



# SORTIE-ND: A growth and yield model for complex mixed-species stands

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**S**ORTIE-ND is an individual-tree, spatially explicit model of forest dynamics which is being used and adapted in many corners of the world to simulate how complex mixed-species stands grow and develop. This emphasis on multi-species, complex-structured stands makes this model different from most traditional growth and yield models, which focus on single-species stands under even-aged conditions. With SORTIE-ND, model behaviours and related parameters are user defined; this means the model can be adapted to a wide range of specific conditions.

The original SORTIE model, which was developed and tested in the early 1990s in the northeastern United States for transitional oak-northern hardwood forests, was brought to British Columbia by **Dave Coates** (BC Ministry of Forests and Range) and others to help study the transitional Interior Cedar–Hemlock (ICH) forests of northwestern British Columbia. It is currently fully parameterized for portions of the ICH and Sub-boreal Spruce (SBS) zones in Northern BC, and extensive work is underway on the southern ICH and Montane Spruce (MS) zones.

In the early 2000s, the model was restructured and reprogrammed and its name changed to SORTIE-ND to focus on local neighbourhood dynamics (ND). The model is designed to predict growth for individual species in multi-species, complex-structured stands and to study neighbourhood processes.

SORTIE-ND is primarily a research model that uses experimentation to determine the fine-scale and short-term interactions between individual trees. “As a research model, it is developing an understanding of the processes driving recruitment, growth, and survival of individuals as a function of local neighbourhood conditions that is most important,” notes Coates.

The model has the flexibility to incorporate new research findings as new behaviours, thereby allowing it to keep evolving. The model is not deterministic in that it allows the development of complex behaviour by using rules that describe the

interactions with other individuals or the environment.

Many research projects, including those funded by the Forest Investment Account–Forest Science Program (FSP), as well as other funding sources, have been conducted to parameterize, refine, and improve the model as well as to test its use. This article describes some of those projects.

## Predicting development and productivity of Southern Interior mixed-species stands following mountain pine beetle attack

Time was of the essence with this 2-year study initiated in 2006 to parameterize the SORTIE-ND model for MS zone stands in the Southern Interior of British Columbia. With the mountain pine beetle (MPB) infestation and follow-up salvage harvesting sweeping across the region, available sample stands with the range of characteristics necessary to properly parameterize the model were quickly becoming scarce. This was especially true for those stands containing mature lodgepole pine. With sampling focused on Interior spruce, subalpine fir, and lodgepole pine, **Suzanne Simard** (University of British Columbia) and her team quantified the growth response of juvenile trees (< 10-cm diameter) growing under variable light environments, characterized the probability of juvenile tree mortality, and investigated the effects of competition on the growth and survival of adult trees (> 10-cm diameter). This data was used to complete an initial parameterization of SORTIE-ND for Southern Interior MS mixtures.

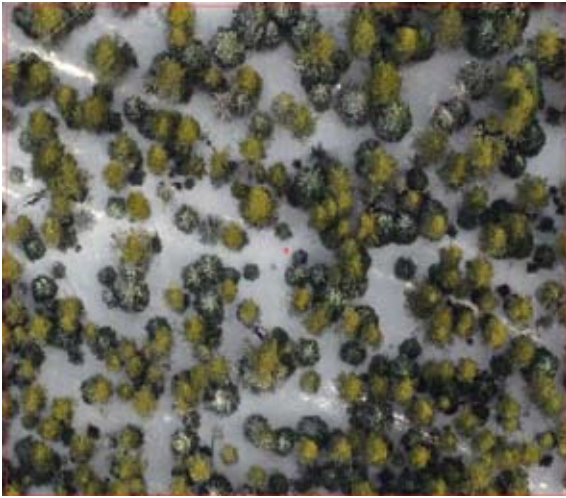
The research team then used the model to observe and quantify how these stands will develop following a mountain pine beetle attack. Preliminary results from one simulation indicated that the understory species (Interior spruce and subalpine fir) will gradually release as the overstorey pine die, lose their needles, and eventually fall. The simulation also showed that spruce responds more favorably than subalpine fir to the increase in light resources. Two other simulations to determine the ideal timing for underplanting in MPB-affected stands indicated that seedlings planted 9 years post-MPB attack have less seedling mortality and grow faster than

