statistics and graphical products. We will present this comparison to Forest Analysis Branch staff and the choice of the calibrated or non-calibrated model can be made by the individual user.

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