Using the Monte Carlo Method to Quantify Uncertainty in Predictions of a Soil Carbon Cycle Model in Balsam Fir (*Abies balsamea* (L.) Mill.) and Black Spruce (*Picea mariana* (Mill.) B.S.P.) Forest Ecosystems in the Boreal Forest

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EXTENDED ABSTRACT

The majority of process-based models of the carbon cycle in forest ecosystems are deterministic. Very few components have been implemented in these models to represent the uncertainty that may result from natural variation, model structure and parameter estimates. There are many sources of natural variation in the carbon cycle of forest ecosystems. The main sources of variation occur in the soil organic matter (SOM) in terms of quantity and quality, both of which vary according to vegetation type, climatic conditions, soil characteristics (texture and structure) and carbon fluxes. For instance, the litterfall rate and periodicity influence significantly the carbon input in the soil organic and mineral horizons. The litter carbon and nutrient contents affect both the SOM turnover and nutrient cycling rates. While a proportion of the natural variation observed may be explained by the differences in species composition, climatic conditions or soil characteristics, the amplitude of natural variation can nevertheless be important within a forest ecosystem due to the importance of extreme small-scale natural variations in soil characteristics and microclimatic conditions. Models can theoretically capture the last type of variation by using many variables in the description of the processes. However, the use of many variables may be impractical. The more variables and parameters a model contains, the more likely its capacity of application to simulate the carbon cycle for different forest ecosystem types will decrease. Thus, there has to be a compromise between the number of variables that must be included in a model and its intended use. On the other hand, the interactions among site variables also contribute to creating the stochasticity observed in forest ecosystems. These facts highlight the necessity of integrating stochasticity components in carbon cycle models to better deal with uncertainty.

The amplitude of uncertainty in model predictions may be important and have an effect on the degree to which a model is sensitive to relatively small variations in the inputs. As the development of forest management policies relies more and more on the use of models, it is essential that policy makers have good estimates of the level of uncertainty in the predictions. Several approaches based on Monte Carlo simulations can be used to quantify uncertainty. However, for a complex dynamic model that contains several state variables and fluxes, the application of Monte Carlo methods can be cumbersome.

For the present study, we discuss uncertainty and sensitivity issues by applying the Monte Carlo method to a soil carbon cycle model developed for balsam fir (*Abies balsamea* (L.) Mill.) and black spruce (*Picea mariana* (Mill.) B.S.P.) forest ecosystems in the boreal forest. The structure of the model is based on the presence of litter and SOM pools. Litter pools consist of plant material (foliage, twigs, understory species) and fine roots. The SOM in the organic and mineral horizons is subdivided into active, slow and passive pools that differ in mineralization rate. The effect of temperature on the mineralization rate was modelled using results from incubation experiments. Gaussian random distributions were computed on key parameters of the model. Compared with predictions using a deterministic version of the model, the introduction of stochasticity may generate fluctuations without modifying appreciably the overall patterns of prediction.