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Example of a high-resolution aerial photograph taken during overcast conditions in late winter.

seedlings planted one year post-MPB due to improved light conditions during seedling establishment. More details on the simulations are included in the final technical report for this project ([www.for.gov.bc.ca/hfd/library/FIA/2008/FSP\\_M086020.pdf](http://www.for.gov.bc.ca/hfd/library/FIA/2008/FSP_M086020.pdf)). This project also received FSP funding through to 2010 to gather additional data for lodgepole pine and

also gather parameter data on trembling aspen and Douglas-fir.

### Predicting development and productivity of Southern Interior mixed-species stands through calibration and modelling

Similar to the project described above, Suzanne Simard undertook a 3-year project, from 2004–2007 to parameterize the SORTIE-ND model for the ICH zone in the Southern Interior of British Columbia. Data was collected for paper birch, western redcedar, Douglas-fir, western hemlock, and lodgepole pine. Unfortunately, due to the species' extreme shade intolerance, researchers were unable to find sufficient numbers of western larch growing in the necessary range of neighbourhoods and could not parameterize the model for this species. The parameterized model was used to examine how complex stands respond to a range of silvicultural strategies at different spatial scales and time periods.

For more information on these two projects, contact [suzanne.simard@ubc.ca](mailto:suzanne.simard@ubc.ca)

### Evaluation of the complex stand simulation model SORTIE-ND for timber supply review in sub-boreal forests of northern BC

As described in the introduction of this article, SORTIE-ND is primarily a research model and, as such, is parameterized, but not calibrated. Parameterization is the process by which parameters in an equation are fitted to a dataset. In calibration, predictions are compared with observations and model parameters are then changed to produce predictions that match the observations (Coates et al. 2009).

The intent of this 3-year project, initiated in 2007 by Dave Coates and his team, was to evaluate and

assess SORTIE-ND for use in stands especially impacted by the mountain pine beetle and to determine if calibrating the model is desirable from the perspective of supporting timber supply analysis. Sensitivity analysis, completed for two stand types common to northern BC, revealed that small levels of uncertainty about parameter estimates can lead to large levels of variation in model predictions. Work on model dynamics found some undesirable model behaviour in high-density mixed stands. This was corrected through a minor adjustment to the adult competitive mortality function. Growth predictions for single-species plantations between TIPSY (Table Interpolation Program for Stand Yields) and SORTIE-ND were comparable at intermediate densities (1000–2000 stems per hectare). Results of the comparison of SORTIE-ND growth projections with observations from permanent sample plots were highly variable at both the stand- and individual-tree level, depending on the mix and age of the species. Result details can be found in the executive summary ([http://bvcentre.ca/files/SORTIE-ND\\_reports/SORTIE-ND\\_Executive\\_Summary\\_Year\\_End\\_Report\\_April\\_2009.pdf](http://bvcentre.ca/files/SORTIE-ND_reports/SORTIE-ND_Executive_Summary_Year_End_Report_April_2009.pdf)) for year 2 of this project. Using the results of the previous analyses, calibration of the model is continuing and is expected to be completed by March 31, 2010. For more information contact [dave.doates@gov.bc.ca](mailto:dave.doates@gov.bc.ca)

### Development of a spatially explicit crown allometry model

According to researcher **Hilary Thorpe** (University of British Columbia), one of the major weaknesses with the current version of SORTIE-ND is that tree crown size is predicted independently of spatial “neighbourhood” conditions. This causes the model generally to overestimate light levels in sparse stands and to underestimate light levels in dense stands, which can lead to inaccurate predictions of the growth of regenerating trees.

