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How certain are coniferous forest SOC estimates? A comparison of model simulations and measurements at regional scales

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Soil organic carbon (SOC) in boreal forests is a considerable carbon pool and small changes in this pool have the potential to affect the overall national carbon balances for countries with large forested areas. Sweden report annual SOC changes in forest soils to the UNFCCC and the Kyoto protocol using data from a repeated soil inventory. Another method of predicting change in SOC is process-based models. Determination of a small change in a large pool over a long time span is associated with the risk that the observed change is either non-significant due to random errors or erroneous due to systematic errors. This leads to difficulties in reporting whether forest soils are sinks or sources of CO_2 to the atmosphere. Process-based models are often calibrated to few intensively studied sites which leads to uncertainties in SOC change estimates when up-scaling model predictions. In addition, the driving variables of the models are only available at large scales and applying them at small scales is associated with uncertainties, which lead to additional uncertainty in SOC change predictions. Here we present an analysis of uncertainty sources in SOC stock estimations and how the variability in litter input and climate affect the SOC changes in models. Two models, Yasso07 and Q, were used in the comparison with the inventory data between 1994 and 2000. The analysis included model calibration and validation. The Q model was calibrated with Generalized Likelihood Uncertainty Estimation (GLUE) at county scale and both Q and Yasso07 were validated regionally.

Both model and inventory estimates result in quantitatively substantial, but comparable, uncertainties in SOC change estimations aggregated at the national level. From the inventory the average change in SOC between 1994 and 2000 was estimated to 2 (± 4[1]) Tg yr^{-1}. The corresponding estimate with the Q model was 4 (+9; -9[2]) Tg yr^{-1}, and with the Yasso07 model 1(± 8[1]) Tg yr^{-1}. However, the uncertainties in models and inventory SOC estimates are conceptually not comparable since the sources of the uncertainties differ. The major sources of uncertainty in modeled SOC estimates arise from litter input estimations and parameter uncertainties. Uncertainties in inventory estimates are aggregated from several sources and the main uncertainty is caused by spatial variation in SOC. Both simulated and inventory SOC changes result in considerable inter-annual variation. Inventory SOC change estimates vary between 0.5 and 3 Tg between years, Q model estimates between 1 and 5 and Yasso07 between 0 and 9 Tg C. The inter-annual variations also originate from different sources depending on method used. Inter-annual variations in our simulations are generated mostly by climate variability while the inter-annual variability for measurements could be due to several different reasons. Inter-annual variation and confidence intervals for inventory based estimates become smaller the larger scale and sample size used. The calibrated counties with small sample size resulted in uncertainty bounds[1] of SOC stocks of 100 Mg ha^{-1}, while the counties with larger sample size had uncertainty bounds of 20 Mg ha^{-1} in 2002. The modeled estimates also become more certain at larger scales mainly due to more accurate area estimates. When going from county to regional scale the uncertainties of the SOC stocks estimated by the Q model decreased with 30%, equivalent to 30 Mg ha^{-1}.

[1] 95% confidence interval
[2] 5^{th} and 95^{th} percentiles