Therefore, the goal of this project was to develop and parameterize a new, competition-dependent crown model for subalpine fir, lodgepole pine, and Interior spruce that could be implemented in SORTIE-ND. Results from the study confirmed that the effect of competition on crown dimensions was strong, with all species showing declines in predicted crown size as neighbourhood competition increased. However, the study also found wide variation among the three species in their sensitivity to competition depending on the size, species, and abundance of neighbouring trees.



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Thorpe notes that this “highlights the complexity of competitive interactions, even in species-poor ecosystems such as the boreal.” Besides improving the predictive ability of the SORTIE-ND model, results from this study will help forest managers design silvicultural treatments that maximize positive interactions among neighbours. For example, trees in high-competition environments were consistently associated with larger-than-predicted crown sizes in mixed-species scenarios than in monocultures, suggesting that forest productivity may be improved by encouraging mixed-species stands. More study details and results can be found in the Final Technical report ([http://bvcentre.ca/files/research\\_reports/08-10FinalTechnicalReport.pdf](http://bvcentre.ca/files/research_reports/08-10FinalTechnicalReport.pdf)) and in the related manuscript (Thorpe et al., in review) currently in review at *Forest Ecology and Management*. For more information about this study or to request a copy of the manuscript, contact [hilary.thorpe@ubc.ca](mailto:hilary.thorpe@ubc.ca)

### Crown competition and efficiency, tree growth, and site type: Quantification with terrestrial LiDAR

To improve the predictive ability of SORTIE-ND, additional information is needed on the key processes that govern individual tree performance. This 3-year study, initiated in 2008 by **Bruce Larson** (University of British Columbia), looks at how tree growth in complex stands is affected by competition for growing space, nutrients, and moisture. It is also examining the spatial pattern of neighbourhood trees of different canopy positions and aims to provide more data on some of the basic relationships that are required to predict growth and stand development. Findings from this study could result in new behaviours being added to the SORTIE-ND model and may also aid in model testing and validation. For more information on this project contact [bruce.larson@ubc.ca](mailto:bruce.larson@ubc.ca)

### Effect of site type and stand structure on the relationship between growth and light availability for understory trees

To predict the growth of complex stands, it is essential to understand the factors controlling the growth of the understory trees. The primary objective of this project, conducted by **Erica Lilles** (Bulkley Valley Research Centre), is to understand how light availability, site type, and canopy structure influence understory tree growth in sub-boreal forests and to develop statistical models that can be used, in conjunction with simulation models, to predict understory tree growth. These models will be incorporated into SORTIE-ND to

improve projections of understory tree growth in complex stands. The new models could also be used on their own as a decision-support tool for silviculture decisions in complex stands. A draft manuscript titled “Multiple Resource Limitation of Sapling Growth in Sub-boreal Forests” is in preparation. For more information on this project contact [erica.lilles@bvcentre.ca](mailto:erica.lilles@bvcentre.ca) or [dave.coates@gov.bc.ca](mailto:dave.coates@gov.bc.ca)

### Effect of site type on competitive interactions among trees in complex-structured, mixed-species, sub-boreal forests

Maximum potential growth rates increase and below-ground competitive effects decrease as soil nutrient availability increases and the magnitude of these effects varies by tree species. This was the main conclusion from a project led by Dave Coates and completed in 2008 to answer the question of how soil resources affect above- and below-ground competitive interactions among trees. The study noted that soil-nutrient availability had little effect on the light-growth relationship (above-ground competition). Research on this topic had been limited, even though nutrient availability and below-ground competition is thought to be one of the major influences on forest stand dynamics. Models developed from the data gathered are being incorporated into SORTIE-ND, which should increase the accuracy of tree-growth predictions across a gradient of soil nutrient availability. A project poster ([http://bvcentre.ca/files/research\\_reports/07-06StemMappingPoster.pdf](http://bvcentre.ca/files/research_reports/07-06StemMappingPoster.pdf)) provides more detailed results.

The second part of this study investigated the use of high-resolution, visible-spectrum aerial images taken in the winter under overcast conditions and with ground snow cover to increase the accuracy of identifying and extracting measurement data on individual tree crowns. This technique proved to be more effective than summer photography (both under sunny and cloudy conditions) as the winter snow obscured the ground cover while the overcast conditions minimized the loss of smaller trees due to shading. However, timing of the photography is critical to ensure that there is no snow on the trees. A technical report covering both aspects of this project is currently in production. For more information on this project contact [dave.coates@gov.bc.ca](mailto:dave.coates@gov.bc.ca)

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### Growth and release of understorey trees in partially cut pine stands EP591

Uncertainty in the successional patterns and response of understorey spruce in lodgepole pine stands following mountain pine beetle attack is a significant concern for natural resource managers in British Columbia. Knowledge on this topic is essential for predicting forest dynamics and determining future timber supply. This project, led by Dave Coates, will compile and analyze growth data from four remeasurements of a trial (EP591) established in 1962 to investigate the development of planted, seeded, and naturally regenerated spruce seedlings in a partially harvested lodgepole pine stand. The pine trees in the trial have also recently been attacked by mountain pine beetle. This study, which should be completed in 2010, will help to improve our understanding of:

1. understorey tree growth and release after disturbance, including partial cutting,
2. complex stand management, and
3. different silviculture systems and their effects on growth and yield.

The data from this trial will also be used to help evaluate the SORTIE-ND model. For more information on this project contact [dave.coates@gov.bc.ca](mailto:dave.coates@gov.bc.ca)


### Regeneration and stand structure following mountain pine beetle infestation in the Sub-boreal Spruce zone

“MPB-disturbed forests are undergoing a substantial shift in landscape-level species composition” (Astrup et al. 2008). This was the major conclusion from a study that examined seedling recruitment in lodgepole pine stands impacted by mountain pine beetle.

The study, led by Dave Coates and completed in 2008, looked at seed source availability, seedbed substrate, overstorey structure, and time since MPB attack. Results of the study indicated that recruitment post-MPB was sparse. Subalpine fir was the dominant species, increasing as the parent-tree basal area and proximity to a major seed source increased. This resulted in a patchy distribution for this species. Recruitment of lodgepole pine and Interior spruce seedlings decreased as overstorey basal area increased. However, seedbed substrate

was the major factor influencing post-MPB seedling recruitment for all species. Seedbeds in the stands studied were dominated by moss, which is known to be a poor substrate in northern forests (Astrup et al. 2008). In addition, no pulse of regeneration up to 10 years post-MPB attack was evident and the researchers noted that unless this changes, the species composition of these stands will likely shift to mostly sub-alpine fir. Data from this study will also be used to refine the SORTIE-ND model. For more information on the results of this project refer to the cited journal article or contact [dave.coates@gov.bc.ca](mailto:dave.coates@gov.bc.ca)

Information on a couple of other research projects has been previously published in *LINK*. A project “Modelling light, site quality, and crowding effects on growth of understorey subalpine fir in lodgepole pine forests” by Suzanne Simard, which also added to the SORTIE-ND knowledge base, was recently described in *LINK* 10(3) ([www.forrex.org/publications/LINK/ISS53/vol10\\_no3\\_art3.pdf](http://www.forrex.org/publications/LINK/ISS53/vol10_no3_art3.pdf)) while information on the project “Using SORTIE-ND for predicting climate change impacts on tree regeneration” by Craig Nitschke was published in *LINK* 9(3) ([www.forrex.org/publications/link/ISS50/vol9\\_no3\\_art2.pdf](http://www.forrex.org/publications/link/ISS50/vol9_no3_art2.pdf)).

For more details on these projects and others and for more information on the SORTIE-ND model, please visit [www.bvcentre.ca/sortie-nd](http://www.bvcentre.ca/sortie-nd) and <http://www.sortie-nd.org/index.html> 

### References

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